FRIEDA RIVER

Frieda River Limited
Sepik Development Project
Environmental Impact Statement

Appendix 12a – Vanimo Ocean Port Marine Ecology Baseline Study

SDP-6-G-00-01-T-003-023

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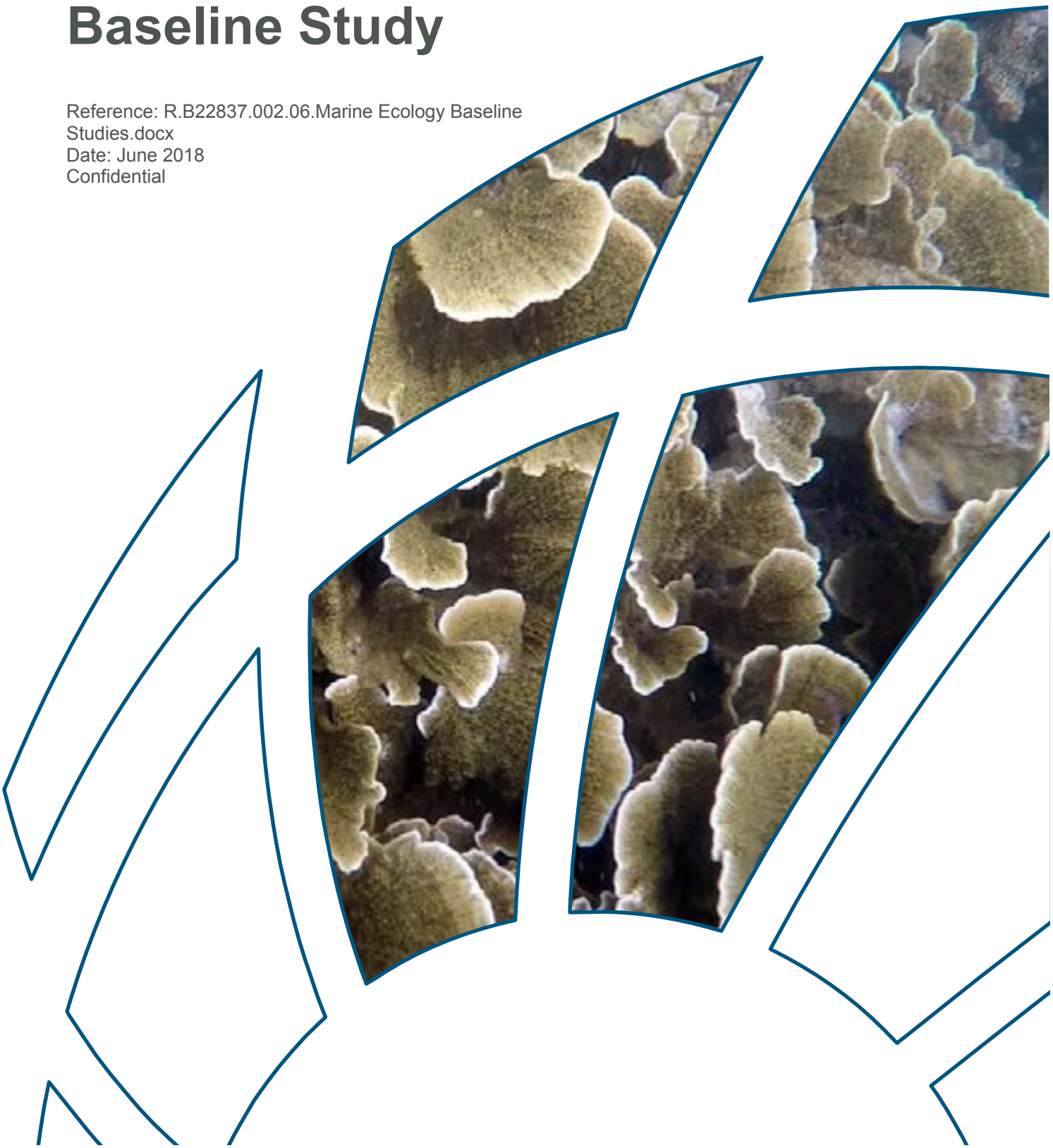
Sepik Development Project – Vanimo Ocean Port Marine Ecology Baseline Study

Reference: R.B22837.002.06.Marine Ecology Baseline Studies.docx
Date: June 2018
Confidential



Document Control Sheet

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Document:	R.B22837.002.06.Marine Ecology Baseline Studies.docx
Title:	Sepik Development Project – Vanimo Ocean Port Marine Ecology Baseline Study
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Client Reference:	
Synopsis:	

REVISION/CHECKING HISTORY

Revision Number	Date	Checked by		Issued by	
0	9th Feb 2018	CMJ		BMG	
1	19th March 2018	CMJ		BMG	
2	13th April 2018	CMJ		BMG	
3	3rd May 2018	CMJ		BMG	
4	24th May 2018	CMJ		BMG	
5	11th June 2018	CMJ		BMG	
6	22nd June 2018	CMJ		BMG	

DISTRIBUTION

Destination	Revision										
	0	1	2	3	4	5	6	7	8	9	10
Coffey	PDF	PDF	PDF	PDF	PDF	PDF	PDF				
BMT File	PDF	PDF	PDF	PDF	PDF	PDF	PDF				
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Glossary and Abbreviations

Abbreviation	Meaning
Abbreviations and acronyms	
ALS	Australian Laboratory Services
ANZECC	Australian and New Zealand Environment Conservation Council
ANZFA	Australia New Zealand Food Authority
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
BRUV	Baited remote underwater video
ECoP	Environmental Code of Practice
EIS	Environmental Impact Statement
ER	Environment Regulation
FAO	Food and Agricultural Organization of the United Nations
FRL	Frieda River Limited
FSANZ	Food Standards Australia New Zealand
GEL	Generally Expected Level
IUCN	International Union for Conservation of Nature
LOR	Limit of Reporting
ML	Maximum Level
NATA	National Association of Testing Authorities
NMI	National Measurement Institute
NTU	Nephelometric Turbidity Units
PNG	Papua New Guinea
QA	Quality assurance
QC	Quality control
RPD	Relative Percentage Difference
WHO	World Health Organization
Technical terms	
Accreted corraline sediment	Sediments derived from coral reefs that has accumulated in an area.
Bedforms	A feature that develops at the interface of fluid and a moveable bed, the result of bed material being moved by fluid flow.
Benthic reflective index	A measure of how much light from different wavelengths is returning to a satellite sensor.
Bioturbation	The disturbance of sedimentary deposits by living organisms.
Deglinted	When processing satellite imagery, deglinting is the removal of water-surface-reflected sunlight along the slopes or crests of waves to enhance the information in the visible bands.

Abbreviation	Meaning
Deltaic muddy sands	Muddy sands located at a river delta or originating from a river delta
Fluvial sediment	Sediments transported and deposited by rivers
Metal burden	The accumulation of heavy metals within biota
Photic zone	Depth of water column that receives sunlight
Purse Seiner	Fishing vessel that uses a purse seine to catch fish. A purse seine is a large wall of netting deployed around an entire area or school of fish.
Seining	To catch fish with a seine net, which is a net that hangs vertically in the water with floats at the upper edge and sinkers at the lower edge.
Stratification	Stratification is when water masses with different properties - salinity (halocline), oxygenation (chemocline), density (pycnocline), temperature (thermocline) - form layers that act as barriers to water mixing.

Executive Summary

Frieda River Limited (FRL) is assessing the feasibility of the Sepik Development Project (the Project) in northwest Papua New Guinea (PNG). The Sepik Development Project is underpinned by the Frieda River Copper-Gold Project (FRCGP) and supported by three separate but interdependent projects which provide key infrastructure including Frieda River Hydroelectric Project (FRHEP) the Sepik Power Grid Project (SPGP), and the Sepik Infrastructure Project (SIP).

The four elements of the Sepik Development Project are located in the Sandaun and East Sepik provinces.

An infrastructure corridor will be developed between the mine site and an ocean port at Vanimo as a part of the Project for use during operations. BMT was engaged by Coffey, on behalf of FRL, to prepare a description of the existing nearshore marine environment at the proposed port location at Vanimo to support an Environmental Impact Statement (EIS).

The study scope of work comprised the following:

- Habitat mapping using remote sensing.
- Ground-truthing of habitat mapping (during a site visit in November 2017).
- Baited remote underwater video (BRUV).
- Characterisation of fish communities and existing fisheries.
- Water quality and sediment quality sampling at sites in Dakriro Bay and Daumlinge Bay.
- Fish tissue metal analysis.

The key findings from the study are summarised below:

Climate Bathymetry and Landform:

- The Study Area experiences seasonal differences in wave climate with more rainfall, wind and swell from November to April, and calmer, drier conditions over the remainder of the year.
- Accreted coralline and fluvial sediment has bridged the shoreline to a former island, creating the area of land that is presently the town centre of Vanimo.
- Dakriro Bay is a natural embayment between the peninsulas of Lido and Cis Point. Fringing reefs surround these peninsulas and there are gently sloping, unconsolidated sediments between them.
- Fringing reefs form a flat to a crest, sloping away from the crest at gradients that vary from vertical to low-relief; bathymetry is generally non-complicated apart from the inlet south of Cis Point.
- The width of reef flat and depth of fringing reef slope increases in a northerly direction away from the main landmass in association with clearer water, more wave energy and less sedimentation.

Marine Habitats

- Marine habitats within the Study Area consist of sandy beaches, subtidal sands, fringing coral reefs, and seagrass meadows. The highest value habitats included corals and seagrass meadows, with the latter generally in good condition and highly diverse.

- Coral communities are the most extensive, high-value marine habitat within the project area, but exist in a highly altered state under intense anthropogenic pressure. Likely stressors include:
  - thermal bleaching;
  - over-fishing;
  - physical damage from wave energy, anchoring and harvesting;
  - Poor water clarity in terms of coral health (corals typically require very low suspended sediments in the water column); and
  - marine debris.
- Mean coral cover on the reef slope varied between 4 and 24% with the lowest cover recorded near Cis Point, the ocean port, and the logging port. Higher coral cover was observed at Lido Village and opposite the hospital.
- Macroalgal communities were extensive, in direct competition with corals, and were densest near the reef crest where sunlight was high and wave energy was high.

Fish Communities and Fisheries

- Fish and shellfish communities are highly overfished compared to other managed tropical fisheries. Very few large fish were observed in the water and all large fish in the marketplace were caught elsewhere. Fish communities near the proposed ocean port and the existing logging port were almost non-existent. Fish communities from the western side of Dakriro Bay (Lido Village sites) and near the hospital are heavily overfished, but much more rich and abundant than reefs on the eastern side of Dakriro Bay.

Water quality:

- Water quality was typified by warm waters with total suspended sediments of 1-5 mg/L (turbidity of 0.8-3.3 NTU) and low concentrations of nutrients, metals/metalloids and hydrocarbons (with concentrations mostly below laboratory limits of reporting and water quality guideline values/criteria. Turbidity was higher near the sea floor.
- All sites had dissolved metal/metalloid concentrations below PNG and Australian water quality guideline values/criteria. The exception to this was dissolved boron which exceeded the PNG water quality criterion (2,000 µg/L) at all sites. However, dissolved boron concentrations were similar to concentrations typically found in seawater.
- Water quality depth profiling through the water column indicated that water quality did not change much from surface to seabed at each site, indicating that stratification was not evident at the time of sampling.

Sediment quality:

- The substrate adjacent to the proposed port facility (site M1) and near Lido Village (M3) consisted predominately of sands and muds (particle size 0.006-2.00 mm) whilst muds and clays (particle size <60 µm) were more pronounced in central Dakriro Bay (M2) and coastal foreshore (site M4) survey sites.
- Concentrations of most metals/metalloids in whole sediment samples were below sediment quality guideline levels (Simpson et al 2013), except for nickel. Nickel concentrations at sites M2 and M3 were

above the sediment quality Guideline Value of 21 mg/kg and concentrations at M4 exceeded the sediment quality guideline high value (SQG-high) of 52 mg/kg.

- Concentrations of metals/metalloids, nutrients and hydrocarbons in sediment were generally higher at survey sites in central Dakriro Bay (M2) and coastal foreshore (site M4) compared to sites at the proposed port facility (site M1) and Lido Village (M3).
- Concentrations of total petroleum hydrocarbons (TPH) were below the laboratory limit of reporting for the volatile hydrocarbon fractions (C6-C9 fractions) at all survey sites. All other TPH fractions (semi-volatiles) had detections but were below the guideline value of 550 mg/kg.
- Polyaromatic hydrocarbons (PAHs) were typically below the laboratory limit of reporting at all survey sites, except for perylene which was detected at low concentrations (8-10 mg/kg).

Fish Tissue Metal Burden:

- Arsenic and zinc concentrations in fish tissue exceeded the food standards and/or indicative guideline values, and this contamination was present in a range of feeding guilds.

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1 Introduction

1.1 Background

Frieda River Limited (FRL) is assessing the feasibility of the Sepik Development Project (the Project) in northwest Papua New Guinea (PNG). The Sepik Development Project is underpinned by the Frieda River Copper-Gold Project (FRCGP) and supported by three separate but interdependent projects which provide key infrastructure including Frieda River Hydroelectric Project (FRHEP) the Sepik Power Grid Project (SPGP), and the Sepik Infrastructure Project (SIP).

The four elements of the Sepik Development Project are located in the Sandaun and East Sepik provinces.

An infrastructure corridor will be developed between the mine site and an ocean port at Vanimo, located on the north coast of mainland PNG, as a part of the Project for use during operations.

BMT was engaged by Coffey, on behalf of FRL, to prepare a description of the existing nearshore marine environment at the proposed port location at Vanimo to support an Environmental Impact Statement (EIS).

1.2 Location Terminology

The following terminology has been adopted to describe locations:

- Study Area: areas surveyed for the study, which includes the marine areas shown within the map extent in Figure 1-1.
- Nearshore marine environment: intertidal, tidal, shallow marine and reef patches.

1.3 Study Objectives

The objectives of the study were to:

- Identify current and relevant international, PNG Government and local government policies, legislation and guidelines regarding aquatic biota, marine biological communities, habitats, and surface water.
- Characterise spatial and temporal patterns in the physio-chemical properties of surface waters and sediments within the Study Area.
- Characterise spatial and temporal patterns in the aquatic habitats, flora and fauna within the Study Area.
- Document any rare, threatened, undescribed or otherwise noteworthy aquatic fauna and flora species (i.e. International Union for Conservation of Nature (IUCN) listed or community significance), biological communities and habitats present within the Study Area.
- Describe existing metal/metalloid concentrations in the tissues of selected aquatic fauna species.

LEGEND

Title:
Study Area

Figure: 1-1

Rev: A

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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Approx. Scale

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1.4 Project Description

The Project is primarily located within the Sepik River catchment and comprises development of a copper-gold deposit in Sandaun Province and supporting infrastructure and facilities in the Sandaun and East Sepik provinces. Ore mined at the FRCGP will be processed at a process plant to produce a copper-gold concentrate.

A 325 km infrastructure corridor will be developed between the mine site and an ocean port at Vanimo, located on the north coast of mainland PNG, as a part of the Project for use during operations. A concentrate pipeline that follows the road corridor will transport the copper-gold concentrate produced at the process plant to a concentrate dewatering, storage and export facility located at the Ocean Port.

This study focused on the area that comprises the nearshore marine environment at the Ocean Port. The proposed concept design for the Ocean Port is shown in Figure 1-2.

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Port Concept Design

Reclaim Area 1

Reclaim Area 2

Title:
Ocean Port Concept Design

Figure: 1-2

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1.5 Study Area Context

1.5.1 Background

The Ocean Port is located within the naturally occurring harbour of Dakriro Bay on the northern PNG coastline, within the Sandaun Province. Subtidal marine habitats in Vanimo belong to the Coral Triangle, which includes the highest diversity marine ecosystems in the world (Veron 2000). The Coral Triangle extends from Malaysia at its western extremity to the Philippines at its northernmost, and eastward to the Solomon Islands. Vanimo lies within the most diverse region for coral species, with reefs typically having 500-600 species of coral (Veron 2000). In recognition of the potentially diverse and abundant marine ecosystems that exist regionally, a detailed baseline assessment was performed to characterise the environmental value of habitats within the Study Area.

Dakriro Bay is a natural harbour used extensively by logging companies and commercial fishing fleets as an anchorage and port. Logging in the Sandaun Province and disturbance to the landform is a major source of suspended sediment for rivers in the upper catchment.

The Nemayer River is the nearest large source of fluvial sediment to Vanimo and its mouth is situated 16 km to the east. Wet-season plumes at the time of survey did not visually extend to Vanimo, but longshore drift associated with predominantly easterly winds and north-easterly swells and westerly currents offshore (Section 1.5.2) likely advect some of this sediment into Dakriro Bay. Dakriro Bay receives freshwater, sediment, and pollutants directly from several small tributaries and open drains from the town centre.

1.5.2 Climate and Metocean Conditions

Papua New Guinea has a tropical climate, with the majority of the country experiencing high annual rainfalls, high average temperatures and high humidity. Vanimo's climate is typified by moderate seasonality (small temperature differences between the wet and dry seasons) and a moderate range in rainfall variability (intermediate to heavy), with the maximum rainfall experienced in January to April (McAlpine *et al*. 1983). The proximity to the equator sees sub-equatorial doldrum conditions and light winds over much of the year. Stronger winds typically come from either the east (dry season) or west to north-west (associated with wet season monsoon) (Figure 1-3). Most of the time (99 percent) winds speeds are less than 20 knots.

The primary wave energy comes from either the north or north-east, with the largest and most consistent waves arriving from the north-east (Figure 1-4). Generally, mean significant wave height varies between 1 to 1.5 m, with occasional mean significant wave height increasing to 1.5 to 2.5 m. November to March is considered the surf season, when Lido Village is visited by surf tourists. Surfing occurs at four locations within Dakriro Bay:

- Lido Lefts, at the north-west extremity of Dakriro Bay.
- town beach (a beach break).
- Log Point (located near Cis Point).
- the section of reef within the ocean port footprint.

Extensive logging within the catchment is likely contributing to increased erosion and suspended sediments in nearshore marine waters, which reduces visibility, particularly during the monsoon season. Therefore, the combination of large waves, suspended sediment, and wind significantly reduces visibility in the wet season, compared to the dry season.

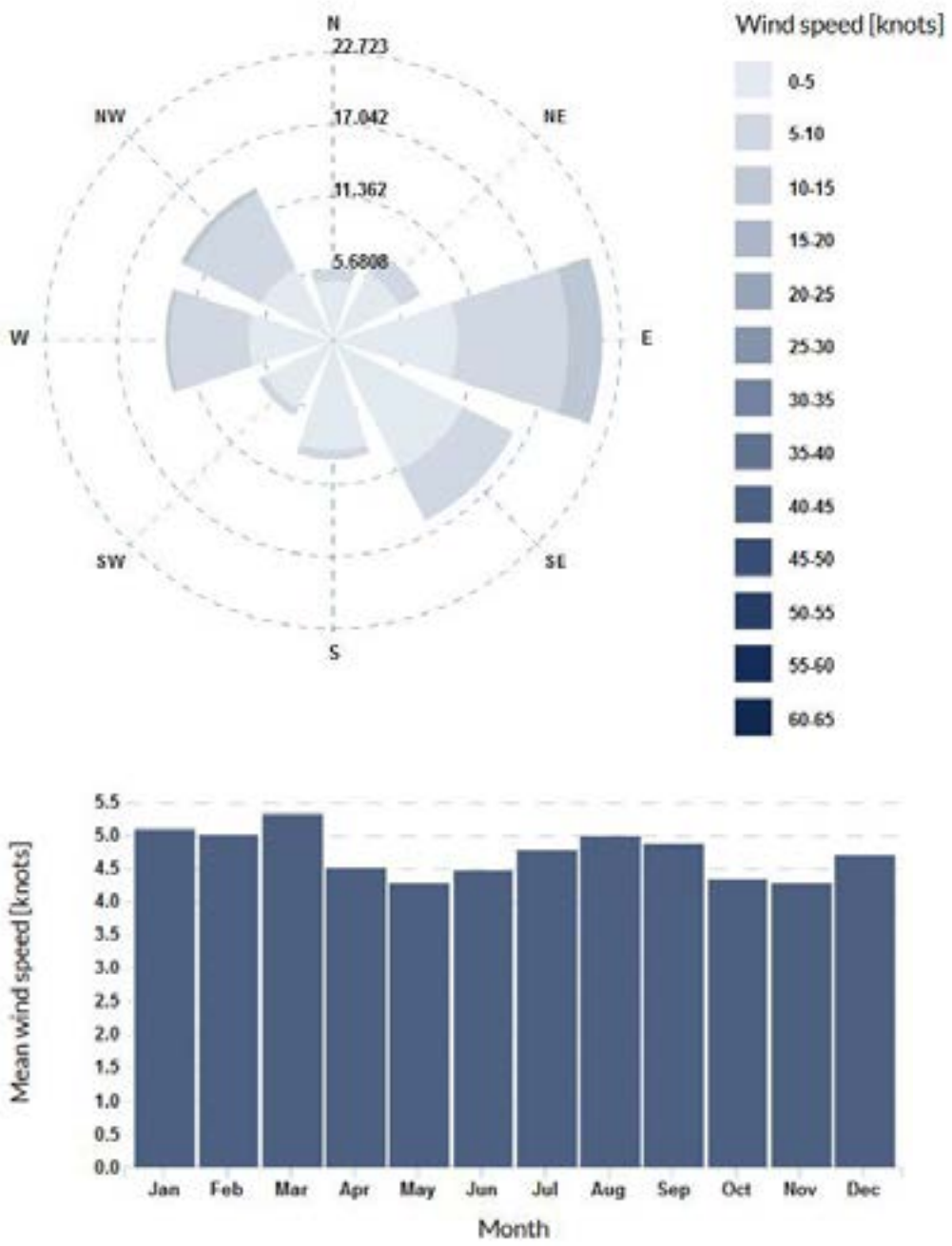


Figure 1-3 Model hindcast wind conditions from NOAA CFSR for Vanimo: Wind rose (above) and monthly average wind speed (below) (www.metocean.co.nz)

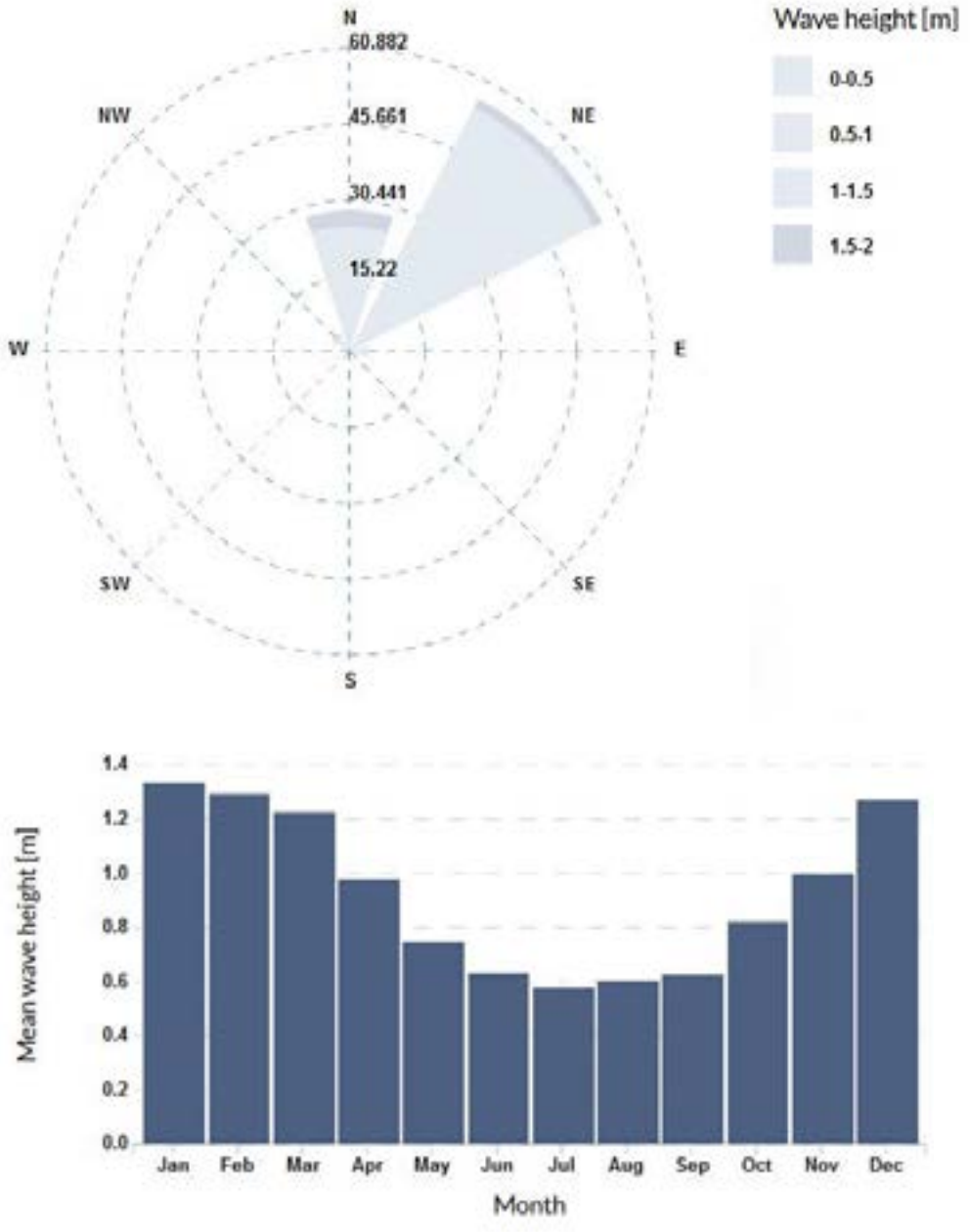


Figure 1-4 Model hindcast wave conditions from MSL SWAN for Vanimo: Wave rose (above) and monthly average significant wave height (below) (www.metocean.co.nz)

Current direction data along the shoreline near Vanimo is not available, but offshore seasonal current vectors show a westerly component from June to November and an opposing easterly direction from December to May (Figure 1-5). These broad patterns in oceanic currents differ to small-scale currents driven by waves and winds inshore. These are discussed further in Section 3.1.

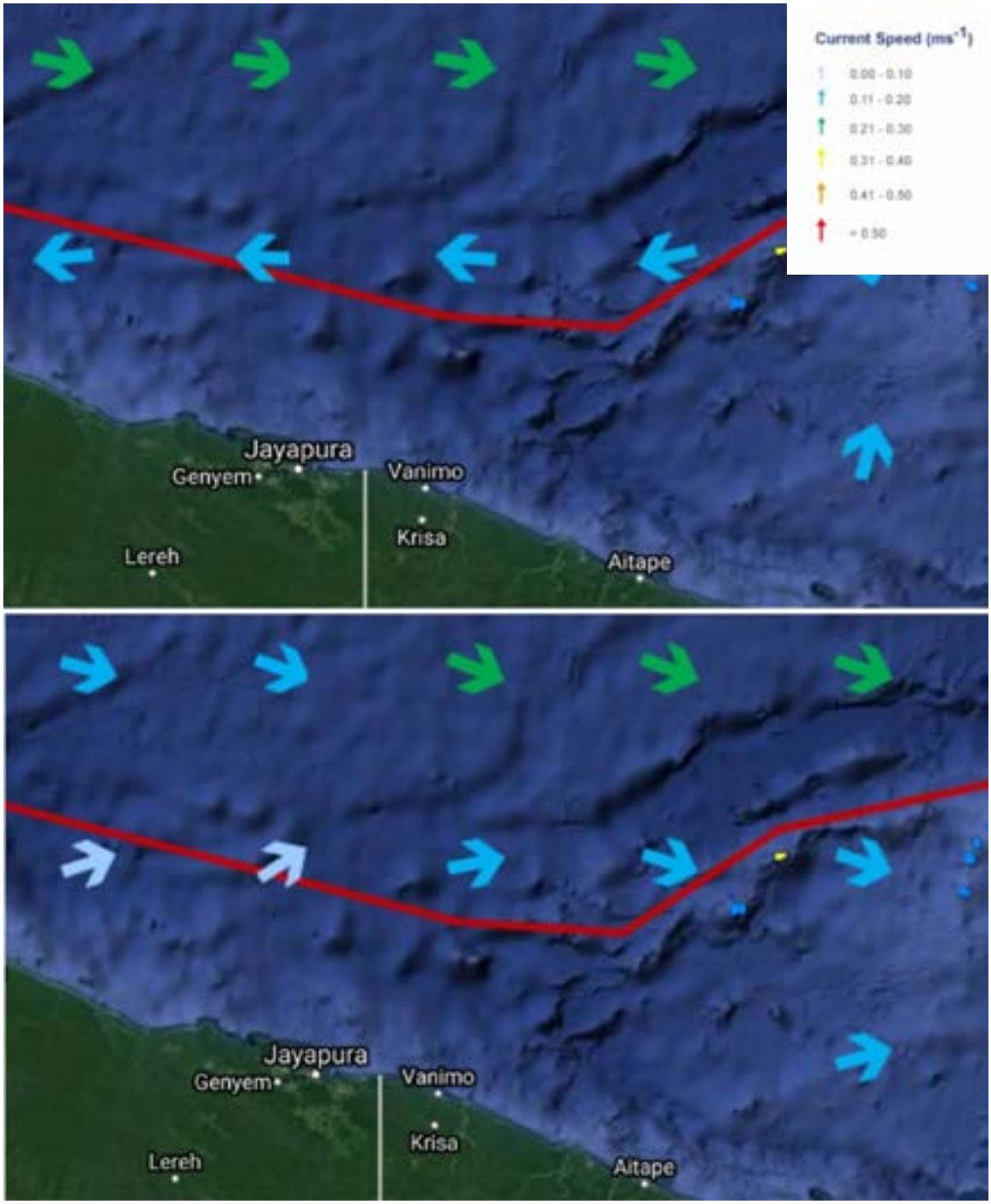


Figure 1-5 Typical offshore current vectors for June to November and (top) and December to May (below)(CTI Atlas 2018)

2 Methods

2.1 Existing Data

Historical information describing biological or physical data for the region are extremely limited. The Coral Triangle Initiative (CTI) includes biological and integrated threat mapping for thousands of reefs within the Coral Triangle, but the coastal reefs along the north coast of PNG and West Papua are excluded from this dataset despite the presence of an extensive reef network. While there are some descriptions of species richness and benthic cover near Madang (Tursch and Tursch 1982), data for most of the north coast of PNG and Vanimo are not available.

High-level evaluations of threats to PNG reefs from the CTI (Asian Development Bank 2014) and Huber (1994) agree broadly with field observations (regarding the condition of the reef), but do not contain regionally specific information of use to this assessment.

In the absence of published background information, information on historical biological and physical conditions of the nearshore marine environment at Vanimo was obtained from local and traditional knowledge. Anecdotal information was obtained from conversations with a wide variety of community members, including provincial government officials, fisheries officers, local fishermen, market vendors, and field assistants. The synthesis of these conversations, combined with field observations is included in Section 3.

2.2 Baseline Surveys in 2017

The baseline survey carried out from 28 to 30 November 2017 represents the most recent and relevant information to the EIS. These studies also describe quality assurance (QA) and quality control (QC) procedures and results, providing confidence in data integrity.

The primary goal of this study was to characterise habitats significant to regional ecology, biological communities, fisheries resources and threatened species. The study sought to classify habitat extent and condition first and foremost with a secondary emphasis on species presence. Coral cover and taxonomic diversity are considered key metrics of habitat health because healthy and diverse coral communities provide crucial physical and biological conditions for oligotrophic (nutrient poor) tropical ecosystems. The methodologies used in the baseline surveys are summarised below.

2.2.1 Habitat Mapping

Ten-metre pixel resolution, multispectral satellite data (Sentinel 2) captured in May 2017 were downloaded from the Copernicus Sci-hub. Data were de-glinted to remove reflected light (Hedley *et al.,* 2005), and bathymetry from the Australian Hydrographic Service were purchased to calculate the Benthic Reflective Index (Sagawa *et al*., 2010).

The Benthic Reflective Index (BRI) is a measure of how much light from different wavelengths is returning to the satellite sensor. It is calculated by understanding the relationship between signal attenuation (each band) and depth. Different substrates have spectral signatures (specific combinations of reflected light) and the BRI is a method of adjusting these based on known bathymetry.

Ground-truthing of representative habitats was used to determine spectral signatures and applied to the whole dataset. This was done with a supervised classification of the different Benthic Reflective Indices for blue, green and red bands to determine areas of high-coral cover, seagrass, macroalgal dominated reef, and sand and rock layers at different depths. Ground-truthing was also performed in representative habitat types and at intervals in waters too deep or too turbid to be remotely sensed. A visual representation of this process is shown in Figure 2-1.

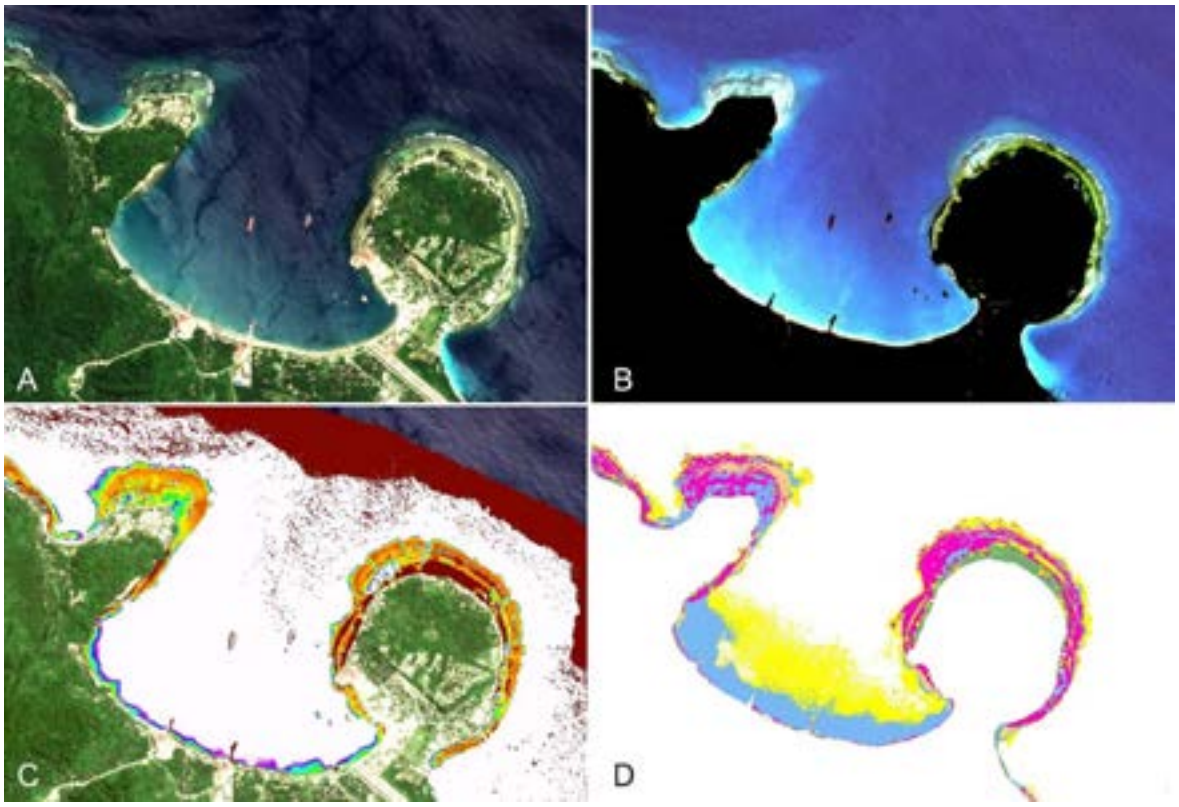
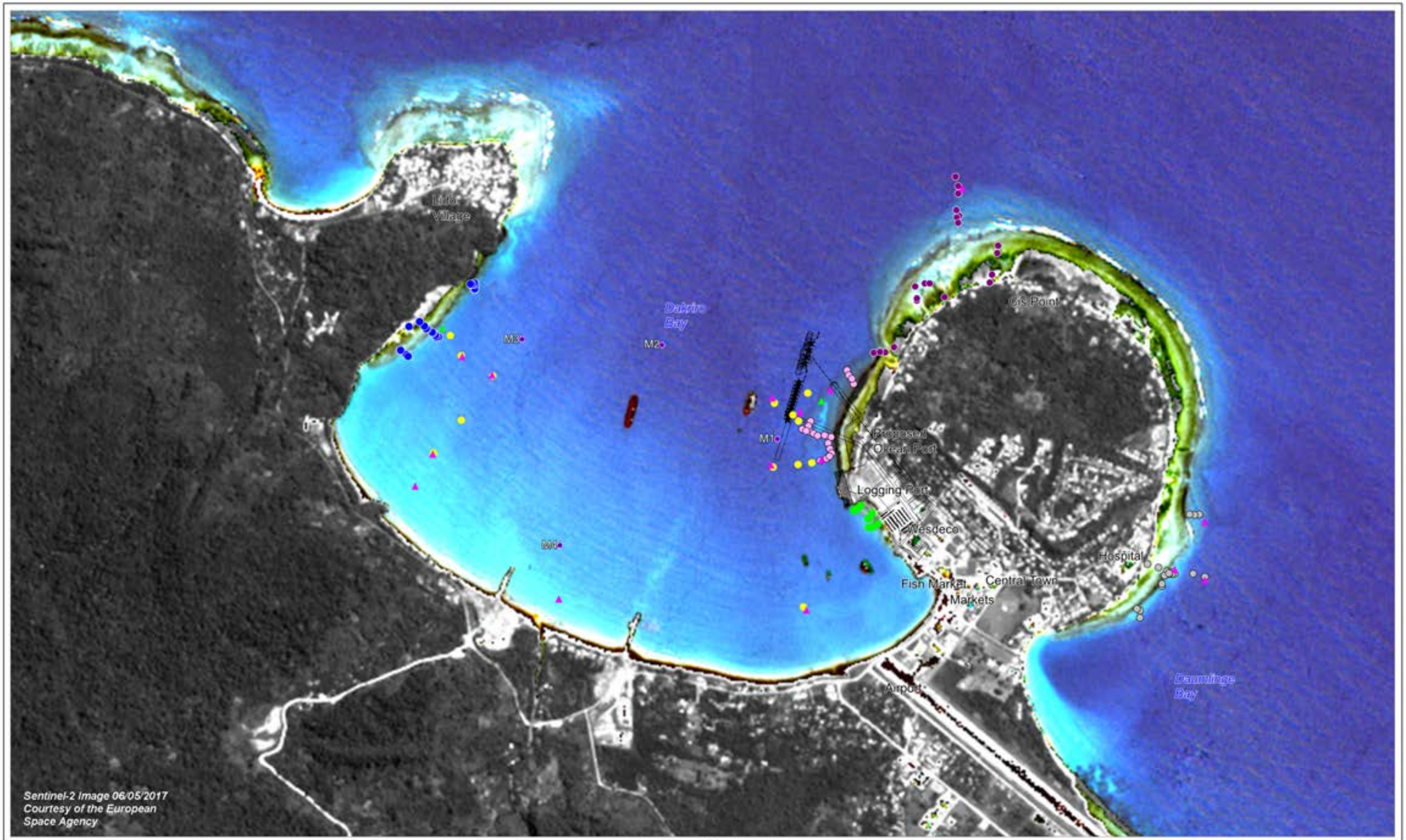


Figure 2-1 Sentinel-2 natural colour (A); deglinted and masked image (B); intensity of the benthic reflective index for the green band (C); and classified habitats (D).

A diver on snorkel recorded a 5 m linear transect of benthos in reef areas using a high-definition underwater video camera, while a vessel-based drop camera was used over unconsolidated sediments and waters deeper than 10 m. These sites are shown in Figure 2-2. Ground-truthing sites were selected based on the following factors:

- Sites were located within potential port infrastructure footprints, and conducted as short video transects describing benthic communities and any notable marine life such as fish and turtles.
- Sites were located outside of potential port infrastructure to provide broader environmental context. These included the sewage outfall east of the hospital, and areas open drain outlets near the fish market and existing logging port.
- Aquatic environments were characterised in areas potentially affected by the Project that have not previously been surveyed.



LEGEND

- Water Quality Transects and Ground Truthing Sites
- BRUV Sites
- Water and Sediment Quality Sites (M1 - M4)

Ground-truthing Sites

- Lido Village
- Dakriro Bay
- Ocean Port
- Logging Port
- Cis Point
- Hospital

Title:
Survey Sites

Figure: 2-2

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2.2.2 Baited Remote Underwater Videos (BRUVs)

Baited Remote Underwater Videos (BRUVs) were deployed at two locations shown in Figure 2-2. Each BRUV was set using a bait of thawed Pacific mackerel for a deployment period of 30 min with a high-definition video camera recording continuously.

2.2.3 Water Quality and Sediment Quality

2.2.3.1 Survey Sites

Water quality and sediment quality sampling was undertaken at four sites in the Study Area as per Table 2-1 and shown in Figure 2-2.

Table 2-1 Marine Survey Sites

Site ID	Coordinates		Approximate Water Depth
	Latitude	Longitude	
M1	-2.676102	141.291438	14 m
M2	-2.671308	141.285600	20 m
M3	-2.671022	141.278508	10 m
M4	-2.681503	141.280427	5 m

2.2.3.2 Water Quality Sampling and Analysis

Sampling was undertaken in accordance with relevant international standards including ISO 5667-1:2006, ISO 5667-2:1991, and ISO 5667-3:2003, along with relevant Australian Standards including AS/NZS 5667.1:1998.

Physico-chemical water quality measurements were recorded *in situ* at each site using a multi-parameter water quality sonde. This instrument was calibrated prior to the site visit and the calibration was checked again once at site using appropriate calibration solutions. The instrument accuracy was checked regularly during the field program, and a final calibration was performed at the completion of the field program to check for any drift in parameters.

At each site the following was undertaken:

- The instrument was lowered to a water depth of 0.3 m below the water surface (where possible) and allowed to stabilise to ambient conditions (typically less than one minute).
- Optical sensors were wiped to remove air bubbles, debris or sediment.
- Water quality measurements were logged at one second intervals over a period of approximately one minute.
- The mean value for each parameter was calculated for each site.

The following parameters were measured *in situ* at each site:

- pH
- Electrical conductivity (EC)
- Turbidity
- Dissolved oxygen (DO).

- Temperature

In situ water quality depth profiling was also undertaken at each site. This involved lowering the water quality instrument through the water column from surface to bottom, with measurements logged once per second.

Water samples were collected at each site for laboratory analysis. These samples were stored and transported in clean, sterile sample containers supplied by National Association of Testing Authorities (NATA) accredited Australian Laboratory Services (ALS) in Brisbane. Samples requiring field filtration (i.e. dissolved metals/metalloids and dissolved organic carbon) were filtered at each monitoring site using a syringe and 0.45 µm filter cartridges. The laboratory analytical suite included the following parameters:

- Total suspended solids (TSS)
- Total dissolved solids (TDS)
- Total and dissolved metals/metalloids including silver (Ag), arsenic (As), barium (Ba), boron (B), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), mercury (Hg), manganese (Mn), zinc (Zn), selenium (Se), lead (Pb), nickel (Ni), aluminium (Al), tin (Sn) and vanadium (V)
- Oil & grease
- Total organic carbon (TOC)
- Dissolved organic carbon (DOC)
- Nutrients - total nitrogen (TN), oxidised nitrogen (NOx), ammonia, filterable reactive phosphorus (FRP) and total phosphorus (TP)
- Total Petroleum Hydrocarbons (TPH), Total Recoverable Hydrocarbons (TRH) Polynuclear Aromatic Hydrocarbons (PAH) and Benzene Toluene Ethylbenzene Xylenes and Naphthalene (BTEXN)

Water samples were kept chilled (and in the dark) in the field using insulated portable containers with ice bricks, and then placed into a refrigerator until ready for shipment. Samples were transported in insulated portable containers with ice bricks to ALS in Brisbane for analysis.

2.2.3.3 Sediment Quality Sampling and Analysis

Sediment sampling was undertaken in accordance with relevant international standards including ISO 5667-1:2006, ISO 5667-2:1991, and ISO 5667-3:2003, along with relevant Australian standards including AS/NZS 5667.12:1999.

Sediment samples were collected at each site using a Van Veen grab sampler (0.028 m^3 grab). Approximately ten (10) sediment sub-samples were placed into a large clean plastic tray, mixed thoroughly using a plastic trowel, and placed in clean, sterile sample containers supplied by ALS in Brisbane. This method resulted in a composite sample representing the range of bottom sediments present at each site.

Whole sediment samples collected at each site were analysed for the following parameters:

- Particle size distribution (PSD).
- Total metals/metalloids concentrations: Ag, Al, As, Ba, Bo, Cd, Cr, Cu, Co, Fe, Hg, Mn, Ni, Pb, Sb, Se, Sn Zn, Va.

- Nutrients: total nitrogen (TN), oxidised nitrogen (NOx), ammonia, filterable reactive phosphorus (FRP) and total phosphorus (TP).
- Total organic carbon (TOC).
- Total Petroleum Hydrocarbons (TPH), Total Recoverable Hydrocarbons (TRH), Polynuclear Aromatic Hydrocarbons (PAH) and BTEXN.

Sediment samples were kept chilled in the field using insulated portable containers with ice bricks, and then placed into a refrigerator until ready for shipment. Samples were shipped in insulated portable containers with ice bricks to ALS in Brisbane for analysis.

All sediment quality results (other than PSD) within this report use the units of mg/kg (dry weight), referred to here after as mg/kg.

2.2.3.4 *Quality Assurance/Quality Control*

To ensure good quality data was collected during the field program, a number of QA/QC procedures were adhered to during all field work. These included the following:

- Proper training and supervision of field staff.
- Use and maintenance of appropriate sampling equipment, and implementation of appropriate calibration procedures (including use of controlled standard solution supplied by ALS in Brisbane).
- Use of proper sampling techniques in accordance with relevant water and sediment quality sampling guidelines and standards (e.g. AS/NZS 5667.1:1998 and AS/NZS 5667.12:1999).
- Sample containers were clearly and accurately labelled and a log of collected samples was maintained and updated.
- Chain of custody forms were maintained and included with samples.
- Data validation included cross check by a second scientist after entry into the database.

Water sample preservation and handling procedures were followed and samples were supplied to the laboratory within nominated holding times as far as practicable. Holding times were not able to be met for some nutrients (holding times of 2 days) due to the remote sampling location.

Quality Control Samples

Additional field samples were collected for quality control (QC) purposes to assess the repeatability and precision of laboratory results, and consisted of intra-laboratory duplicates – water/sediment samples were split into two duplicate sub-samples in the field and tested as separate (blind) samples by the primary laboratory (ALS). Intra-laboratory duplicates were collected at 10% of monitoring sites.

To assess whether laboratory results from primary and duplicate samples were within an acceptable range, the relative percent difference (RPD) between samples was determined. RPD was calculated using the following equation:

$$RPD(\%) = \frac{|X_1 - X_2|}{\overline{X}} \times 100$$

where: X_1 = primary sample
X_2 = duplicate sample
$\overline{X}$ = mean of results

An acceptable RPD varies depending on how close the concentration is to the laboratory limit of reporting (LOR). The closer to the LOR, the more variability is expected between results. Therefore, RPD acceptability was deemed as being:

- 0-100% when concentration is less than 5 times the LOR.
- 0-75% when concentration is 5 to 10 times the LOR.
- 0-50% when concentration is greater than 10 times the LOR.

The results of the RPD analysis on the intra-laboratory duplicates indicated that all primary samples and duplicates were within the acceptable RPD range. Therefore, the data presented in this report can be considered to be of acceptable quality.

Laboratory Quality Control Measures

Routine laboratory control samples used at ALS include:

- Certified reference materials;
- Laboratory duplicates;
- Laboratory control spikes;
- Matrix spikes;
- Surrogates;
- Secondary and project standards;
- Inter laboratory (proficiency) testing; and
- Client and industry managed independent audits and accreditations.

BMT reviewed QA/QC documentation supplied by the primary laboratory and there were no issues identified.

2.2.4 Comparison of Data to Water Quality Objectives and Guideline Values

2.2.4.1 Water Quality

Water quality results were compared to existing water quality objectives and guideline values to assess ambient water quality 'condition'. There are a number of PNG and Australian-based legislation and guideline documents which contain a variety of water quality objectives and/or guideline values. Those which are considered most relevant to the Study Area include the following:

- **PNG ER**: Schedule 1 of the *Environment (Water Quality Criteria) Regulation 2002*, which is subordinate legislation under the *Environment Act 2000*, specifies water quality objectives relevant to permit conditions. These are legally enforceable water quality criteria.

- **PNG ECoP**: Appendix 1 of the Environmental Code of Practice for the PNG Mining Industry – PNG guideline with recommended guideline values based on international standards. Compliance with the ECoP is voluntary.
- **ANZECC**: ANZECC/ARMCANZ (2000) Water Quality Guidelines – Australian guideline document containing numerical guideline values (referred to as trigger values). Guideline values based on 95% level of species protection were used as the study area can be considered a slightly–moderately disturbed system.

In PNG, the first priority in assessing ecological impacts is to use criteria provided in the *Environment (Water Quality Criteria) Regulation 2002* and the PNG ECoP. However, ANZECC guideline values are also often used to supplement the PNG criteria. Table 2-2 is a summary of the various water quality objectives and guideline values derived from the documents listed above.

Table 2-2 Water Quality Objectives and Guideline Values

Parameter	Units	Water Quality Objectives / Guideline Values		
		PNG ER [1]	PNG ECoP [1]	ANZECC [2]
Temperature	°C	No alteration >2°C	No alteration >2°C	-
Dissolved Oxygen	% sat	-	>80-90% saturation	-
	mg/L	>5	> 6	-
Turbidity	NTU	No alteration >25	<10% change from background seasonal mean	-
Electrical Conductivity	µS/cm	-	<5% change from background seasonal mean	-
pH	-	No alteration to natural pH	<0.2 pH unit change from normal pH	-
Total Suspended Solids	mg/L	-	<10% change from background seasonal mean	-
Potassium (K)	mg/L	450	-	-
Sulphate (SO_4^{2-})	mg/L	-	-	-
Silver (Ag)	µg/L	50	1	1.4
Arsenic (As)	µg/L	50	50	-
Barium (Ba)	µg/L	1,000	-	-
Boron (B)	µg/L	2,000	-	-
Cadmium (Cd)	µg/L	1	2	0.7 ^
Chromium (Cr) as Cr VI	µg/L	10	50	4.4
Cobalt (Co)	µg/L	Limit of detection	0.9	1
Copper (Cu)	µg/L	30	5	1.3
Iron (Fe)	µg/L	1,000	-	-
Mercury (Hg)	µg/L	0.2	0.1	0.1 ^
Manganese (Mn)	µg/L	2,000	100	-
Zinc (Zn)	µg/L	5,000	50	15
Selenium (Se)	µg/L	10	70	-
Lead (Pb)	µg/L	4	5	4.4
Nickel (Ni)	µg/L	1,000	15	7 ^
Aluminium (Al)	µg/L	-	-	-
Antimony (Sb)	µg/L	-	0.5	-
Tin (Sn)	µg/L	0.5	-	-
Vanadium (V)	µg/L	-		100
Total Nitrogen	mg/L	-	-	-
Total Phosphorus	mg/L	-	-	-
Ammonia	mg/L	-	-	0.91
Nitrate	mg/L	45	-	-
Soluble reactive phosphorus	mg/L	-	-	-
Oil & Grease	mg/L	None present	-	-

Note: Water quality objectives/guideline values for metals/metalloids are for dissolved metals/metalloids.

[1] PNG ER and PNG ECoP guideline values based on protection of aquatic life in marine waters

[2] ANZECC/ARMCANZ (2000) values based on a marine waters at 95% level of species protection for metals/metalloids in typical slightly–moderately disturbed systems except: ^ cadmium, mercury and nickel values are for protection of 99% of species in typical slightly–moderately disturbed systems as per ANZECC/ARMCANZ (2000).

* Water quality objectives/guideline values for Cd, Cu, Pb, Ni, Zn are dependent on water hardness in PNG ECoP guideline and ANZECC/ARMCANZ (2000) – values presented are based on a hardness of <50 mg/L of $CaCO_3$.

2.2.4.2 Sediment Quality

There are currently no PNG sediment quality guidelines. Therefore, sediment quality data was compared to Australian sediment quality guideline values specified in Simpson *et al.* 2013, which updated the interim sediment quality guideline values specified in ANZECC/ARMCANZ (2000).

Simpson *et al.* 2013 specifies sediment quality guideline values which are presented as two trigger values, as follows:

- Guideline Value: concentration level below which adverse effects to benthic biota are unlikely.
- Sediment quality guideline-high (SQG-High): concentration level above which there is a higher probability of adverse effects to benthic biota.

Relevant sediment guideline values for the present study are summarised in Table 2-3.

These values are considered reasonably accurate at determining the extremes of effects. However, information is lacking in the intermediate range, where effects may or may not be occurring.

Table 2-3 Sediment Quality Guidelines

Analyte	Units (dry weight)	Simpson *et al.* 2013 Sediment Quality Guidelines	
		Guideline Value	SQG-High
Silver (Ag)	mg/kg	1	4.0
Arsenic (As)	mg/kg	20	70
Cadmium (Cd)	mg/kg	1.5	10
Chromium (Cr)	mg/kg	80	370
Copper (Cu)	mg/kg	65	270
Mercury (Hg)	mg/kg	0.15	1
Nickel (Ni)	mg/kg	21	52
Lead (Pb)	mg/kg	50	220
Antimony (Sb)	mg/kg	2	25
Zinc (Zn)	mg/kg	200	410
Total Petroleum Hydrocarbons (TPH)	mg/kg	280	550
Sum of PAHs	mg/kg	10,000	50,000

2.2.5 Metal Tissue Analyses

Metal tissue analysis was undertaken to describe the baseline metal burdens in aquatic biota (i.e. fish and prawns).

Tissue samples (whole fish) were taken from ten specimens collected by a local fisherman at the reef area in front of the Vanimo Hospital (within the Study Area). Whole fish samples were weighed and placed into individual plastic zip lock bags and immediately frozen. Frozen samples were then transported for tissue metal analysis in the laboratory. Samples were analysed by the National Measurement Institute (NMI) using Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) or Inductively Coupled Plasma Mass Spectroscopy (ICP-MS) as appropriate.

Metal burdens were expressed on a dry weight basis (mg/kg) by the lab (NMI). Dry weights were converted to wet weight using the supplied moisture content (%) to enable comparisons to the relevant food standards and guidelines.

The list of metal parameters tested and their limit of reporting is shown in Table 2-4.

Table 2-4 Metal species analysed within fish and macro-crustacean tissue samples

Parameter	Units (dry weight)	Limit of Reporting (LOR)
Silver (Ag)	mg/kg	0.02
Aluminium (Al)	mg/kg	0.5
Arsenic (As)	mg/kg	0.05
Cadmium (Cd)	mg/kg	0.01
Chromium (Cr)	mg/kg	0.05
Copper (Cu)	mg/kg	0.01
Mercury (Hg)	mg/kg	0.01
Lead (Pb)	mg/kg	0.01
Manganese (Mn)	mg/kg	0.01
Nickel (Ni)	mg/kg	0.01
Antimony (Sb)	mg/kg	0.01
Selenium (Se)	mg/kg	0.05
Zinc (Zn)	mg/kg	0.01

Metal/metalloid concentrations in tissues were compared against various food standards and guidelines, as follows:

- ANZFA (2001 & 2015) Food Standards. These refer to Generally Expected Levels (GELs) and Maximum Levels (ML). GELs are guideline values based on analysis of a large number of samples of the edible portions fish/ macro-crustaceans (and other foods not relevant to this study). GELs describe both median and the 90th percentile concentrations for contaminants. For the purposes of this study, comparisons of 90th percentile values were used. In comparison, MLs are levels above which an unacceptable risk to human health is perceived. MLs are set for lead, arsenic and mercury, whereas GELs are available for copper, selenium and zinc in a variety of aquatic biota tissue types.
- Food and Agriculture Organisation of the United Nations and World Health Organisation (FAO and WHO, 2006) proposed CODEX standards for the protection of human health.

Guideline values and standards used are presented in Table 2-5.

Table 2-5 Food standards used for screening tissue metal results

Analyte	ANZFA/FSANZ Food Standards Code		FAO/WHO CODEX Standards
	Fish flesh	Prawn flesh	Fish flesh
Units	mg/kg (wet weight)	mg/kg (wet weight)	mg/kg (wet weight)
Ag	-	-	-
Al	-	-	-
As	2	2	-
Cd	-	-	-
Cr	-	-	-
Cu	2	20	-
Pb	-	-	0.3
Hg	0.5	0.5	0.5
Mn	-	-	-
Ni	-	-	-
Se	2	1	-
Sb	-	-	-
Zn	15	40	-

ANZFA/FSANZ = Black text denotes the ML; shaded grey denotes the GEL
Dash (-) indicates no standard or guideline.

2.3 Limitations

The ground-truthing survey was conducted over a reduced window of 2.5 days due to weather and other logistical constraints. It focussed on representative areas at potential port locations, but outer reef fronts and inner Dakriro Bay sites had low survey effort due to conditions. Large swell and heavy rain created zero visibility conditions near the shoreline in Dakriro Bay, and waves breaking on the northern faces of the fringing reefs created surge and wave conditions that were unsafe for divers (loss of visual contact with vessel between waves, large amounts of aeration, and 15 m horizontal surges). A survey was attempted at the northern most reef at Lido Village, but aborted due to safety concerns.

It should be noted that the high degree of macroalgal cover across most reef areas above the 5 m depth contour makes distinguishing small areas of high coral cover very difficult with remote sensing, particularly given the pixel size of available imagery and the loss of red light to effectively distinguish algal and coral signatures beyond this depth. Therefore, the primary habitat classes shown in Figure 3-2 depict dominant classes, but macroalgal dominated areas also contain seagrass, coral dominant areas also contain macroalgae, and vice versa.

Divers were cognisant of locating potential large invasive marine species; however, this survey was not designed as a comprehensive assessment of invasive marine species, and existing port infrastructure, such as pylons and breakwaters were not surveyed.

Despite the above limitations, the data collected and presented in this report is considered adequate for EIS baseline characterisation.

3 Results

3.1 Bathymetry and Landform

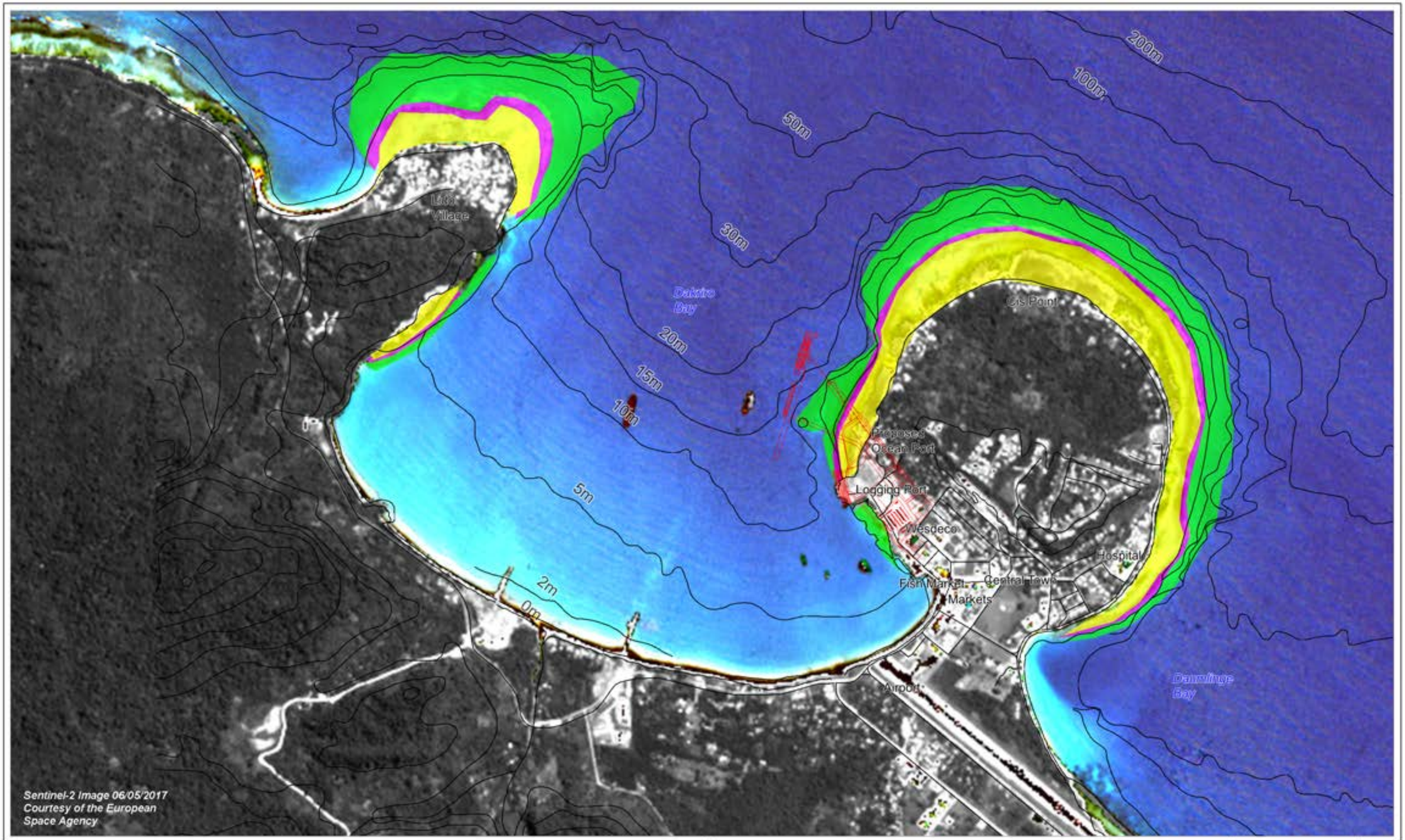
Dakriro Bay is a natural embayment created between the peninsula of Lido Village (sometimes referred to as Vanimo Village by locals) and Cis Point. Peninsular Vanimo (where the town centre is located) appears to have formed by the accretion of coralline and fluvial sediment that has bridged the shoreline to a former island (Figure 3-1). The fringing reef surrounding these features forms a reef flat to a crest, before sloping away at gradients that vary from vertical to low-relief. Shoreward from the beaches, the bathymetry is gently sloping (sand) to the centre of the bay.

The depth contours show an embayment in the reef platform south of Cis Point, that runs from 10 m below sea level to the reef crest. This break in the reef (and wave zone) is utilised extensively by local vessels. Water currents across the reef move in a north to south direction, across the reef flat, driven by the prevailing wave set-up originating from the north or north-east (see Section 1.5.2). At this break in the reef, water exits via this small natural harbour. Further south of Cis Point, near the ocean port, is a ledge of reef that extends in a south-westerly direction finishing in a small circular rise between the 5 and 10 m contours. The reef edge on the opposite side of Dakriro Bay is far less complex.

The central outer bay has a maximum depth of 50 m and is below the photic zone for the survival of coral reefs. Much of the inner part of Dakriro Bay is situated within the 20 m depth contour and has the potential to support deep water coral communities (Figure 3-1). Yet with the exception of the fringing reefs, there are no coral reefs charted within Dakriro Bay. Local knowledge is largely consistent with this information, apart from the presence of one small reef reported within south-eastern Dakriro Bay. It is also possible that non-photosynthetic rubble/ soft coral patches exist beyond the 30 m depth contour, as these are not of concern to navigation (therefore not charted), are deeper than most locals dive to, and are beyond the remote sensing limit.

The shoreline near the proposed ocean port and the hospital appears to be eroding is places, with high-tides and large wave events resulting in seawater entering typically terrestrial vegetation, such as grasses and gardens. Large logs line the shoreline where the ocean port is proposed, and act as a breakwater and waves of half a metre in height were observed breaking against them during the survey. We could not determine whether they were placed their intentionally or just washed up. It is suspected that they washed up and have been used opportunistically as a breakwater.

There are also patches of disturbance along the reef flat, where large areas of seagrass have recently been removed, and this coincided with patches of downed trees; consistent with wave or storm damage. There is very little if any vertical buffer between low-lying houses and gardens and the high-tide mark.



LEGEND

- Reef slope
- Reef crest
- Reef flat

Ocean Port Footprint

Title:
Bathymetry and Reef Zonation

Figure: 3-1

Rev: A

N

0 0.5 1 km

Approx. Scale

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3.2 Marine Habitats

Marine habitats within the Study Area consist of sandy beaches, subtidal sands, fringing coral reefs, and seagrass meadows. Quantifiable stands of mangroves were not observed within the Study Area, likely due to the wave energy, relatively coarse substrates and little riverine input.

Fringing coral reefs were covered by a mixture of sand, rubble, seagrasses and macroalgae over the reef flats, with substrate cover dominated by macroalgae, turfing algae, and coral down the reef slopes. The extents of these habitats are shown in Figure 3-2.

3.2.1 Unconsolidated Sediments

Unconsolidated sediment communities consisted of sands and muds, with fine fractions appearing more prevalent near drains, river mouths and the central bay (Figure 3-3 A, F, H). Sandy unconsolidated sediments over reef flats (Figure 3-3 C, D) and at the base of the reef slope (Figure 3-3 E) consisted almost entirely of calcium carbonate sands (coral sand). These shallow and deep sands are mapped as blue and yellow polygons, respectively in Figure 3-2.

As described in Section 3.1, the shoreline profile of all beaches was very gradual and lacked any significant dunes. Intertidal unconsolidated sediments were littered with marine debris, primarily hard and soft plastics, cans and bottles. The highest density of this debris was near open drains entering Dakriro Bay adjacent to the outdoor market and supermarket. No bioturbation (burrows) was observed at any of the beaches and it is unlikely that the beach width supports much infauna apart from ghost crabs and small hermit crabs.

With increasing distance offshore, the sand appeared to become slightly muddier in the central bay, and no bioturbation was observed; however, visibility conditions were very poor. Some slight bedforms were observed but without burrows. Visibility was insufficient to determine the presence of ray pits or flatfishes, but these deltaic muddy sands may support a range of flatfishes, rays, and inshore schooling species such as mullet and herring. The unconsolidated sediment area was not reported to be a significant fishing habitat by local fishermen, apart from occasionally finding rock lobsters beneath stray logs.

Coral sand and rubble on the reef flat supported similar species to those found in seagrass meadows, with the exception of sea urchins, which were more abundant in rubble areas than they were in dense seagrass. Echinoderms including urchins, sea stars, and sea cucumbers were the most dominant fauna of unconsolidated sediments on the reef flats (Figure 3-3 B, C). Bioturbation was not observed in unconsolidated reef sediments on the reef flat or at the base of reefs.

Dairiro Bay

Proposed Ocean Port

Logging Port

Wesdeco

Hospital

Fish Market

Central Town

Markets

Airport

Drainage Bay

Sentinel-2 Image 06/05/2017
Courtesy of the European Space Agency

LEGEND

- Seagrass Dominant
- Shallow Sand
- Deep Sand or Bare Reef
- Reef Dominated by Turfing Algae or Macroalgae
- Reef with High Coral Cover

Ocean Port Footprint

Title:
Marine Habitats

Figure: **3-2**

Rev: **A**

N

0 0.5 1 km

Approx. Scale

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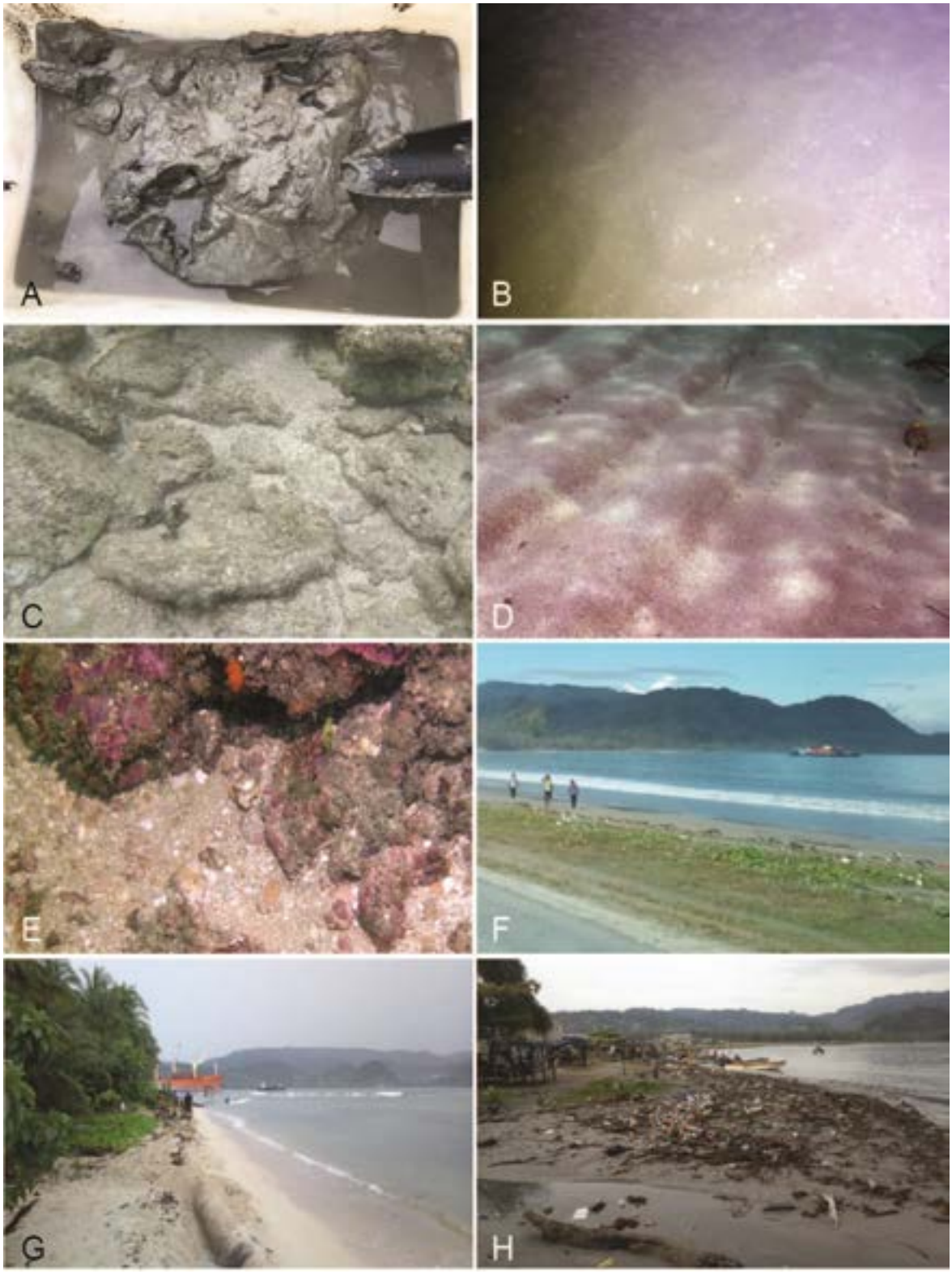


Figure 3-3 Examples of unconsolidated sediment: muddy sand from central Dakriro Bay (A); mixture of sand, mud and shell grit offshore from the proposed ocean port (B); coral sand amongst cobble on the ocean port reef flat (C); large bedforms in coral sand on the reef flat (D); coral sand and grit at the reef base in 15 m of water (E); beaches showing shallow profiles and marine debris near the airport (F), ocean port (G), and town centre (H)

3.2.2 Coral Communities

Coral communities are the most extensive, high-value marine habitat within the Study Area, but exist in a highly altered state under intense anthropogenic pressure. Stressors include thermal bleaching, sea-level rise, over-fishing, physical damage, low water quality as a result of stormwater and deforestation, and marine debris, which are likely affecting the health of coral reefs in the region cumulatively.

Areas of reef habitat are shown in Figure 3-2. The pink reef habitat area contains coral, but turfing and macroalgae substrates are considered dominant. Areas of more extensive coral cover (higher ecological value) are shown as a light orange polygon in Figure 3-2. Some areas of reef with high coral cover were considered artefacts of the capture period (due to aerated or turbid water reducing the macroalgal signature) and were replaced with shallow sand classifications after ground-truthing.

The most extensive reef areas exist near Cis Point and north of Lido Village, where the reef slope runs from the reef crest gradually down to the 20 m depth contour (Figure 3-2). While reef habitats are extensive at Cis point, living coral cover is typically low (Figure 3-4). The reef flat is also widest at these locations, becoming narrower with distance inside Dakriro Bay. At the southern limits of these reefs (farthest inside Dakriro Bay), the coral / algal substrate gives way to unconsolidated habitat at the 5 m contour. The difference in depth penetration of coral communities among various parts of the fringing reef is likely the result of water quality (turbidity and salinity) and hydrodynamics. Reefs that are far away from river mouths and stormwater outlets, and exposed to more oceanic water, are more extensive. Unconsolidated sediments on the reef flat and at the base of the reef slope at the southern reef extremities consisted of a mixture of fine particles as well as calcium carbonate sands. Conversely, sediments at the outermost (northern) parts of the fringing reef were lacking fine particles, the water was consistently clear, and wave size was large.

The combination of large waves, clear water, and greater distance from catchment input at the northern reef fronts has facilitated these habitats to remain free of turbidity and deposited fine sediment deposition, which has allowed them to proliferate to greater depths and establish wider reef flats. Lower wave energy within the southern part of Dakriro Bay allows the settlement of fine particles which affects the light regime and benthic composition, resulting in lower rates of calcification (coral growth), more sediment accumulation, less depth range and less extensive reef flats.

Although the reef flats are dominated by seagrasses, unconsolidated sediments and macroalgae, occasional coral colonies (*Goniastrea, Porites lobata* and *P. latistella*) were found in small lagoons, depressions, and pools. The cover of corals increased across the reef flat with proximity to the reef crest. Very protected reefs such as the reef closest to the central town did not have an obvious reef crest and the transition from shore to reef edge was more gradual.

Sections of fringing reef exposed to high wave energy have a well-established reef crest, composed of cemented coral fragments with a dense covering of *Turbinaria* algae. These form short (a few centimetres) to long (1 m) ropes of algae in the wave-break area, with very high wave-energy areas having shorter strands. *Turbinaria* is heavily calcified yet flexible, and its movement affects the ability of corals to settle and survive due to physical abrasion. Wave climate, although highly seasonal (Section 1.5.2), is significant enough to create large spur and groove formations on the reef fronts (Figure 3-5 G).

Reef slopes typically had the highest cover of living coral, but this was highly variable among ground-truthing sites located in close proximity (Figure 3-4). Very high coral cover was observed at one location on the reef slope near the proposed ocean port (representing a large coral outcrop), but generally it was low and had an overall average cover of almost 13% on the reef slope and crest (Appendix A, Table A-1). Twenty genera were observed, and up to eight coral genera were recorded in any one transect. Example imagery from the reef near the proposed ocean port is shown in Figure 3-5.

The lowest level of coral cover over reef substrate was recorded at transects near Cis Point (Appendix A, Table A-1; Figure 3-2). These surfaces tended to be heavily covered in turfing algae and macroalgae, with the surveyed area having an overall average living coral cover of approximately 5%. Fifteen genera were recorded here with seven genera being the highest number of corals recorded on any one transect (Appendix A, Table A-1). However, it should be noted that shallow areas near the wave break zone were not surveyed comprehensively due to safety concerns, as waves of 2 m or greater were present at this location for the duration of the field trip.

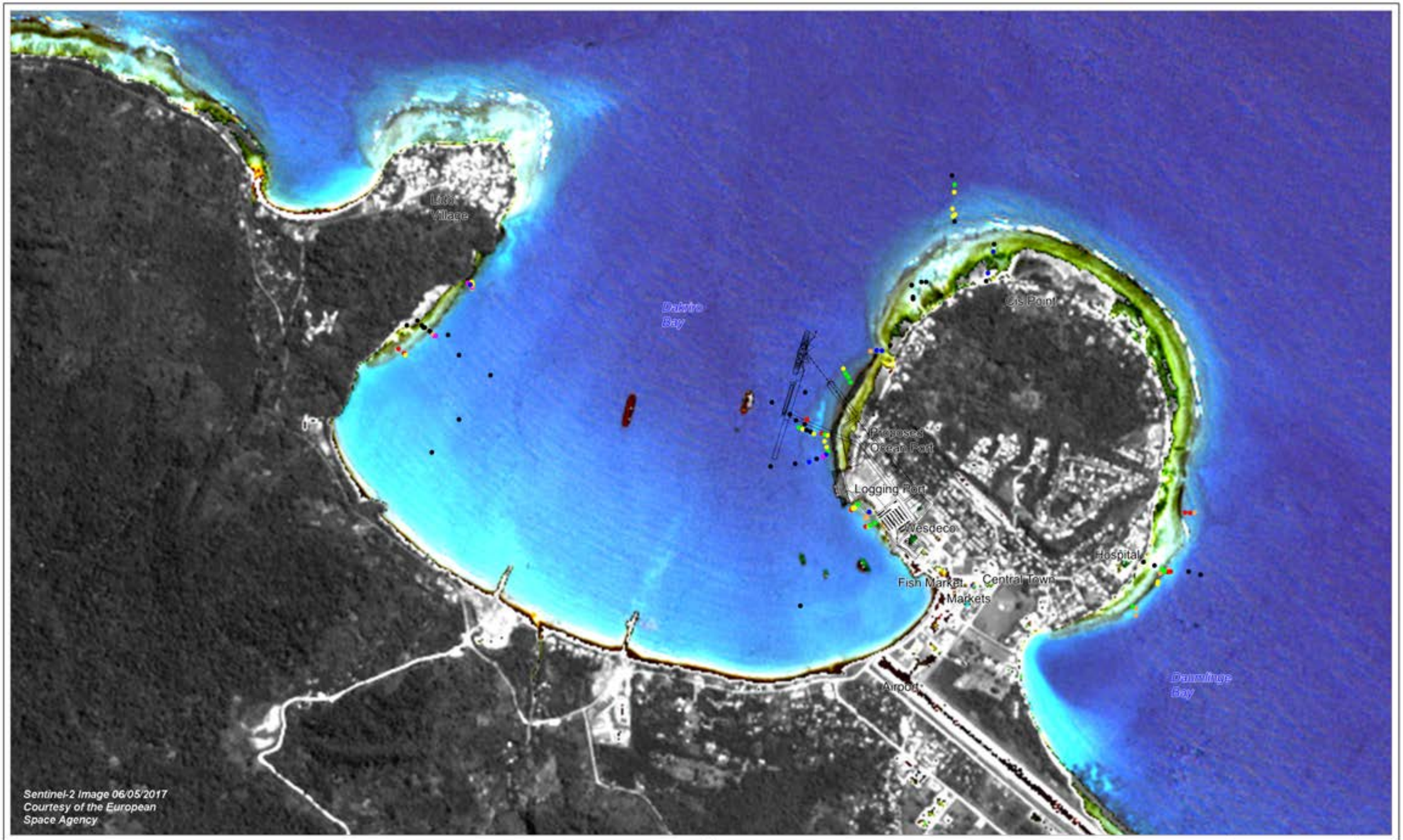
Transects east of the hospital on the reef crest and slope had an average coral cover of 16.7%, and coral richness of 22 genera (Appendix A, Table A-1). This area had the highest coral richness and was the second highest area for coral cover. The reef south of the existing logging port had an average coral cover of 12.9% and an overall richness of 15 genera. Up to eight genera were observed within individual transects at the hospital and the logging port areas.

The reef at Lido Village (Lido) had the highest average coral cover (24.7%) over the reef crest and slope, with a total generic richness of 15. A single transect at this reef had the highest coral richness across the entire study, with nine genera observed within 5 m.

Transects located off the reef edge in unconsolidated sediment are collectively referred to as Dakriro Bay sites in Table A-1 (Appendix A). Very little coral was present at these sites; there was only one small colony observed on rubble near the existing logging port, otherwise Dakriro Bay sites were without coral.

Sample photos from the reef near Lido Village are shown in Figure 3-6. Reef communities at the northern extremity of Lido Village were not assessed due to large breaking waves at the time of the survey. However, local guides suggested that the area supported some of the best reef in Dakriro Bay in terms of coral cover and fish abundance.

Based on the above data and field observations, reefs throughout the region appear to be heavily affected by human activities. Coral cover is generally low and there was evidence of thermal bleaching, sedimentation, and copious marine debris at various places across the Study Area. The reef at Lido Village appeared to be in better condition than other areas, and more fish were observed here than the reefs at the proposed ocean port or near the existing logging port (Section 3.3).



LEGEND

- 0% Coral Cover
- 1 - 2 % Coral Cover
- 2 - 5 % Coral Cover
- 5 - 15 % Coral Cover
- 15 - 30 % Coral Cover
- 30 - 50% Coral Cover
- > 50% Coral Cover

Ocean Port Footprint

Title:
Thematic Coral Cover

Figure: 3-4

Rev: A

N

0 0.5 1 km

Approx. Scale

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Figure 3-5 Coral communities on reefs near the proposed ocean port: (A) *Leptoria* and *Montastrea*; (B) *Seriatophora*; (C) *Porites*; (D) *Sandolitha*; (E) *Oulophyllia*; (F)*Sarcophyton*; (G)spur and groove formation on the reef front; (H)plastic waste

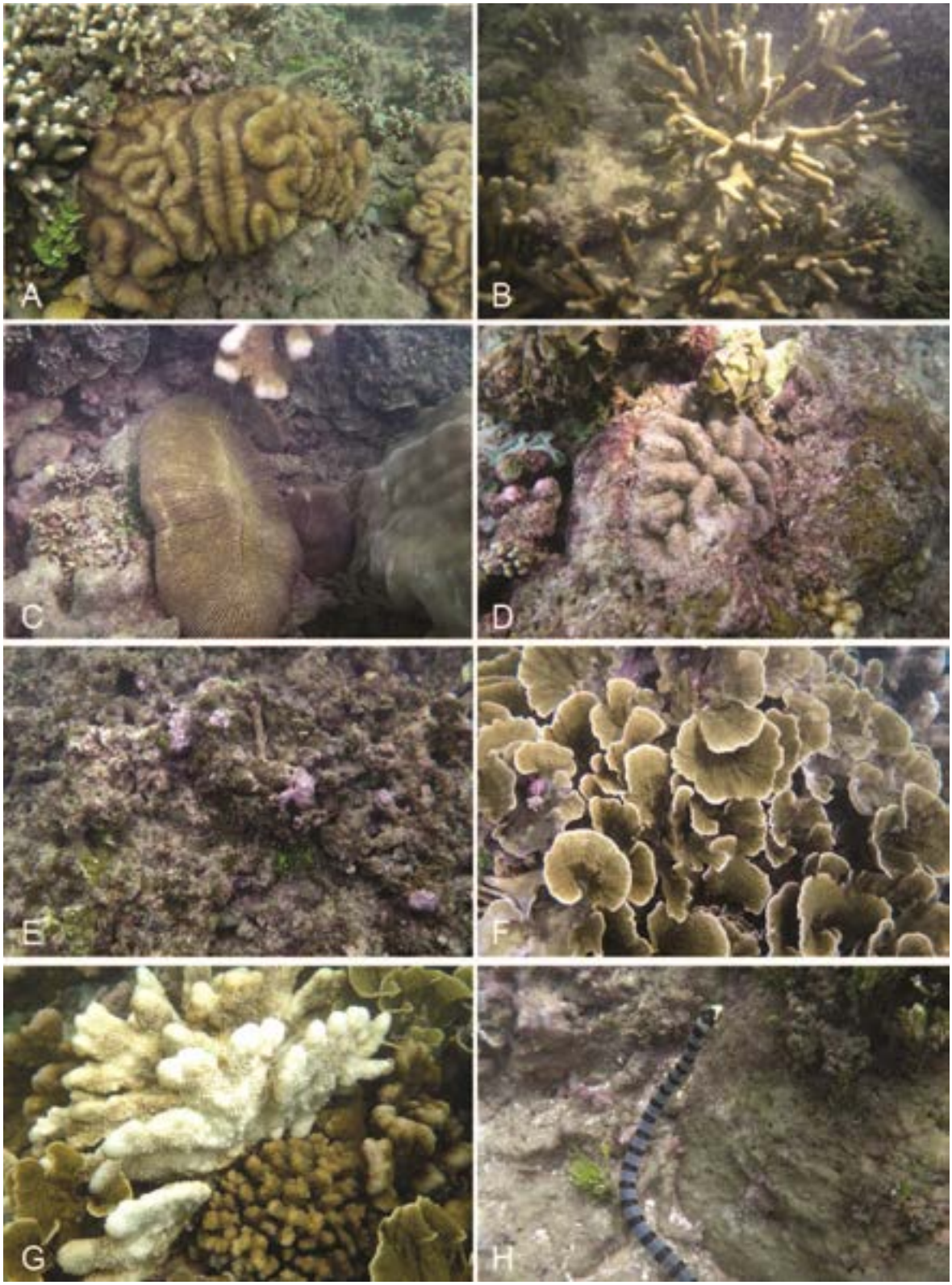

Figure 3-6 Coral communities of the Lido Village fringing reef: (A) *Lobophyllia*; (B)*Porites latistella*; (C) *Ctenactis* and *Fungia*; (D) *Symphyllia*; (E) crest community; (F) dense stands of plating *Montipora*; (G) bleached *Isopora palifera*; (H) banded sea krait *Laticauda colubrina*

3.2.3 Macroalgae

Macroalgal communities were highly abundant at all the reefs visited and were most dominant near the reef crest and landward of the crest across the reef flat, but could be found in patches across seagrass meadows and throughout the reef slope. Species of *Sargassum, Halimeda* and *Padina* dominated the reef flat (Figure 3-7 A), while *Turbinaria* (algae) and encrusting red algae were dominant in wave break areas (Figure 3-7 B, C, D).

Where the reef flat was wide and subject to more wave energy, *Sargassum* was most prevalent near the reef crest, but could be found occasionally in seagrass meadows, among the crest community (Figure 3-7 E), and in depressions on the reef flat.

With depth away from the reef crest, large fleshy macroalgae became less abundant, and species such as *Halimeda* and cementing forms such as crustose coralline algae became more prevalent (Figure 3-7 F).

3.2.4 Seagrass

Seagrass communities were the dominant marine plants over much of the reef flat in the Study Area (Figure 3-2). Areas of seagrass depicted in Figure 3-2 show dense meadows similar to that shown in Figure 3-8 D. However, it should be noted that other areas of reef flat not classified as seagrass also contained sparser cover of seagrass amongst macroalgae, sand, and coral (Figure 3-8F).

Dense seagrass communities were typically dominated by *Thalassia hemprichii, Halodule uninervis, Cymodocea serrulata* and *C. rotundata* (Figure 3-8 C, D). However, other species including *Halophila ovalis* (Figure 3-8 F*,) Syringodium isoetifolium,* and *Enhalus acoroides* (Figure 3-8 A), were found amongst these denser species, occasionally forming small dense patches of cover alone.

In terms of spatial pattern, *E. acoroides* tended to be found in established, dense meadows on the reef flat, or in more turbid parts of Dakriro Bay that experience less wave energy. *Halophila ovalis* was usually present as a minor understory component of dense meadows, or as a thin veneer over reef sediments.

Where seagrass was present, it appeared to be in good health with few epiphytes, with the exception of areas near Cis Point. There were often calcareous epiphytes growing on *E. acoroides,* but this is not unusual given its long life and large growth form. As mentioned in Section 3.1, there were several areas of the reef flat near Cis Point which appeared to have recently experienced a significant disturbance, which coincided with areas of disturbed shoreline, including fallen vegetation and erosion. Seagrass meadows directly in front of these areas consisted of root mass without any above-ground vegetation (Figure 3-8 E), as though a very large meadow had been recently removed, leaving only rhizomes. Apart from these disturbance areas near Cis Point, seagrass communities appeared to be in good health.

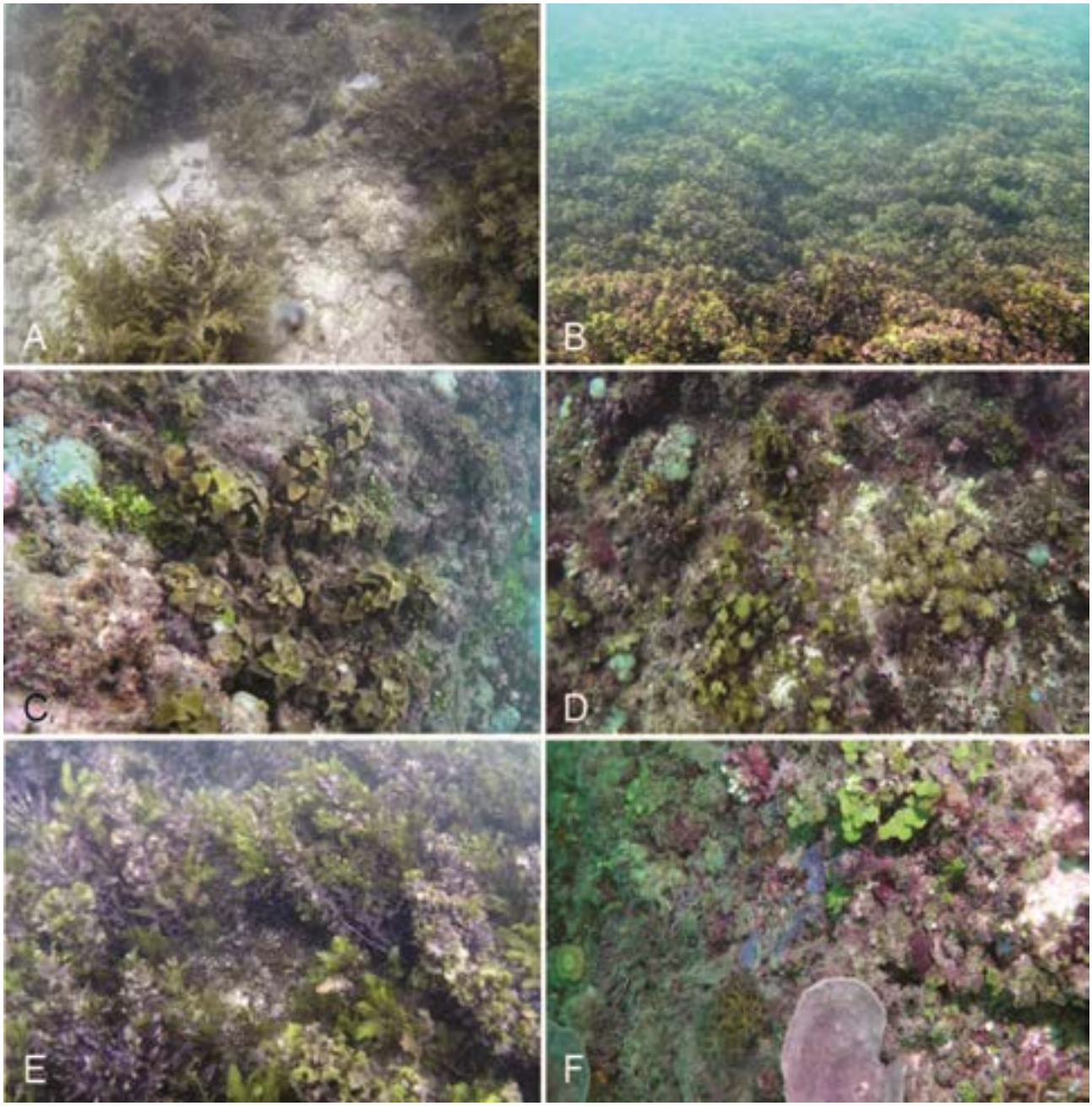

Figure 3-7 Macroalgal communities: (A) *Sargassum* spp.; (B) thick rope-like *Turbinaria*; (C) moderately long *Turbinaria* on the reef crest; (D) sparse *Turbinaria,* turfing algae, and corals; (E)dense *Sargassum* and turf; (F)*Halimeda,* sponges, and crustose coralline algae in deeper clear waters

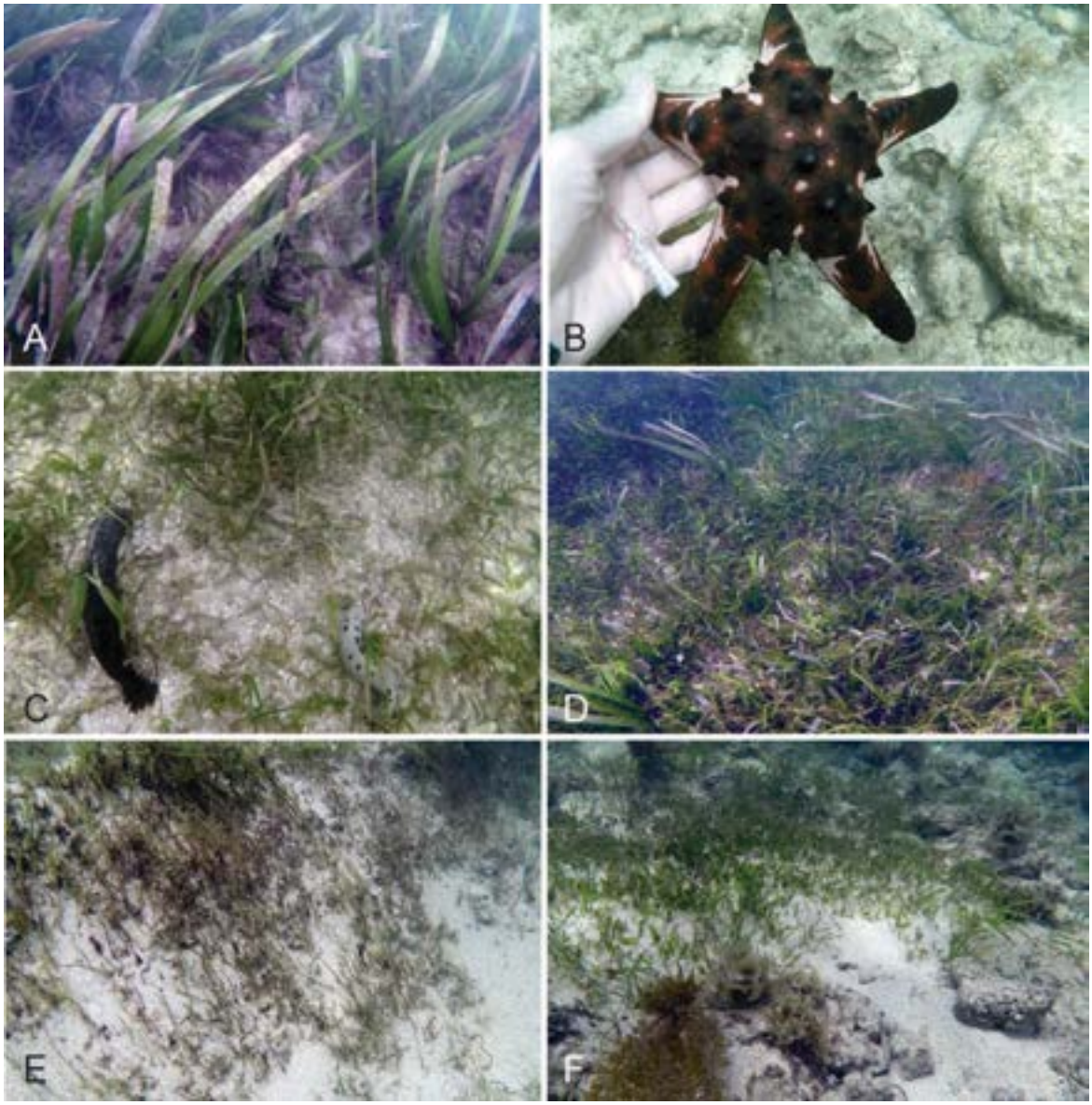

Figure 3-8 Seagrass communities of Dakriro Bay: (A) thick *Enhalus acoroides*; (B) sea stars *Protoreaster nodulosus*; (C) sea cucumbers *Holothuria leucospilota* and *H. atra*; (D) dense mixed community of *E. acroides, Syringoidum isoetifolium, Cymodocea* spp. and *H. ovalis*; (E) rhizomes and below ground biomass visible in disturbance areas; (F) mixtures of seagrass, rubble and macroalgae on the reef flat

3.2.5 Invasive Marine Species

While a survey of introduced marine species was not specifically conducted, during benthic surveys, none of the following large invasive species known from tropical northern Australia were seen: *Plumularia setacea,* (plume hydroid), *Perna viridis* (Asian green mussel), *Mytilopsis sallei* (black-striped mussel), *Megabalanus tintinnabulum* (tital acron barnacle), *Hydroides sanctaecrucis* (tubeworm), or *Caulerpa taxifolia.*

3.3 Fish Communities and Fisheries

3.3.1 BRUVs

BRUV data showed that fish communities in Dakriro Bay are highly overfished compared to other managed tropical fisheries, such as those in northern Australia. Reefs close to large villages in PNG typically have low numbers of reef fish, but the reefs of Dakriro Bay had low abundance, even in the context of PNG. Typical numbers of individuals observed on Australian coral reefs ('MaxN'; the maximum number of fish observed on the screen) vary between 30 and 50 individuals and from 11 to 16 species (Dorman et al., 2012). Of the two deployments in Dakriro Bay, no fish were observed at the reef near the proposed ocean port, and one school of passing fish fry was observed at Lido Village (Figure 3-9 A).

While very few fish were seen on the BRUVs, some very reduced communities were observed nearby while swimming. This suggests that some of the absence of fish in BRUVs is related to behavioural changes, as well as reduced abundance. It is likely that persistent, strong fishing pressure in the form of spear and line fishing has led to bait avoidance, and a restriction of home ranges in the fish that remain on the reef.

3.3.2 Observed Communities

Fish were seldom observed during diver ground-truthing of transects. Fish size and abundance was far lower than comparable fringing reefs in northern Australia, and was also lower than we have observed in other locations in PNG, such as Manus Island, the Admiralty Islands, Alotau, Daru, and Caution Bay.

Field observations made during the survey generally agreed with information from discussions with local divers, and market vendors. The reefs near the proposed ocean port and the logging port, had the most depauperate communities; very few fish were sighted apart from some anemonefish, very occasional small damsels and wrasses, and one large unicorn fish (*Naso unicornis*). The fish communities appeared more abundant at the reefs south of Lido Village, than the reefs near the proposed ocean port or the existing logging port. While few fish were observed at Lido Village sites, some small butterflyfish, bannerfish, damselfish and wrasses were present (Figure 3-9 B) as well as a banded sea snake (Figure 3-6 H). All fish observed were incredibly wary of observation and displayed strong avoidance behaviour. Where fish were present, they tended to associate with areas of living coral, and were seldom observed in dense macroalgae.

The most abundant, and largest fish were observed in transects south of the hospital (Figure 3-9 C). Fish including moderate to small wrasses (Labridae), snappers (Lutjanidae), surgeonfishes (Acanthuridae), butterflyfish, damselfish and a green sea turtle (Figure 3-9 H) were also observed at this location. Specimens were collected for metal burden testing from this location and included surgeonfish, trigger fish (*Rhinecanthus verrucosus*), goatfish (Mullidae), and small wire-netting cod (*Epinephelus merra*) (see Section 3.6).

Attempts by fishermen to collect fish specimens directly from the reef near the proposed ocean port or the logging port for metal burden testing, were unsuccessful. Fish for metal burden testing were instead collected from the reef in front of the hospital, which coincided with where we saw the most fish.

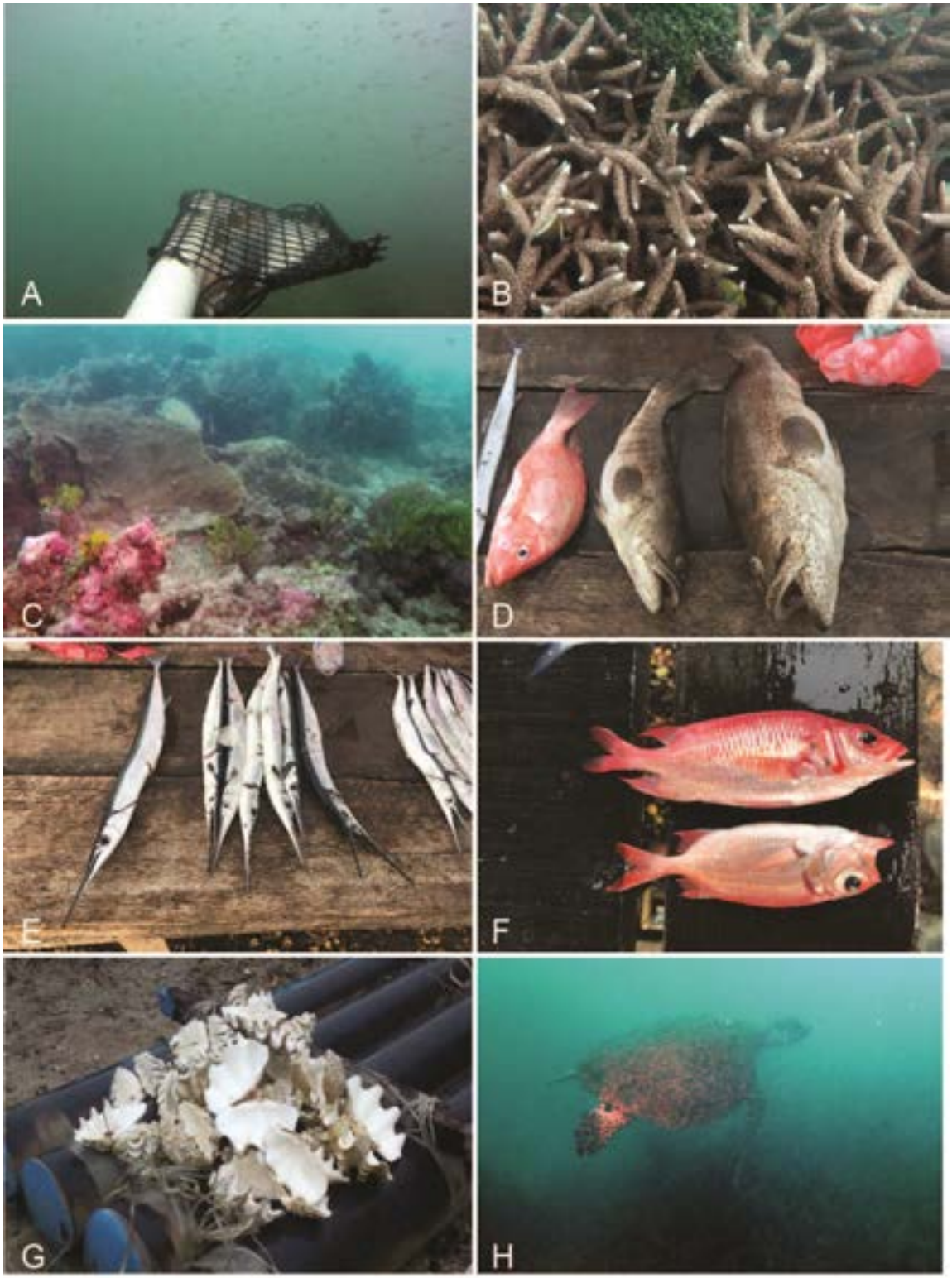

Figure 3-9 Fish communities and marine resources in the Study Area: (A) fry observed at a BRUV at Lido Village; (B) bannerfish (*Heniochus varius*) and *Chromis* spp. at Lido Village; (C) snapper (lutjanids) and surgeonfish (acanthurids) near the Hospital; (D) scarlet sea perch (*Lutjanus malabaricus)* and estuary cod (*Epinephelus coioides*); (E) long tom; (F) squirrelfishes (Holocentridae); (G) giant clams (*Tridacna squamosa*); (H) green turtle (*Chelonia mydas*)

3.3.3 Fisheries

Fisheries within the Study Area are comprised of artisanal (for direct consumption), local (for market) and commercial fishing.

Artisanal fishing is conducted by the residents living adjacent to the reefs in the Study Area. Fishing occurs at night using flashlights and spears, to take advantage of sleeping fish. Spearfishing also occurs during the day; however, usually with less success. Spearfishing is more common in the dry season, when conditions are more favourable with better visibility and smaller waves. The fish that remain on the reef are extremely wary due to the intense artisanal fishing pressure.

Locals report that the reef front north of Lido Village has good coral cover, and is one of the better locations for spearfishing, as the fish are larger and more abundant. Line and net fishing occurs along the beaches near central town by fishers lacking boats or means to travel further afield. Nets are occasionally pulled across the beaches (seined) for small schooling fish. Seining was not observed during the survey but is reported to occur at other times.

Fishers with access to vessels Line-fish deeper reef areas offshore from the entrance to Dakriro Bay, which can yield larger reef fish. From June to September, there are greater numbers of pelagic species such as tuna, and local fishermen troll for them with feathered lures on monofilament lines. Also during the dry season (June and July), red emperor (*Lutjanus* spp.) are caught within Dakriro Bay over deep gravel habitats. Fish are sold at the market when artisanal catches are larger than what can be consumed (they sell excess catch).

During the survey, excess catch was sold at the local fish market from sunrise until 7 am. During the survey very few fish were being sold (there were several days where catch was not available), and days when the fish for sale were not from Dakriro Bay. Specimens included freshwater fish (*Tilapia*), which were fresh or smoked and brought in by road or opportunistically by plane from elsewhere.

Marine fish for sale included:

- Long-tom (Belonidae), available most days, collected from surface waters beyond Dakriro Bay (Figure 3-9 E).
- small garfish and flying fish.
- estuary cod (*Epinephelus coioides*) (Figure 3-9 D).
- scarlet sea perch (*Lutjanus malabaricus*) (Figure 3-9 D).
- squirrelfishes (Holocentridae) (Figure 3-9 F).

Unlike other parts of PNG, trepang (sea cucumbers) are not collected for export or local consumption, nor are there any established diving industries for crayfish, pearls, or shellfish.

Overseas fishing vessels operate offshore from Vanimo, with Global Fishing Watch (2018) showing the efforts of four vessels (through Automatic Identification System [AIS] tracking) in the last six months. The intensity of fishing from these vessels (Figure 3-10), shows that most of this activity is restricted to offshore waters starting approximately 30 km north of Vanimo. Smaller vessels fish for tuna and mackerel within the Study Area (outside Dakriro Bay).

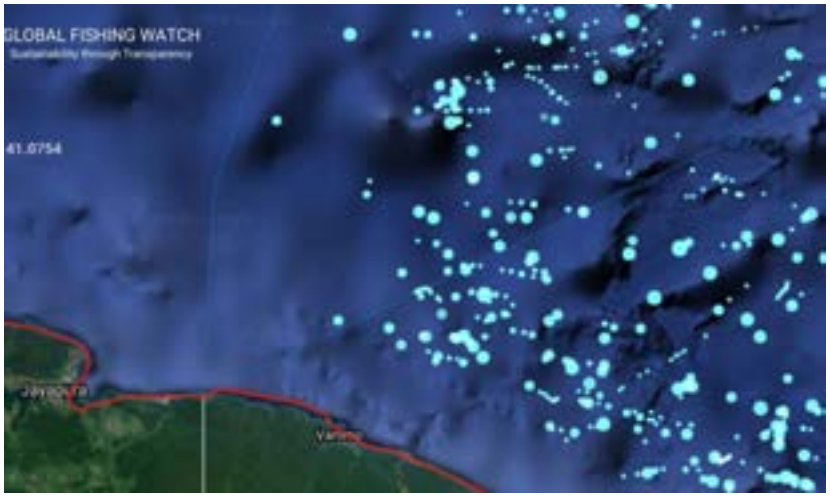

Figure 3-10 Offshore fishing effort in the six months (June to November) 2017 (Global Fishing Watch 2018)

Historical data for this region (Kumoru and Koren 2006) suggests that the offshore vessels are primarily purse seiners. Global fishing watch lists vessels from PNG, the Philippines and China as participating in fishing activities in the last six months, while Kumoru and Koren (2006) also mention Korea and Chinese Taipei in the purse seine fleet. These vessels target skipjack, yellowfin, and bigeye tuna, but also take small pacific mackerel, frigate tuna, mackerel tuna, sharks and rays.

Foreign vessel catch is regulated by the PNG Fisheries based in Vanimo. Licensees pay a fee of ~$8,000 USD per day for access to the tuna fisheries.

3.3.4 Species of Conservation Significance

No living clams (*Tridacna gigas*, Vulnerable under the International Union for the Conservation of Nature [IUCN]; *T. squamosa*, IUCN Lower Risk) were observed during ground-truthing exercises, but numerous *T. squamosa* shells were found in gardens around the shoreline (Figure 3-9 G). It is likely that all tridacnid species have occurred historically in the survey area, but are heavily fished and may be locally extinct.

Two green turtles (*Chelonia mydas,* Endangered) were observed during ground-truthing, one directly in front of the logging port and a second animal in 12m of water offshore from the hospital (Figure 3-9 H). Other marine turtle species including loggerheads, leatherback, olive-Ridley turtles, and Hawksbill turtles have ranges and habitats overlapping with the Study Area, but were not observed at the time of survey. Beaches above the fringing reefs are not sufficiently high above sea level to support sea turtle nesting. Sandy beaches without fringing reefs (between the peninsulas of Dakriro Bay) are wide enough and high enough to support turtle nesting, but it is not known whether turtles utilise these beaches or whether egg harvesting occurs. All beaches in Dakriro Bay are regularly frequented by locals (fishing and collecting) and the beach profiles have been modified by log export facilities. These impacts may limit the utility of these beaches to nesting turtles.

There is no locally specific information regarding the presence of other threatened species in the Study Area and apart from tridacnid clams and green turtles, no others were observed.

3.4 Water Quality

Table 3-1 presents the water quality results for each of the survey sites. Laboratory reports are provided in Appendix B.

Water quality depth profiling data (*in situ* measurements recorded through the water column from surface to bottom) from each survey site are presented in Figure 3-11 and Figure 3-12.

In brief, water quality characteristics were similar at all sites, with sites generally typified by warm waters with low concentrations of suspended sediments (TSS and turbidity) and low concentrations of nutrients, metals/metalloids and hydrocarbons. Exceedances of the most stringent guideline values are indicated in Table 3-1 as highlighted cells. Water quality results can be summarised as follows:

- Water temperature was consistent among the survey sites, with temperature around 30°C at the surface and changing little with depth (Figure 3-11).
- Conductivity and salinity values were typical of marine waters, with conductivity of ~52,000 µS/cm and salinity of ~34 ppt in surface waters. Conductivity increased slightly up to 53,000 µS/cm in water depths greater than 5 m (Figure 3-11).
- Turbidity ranged from 0.8 to 3.3 NTU in surface waters (i.e. at 0.3 m depth), and TSS ranged from 1 to 5 mg/L. The highest turbidity and TSS was recorded at site M4 located in the nearshore environment in Dakriro Bay (Table 3-1). Turbidity spiked in bottom waters at most sites (Figure 3-11), most likely due to increased suspended sediments from the sea bed.
- Dissolved oxygen at each site was between 93% saturated and 98% saturated, and between 6.0 mg/L and 6.1 mg/L. Dissolved oxygen levels at all sites were above the PNG ER criteria (>5 mg/L) and the PNG ECoP guideline value (>6 mg/L). Dissolved oxygen was slightly higher (by 2-3 % sat) in water depths around 5 m, then decreased slightly (by 3-5 % saturated) in water depths greater than 5 to 10 m (Figure 3-11).
- pH was also consistent among the survey sites, with pH values of around 8.2, and remained consistent through the water column (Figure 3-12). This pH is typical of seawater.
- Total and dissolved metal/metalloid concentrations were generally consistent among survey sites. The exception was site M4 which had higher concentrations of a number of total metals/metalloids, which reflects the higher TSS at this site. However, dissolved concentrations of metals/metalloids at site M4 were similar to other sites.
- All sites had dissolved metal/metalloid concentrations below guideline values. The exception to this was dissolved boron which exceeded the PNG ER (2,000 µg/L) at all sites. However, the concentrations of boron detected at the sites (4,150 to 5,380 µg/L) are typical concentrations found in seawater (4,500 to 5,100 µg/L as per Section 8.3.7.1 of ANZECC/ARMCANZ 2000).
- Nutrients were mostly below the laboratory limit of reporting (LOR) at each site. The only detections were low levels (0.02 to 0.11 mg/L) of ammonia at all sites, however the concentrations were all below guideline values.

- Hydrocarbons (TPH, TRH, BTEXN, PAH and oil & grease) were recorded at concentrations below the LOR at all sites.

Table 3-1 Water Quality Results

Parameter	Units	Survey Sites				Guideline Values		
		M1	M2	M3	M4	*PNG ER*	*PNG ECoP*	*ANZECC*
Temperature	°C	29.7	29.9	29.7	29.9	-	-	-
Electrical Conductivity (EC)	µS/cm	52,302	52,618	52,118	52,152	-	-	-
Salinity	Ppt	34.3	34.5	34.2	34.2	-	-	-
pH	-	8.17	8.21	8.18	8.18	no alteration	-	-
Turbidity	NTU	1.5	0.8	2.3	3.3	no alteration >25	-	-
Dissolved Oxygen (DO)	% sat	93.9	98.1	97.5	97.9	-	>80	-
	mg/L	6.0	6.2	6.1	6.1	>5	>6	-
Total suspended solids (TSS)	mg/L	1	2	1	5	-	-	-
Total Metals/Metalloids								
Aluminium (Al)	µg/L	33	44	61	102	-	-	-
Arsenic (As)	µg/L	1.5	1.5	1.5	1.4	-	-	-
Barium (Ba)	µg/L	4	4	4	6	-	-	-
Boron (B)	µg/L	5,180	5,310	5,380	4,150	-	-	-
Cadmium (Cd)	µg/L	<0.2	<0.2	<0.2	<0.2	-	-	-
Chromium (Cr)	µg/L	<0.5	<0.5	<0.5	2.8	-	-	-
Cobalt (Co)	µg/L	<0.2	<0.2	<0.2	0.5	-	-	-
Copper (Cu)	µg/L	<1	<1	<1	1	-	-	-
Iron (Fe)	µg/L	70	71	107	184	-	-	-
Mercury (Hg)	µg/L	<0.04	<0.04	<0.04	<0.04	-	-	-
Manganese (Mn)	µg/L	1.1	1.4	1.4	12.2	-	-	-
Nickel (Ni)	µg/L	<0.5	<0.5	<0.5	25.1	-	-	-
Lead (Pb)	µg/L	<0.2	<0.2	<0.2	<0.2	-	-	-
Selenium (Se)	µg/L	5	5	5	6	-	-	-
Silver (Ag)	µg/L	<0.1	<0.1	0.2	<0.1	-	-	-
Tin (Sn)	µg/L	<5	<5	<5	<5	-	-	-
Vanadium (V)	µg/L	1.2	1.3	1.3	1.8	-	-	-
Zinc (Zn)	µg/L	<5	<5	<5	<5	-	-	-
Dissolved Metals/Metalloids								
Aluminium (Al)	µg/L	<5	<5	<5	<5	-	-	-
Arsenic (As)	µg/L	1.3	1.5	1.3	1.2	50	50	-
Barium (Ba)	µg/L	4	5	4	5	1,000	-	-
Boron (B)	µg/L	4,320	3,500	4,280	3,990	2,000	-	-
Cadmium (Cd)	µg/L	<0.2	<0.2	<0.2	<0.2	1	2	0.7
Chromium (Cr)	µg/L	<0.5	<0.5	<0.5	<0.5	10	50	4.4

Parameter	Units	Survey Sites				Guideline Values		
		M1	M2	M3	M4	*PNG ER*	*PNG ECoP*	*ANZECC*
Cobalt (Co)	µg/L	<0.2	<0.2	<0.2	<0.2	0.2	0.9	1
Copper (Cu)	µg/L	<1	<1	<1	<1	30	5	1.3
Iron (Fe)	µg/L	<5	<5	<5	<5	1,000	-	-
Mercury (Hg)	µg/L	<0.04	<0.04	<0.04	<0.04	0.2	0.1	0.1
Manganese (Mn)	µg/L	<0.5	<0.5	<0.5	<0.5	2,000	100	-
Nickel (Ni)	µg/L	<0.5	<0.5	<0.5	<0.5	1,000	15	7
Lead (Pb)	µg/L	<0.2	<0.2	<0.2	<0.2	4	5	4.4
Selenium (Se)	µg/L	3	3	4	3	10	70	-
Silver (Ag)	µg/L	<0.1	<0.1	<0.1	<0.1	50	1	1.4
Tin (Sn)	µg/L	<5	<5	<5	<5	0.5	-	-
Vanadium (V)	µg/L	1.6	1.8	1.7	1.6	-	-	100
Zinc (Zn)	µg/L	<5	<5	<5	<5	5,000	50	15
Nutrients								
Total nitrogen	mg/L	<0.5	<0.5	<0.5	<0.5	-	-	-
Total Kjeldahl nitrogen	mg/L	<0.5	<0.5	<0.5	<0.5	-	-	-
Nitrite	mg/L	<0.01	<0.01	<0.01	<0.01	-	-	-
Nitrate	mg/L	<0.01	<0.01	<0.01	<0.01	45	-	-
NOx	mg/L	<0.01	<0.01	<0.01	<0.01	-	-	-
Ammonia	mg/L	0.02	0.05	0.11	0.11	-	-	0.91
Total phosphorus	mg/L	<0.05	<0.05	<0.05	<0.05	-	-	-
Reactive phosphorus	mg/L	<0.01	<0.01	<0.01	<0.01	-	-	-
Total Petroleum Hydrocarbons (TPH)								
C6 - C9 Fraction	µg/L	<20	<20	<20	<20	-	-	-
C10 - C14 Fraction	µg/L	<50	<50	<50	<50	-	-	-
C15 - C28 Fraction	µg/L	<100	<100	<100	<100	-	-	-
C29 - C36 Fraction	µg/L	<50	<50	<50	<50	-	-	-
C10 - C36 Fraction (sum)	µg/L	<50	<50	<50	<50	-	-	-
Total Recoverable Hydrocarbons (TRH)								
C6 - C10 Fraction	µg/L	<20	<20	<20	<20	-	-	-
C6 - C10 Fraction minus BTEX (F1)	µg/L	<20	<20	<20	<20	-	-	-
>C10 - C16 Fraction	µg/L	<100	<100	<100	<100	-	-	-
>C16 - C34 Fraction	µg/L	<100	<100	<100	<100	-	-	-
>C34 - C40 Fraction	µg/L	<100	<100	<100	<100	-	-	-
>C10 - C40 Fraction (sum)	µg/L	<100	<100	<100	<100	-	-	-
>C10 - C16 Fraction minus Naphthalene (F2)	µg/L	<100	<100	<100	<100	-	-	-
BTEXN								
Benzene	µg/L	<1	<1	<1	<1	-	-	-
Toluene	µg/L	<2	<2	<2	<2	-	-	-

Parameter	Units	Survey Sites				Guideline Values		
		M1	M2	M3	M4	*PNG ER*	*PNG ECoP*	*ANZECC*
Ethylbenzene	µg/L	<2	<2	<2	<2	-	-	-
meta- & para-Xylene	µg/L	<2	<2	<2	<2	-	-	-
ortho-Xylene	µg/L	<2	<2	<2	<2	-	-	-
Total Xylenes	µg/L	<2	<2	<2	<2	-	-	-
Sum of BTEX	µg/L	<1	<1	<1	<1	-	-	-
Naphthalene	µg/L	<5	<5	<5	<5	-	-	-
Oil & Grease								
Oil & Grease	mg/L	<5	<5	<5	<5	None present	-	-
Polynuclear Aromatic Hydrocarbons								
Naphthalene	mg/L	<1.0	<1.0	<1.0	<1.0	-	-	-
Acenaphthylene	mg/L	<1.0	<1.0	<1.0	<1.0	-	-	-
Acenaphthene	mg/L	<1.0	<1.0	<1.0	<1.0	-	-	-
Fluorene	mg/L	<1.0	<1.0	<1.0	<1.0	-	-	-
Phenanthrene	mg/L	<1.0	<1.0	<1.0	<1.0	-	-	-
Anthracene	mg/L	<1.0	<1.0	<1.0	<1.0	-	-	-
Fluoranthene	mg/L	<1.0	<1.0	<1.0	<1.0	-	-	-
Pyrene	mg/L	<1.0	<1.0	<1.0	<1.0	-	-	-
Benz(a)anthracene	mg/L	<1.0	<1.0	<1.0	<1.0	-	-	-
Chrysene	mg/L	<1.0	<1.0	<1.0	<1.0	-	-	-
Benzo(b+j)fluoranthene	mg/L	<1.0	<1.0	<1.0	<1.0	-	-	-
Benzo(k)fluoranthene	mg/L	<1.0	<1.0	<1.0	<1.0	-	-	-
Benzo(a)pyrene	mg/L	<0.5	<0.5	<0.5	<0.5	-	-	-
Indeno(1.2.3.cd)pyrene	mg/L	<1.0	<1.0	<1.0	<1.0	-	-	-
Dibenz(a.h)anthracene	mg/L	<1.0	<1.0	<1.0	<1.0	-	-	-
Benzo(g.h.i)perylene	mg/L	<1.0	<1.0	<1.0	<1.0	-	-	-
Sum of polycyclic aromatic hydrocarbons	mg/L	<0.5	<0.5	<0.5	<0.5	-	-	-
Benzo(a)pyrene TEQ (zero)	mg/L	<0.5	<0.5	<0.5	<0.5	-	-	-

Note: highlighted cells indicate exceedance of the most stringent of the stated criteria/guideline values

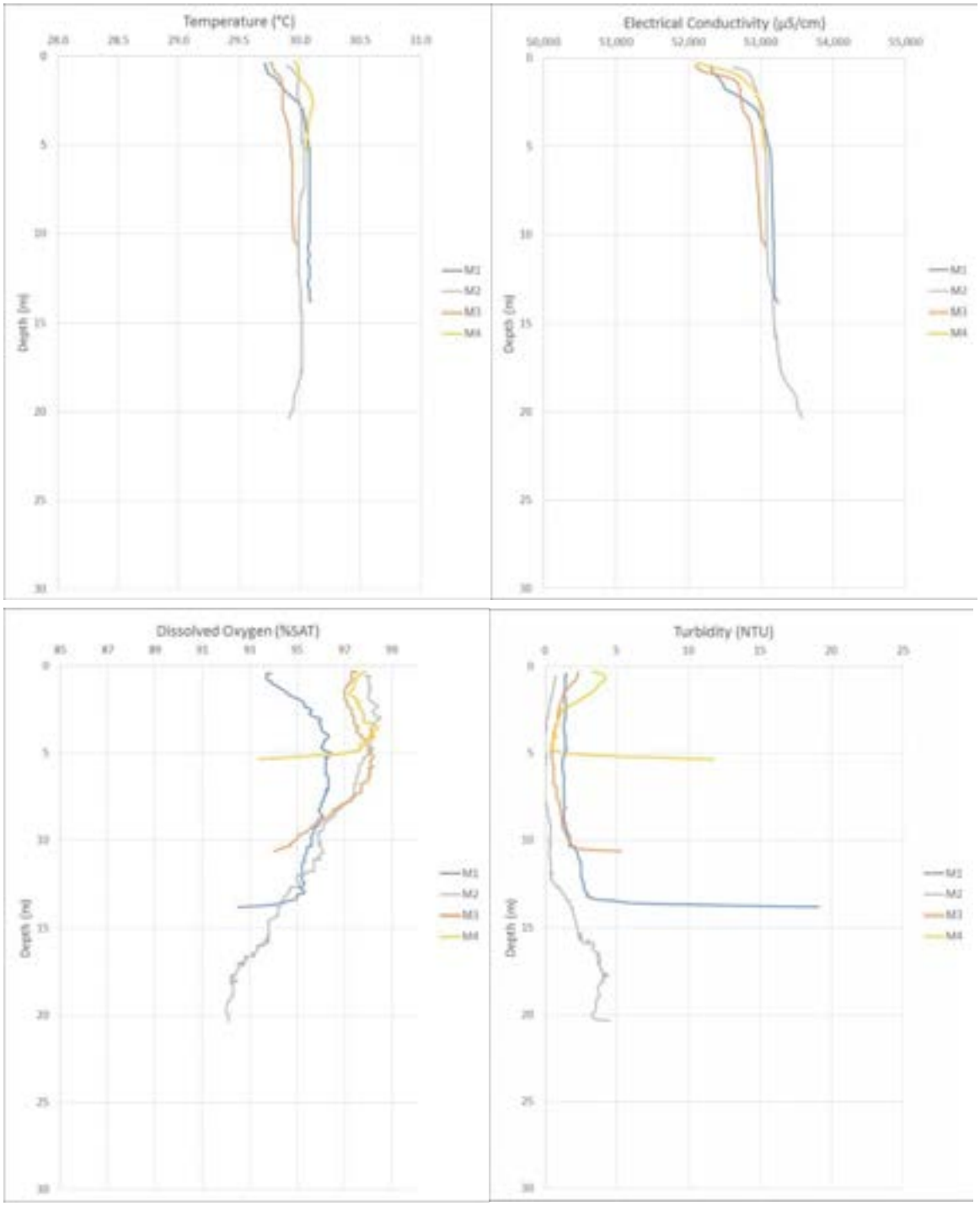

Figure 3-11 Water quality depth profiling data – temperature, electrical conductivity, dissolved oxygen and turbidity

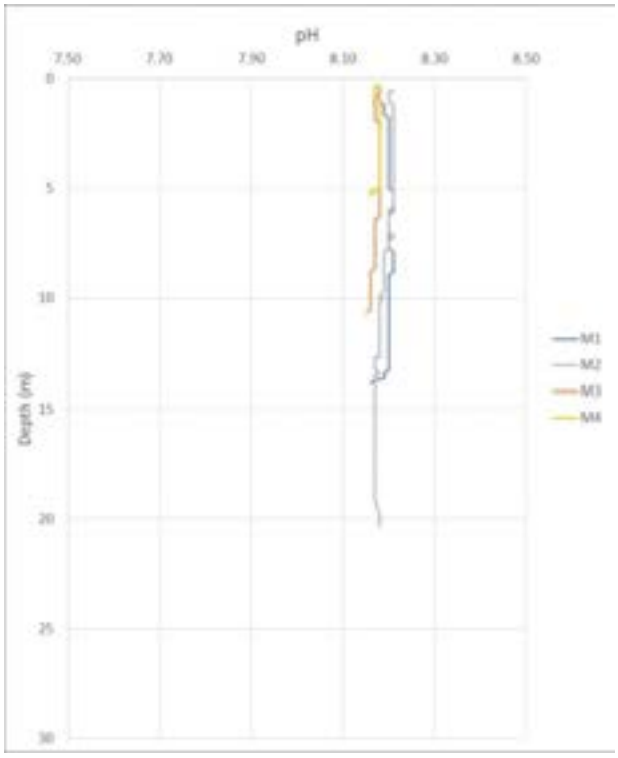

Figure 3-12 Water quality depth profiling data – pH

3.5 Sediment Quality

Sediment quality data collected during the survey is presented in this section. The data has been compared to sediment quality guideline values as per Simpson *et. al.* (2013), which are an update to the ANZECC/ARMCANZ (2000) interim sediment quality guideline values.

The particle size distribution (PSD) data is presented in Figure 3-13 and summary data for analytical results are presented in Table 3-2. The PSD results indicate the substrate adjacent to the proposed ocean port site (site M1) and Lido Village (M3) consisted predominately of sands and muds (particle size 0.006-2.00 mm) whilst muds and clays (particle size <60 μm) were more pronounced in central Dakriro Bay (M2) and coastal foreshore (site M4) survey sites.

Boron, antimony, cadmium and silver had concentrations below the laboratory limit of reporting (LOR) at all survey sites, while mercury concentrations were slightly greater than the LOR (0.01 mg/kg) at sites M2 and M4. Concentrations of most metals/metalloids within the individual survey sites were below sediment quality guideline levels, except for nickel. Nickel concentrations at sites M2 and M3 were above the Guideline Value of 21 mg/kg and concentrations at M4 exceeded the SQG-high guideline of 52 mg/kg.

Concentrations of metals/metalloids in sediment were typically greater at survey sites M2 and M4.

Total nitrogen and ammonia concentrations across the survey sites ranged from 300 to 880 mg/kg and 3 to 8 mg/kg, respectively. Apart from M3, concentrations of nitrite, nitrate and nitrogen oxides (NOx) were generally less than the LOR. Total phosphorus concentrations ranged from 354 to 498 mg/kg across the survey sites. Similar to metals/metalloids, total phosphorus concentrations were greater at sites M2 and M4.

Concentrations of total petroleum hydrocarbons (TPH) were below the LOR for the C6-C9 fraction at all survey sites. All other TPH fractions were below the guideline value of 550 mg/kg. Similar to the metals/metalloids, TPH concentrations were generally greater at monitoring locations M2 and M4.

Polyaromatic hydrocarbons (PAHs) were typically below the LOR at all survey sites, except for perylene which was recorded at low levels (8 to 10 mg/kg). Total PAHs concentrations were below the guideline value of 10,000 mg/kg.

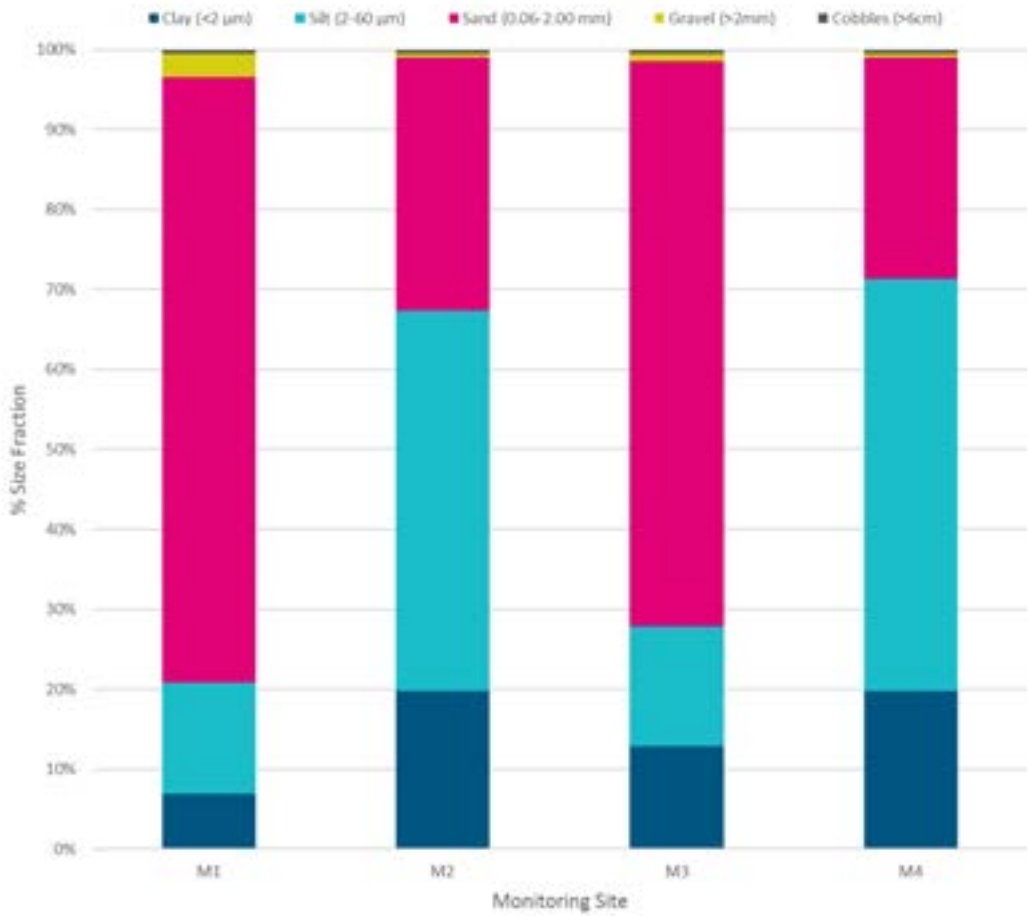

Figure 3-13 Particle Size Distribution Results

Table 3-2 Sediment quality results (mg/kg, dry weight) – December 2017

Parameter	LOR	SQG-Low	SQG-High	M1	M2	M3	M4
Metals and Metalloids							
Aluminium	50	-	-	2,150	5,930	3,300	6,710
Iron	50	-	-	5,440	15,600	8,540	17,600
Boron	50	-	-	<50	<50	<50	<50
Antimony	0.5	2	25	<0.50	<0.50	<0.50	<0.50
Arsenic	1	20	70	6.04	9.12	7.19	7.22
Cadmium	0.1	1.5	10	<0.1	<0.1	<0.1	<0.1
Chromium	1	80	370	13.5	35.1	20.5	47.4
Copper	1	65	207	3.6	7.8	2.3	8
Cobalt	0.5	-	-	2.1	6.5	3.8	7.7
Lead	1	50	220	3.2	5.4	2.8	5
Manganese	10	-	-	125	190	130	184
Nickel	1	21	52	12.7	42.6	22.5	56.2
Selenium	0.1	-	-	0.2	0.3	0.1	0.2
Silver	0.1	1	4	<0.1	<0.1	<0.1	<0.1
Vanadium	2	-	-	10.2	22.3	11.8	23.5
Zinc	1	200	410	10.3	27.5	16.8	31.6
Barium	0.1	-	-	5.3	5.6	4.5	11.5
Tin	0.1	-	-	<0.1	0.2	0.1	0.1
Mercury	0.01	0.15	1	<0.01	0.03	<0.01	0.02
Nutrients							
Ammonia	1	-	-	8	7	5	3
Nitrite	0.1	-	-	<0.1	<0.1	<0.1	<0.1
Nitrate	0.1	-	-	<0.1	<0.1	2.7	<0.1
Nitrite + Nitrate	0.1	-	-	<0.1	<0.1	2.7	<0.1
Total Kjeldahl Nitrogen	20	-	-	430	880	300	530
Total Nitrogen	20	-	-	430	880	300	530
Total Phosphorus	2	-	-	354	441	360	498
Reactive Phosphorus	0.1	-	-	0.5	0.2	0.3	<0.1
Total Organic Carbon (TOC)							
Total Organic Carbon	0.02	-	-	0.32	1.05	0.25	0.54
Total Petroleum Hydrocarbons							
C6 - C9 Fraction	3	-	-	<3	<3	<3	<3
C10 - C14 Fraction	3	-	-	6	10	5	6
C15 - C28 Fraction	3	-	-	14	38	17	30
C29 - C36 Fraction	5	-	-	11	37	10	28
C10 - C36 Fraction (sum)	3	280	550	31	85	32	64
Total Recoverable Hydrocarbons							
C6 - C10 Fraction	3	-	-	<3	<3	<3	<3

Parameter	LOR	SQG-Low	SQG-High	M1	M2	M3	M4
C6 - C10	3	-	-	<3.0	<3.0	<3.0	<3.0
BTEXN							
Benzene	0.2	-	-	<0.2	<0.2	<0.2	<0.2
Toluene	0.2	-	-	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	0.2	-	-	<0.2	<0.2	<0.2	<0.2
Meta- & para-Xylene	0.2	-	-	<0.2	<0.2	<0.2	<0.2
Ortho-Xylene	0.2	-	-	<0.2	<0.2	<0.2	<0.2
Total Xylenes	0.5	-	-	<0.5	<0.5	<0.5	<0.5
Sum of BTEX	0.2	-	-	<0.2	<0.2	<0.2	<0.2
Naphthalene	0.2	-	-	<0.2	<0.2	<0.2	<0.2
Total Recoverable Hydrocarbons							
>C10 - C16 Fraction	3	-	-	5	10	4	7
>C16 - C34 Fraction	3	-	-	20	59	23	45
>C34 - C40 Fraction	5	-	-	6	24	6	21
>C10 - C40 Fraction (sum)	3	-	-	31	93	33	73
>C10 - C16	3	-	-	5	10	4	7
Polynuclear Aromatic Hydrocarbons							
Naphthalene	5	-	-	<5	<5	<5	<5
2-Methylnaphthalene	5	-	-	<5	<5	<5	<5
Acenaphthylene	4	-	-	<4	<4	<4	<4
Acenaphthene	4	-	-	<4	<4	<4	<4
Fluorene	4	-	-	<4	<4	<4	<4
Phenanthrene	4	-	-	<4	<4	<4	<4
Anthracene	4	-	-	<4	<4	<4	<4
Fluoranthene	4	-	-	<4	<4	<4	<4
Pyrene	4	-	-	<4	<4	<4	<4
Benz(a)anthracene	4	-	-	<4	<4	<4	<4
Chrysene	4	-	-	<4	<4	<4	<4
Benzo(b+j)fluoranthene	4	-	-	<4	<4	<4	<4
Benzo(k)fluoranthene	4	-	-	<4	<4	<4	<4
Benzo(e)pyrene	4	-	-	<4	<4	<4	<4
Benzo(a)pyrene	4	-	-	<4	<4	<4	<4
Perylene	4	-	-	<4	10	<4	8
Benzo(g.h.i)perylene	4	-	-	<4	<4	<4	<4
Dibenz(a.h)anthracene	4			<4	<4	<4	<4
Indeno(1.2.3.cd)pyrene	4			<4	<4	<4	<4
Coronene	5			<5	<5	<5	<5
Sum of PAHs	4	10,000	50,000	<4	10	<4	8

Note: Orange highlight indicates exceedance of the Guideline Value indicating ***possible*** ecotoxicological effects. Red highlight indicates exceedance of the SQG-High guideline value indicating ***likely*** ecotoxicological effects

3.6 Metals in Fish Tissue

Results for fish biota have been summarised in Table 3-3 and laboratory reports are provided in Appendix C. To allow comparison to food guidelines and standards, raw data in Appendix C (dry weight) was converted to wet weight data using moisture content (%), with converted wet weight data presented in Table 3-3.

Concentrations of arsenic and zinc exceeded the food standards and/or indicative guideline values, as summarised below.

- Zinc was recorded in all fish tissue samples, with concentrations ranging from 3.32 to 19.61 mg/kg. Apart from a *Rhinecanthus verrucosus* (Blackpatch Triggerfish) specimen (sample ID 'Reef 4'), which had a concentration of 19.61 mg/kg, all other fish tissue samples had zinc concentrations below the 15 mg/kg ANZFA GEL.
- Likewise, arsenic was recorded in all fish tissue samples and concentrations in Reef 3, Reef 4, Reef 6 and Reef 9 (ranging from 2.66 to 22.8 mg/kg) were greater than the ANZFA (ML) guideline value of 2 mg/kg. There appears to be no correlation in the types of feeding guilds (i.e. herbivore, omnivores, etc) and the elevated concentrations.

Other metals/metalloids were recorded in concentrations below relevant guidelines/standards. Key trends in other metalloids/metalloids are summarised below:

- The range of aluminium concentrations was highly variable, ranging from <0.5 mg/kg to 338.4 mg/kg. There are no relevant guidelines or standards for this metal however two samples, Reef 7 and Reef 10 were significantly higher than all other samples.
- Copper, lead and selenium concentrations were detected in all fish tissue samples and all concentrations were below their respective guideline values.
- There were no clear trends in concentrations within the samples however copper, selenium and mercury were typically higher in sample Reef 4.
- Silver and antimony concentrations were typically close to or below the LORs.

Table 3-3 Metal concentrations recorded in fish tissue (mg/kg, wet weight)

Parameter			Al	Sb	As	Cd	Cu	Pb	Mn	Hg	Ni	Se	Ag	Zn
Limit of Reporting (LOR)			0.5	0.01	0.05	0.01	0.01	0.01	0.01	0.01	0.01	0.05	0.02	0.01
ANZFA/FSANZ Food Standard (ML)					2					0.5				
ANZFA/FSANZ Food Standard (GEL)							2					2		15
FAO/WHO CODEX Standard								0.3		0.5				
Biota	**Length (mm)**	**Weight (g)**												
Reef 1 - Sargocentron lepros	129	38.3	1.12	<0.01	1.15	0.04	0.3	0.02	0.7	0.03	0.02	0.4	0.01	6.47
Reef 2 - Scarus psittacus	140	51.7	<0.5	<0.01	0.68	0.004	0.2	0.01	0.14	0.004	0.03	0.1	0.01	3.54
Reef 3 – *Rhinecanthus verrucosus*	110	49.3	0.43	<0.01	7.74	0.01	0.54	0.02	0.71	0.01	0.05	0.13	0.01	13.76
Reef 4 – *Rhinecanthus verrucosus*	159	97.4	0.89	<0.01	22.8	0.06	0.73	0.04	1.78	0.04	0.02	0.36	<0.02	19.61
Reef 5 – *Acanthurus leucocheilus*	175	113.9	0.15	<0.01	0.77	<0.01	0.07	0.02	0.22	0.002	<0.01	0.11	<0.02	3.32
Reef 6 – *Acanthurus leucocheilus*	111	26.3	2.11	<0.01	2.66	<0.01	0.11	0.03	0.19	0.01	<0.01	0.11	<0.02	3.32
Reef 7 – *Acanthurus leucocheilus*	110	36.5	338.4	<0.01	0.54	0.01	0.38	0.08	0.4	<0.01	0.09	0.05	0.01	7.76
Reef 8 – *Acanthurus leucocheilus*	95	24.5	1.62	<0.01	0.63	0.01	0.17	0.17	0.25	<0.01	0.01	0.05	0.01	5.57
Reef 9 – Parupeneus crassilabrus	192	116.2	0.28	<0.01	6.79	0.004	0.19	0.04	0.12	0.03	<0.01	0.19	<0.02	10.76
Reef 10 – Epinephelus merra	182	101.2	45.6	<0.01	1.87	0.01	0.2	0.003	0.16	0.03	<0.01	0.3	<0.02	4.56

Note: green highlight denotes an exceedance of a ANZFA Maximum Level (ML) guideline value, yellow highlight denotes exceedance of a ANZFA GEL guideline value, grey highlight denotes exceedance of a FAO/WHO CODEX guideline value, and red highlight denotes exceedance of both guideline values.

4 References

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Appendix A Coral Transect Data

Coral Transect Data

Table A-1 Coral cover, genera present, and dominant substrates at ground-truthing locations. Habitat codes: SD= Seagrass Dominant, SS= Shallow Sand, D/B Deep sand / Bare Reef, TM= Reef dominated by Turfing or Macroalgae, HC= reef with high hard coral cover

Area	WP	Latitude	Longitude	percent coral	Habitat Class	Dominant substrate	percent dominant	Acanthastrea	Acropora	Astreopora	Ctenactis	Distichophora	Diploastrea	Echinopora	Favia	Favites	Fungia	Galaxea	Goniastrea	Goniopora	Halomitra	Heliopora	Herptolitha	Hydnophora	Isopora	Junceella	Leptoria	Lobophyllia	Lobophytum	Millepora	Montastrea	Montipora	Oulophyllia	Pachyseris	Pavona	Platygrya	Pocillopora	Porites	Sandolitha	Sarcophyton	Seriatophora	Stylophora	Symphyllia	Tubastrea	Turbinaria	Generic Richness
	1	-2.682429	141.310184	0	-	seagrass	45																																						0
	2	-2.682607	141.310736	0	SS	Sargassum	50																																						0
	3	-2.682812	141.311157	2	TM	Turbinaria	95		x																												x								2
	4	-2.682952	141.311256	3	TM	Turbinaria	95																																						0
	5	-2.683009	141.311035	15	TM	Turf	85											x									x		x		x					x		x			x				7
	97	-2.683071	141.313087	0	D/B	mud	100																																						0
	98	-2.682911	141.31248	0	D/B	Sand	100																																						0
	99	-2.682821	141.311487	15	D/B	Turf	60																			x				x								x	x						x	5
	100	-2.682915	141.311562	30	D/B	Turf	60	x																				x				x				x		x							5
Hospital	101	-2.682942	141.311412	30	TM	Turf	60		x				x		x																						x	x			x				6
	102	-2.68289	141.311265	2	TM	Turbinaria	30					x																										x								2
	103	-2.683434	141.31092	7	TM	Turf	45																					x				x					x								3
	104	-2.683541	141.310909	5	TM	Turf	50		x																						x	x						x							4
	105	-2.6848	141.309801	20	D/B	Turf	50																															x								1
	106	-2.684698	141.309632	2	TM	Turbinaria	70																															x								1
	107	-2.68516	141.309804	20	D/B	Turf	50																															x								1
	108	-2.679921	141.312557	40	HC	Coral	40							x												x				x							x	x			x	x			7
	109	-2.679898	141.312311	40	HC	Coral	40		x							x		x																		x									4
	110	-2.679896	141.312791	20	D/B	Turf	50																							x		x	x	x				x	x			x	x			8
	Average Coral Cover			**16.73**				1	4			1	1	1	1	1		2							1	1	1	2	3	1	3	4	1			3	6	11			4	2			1	22
	6	-2.675175	141.29311	40	TM	Coral	40										x															x					x	x							4
	7	-2.675433	141.293	0	TM	Sand	100																																						0
	8	-2.675585	141.29269	2	D/B	Turf	80																																	x					1
	9	-2.675673	141.292882	10	D/B	Turf	80																								x		x					x			x				4
	10	-2.675721	141.293079	0	D/B	Sand	90																																						0
	11	-2.6758	141.293273	0	D/B	Sand	100																																						0
	12	-2.675923	141.293459	5	D/B	Turf	60								x																	x	x			x		x						5
Potential	13	-2.675909	141.29383	35	TM	Coral	35		x	x						x		x														x	x					x			x				8
Ocean	14	-2.675949	141.293988	2	TM	Turf	80																														x								1
Port	15	-2.675979	141.294146	5	TM	Turf	80								x									x								x				x								4
	16	-2.6763	141.294001	5	TM	Turf	60									x																					x	x							3
	17	-2.676591	141.294101	5	TM	Turf	61								x																	x						x				x			4
	18	-2.676814	141.294168	3	TM	Turf	50													x			x															x							3
	19	-2.676967	141.294076	1	D/B	rubble	60																																						x	1
	20	-2.677086	141.293907	80	TM	Coral	80		x																												x								2
	21	-2.67258	141.294948	5	TM	Turf	85		x																						x							x							3
	22	-2.672835	141.29505	3	TM	Turf	85																															x								1
	23	-2.67301	141.295203	3	TM	Turf	85																															x								1
	24	-2.673272	141.295293	3	TM	Turf	85		x																																					1
	Average Coral Cover			**12.94**					4	1					3	2	1	1		1				1	1							3	5	2			1	6	8	1	1	2	1			1	20
Lido	25	-2.670914	141.27426	60	TM	Coral	60		x							x	x											x				x													5
Village	26	-2.670916	141.274164	55	TM	Coral	55		x							x	x															x					x	x							6
	27	-2.670827	141.274111	25	TM	Turf	50									x															x				x		x			x				5
	28	-2.67072	141.273988	1	TM	Sargassum	65																															x								1
	29	-2.670671	141.273951	0	TM	seagrass	40																																							0

Coral Transect Data

Area	WP	Latitude	Longitude	percent coral	Habitat Class	Dominant substrate	percent dominant	Acanthastrea	Acropora	Astreopora	Ctenactis	Distichophora	Diploastrea	Echinopora	Favia	Favites	Fungia	Galaxea	Goniastrea	Goniopora	Halomitra	Heliopora	Herpolitha	Hydnophora	Isopora	Junceella	Leptoria	Lobophyllia	Lobophytum	Millepora	Montastrea	Montipora	Oulophyllia	Pachyseris	Pavona	Platygrya	Pocillopora	Porites	Sandolitha	Sarcophyton	Seriatophora	Stylophora	Symphyllia	Tubastrea	Turbinaria	Generic Richness
Lido Village	30	-2.67049	141.27371	0	SD	seagrass	50																																						0
	31	-2.670481	141.273635	0	SD	seagrass	60																																						0
	32	-2.670366	141.273553	0	SD	seagrass	45																																						0
	33	-2.670132	141.273319	0	SD	Turf	95																																						0
	34	-2.670377	141.272786	0	SD	seagrass	70																																						0
	35	-2.671583	141.27236	35	TM	Coral	35		x																													x							2
	36	-2.671813	141.27265	35	HC	Coral	36		x																																				1
	37	-2.671907	141.272723	5	SS	Turf	65										x															x												x	3
	38	-2.668493	141.2761	5	TM	Turf	65										x																					x				x				3
	39	-2.66845	141.276111	50	HC	Coral	50		x		x						x														x	x					x	x			x			x		9
	40	-2.668371	141.276122	25	HC	Turf	70		x								x								x						x											x		x			6
	41	-2.668239	141.276136	5	TM	Turf	70																		x												x									2
	42	-2.668165	141.276083	5	TM	Turf	70		x																							x														2
	43	-2.668218	141.275971	5	D/B	Turf	70		x																							x														2
	44	-2.668201	141.27588	60	D/B	Coral	60		x																x							x														4
		Average Coral Cover		**24.73**					9		1					3	6								3			1			3	7				1	3	6			4	1	1	1	1	15
Cis Point	45	-2.668289	141.276006	1	TM	Turf	70																															x								1
	46	-2.664721	141.300619	5	TM	Turf	75		x								x															x						x				x				5
	47	-2.664417	141.300492	10	D/B	Turf	85																								x	x													4
	48	-2.664806	141.300515	10	TM	Turf	60		x							x			x				x															x	x							x	7
	49	-2.665068	141.300587	0	SD	seagrass	80																																							0
	50	-2.671406	141.297336	0	TM	rubble	60																																							0
	51	-2.669018	141.298483	0	SD	seagrass	40																																							0
	52	-2.668917	141.298486	0	SS	seagrass	40																																							0
	53	-2.668328	141.298411	0	TM	Sargassum	40																																							0
	54	-2.668322	141.298412	0	TM	seagrass	95																																							0
	55	-2.668167	141.2989	0	SD	seagrass	95																																							0
	56	-2.668147	141.299141	0	SD	seagrass	95																																							0
	57	-2.668842	141.299903	0	S	rubble	95																																							0
	58	-2.668109	141.302193	0	SD	seagrass	65																																							0
	59	-2.667712	141.302295	1	SD	Sargassum	40																															x								1
	60	-2.666606	141.302553	1	TM	Sargassum	40																															x								1
	61	-2.66623	141.3026	0	TM	Sargassum	40																															x								1
	62	-2.671665	141.296897	1	TM	Sargassum	40																																							0
	63	-2.671654	141.296634	1	TM	rubble	70																																							0
	65	-2.671696	141.296322	20	TM	Turf	70								x	x															x							x			x				5
	94	-2.663579	141.300573	7	TM	Turf	75		x						x		x															x	x						x				x		x	7
	95	-2.663185	141.300587	2	D/B	Turf	60		x																								x													2
	96	-2.662729	141.300459	0	D/B	rubble	50																																							0
		Average Coral Cover		**4.75**					4						2	2	2		1				1								1	2	4					1	7			2	1	1		3	15
Logging Port	66	-2.679768	141.295319	10	SS	Turf	70		x						x				x												x							x				x				6
	67	-2.679766	141.295355	40	TM	Turf	60												x															x					x	x							4
	68	-2.67971	141.295438	10	TM	Turf	60		x								x		x																			x	x							5
	69	-2.679676	141.295517	5	TM	Sargassum	50									x																						x								2
	70	-2.679532	141.295688	3	TM	seagrass	50																															x								1
	71	-2.679886	141.296262	1	TM	seagrass	50												x																												1
	72	-2.680099	141.296142	20	TM	Turf	50		x						x				x												x		x				x								7
	73	-2.680193	141.296058	20	TM	Turf	60								x		x														x		x					x	x	x						8
	74	-2.680619	141.296076	30	SS	Turf	60		x							x															x								x				x				5

Coral Transect Data

Area	WP	Latitude	Longitude	percent coral	Habitat Class	Dominant substrate	percent dominant	Acanthastrea	Acropora	Astreopora	Ctenactis	Distichophora	Diploastrea	Echinopora	Favia	Favites	Fungia	Galaxea	Goniastrea	Goniopora	Halomitra	Heliopora	Herpolitha	Hydnophora	Isopora	Junceella	Leptoria	Lobophyllia	Lobophytum	Millepora	Montastrea	Montipora	Oulophyllia	Pachyseris	Pavona	Platygrya	Pocillopora	Porites	Sandolitha	Sarcophyton	Seriatophora	Stylophora	Symphyllia	Tubastrea	Turbinaria	Generic Richness
Logging Port	75	-2.680628	141.296242	10	SS	Turf	70		x							x														x								x			x	x				6
	76	-2.680571	141.296314	3	TM	Sargassum	60																														x								1
	77	-2.680439	141.296556	3	TM	rubble	75																														x								1
		Average Coral Cover		**12.92**					5						3	3	2		5											5		2		1	1	1	3	11			1	3	1			15
Dakriro Bay	79	-2.674321	141.291313	0	-	mud	100																																						0
	80	-2.674915	141.292233	0	D/B	Sand	100																																						0
	81	-2.675219	141.292536	0	D/B	Sand	100																																						0
	82	-2.673803	141.293002	0	-	Sand	100																																						0
	83	-2.677189	141.293596	0	D/B	mud	100																																						0
	84	-2.67735	141.293211	1	-	rubble	75																																					x	1
	85	-2.677433	141.292502	0	D/B	mud	100																																						0
	86	-2.677569	141.291251	0	D/B	mud	100																																						0
	88	-2.67087	141.274889	0	-	mud	100																																						0
	89	-2.671891	141.275436	0	D/B	Sand	100																																						0
	90	-2.672916	141.277048	0	D/B	Sand	100																																						0
	91	-2.67518	141.275436	0	SS	Sand	100																																						0
	92	-2.676871	141.274054	0	SS	Sand	100																																						0
	93	-2.684671	141.292779	0	SS	Sand	100																																						0
		Average Coral Cover		**0.07**																																								1	1

Appendix B Water and Sediment Laboratory Data

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB1725906**	Page	: 1 of 17
Client	: **BMT WBM GROUP LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR BRAD GRANT	Contact	: Customer Services EB
Address	: PO BOX 203 SPRING HILL BRISBANE QLD 4004	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: +61 07 3831 6744	Telephone	: +61-7-3243 7222
Project	: Frieda River B22837	Date Samples Received	: 06-Dec-2017 12:05
Order number	: ----	Date Analysis Commenced	: 08-Dec-2017
C-O-C number	: ----	Issue Date	: 15-Jan-2018 22:25
Sampler	: BRAD HILES		
Site	: ----		
Quote number	: BN/399/17 V2		
No. of samples received	: 18		
No. of samples analysed	: 18		

ilac-MRA NATA
Accreditation No. 825
Accredited for compliance with ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

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

Signatories

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

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Inorganic Chemist	Sydney Inorganics, Smithfield, NSW
Ben Felgendrejeris		Brisbane Acid Sulphate Soils, Stafford, QLD
Diana Mesa	2IC Organic Chemist	Brisbane Organics, Stafford, QLD
Edwandy Fadjar	Organic Coordinator	Sydney Organics, Smithfield, NSW
Greg Vogel	Laboratory Manager	Brisbane Inorganics, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Matt Frost	Senior Organic Chemist	Brisbane Inorganics, Stafford, QLD

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.
~ = Indicates an estimated value.

- It is recognised that EP005 (Total Organic Carbon) is less than EP002 (Dissolved Organic Carbon) for some samples. However, the difference is within experimental variation of the methods.
- It is recognised that EG093T (Total Metals in Saline Water) is less than EG093F (Dissolved Metals in Saline Water) for some samples. However, the difference is within experimental variation of the methods.
- EK061G (Total Kjeldahl Nitrogen as N) / EK067G (Total Phosphorus as P) / EKO62G (TN): Some samples were diluted due to matrix interference. LOR adjusted accordingly.
- EG035T-LL (Total Mercury Low Level) Sample EB1725906-016 shows poor matrix spike recovery due to sample heterogeneity. Confirmed by visual inspection.
- **Specialty Organics analysis will be conducted by ALS Environmental, Sydney, NATA accreditation no. 825, Site No. 10911 (Micro site no. 14913).**
- Benzo(a)pyrene Toxicity Equivalent Quotient (TEQ) is the sum total of the concentration of the eight carcinogenic PAHs multiplied by their Toxicity Equivalence Factor (TEF) relative to Benzo(a)pyrene. TEF values are provided in brackets as follows: Benz(a)anthracene (0.1), Chrysene (0.01), Benzo(b+j) & Benzo(k)fluoranthene (0.1), Benzo(a)pyrene (1.0), Indeno(1.2.3.cd)pyrene (0.1), Dibenz(a.h)anthracene (1.0), Benzo(g.h.i)perylene (0.01). Less than LOR results for 'TEQ Zero' are treated as zero.

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	M1	M2	M3	M4	4D
				Client sampling date / time	03-Dec-2017 10:00	03-Dec-2017 10:30	03-Dec-2017 10:40	03-Dec-2017 11:30	03-Dec-2017 12:00
Compound	CAS Number	LOR	Unit		EB1725906-001	EB1725906-002	EB1725906-003	EB1725906-004	EB1725906-005
					Result	Result	Result	Result	Result
EA055: Moisture Content (Dried @ 105-110°C)									
Moisture Content	----	1.0	%		33.6	39.8	27.3	30.6	31.9
EA150: Particle Sizing									
+75µm	----	1	%		74	28	54	16	----
+150µm	----	1	%		41	7	17	<1	----
+300µm	----	1	%		14	4	6	<1	----
+425µm	----	1	%		11	3	4	<1	----
+600µm	----	1	%		8	3	4	<1	----
+1180µm	----	1	%		4	1	2	<1	----
+2.36mm	----	1	%		2	<1	<1	<1	----
+4.75mm	----	1	%		<1	<1	<1	<1	----
+9.5mm	----	1	%		<1	<1	<1	<1	----
+19.0mm	----	1	%		<1	<1	<1	<1	----
+37.5mm	----	1	%		<1	<1	<1	<1	----
+75.0mm	----	1	%		<1	<1	<1	<1	----
EA150: Soil Classification based on Particle Size									
Clay (<2 µm)	----	1	%		7	20	13	20	----
Silt (2-60 µm)	----	1	%		14	48	15	52	----
Sand (0.06-2.00 mm)	----	1	%		76	32	71	28	----
Gravel (>2mm)	----	1	%		3	<1	1	<1	----
Cobbles (>6cm)	----	1	%		<1	<1	<1	<1	----
EA152: Soil Particle Density									
Soil Particle Density (Clay/Silt/Sand)	----	0.01	g/cm3		2.57	2.44	2.54	2.67	----
EG005-SD: Total Metals in Sediments by ICP-AES									
Aluminium	7429-90-5	50	mg/kg		2150	5930	3300	6710	6240
Iron	7439-89-6	50	mg/kg		5440	15600	8540	17600	16300
EG005T: Total Metals by ICP-AES									
Boron	7440-42-8	50	mg/kg		<50	<50	<50	<50	<50
EG020-SD: Total Metals in Sediments by ICPMS									
Antimony	7440-36-0	0.50	mg/kg		<0.50	<0.50	<0.50	<0.50	<0.50
Arsenic	7440-38-2	1.00	mg/kg		6.04	9.12	7.19	7.22	6.64
Cadmium	7440-43-9	0.1	mg/kg		<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg		13.5	35.1	20.5	47.4	43.5
Copper	7440-50-8	1.0	mg/kg		3.6	7.8	2.3	8.0	7.6
Cobalt	7440-48-4	0.5	mg/kg		2.1	6.5	3.8	7.7	7.2

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	M1	M2	M3	M4	4D
				Client sampling date / time	03-Dec-2017 10:00	03-Dec-2017 10:30	03-Dec-2017 10:40	03-Dec-2017 11:30	03-Dec-2017 12:00
Compound	CAS Number	LOR	Unit		EB1725906-001	EB1725906-002	EB1725906-003	EB1725906-004	EB1725906-005
					Result	Result	Result	Result	Result
EG020-SD: Total Metals in Sediments by ICPMS - Continued									
Lead	7439-92-1	1.0	mg/kg		3.2	5.4	2.8	5.0	4.7
Manganese	7439-96-5	10	mg/kg		125	190	130	184	173
Nickel	7440-02-0	1.0	mg/kg		12.7	42.6	22.5	56.2	53.1
Selenium	7782-49-2	0.1	mg/kg		0.2	0.3	0.1	0.2	0.2
Silver	7440-22-4	0.1	mg/kg		<0.1	<0.1	<0.1	<0.1	<0.1
Vanadium	7440-62-2	2.0	mg/kg		10.2	22.3	11.8	23.5	21.8
Zinc	7440-66-6	1.0	mg/kg		10.3	27.5	16.8	31.6	29.6
EG020T: Total Metals by ICP-MS									
Barium	7440-39-3	0.1	mg/kg		5.3	5.6	4.5	11.5	11.1
Tin	7440-31-5	0.1	mg/kg		<0.1	0.2	0.1	0.1	0.1
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.01	mg/kg		<0.01	0.03	<0.01	0.02	0.02
EK055: Ammonia as N									
Ammonia as N	7664-41-7	1	mg/kg		8	7	5	3	4
EK057G: Nitrite as N by Discrete Analyser									
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg		<0.1	<0.1	<0.1	<0.1	<0.1
EK058G: Nitrate as N by Discrete Analyser									
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg		<0.1	<0.1	2.7	<0.1	<0.1
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		<0.1	<0.1	2.7	<0.1	<0.1
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	20	mg/kg		430	880	300	530	580
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	20	mg/kg		430	880	300	530	580
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	2	mg/kg		354	441	360	498	484
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.1	mg/kg		0.5	0.2	0.3	<0.1	<0.1
EP003: Total Organic Carbon (TOC) in Soil									
Total Organic Carbon	----	0.02	%		0.32	1.05	0.25	0.54	0.56
EP004: Organic Matter									
Organic Matter	----	0.5	%		1.2	3.6	1.1	2.2	2.0
Total Organic Carbon	----	0.5	%		0.7	2.1	0.7	1.2	1.2

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	M1	M2	M3	M4	4D
				Client sampling date / time	03-Dec-2017 10:00	03-Dec-2017 10:30	03-Dec-2017 10:40	03-Dec-2017 11:30	03-Dec-2017 12:00
Compound	CAS Number	LOR	Unit		EB1725906-001	EB1725906-002	EB1725906-003	EB1725906-004	EB1725906-005
					Result	Result	Result	Result	Result
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions									
>C10 - C16 Fraction	----	3	mg/kg		**5**	**10**	**4**	**7**	**18**
>C16 - C34 Fraction	----	3	mg/kg		**20**	**59**	**23**	**45**	**82**
>C34 - C40 Fraction	----	5	mg/kg		**6**	**24**	**6**	**21**	**29**
>C10 - C40 Fraction (sum)	----	3	mg/kg		**31**	**93**	**33**	**73**	**129**
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg		**5**	**10**	**4**	**7**	**18**
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons									
C6 - C9 Fraction	----	3	mg/kg		<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg		**6**	**10**	**5**	**6**	**16**
C15 - C28 Fraction	----	3	mg/kg		**14**	**38**	**17**	**30**	**59**
C29 - C36 Fraction	----	5	mg/kg		**11**	**37**	**10**	**28**	**43**
^ **C10 - C36 Fraction (sum)**	----	3	mg/kg		**31**	**85**	**32**	**64**	**118**
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons									
C6 - C10 Fraction	C6_C10	3	mg/kg		<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg		<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN									
Benzene	71-43-2	0.2	mg/kg		<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg		<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg		<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg		<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg		<0.2	<0.2	<0.2	<0.2	<0.2
^ **Total Xylenes**	----	0.5	mg/kg		<0.5	<0.5	<0.5	<0.5	<0.5
^ **Sum of BTEX**	----	0.2	mg/kg		<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg		<0.2	<0.2	<0.2	<0.2	<0.2
EP132B: Polynuclear Aromatic Hydrocarbons									
Naphthalene	91-20-3	5	µg/kg		<5	<5	<5	<5	<5
2-Methylnaphthalene	91-57-6	5	µg/kg		<5	<5	<5	<5	<5
Acenaphthylene	208-96-8	4	µg/kg		<4	<4	<4	<4	<4
Acenaphthene	83-32-9	4	µg/kg		<4	<4	<4	<4	<4
Fluorene	86-73-7	4	µg/kg		<4	<4	<4	<4	<4
Phenanthrene	85-01-8	4	µg/kg		<4	<4	<4	<4	<4
Anthracene	120-12-7	4	µg/kg		<4	<4	<4	<4	<4
Fluoranthene	206-44-0	4	µg/kg		<4	<4	<4	<4	<4

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	M1	M2	M3	M4	4D
				Client sampling date / time	03-Dec-2017 10:00	03-Dec-2017 10:30	03-Dec-2017 10:40	03-Dec-2017 11:30	03-Dec-2017 12:00
Compound	CAS Number	LOR	Unit		EB1725906-001	EB1725906-002	EB1725906-003	EB1725906-004	EB1725906-005
					Result	Result	Result	Result	Result
EP132B: Polynuclear Aromatic Hydrocarbons - Continued									
Pyrene	129-00-0	4	µg/kg		<4	<4	<4	<4	<4
Benz(a)anthracene	56-55-3	4	µg/kg		<4	<4	<4	<4	<4
Chrysene	218-01-9	4	µg/kg		<4	<4	<4	<4	<4
Benzo(b+j)fluoranthene	205-99-2 205-82-3	4	µg/kg		<4	<4	<4	<4	<4
Benzo(k)fluoranthene	207-08-9	4	µg/kg		<4	<4	<4	<4	<4
Benzo(e)pyrene	192-97-2	4	µg/kg		<4	<4	<4	<4	<4
Benzo(a)pyrene	50-32-8	4	µg/kg		<4	<4	<4	<4	<4
Perylene	198-55-0	4	µg/kg		<4	**10**	<4	**8**	**7**
Benzo(g.h.i)perylene	191-24-2	4	µg/kg		<4	<4	<4	<4	<4
Dibenz(a.h)anthracene	53-70-3	4	µg/kg		<4	<4	<4	<4	<4
Indeno(1.2.3.cd)pyrene	193-39-5	4	µg/kg		<4	<4	<4	<4	<4
Coronene	191-07-1	5	µg/kg		<5	<5	<5	<5	<5
^ Sum of PAHs	----	4	µg/kg		<4	**10**	<4	**8**	**7**
EP080-SD: TPH(V)/BTEX Surrogates									
1.2-Dichloroethane-D4	17060-07-0	0.2	%		**87.7**	**86.5**	**83.9**	**85.8**	**92.0**
Toluene-D8	2037-26-5	0.2	%		**97.2**	**89.0**	**83.3**	**87.1**	**96.3**
4-Bromofluorobenzene	460-00-4	0.2	%		**112**	**103**	**101**	**108**	**110**
EP132T: Base/Neutral Extractable Surrogates									
2-Fluorobiphenyl	321-60-8	10	%		**79.6**	**83.9**	**77.4**	**83.9**	**70.6**
Anthracene-d10	1719-06-8	10	%		**101**	**95.9**	**94.3**	**109**	**89.0**
4-Terphenyl-d14	1718-51-0	10	%		**105**	**97.3**	**97.4**	**108**	**91.0**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S7	S8	S7 <63µm Fraction	S8 <63µm Fraction	S7 <2000µm Fraction
			Client sampling date / time	29-Nov-2017 14:00	30-Nov-2017 09:00	29-Nov-2017 14:00	30-Nov-2017 09:00	29-Nov-2017 14:00
Compound	CAS Number	LOR	Unit	EB1725906-006	EB1725906-007	EB1725906-015	EB1725906-016	EB1725906-017
				Result	Result	Result	Result	Result
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	34.6	26.8	----	----	----
EA150: Particle Sizing								
+75µm	----	1	%	26	58	----	----	----
+150µm	----	1	%	11	49	----	----	----
+300µm	----	1	%	2	45	----	----	----
+425µm	----	1	%	1	44	----	----	----
+600µm	----	1	%	<1	43	----	----	----
+1180µm	----	1	%	<1	35	----	----	----
+2.36mm	----	1	%	<1	13	----	----	----
+4.75mm	----	1	%	<1	<1	----	----	----
+9.5mm	----	1	%	<1	<1	----	----	----
+19.0mm	----	1	%	<1	<1	----	----	----
+37.5mm	----	1	%	<1	<1	----	----	----
+75.0mm	----	1	%	<1	<1	----	----	----
EA150: Soil Classification based on Particle Size								
Clay (<2 µm)	----	1	%	19	13	----	----	----
Silt (2-60 µm)	----	1	%	53	27	----	----	----
Sand (0.06-2.00 mm)	----	1	%	28	40	----	----	----
Gravel (>2mm)	----	1	%	<1	20	----	----	----
Cobbles (>6cm)	----	1	%	<1	<1	----	----	----
EA152: Soil Particle Density								
Soil Particle Density (Clay/Silt/Sand)	----	0.01	g/cm3	2.48	2.73	----	----	----
EG005-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	----	----	22400	23300	12600
Iron	7439-89-6	50	mg/kg	----	----	50400	48400	32800
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	----	----	<0.50	<0.50	<0.50
Arsenic	7440-38-2	1.00	mg/kg	----	----	4.78	5.51	1.69
Cadmium	7440-43-9	0.1	mg/kg	----	----	0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	----	----	45.5	58.8	18.8
Copper	7440-50-8	1.0	mg/kg	----	----	70.9	54.2	29.2
Cobalt	7440-48-4	0.5	mg/kg	----	----	21.2	20.0	12.6
Lead	7439-92-1	1.0	mg/kg	----	----	7.2	8.2	2.4
Manganese	7439-96-5	10	mg/kg	----	----	880	670	549

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	S7	S8	S7 <63µm Fraction	S8 <63µm Fraction	S7 <2000µm Fraction
				Client sampling date / time	29-Nov-2017 14:00	30-Nov-2017 09:00	29-Nov-2017 14:00	30-Nov-2017 09:00	29-Nov-2017 14:00
Compound	CAS Number	LOR	Unit		EB1725906-006	EB1725906-007	EB1725906-015	EB1725906-016	EB1725906-017
					Result	Result	Result	Result	Result
EG020-SD: Total Metals in Sediments by ICPMS - Continued									
Nickel	7440-02-0	1.0	mg/kg		----	----	**45.0**	**72.6**	**19.2**
Selenium	7782-49-2	0.1	mg/kg		----	----	**0.3**	**0.3**	**0.1**
Silver	7440-22-4	0.1	mg/kg		----	----	<0.1	<0.1	<0.1
Vanadium	7440-62-2	2.0	mg/kg		----	----	**118**	**95.2**	**82.6**
Zinc	7440-66-6	1.0	mg/kg		----	----	**86.8**	**79.3**	**51.6**
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.01	mg/kg		----	----	**0.03**	**0.04**	<0.01
GEO26: Sieving									
-2000µm	----	0.01	%		----	----	----	----	**17.4**
-63µm	----	0.01	%		----	----	**7.62**	**5.80**	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	S8 <2000µm Fraction	----	----	----	----
				Client sampling date / time	30-Nov-2017 09:00	----	----	----	----
Compound	CAS Number	LOR	Unit		EB1725906-018	--------	--------	--------	--------
					Result	----	----	----	----
EG005-SD: Total Metals in Sediments by ICP-AES									
Aluminium	7429-90-5	50	mg/kg		**17900**	----	----	----	----
Iron	7439-89-6	50	mg/kg		**26700**	----	----	----	----
EG020-SD: Total Metals in Sediments by ICPMS									
Antimony	7440-36-0	0.50	mg/kg		<0.50	----	----	----	----
Arsenic	7440-38-2	1.00	mg/kg		**1.37**	----	----	----	----
Cadmium	7440-43-9	0.1	mg/kg		<0.1	----	----	----	----
Chromium	7440-47-3	1.0	mg/kg		**19.2**	----	----	----	----
Copper	7440-50-8	1.0	mg/kg		**28.1**	----	----	----	----
Cobalt	7440-48-4	0.5	mg/kg		**14.9**	----	----	----	----
Lead	7439-92-1	1.0	mg/kg		**1.2**	----	----	----	----
Manganese	7439-96-5	10	mg/kg		**611**	----	----	----	----
Nickel	7440-02-0	1.0	mg/kg		**25.3**	----	----	----	----
Selenium	7782-49-2	0.1	mg/kg		**0.1**	----	----	----	----
Silver	7440-22-4	0.1	mg/kg		<0.1	----	----	----	----
Vanadium	7440-62-2	2.0	mg/kg		**66.6**	----	----	----	----
Zinc	7440-66-6	1.0	mg/kg		**37.1**	----	----	----	----
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.01	mg/kg		<0.01	----	----	----	----
GEO26: Sieving									
-2000µm	----	0.01	%		**32.3**	----	----	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	M1	M2	M3	M4	4D
				Client sampling date / time	03-Dec-2017 10:00	03-Dec-2017 10:30	03-Dec-2017 10:40	03-Dec-2017 11:30	03-Dec-2017 12:00
Compound	CAS Number	LOR	Unit		EB1725906-008	EB1725906-009	EB1725906-010	EB1725906-011	EB1725906-012
					Result	Result	Result	Result	Result
EA025: Total Suspended Solids dried at 104 ± 2°C									
Suspended Solids (SS)	----	1	mg/L		**1**	**2**	**1**	**5**	**3**
EG035F: Dissolved Mercury by FIMS									
Mercury	7439-97-6	0.00004	mg/L		<0.00004	<0.00004	<0.00004	<0.00004	<0.00004
EG035T: Total Mercury by FIMS									
Mercury	7439-97-6	0.00004	mg/L		<0.00004	<0.00004	<0.00004	<0.00004	<0.00004
EG093F: Dissolved Metals in Saline Water by ORC-ICPMS									
Aluminium	7429-90-5	5	µg/L		<5	<5	<5	<5	<5
Arsenic	7440-38-2	0.5	µg/L		**1.3**	**1.5**	**1.3**	**1.2**	**1.1**
Barium	7440-39-3	1	µg/L		**4**	**5**	**4**	**5**	**5**
Boron	7440-42-8	100	µg/L		**4320**	**3500**	**4280**	**3990**	**3860**
Cadmium	7440-43-9	0.2	µg/L		<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5
Cobalt	7440-48-4	0.2	µg/L		<0.2	<0.2	<0.2	<0.2	<0.2
Copper	7440-50-8	1	µg/L		<1	<1	<1	<1	<1
Iron	7439-89-6	5	µg/L		<5	<5	<5	<5	<5
Lead	7439-92-1	0.2	µg/L		<0.2	<0.2	<0.2	<0.2	<0.2
Manganese	7439-96-5	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5
Nickel	7440-02-0	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5
Selenium	7782-49-2	2	µg/L		**3**	**3**	**4**	**3**	**3**
Silver	7440-22-4	0.1	µg/L		<0.1	<0.1	<0.1	<0.1	<0.1
Tin	7440-31-5	5	µg/L		<5	<5	<5	<5	<5
Vanadium	7440-62-2	0.5	µg/L		**1.6**	**1.8**	**1.7**	**1.6**	**1.4**
Zinc	7440-66-6	5	µg/L		<5	<5	<5	<5	<5
EG093T: Total Metals in Saline Water by ORC-ICPMS									
Aluminium	7429-90-5	5	µg/L		**33**	**44**	**61**	**102**	**93**
Arsenic	7440-38-2	0.5	µg/L		**1.5**	**1.5**	**1.5**	**1.4**	**1.5**
Barium	7440-39-3	1	µg/L		**4**	**4**	**4**	**6**	**6**
Boron	7440-42-8	100	µg/L		**5180**	**5310**	**5380**	**4150**	**4180**
Cadmium	7440-43-9	0.2	µg/L		<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L		<0.5	<0.5	<0.5	**2.8**	**4.2**
Cobalt	7440-48-4	0.2	µg/L		<0.2	<0.2	<0.2	**0.5**	**0.6**
Copper	7440-50-8	1	µg/L		<1	<1	<1	**1**	**2**
Iron	7439-89-6	5	µg/L		**70**	**71**	**107**	**184**	**167**
Lead	7439-92-1	0.2	µg/L		<0.2	<0.2	<0.2	<0.2	<0.2

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	M1	M2	M3	M4	4D
				Client sampling date / time	03-Dec-2017 10:00	03-Dec-2017 10:30	03-Dec-2017 10:40	03-Dec-2017 11:30	03-Dec-2017 12:00
Compound	CAS Number	LOR	Unit		EB1725906-008	EB1725906-009	EB1725906-010	EB1725906-011	EB1725906-012
					Result	Result	Result	Result	Result
EG093T: Total Metals in Saline Water by ORC-ICPMS - Continued									
Manganese	7439-96-5	0.5	µg/L		**1.1**	**1.4**	**1.4**	**12.2**	**17.6**
Nickel	7440-02-0	0.5	µg/L		<0.5	<0.5	<0.5	**25.1**	**37.6**
Selenium	7782-49-2	2	µg/L		**5**	**5**	**5**	**6**	**6**
Silver	7440-22-4	0.1	µg/L		<0.1	<0.1	**0.2**	<0.1	<0.1
Tin	7440-31-5	5	µg/L		<5	<5	<5	<5	<5
Vanadium	7440-62-2	0.5	µg/L		**1.2**	**1.3**	**1.3**	**1.8**	**2.0**
Zinc	7440-66-6	5	µg/L		<5	<5	<5	<5	<5
EK055G: Ammonia as N by Discrete Analyser									
Ammonia as N	7664-41-7	0.01	mg/L		**0.02**	**0.05**	**0.11**	**0.11**	**0.04**
EK057G: Nitrite as N by Discrete Analyser									
Nitrite as N	14797-65-0	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
EK058G: Nitrate as N by Discrete Analyser									
Nitrate as N	14797-55-8	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		<0.5	<0.5	<0.5	<0.5	<0.5
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ Total Nitrogen as N	----	0.1	mg/L		<0.5	<0.5	<0.5	<0.5	<0.5
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		<0.05	<0.05	<0.05	<0.05	<0.05
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
EP002: Dissolved Organic Carbon (DOC)									
Dissolved Organic Carbon	----	1	mg/L		**2**	**2**	**2**	**2**	**2**
EP005: Total Organic Carbon (TOC)									
Total Organic Carbon	----	1	mg/L		**2**	**1**	**1**	**2**	**1**
EP020: Oil and Grease (O&G)									
Oil & Grease	----	5	mg/L		<5	<5	<5	<5	<5
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons									
Naphthalene	91-20-3	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthylene	208-96-8	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthene	83-32-9	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	M1	M2	M3	M4	4D
				Client sampling date / time	03-Dec-2017 10:00	03-Dec-2017 10:30	03-Dec-2017 10:40	03-Dec-2017 11:30	03-Dec-2017 12:00
Compound	CAS Number	LOR	Unit		EB1725906-008	EB1725906-009	EB1725906-010	EB1725906-011	EB1725906-012
					Result	Result	Result	Result	Result
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons - Continued									
Fluorene	86-73-7	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
Phenanthrene	85-01-8	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
Anthracene	120-12-7	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
Fluoranthene	206-44-0	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
Pyrene	129-00-0	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
Benz(a)anthracene	56-55-3	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
Chrysene	218-01-9	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(b+j)fluoranthene	205-99-2 205-82-3	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(k)fluoranthene	207-08-9	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(a)pyrene	50-32-8	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
^ Sum of polycyclic aromatic hydrocarbons	----	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5
^ Benzo(a)pyrene TEQ (zero)	----	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5
EP080/071: Total Petroleum Hydrocarbons									
C6 - C9 Fraction	----	20	µg/L		<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L		<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L		<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L		<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L		<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions									
C6 - C10 Fraction	C6_C10	20	µg/L		<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L		<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L		<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L		<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L		<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L		<100	<100	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L		<100	<100	<100	<100	<100
EP080: BTEXN									
Benzene	71-43-2	1	µg/L		<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L		<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L		<2	<2	<2	<2	<2

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	M1	M2	M3	M4	4D
				Client sampling date / time	03-Dec-2017 10:00	03-Dec-2017 10:30	03-Dec-2017 10:40	03-Dec-2017 11:30	03-Dec-2017 12:00
Compound	CAS Number	LOR	Unit		EB1725906-008	EB1725906-009	EB1725906-010	EB1725906-011	EB1725906-012
					Result	Result	Result	Result	Result
EP080: BTEXN - Continued									
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L		<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L		<2	<2	<2	<2	<2
^ Total Xylenes	----	2	µg/L		<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L		<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L		<5	<5	<5	<5	<5
EP075(SIM)S: Phenolic Compound Surrogates									
Phenol-d6	13127-88-3	1.0	%		35.5	38.8	45.4	38.3	43.3
2-Chlorophenol-D4	93951-73-6	1.0	%		70.3	75.2	86.1	76.1	85.9
2.4.6-Tribromophenol	118-79-6	1.0	%		56.8	60.0	62.8	58.1	68.0
EP075(SIM)T: PAH Surrogates									
2-Fluorobiphenyl	321-60-8	1.0	%		76.4	83.9	93.6	88.2	91.7
Anthracene-d10	1719-06-8	1.0	%		84.2	93.7	100.0	92.8	102
4-Terphenyl-d14	1718-51-0	1.0	%		99.1	108	121	114	117
EP080S: TPH(V)/BTEX Surrogates									
1.2-Dichloroethane-D4	17060-07-0	2	%		91.7	103	113	84.1	100
Toluene-D8	2037-26-5	2	%		85.1	113	98.1	101	110
4-Bromofluorobenzene	460-00-4	2	%		99.2	94.2	87.7	92.7	93.6

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	S7	S8	----	----	----
				Client sampling date / time	29-Nov-2017 14:00	30-Nov-2017 09:00	----	----	----
Compound	CAS Number	LOR	Unit		EB1725906-013	EB1725906-014	--------	--------	--------
					Result	Result	----	----	----
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		**238**	**132**	----	----	----
EA025: Total Suspended Solids dried at 104 ± 2°C									
Suspended Solids (SS)	----	1	mg/L		**86**	**90**	----	----	----
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L		<1	<1	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L		<1	<1	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		**100**	**82**	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L		**100**	**82**	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		**12**	**10**	----	----	----
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		**3**	**3**	----	----	----
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		**33**	**22**	----	----	----
Magnesium	7439-95-4	1	mg/L		**4**	**5**	----	----	----
Sodium	7440-23-5	1	mg/L		**6**	**11**	----	----	----
Potassium	7440-09-7	1	mg/L		<1	<1	----	----	----
EG020F: Dissolved Metals by ICP-MS									
Antimony	7440-36-0	0.001	mg/L		<0.001	<0.001	----	----	----
Arsenic	7440-38-2	0.001	mg/L		<0.001	<0.001	----	----	----
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	----	----	----
Chromium	7440-47-3	0.001	mg/L		<0.001	<0.001	----	----	----
Copper	7440-50-8	0.001	mg/L		**0.001**	<0.001	----	----	----
Nickel	7440-02-0	0.001	mg/L		<0.001	<0.001	----	----	----
Lead	7439-92-1	0.001	mg/L		<0.001	<0.001	----	----	----
Zinc	7440-66-6	0.005	mg/L		<0.005	<0.005	----	----	----
Manganese	7439-96-5	0.001	mg/L		**0.007**	**0.004**	----	----	----
Selenium	7782-49-2	0.01	mg/L		<0.01	<0.01	----	----	----
Iron	7439-89-6	0.05	mg/L		<0.05	<0.05	----	----	----
EG020T: Total Metals by ICP-MS									
Antimony	7440-36-0	0.001	mg/L		<0.001	<0.001	----	----	----
Arsenic	7440-38-2	0.001	mg/L		**0.001**	<0.001	----	----	----
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	----	----	----
Chromium	7440-47-3	0.001	mg/L		**0.007**	**0.002**	----	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	S7	S8	----	----	----
				Client sampling date / time	29-Nov-2017 14:00	30-Nov-2017 09:00	----	----	----
Compound	CAS Number	LOR	Unit		EB1725906-013	EB1725906-014	--------	--------	--------
					Result	Result	----	----	----
EG020T: Total Metals by ICP-MS - Continued									
Copper	7440-50-8	0.001	mg/L		**0.016**	**0.003**	----	----	----
Nickel	7440-02-0	0.001	mg/L		**0.007**	**0.002**	----	----	----
Lead	7439-92-1	0.001	mg/L		**0.001**	<0.001	----	----	----
Zinc	7440-66-6	0.005	mg/L		**0.016**	<0.005	----	----	----
Manganese	7439-96-5	0.001	mg/L		**0.174**	**0.031**	----	----	----
Selenium	7782-49-2	0.01	mg/L		<0.01	<0.01	----	----	----
Iron	7439-89-6	0.05	mg/L		**7.00**	**1.65**	----	----	----
EG035F: Dissolved Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L		<0.0001	<0.0001	----	----	----
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L		<0.0001	<0.0001	----	----	----
EG094F: Dissolved Metals in Fresh Water by ORC-ICPMS									
Silver	7440-22-4	0.1	µg/L		<0.1	<0.1	----	----	----
EG094T: Total metals in Fresh water by ORC-ICPMS									
Silver	7440-22-4	0.1	µg/L		<0.1	<0.1	----	----	----
EK055G: Ammonia as N by Discrete Analyser									
Ammonia as N	7664-41-7	0.01	mg/L		**0.02**	**0.01**	----	----	----
EK057G: Nitrite as N by Discrete Analyser									
Nitrite as N	14797-65-0	0.01	mg/L		<0.01	<0.01	----	----	----
EK058G: Nitrate as N by Discrete Analyser									
Nitrate as N	14797-55-8	0.01	mg/L		<0.01	<0.01	----	----	----
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		**0.1**	<0.1	----	----	----
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ Total Nitrogen as N	----	0.1	mg/L		**0.1**	<0.1	----	----	----
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		**0.05**	**0.02**	----	----	----
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.01	mg/L		<0.01	<0.01	----	----	----
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		**2.33**	**1.93**	----	----	----

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)				Client sample ID	**S7**	**S8**	**----**	**----**	**----**
				Client sampling date / time	29-Nov-2017 14:00	30-Nov-2017 09:00	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*		**EB1725906-013**	**EB1725906-014**	**--------**	**--------**	**--------**
					Result	Result	----	----	----
EN055: Ionic Balance - Continued									
Total Cations	----	0.01	meq/L		**2.24**	**1.99**	**----**	**----**	**----**

Surrogate Control Limits

Sub-Matrix: SOIL		Recovery Limits (%)	
Compound	CAS Number	Low	High
EP080-SD: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	51	145
Toluene-D8	2037-26-5	42	144
4-Bromofluorobenzene	460-00-4	58	142
EP132T: Base/Neutral Extractable Surrogates			
2-Fluorobiphenyl	321-60-8	55	135
Anthracene-d10	1719-06-8	70	136
4-Terphenyl-d14	1718-51-0	57	127

Sub-Matrix: WATER		Recovery Limits (%)	
Compound	CAS Number	Low	High
EP075(SIM)S: Phenolic Compound Surrogates			
Phenol-d6	13127-88-3	10	72
2-Chlorophenol-D4	93951-73-6	27	130
2.4.6-Tribromophenol	118-79-6	19	181
EP075(SIM)T: PAH Surrogates			
2-Fluorobiphenyl	321-60-8	14	146
Anthracene-d10	1719-06-8	35	137
4-Terphenyl-d14	1718-51-0	36	154
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	66	138
Toluene-D8	2037-26-5	79	120
4-Bromofluorobenzene	460-00-4	74	118

Appendix C Fish Tissue Data

REPORT OF ANALYSIS

Report No. RN1181308

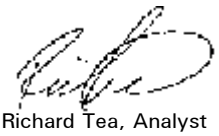
Client	: BMT WBM PTY LTD	**Job No.**	: BMTW01/171206
	PO BOX 203	**Quote No.**	: QT-02018
	SPRING HILL QLD 4004	**Order No.**	:
		Date Sampled	: 1-DEC-2017
		Date Received	: 6-DEC-2017
Attention	: BRAD HILES	**Sampled By**	: CLIENT
Project Name	:		
Your Client Services Manager	: Eric Nieberg	**Phone**	: 07 3613 6113

Lab Reg No.	Sample Ref	Sample Description
NQ17/02870	REEF-1	BIOTA 01/12/17 129/38.3
NQ17/02871	REEF-2	BIOTA 01/12/17 140/51.7
NQ17/02872	REEF-3	BIOTA 01/12/17 TRIGGER FISH 110/49.3
NQ17/02873	REEF-4	BIOTA 01/12/17 TRIGGER FISH 159/97.4

Lab Reg No.		NQ17/02870	NQ17/02871	NQ17/02872	NQ17/02873	
Sample Reference	Units	REEF-1	REEF-2	REEF-3	REEF-4	Method
Total Recoverable Trace Elements by ICP						
Aluminium	mg/kg	4.5	<0.5	2	3.9	NT2_46
Antimony	mg/kg	<0.01	<0.01	<0.01	<0.01	NT2_46
Arsenic	mg/kg	4.6	2.7	36	100	NT2_46
Boron	mg/kg	5.9	3.6	5.6	4.9	NT2_46
Cadmium	mg/kg	0.16	0.015	0.044	0.28	NT2_46
Chromium	mg/kg	0.36	<0.05	0.1	0.26	NT2_46
Cobalt	mg/kg	0.051	0.093	0.021	0.051	NT2_46
Copper	mg/kg	1.2	0.79	2.5	3.2	NT2_46
Iron	mg/kg	260	11	36	120	NT2_46
Lead	mg/kg	0.076	0.029	0.11	0.17	NT2_46
Magnesium	mg/kg	2980	1110	2220	2620	NT2_46
Manganese	mg/kg	2.8	0.55	3.3	7.8	NT2_46
Mercury	mg/kg	0.14	0.015	0.056	0.16	NT2_46
Molybdenum	mg/kg	0.043	0.044	0.027	0.066	NT2_46
Nickel	mg/kg	0.074	0.13	0.22	0.094	NT2_46
Selenium	mg/kg	1.6	0.41	0.61	1.6	NT2_46
Silver	mg/kg	0.028	0.033	0.037	<0.02	NT2_46
Thallium	mg/kg	<0.01	0.019	<0.01	<0.01	NT2_46
Tin	mg/kg	0.024	<0.02	<0.02	<0.02	NT2_46
Vanadium	mg/kg	<0.1	<0.1	<0.1	0.2	NT2_46
Zinc	mg/kg	26	14	64	86	NT2_46
Moisture Content						
Moisture	%	75.1	74.7	78.5	77.2	NT2_49

REPORT OF ANALYSIS

Lab Reg No.		NQ17/02870	NQ17/02871	NQ17/02872	NQ17/02873	
Sample Reference	Units	REEF-1	REEF-2	REEF-3	REEF-4	Method



Richard Tea, Analyst
Inorganics - NSW
Accreditation No. 198

19-DEC-2017

REPORT OF ANALYSIS

Report No. RN1181308

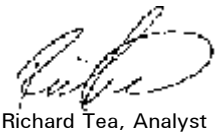
Client	: BMT WBM PTY LTD	**Job No.**	: BMTW01/171206
	PO BOX 203	**Quote No.**	: QT-02018
	SPRING HILL QLD 4004	**Order No.**	:
		Date Sampled	: 1-DEC-2017
		Date Received	: 6-DEC-2017
Attention	: BRAD HILES	**Sampled By**	: CLIENT
Project Name	:		
Your Client Services Manager	: Eric Nieberg	**Phone**	: 07 3613 6113

Lab Reg No.	Sample Ref	Sample Description
NQ17/02874	REEF-5	BIOTA 01/12/17 ACNTHURIDA SP. 175/113.9
NQ17/02875	REEF-6	BIOTA 01/12/17 ACNTHURIDA SP. 111/26.3
NQ17/02876	REEF-7	BIOTA 01/12/17 ACNTHURIDA SP. 110/36.5
NQ17/02877	REEF-8	BIOTA 01/12/17 ACNTHURIDA SP. 95/24.5

Lab Reg No.		NQ17/02874	NQ17/02875	NQ17/02876	NQ17/02877	
Sample Reference	**Units**	**REEF-5**	**REEF-6**	**REEF-7**	**REEF-8**	**Method**
Total Recoverable Trace Elements by ICP						
Aluminium	mg/kg	0.66	7.6	1440	6.4	NT2_46
Antimony	mg/kg	<0.01	<0.01	<0.01	<0.01	NT2_46
Arsenic	mg/kg	3.5	9.6	2.3	2.5	NT2_46
Boron	mg/kg	4.5	3.8	4	5.5	NT2_46
Cadmium	mg/kg	<0.01	<0.01	0.063	0.02	NT2_46
Chromium	mg/kg	0.064	0.068	2.8	0.077	NT2_46
Cobalt	mg/kg	0.071	0.08	0.074	0.031	NT2_46
Copper	mg/kg	0.31	0.39	1.6	0.67	NT2_46
Iron	mg/kg	10	18	27	21	NT2_46
Lead	mg/kg	0.092	0.12	0.36	0.68	NT2_46
Magnesium	mg/kg	1790	1240	2490	2460	NT2_46
Manganese	mg/kg	1	0.67	1.7	1	NT2_46
Mercury	mg/kg	0.01	0.02	<0.01	<0.01	NT2_46
Molybdenum	mg/kg	0.011	0.017	0.068	0.023	NT2_46
Nickel	mg/kg	<0.01	<0.01	0.39	0.036	NT2_46
Selenium	mg/kg	0.51	0.4	0.23	0.2	NT2_46
Silver	mg/kg	<0.02	<0.02	0.027	0.032	NT2_46
Thallium	mg/kg	<0.01	<0.01	<0.01	<0.01	NT2_46
Tin	mg/kg	<0.02	<0.02	4.2	0.23	NT2_46
Vanadium	mg/kg	<0.1	<0.1	0.3	0.31	NT2_46
Zinc	mg/kg	15	12	33	22	NT2_46
Moisture Content						
Moisture	%	77.9	72.3	76.5	74.7	NT2_49

REPORT OF ANALYSIS

Lab Reg No.		NQ17/02874	NQ17/02875	NQ17/02876	NQ17/02877	
Sample Reference	Units	REEF-5	REEF-6	REEF-7	REEF-8	Method



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REPORT OF ANALYSIS

Report No. RN1181308

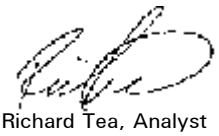
Client	: BMT WBM PTY LTD	**Job No.**	: BMTW01/171206
	PO BOX 203	**Quote No.**	: QT-02018
	SPRING HILL QLD 4004	**Order No.**	:
		Date Sampled	: 1-DEC-2017
		Date Received	: 6-DEC-2017
Attention	: BRAD HILES	**Sampled By**	: CLIENT
Project Name	:		
Your Client Services Manager	: Eric Nieberg	**Phone**	: 07 3613 6113

Lab Reg No.	Sample Ref	Sample Description
NQ17/02878	REEF-9	BIOTA 01/12/17 192/116.2
NQ17/02879	REEF-10	BIOTA 01/12/17 182/101.2

Lab Reg No.		NQ17/02878	NQ17/02879			
Sample Reference	Units	REEF-9	REEF-10			Method
Total Recoverable Trace Elements by ICP						
Aluminium	mg/kg	1.2	200			NT2_46
Antimony	mg/kg	<0.01	<0.01			NT2_46
Arsenic	mg/kg	29	8.2			NT2_46
Boron	mg/kg	2.4	2			NT2_46
Cadmium	mg/kg	0.016	0.025			NT2_46
Chromium	mg/kg	0.25	0.5			NT2_46
Cobalt	mg/kg	0.016	0.015			NT2_46
Copper	mg/kg	0.82	0.87			NT2_46
Iron	mg/kg	12	18			NT2_46
Lead	mg/kg	0.17	0.014			NT2_46
Magnesium	mg/kg	1740	1520			NT2_46
Manganese	mg/kg	0.51	0.72			NT2_46
Mercury	mg/kg	0.11	0.14			NT2_46
Molybdenum	mg/kg	0.024	0.015			NT2_46
Nickel	mg/kg	<0.01	<0.01			NT2_46
Selenium	mg/kg	0.82	1.3			NT2_46
Silver	mg/kg	<0.02	<0.02			NT2_46
Thallium	mg/kg	<0.01	<0.01			NT2_46
Tin	mg/kg	0.029	0.2			NT2_46
Vanadium	mg/kg	<0.1	<0.1			NT2_46
Zinc	mg/kg	46	20			NT2_46
Moisture Content						
Moisture	%	76.6	77.2			NT2_49

REPORT OF ANALYSIS

Lab Reg No.		NQ17/02878	NQ17/02879			
Sample Reference	Units	REEF-9	REEF-10			Method



Richard Tea, Analyst
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Accreditation No. 198

19-DEC-2017

All results are expressed on a dry weight basis.

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Our dedication to developing innovative approaches and solutions enhances our ability to meet our client's most challenging needs.

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