NEARSHORE MARINE IMPACT ASSESSMENT

Esso Highlands Limited

PNG LNG Project

December 2008

An ExxonMobil Affiliate

CR 1284_5_v1

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1 INTRODUCTION

1.1 Project Description

The Papua New Guinea Liquefied Natural Gas (PNG LNG) Project involves the development of a number of gas fields and facilities in a series of development phases to produce liquefied natural gas (LNG) for export. The development will also produce condensate. The development of the Hides, Angore, and Juha gas fields and blowdown of the gas caps at the existing Kutubu, Agogo and Gobe oil fields will supply the gas resources. An extensive onshore and offshore pipeline network will enable transportation of the gas to a new LNG Plant near Port Moresby and stabilised condensate to the existing oil processing and storage, and offloading facilities at the Kutubu Central Processing Facility and Kumul Marine Terminal respectively. Small amounts of condensate are also produced at the LNG Facilities site.

Esso Highlands Limited (Esso), a Papua New Guinea subsidiary of the Exxon Mobil Corporation (ExxonMobil), is the operator of the PNG LNG Project. The PNG LNG Project will be developed in five phases over a period of 10 years to ensure reliability and consistent quality of supply of LNG for over the 30-year life of the project.

A list of the proposed developments is provided below, and Figure 1.01 shows a schematic of facilities and pipelines:

1.1.1 Upstream Development Components

- Hides gas field development:
  - Seven wellpads with a total of eight new wells and re-completion of two existing wells.
  - Hides gathering system including gas flowlines from new and re-completed Hides wells.
  - Hides spineline and mono-ethylene glycol (MEG) Pipeline in the same right of way (ROW).
  - Hides Gas Conditioning Plant.
  - Hides–Kutubu Condensate Pipeline in the same ROW as the LNG Project Gas Pipeline.

- Juha gas field development:
  - Three new wellpads with four new wells.
  - Juha gathering system including gas flowlines from new Juha wells.
  - Juha spinelines and MEG Pipeline in the same ROWs.
  - Juha Production Facility.
  - Juha–Hides pipelines right of way (ROW) containing three pipelines including Juha–Hides Rich Gas Pipeline, Juha–Hides Liquids Pipeline and Hides–Juha MEG Pipeline.

- Angore gas field development:
  - Two new wellpads with two new wells.
  - Angore gathering system including gas flowlines from new Angore wells.
  - Angore spineline and Angore MEG Pipeline to Hides Gas Conditioning Plant, both in the same ROW.

- Gas from existing fields:
  - Gas treatment at the Agogo Production Facility and a new Agogo Gas Pipeline from the Agogo Production Facility to LNG Project Gas Pipeline.

Juha Production Facility
250 Mscfd

Juha
4 new wells

~55 km x 14" rich gas pipeline

~55 km x 8" liquids pipeline

Hides
8 new wells, upgrade of 2 wells

Hides Gas Conditioning Plant
960 Mscfd

Angore
2 new wells

Key
- New facility
- Existing oil operations (Not part of PNG LNG Project)

~104 km x 8" condensate pipeline

~ 19 km gas pipeline

Agogo Production Facility
(existing oil production, additional gas treatment and gas pipeline)

Kutubu Central Processing Facility

Kutubu
(existing oil production, additional gas treatment and gas pipeline)

South East Hedinia
2 new wells

~ 2 km gas pipeline

~ 10 km gas pipeline

Gobe Production Facility
(existing oil production, additional gas treatment and gas pipeline)

~284 km x 32" onshore LNG Project Gas Pipeline

Existing 257 km x 20" crude oil export pipeline

LNG Facilities
- LNG Plant (6.3 Mtpa)
- 2 x 165,000 m³ LNG storage tanks
- 2 x 8,500 m³ condensate storage tanks
- LNG Jetty
- Materials Offloading Facility

Kopi

Kumul Marine Terminal

~407 km x 34" subsea LNG Project Gas Pipeline

LNG carriers/ condensate tankers

Note: Not to scale. Pipeline diameters are indicative only.

PNG LNG	Job No: 1284	Esso Highlands Limited	Project overview: new and existing facilities and pipeline	Figure No: 1.01
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  - Gas treatment at the Gobe Production Facility and a new Gobe Gas Pipeline from the Gobe Production Facility to LNG Project Gas Pipeline.
  - Gas treatment at the Kutubu Central Processing Facility and a new Kutubu Gas Pipeline from the Kutubu Central Processing Facility to the LNG Project Gas Pipeline.
  - South East Hedinia gas field development: one new wellpad and two new wells; new gathering system including gas flow lines from the South East Hedinia new wells to the Kutubu Central Processing Facility in the same ROW as the Kutubu Gas Pipeline.

- Kopi scraper station.

- LNG Project Gas Pipeline:
  - Onshore: from Hides Gas Conditioning Plant to Omati River Landfall.
  - Offshore: Omati River Landfall to Caution Bay Landfall.

1.1.2 LNG Facilities Development Components

- Onshore LNG Plant including gas processing and liquefaction trains, storage tanks, flare system and utilities.

- Marine facilities including jetty, LNG and condensate export berths, materials offloading facility and tug moorage.

1.1.3 Supporting Facilities and Infrastructure

In addition to the principal gas production, processing and transport, and LNG production and export facilities, the project will involve the following permanent infrastructure and facilities:

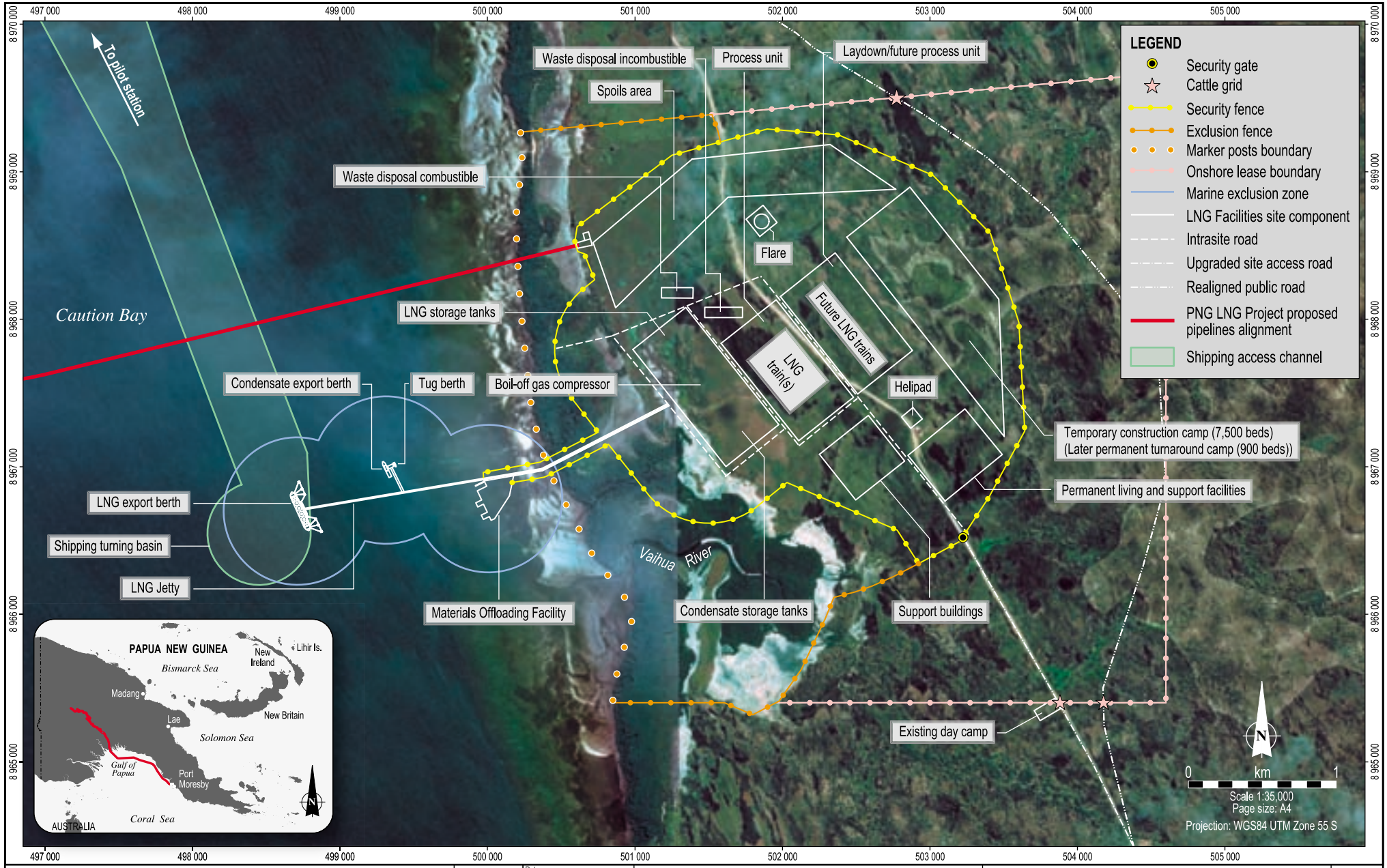
- New roads and upgrade of existing roads.
- New bridges and upgrade of existing bridges.
- Upgrade of two existing airfields (upstream at Komo and Tari).
- New helipads (multiple).
- New wharf and an upgrade of the existing Kopi roll-on, roll-off facility.
- Water supply systems and pipelines, wastewater and waste management facilities.
- Operations Camps (at Hides, Juha and Tari).

A series of temporary works and access roads will also be required during the construction phase, including:

- Construction camps (multiple).
- Material/pipe laydown areas.

1.2 Purpose of this Document

This report summarises the existing physical (Chapter 2) and biological (Chapter 3) characteristics of the nearshore marine environment of Caution Bay traversed by the proposed offshore pipeline and adjacent to the construction of LNG facilities at Portion 152 (Figure 1.02). Potential issues associated with the construction and operation of the offshore pipeline and LNG facilities are described and assessed in Chapter 4. Recommendations on measures that could be implemented by the project to mitigate these issues are also described in Chapter 5.



Note:
Layout is indicative only.
Final placement of all components is contingent on pending soil and geological data.
Pipelines approximate the proposed alignment based on engineering data provided up to 1 October 2008.

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Project components in Caution Bay

Figure No: 1.02

The geographic scope of this assessment is limited to the nearshore marine environment of Caution Bay (Figure 1.03). The offshore marine environment of the rest of the pipeline route from the Omati River to Caution Bay is addressed in a report titled *Offshore Impact Assessment* (Coffey Natural Systems, 2008a), which is an appendix to the PNG LNG Project EIS. Further information about resource utilisation in Caution Bay is also provided in a report titled *Resource Use Survey of Caution Bay* (Coffey Natural Systems, 2008b), which is also an appendix to the PNG LNG Project EIS.

1.3 Methods and Sources of Information

Methods and sources of information used to describe the marine environment are summarised as follows:

- Specialist report prepared by EGS Survey Pty (EGS, 2008) that provided detailed bathymetry of Caution Bay, which allowed identification of offshore coral bommies and rocky outcrops of the nearshore marine environment.
- Specialist report prepared by Global Environmental Modelling Systems (GEMS, 2008) that provided modelling of oceanographic conditions (i.e., current movements, sediment transport and coastal processes) in Caution Bay dredging program simulations.
- Results from a nearshore marine characterisation study of Caution Bay, which included coral reef surveys, underwater seafloor photography and water and sediment quality sampling. Details of survey methods are provided below.

PNG LNG	Date: 23.06.2008 MXD: PNG_LNG_Project_GIS.mxd File Name: 1284_05_F01.03_HB	Esso Highlands Limited PNG LNG Project	Extent of Caution Bay	Figure No: 1.03

2 EXISTING PHYSICAL ENVIRONMENT

EGS Survey Pty (EGS) conducted geophysical and bathymetric studies of the proposed pipeline route using the vessel MV Pacific Conquest during April 2008. This study provided detailed bathymetry of Caution Bay, which allowed identification of offshore coral bommies and rocky outcrops of the nearshore marine environment (EGS, 2008).

Global Environmental Modelling Systems (GEMS) undertook oceanographic studies and dredging program simulations, which involved modelling the oceanographic conditions (i.e., current movements, sediment transport and coastal processes) in Caution Bay (GEMS, 2008).

A summary of the bathymetric and hydrodynamic studies findings are presented in this chapter.

2.1 Physiography

Caution Bay is a shallow coastal basin, located between Porebada and Boera villages, about 20 km northwest of Port Moresby. In the 20-km-long segment where the currently proposed offshore pipeline route enters Caution Bay the seafloor depth reaches 47 m at the seaward margin.

The majority of the Caution Bay seafloor is characterised mainly by terrigenous silt and clay sediments with evidence of epibenthic faunal activity in the form of mounds and burrows which range in size and abundance across the various locations. The deeper waters (30 m to 50 m water depth) have a predominately muddy seafloor and a generally sparse distribution of visible biota. The shallow areas (less than 30 m) closer to the coastal environment are characterised by coarser coral sands and coral rubble.

A continuous barrier reef forms the southwestern (offshore) boundary of the bay and provides protection from ocean swells (see Figure 1.03). There are natural openings in the reef to the north of Idihi Island, which effectively marks the northwestern extent of the barrier reef, and to the south (Liljeblad Passage), which are used by small vessels to move in and out of the reef.

There are a number of offshore coral bommies within Caution Bay, rising to water depths of approximately 5 m and the southern end of the bay is characterised by shallow areas supporting patches of corals and seagrass. Two island groups are located on the boundary of Caution Bay: Vari Vari Island situated to the north is a remnant of the mainland and Idihi Island to the south, located on the barrier reef, is a coral cay.

As the offshore pipeline route approaches the shore, it is proposed to run down a relatively deepwater channel between the nearshore fringing reefs and offshore coral bommies before traversing across the fringing reef, subtidal sandy areas (with patches of seagrass), mangrove and mud flat habitats for approximately 500 m before terminating at the LNG Facilities site. Like the offshore pipeline approach, the marine facilities are aligned perpendicularly to shore and pass through the same nearshore habitat zones.

Within Caution Bay, there is a natural channel of at least 14 m depth and free from coral bommies that runs between Redscar Bluff and Idihi Island and generally follows the alignment of the coast until reaching the area adjacent to the proposed jetty. Further to the south, there are numerous shoals and bommies rising to about 5 m below the water surface.

2.2 Climate

Climate records for Papua New Guinea are fairly limited. An Automatic Weather Station (AWS) was deployed on land near the coast of Caution Bay in February 2008. The location on land is not an ideal for oceanographic studies as the influence of land–sea affects can be significant, particularly in the vicinity of cliffs and hilly topography. As a result, the offshore winds can be expected to differ from the onshore winds measured by the AWS. Also, a relatively short period of data is available from the AWS, which has limited use for climatic studies. Therefore the descriptions of meteorological conditions are based on both measured and modelled climate parameters and are not site specific but are representative of the coastal conditions within the offshore area generally.

2.2.1 Winds

Wind patterns along the southern coast of PNG are highly seasonal (NSR, 1990; Williams, 1994; Woolfe et al., 1997). The two wind regimes that influence climate within Papua New Guinea are:

- *Northwest monsoon* (November to April) winds are generally less than 31 km/hr (17 knots), with wind speeds exceeding this only 15% of the time.
- *Southeast trade winds* (May to October) are coherent winds over distances in the order of 1,000 km across the Coral Sea and Gulf of Papua, exceeding 31 km/hr (17 knots) for 30% of the time in the Gulf of Papua (NSR, 1990).

GEMS analysed three years of offshore Mesoscale Limited Area Prediction System (MesoLAPS) data (GEMS, 2008). Results are summarised in Table 2.01. The results identified three main features of the ambient conditions in Caution Bay:

- The dominance of the southeasterly trade winds offshore.
- The existence of katabatic winds from the northeast off the coastal topography.
- The significant difference in the wind regime between onshore and offshore sites.

Table 2.01 Summary of the analysis of MesoLAPS data from July 2005 to July 2008

Parameter	3 years of MesoLAPS data (July 2005 to July 2008)	3 months of AWS data (February 2008 to April 2008)
Mean Hourly Wind Speed	4.8 m/s	3.1 m/s
Mean Wind Direction	300 deg	85 deg
Average of Top 100 Wind Speeds	11.5 m/s	8.8 m/s
Average Direction of Top 100 Wind Speeds	314 deg	134 deg

2.2.2 Temperature and Rainfall

Daily mean minima and maxima air temperatures are 23°C and 28°C respectively in July, and 24°C and 31°C respectively in November at Port Moresby (BBC Weather, 2006). As the meteorological station located at Port Moresby is situated approximately 20 km from Caution Bay, it is therefore reasonable to use these results as a representative of the ambient conditions.

Although PNG is situated in the tropics, rainfall varies greatly from place to place due to the range of altitudes and exposure to the seasonal wind patterns. Annual rainfall within Port Moresby is approximately 1,125 mm, making it one of the driest parts of the country (BBC Weather, undated).

Rainfall is relatively low throughout the year (18 to 64 mm/month), with a major wet season from December to April when the rainfall rises to an average of 150 mm per month (BBC Weather, 2006).

2.3 Oceanography

2.3.1 Bathymetry

Caution Bay has a wide, westerly facing entrance between Redscar Bluff and Idihi Island, inshore of which, the bathymetry gradually shelves from around 50 m to less than 5 m at the nearshore fringing reef (Figure 2.01). Within the bay, average depths are around 25 m, with many shallower coral bommies, mostly in the southern part of the bay. There is a channel of at least 14 m that is adjacent to the location of the jetty that is free of bommies, and runs north and west to the open sea. To the south and east of Idihi Island, the outer barrier reef forms the southern boundary of Caution Bay, beyond which, the bathymetry drops rapidly off the continental shelf to depths below 1,000 m.

2.3.2 Tides

Port Moresby has semi-diurnal tidal cycles, with two high and low tides per day. Mean spring tidal height in Caution Bay is less than 3 m. Tidal data available for hydrodymanic modelling of sea surface heights was taken from the two sets of data obtained at loggers placed in Caution Bay and in the western side of the Gulf of Papua that (to date) were available from the 5-month period December 20, 2007 to May 8, 2008 (GEMS, 2008). Global tidal data from the Australian region, including the Gulf of Papua was used to compare predicted with observed sea surface heights, and showed that longer time predictions could be made with confidence. Overall sea tidal ranges were between -1.50 and +1.50 m from mean sea level (see Figure 3.5 in GEMS, 2008).

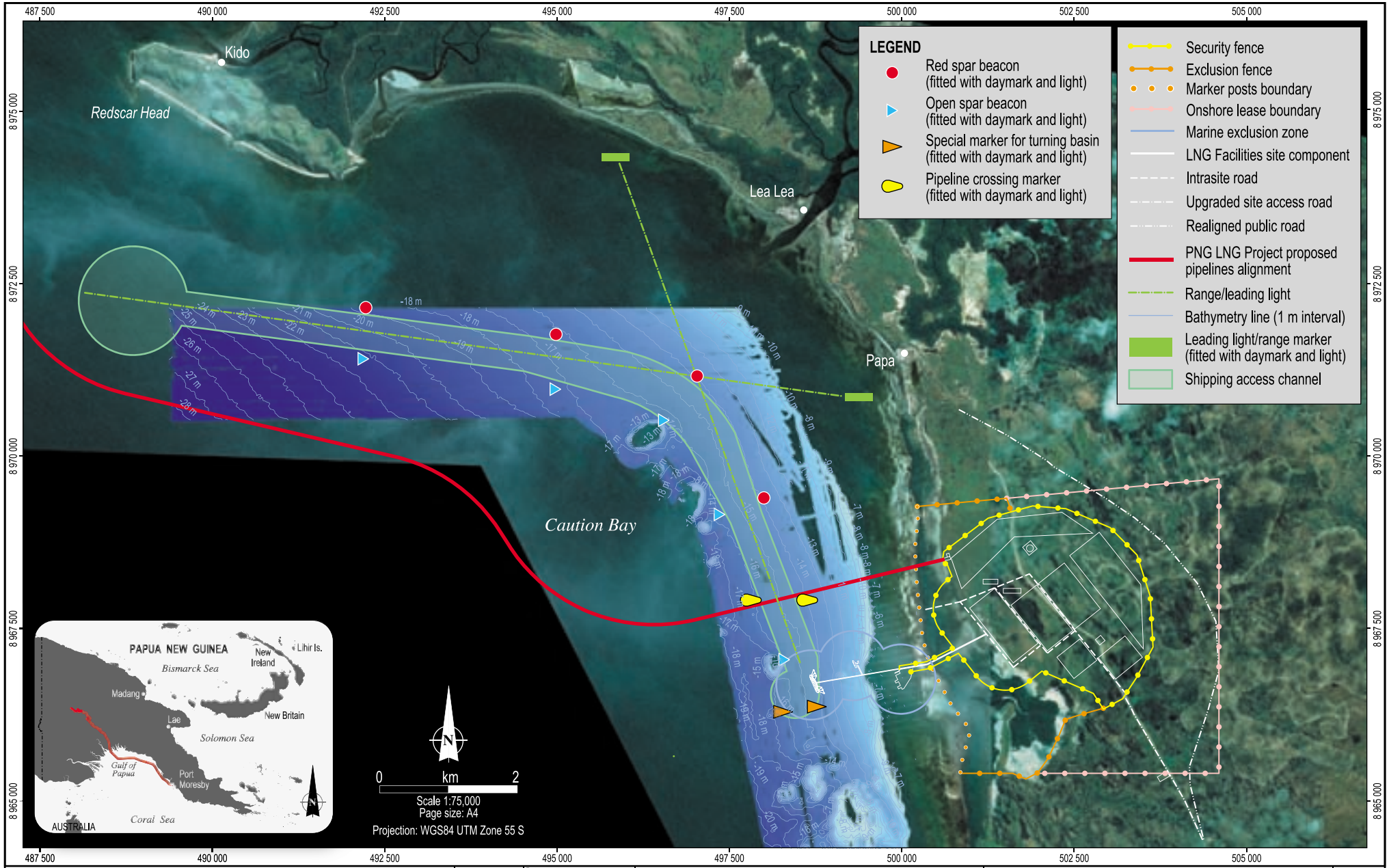
2.3.3 Currents

Oceanic circulation within the Gulf of Papua is dominated by a clockwise gyre (Figure 2.02), generated as the northwards-flowing Coral Sea Coastal Current enters the gulf along the eastern edge of Torres Strait and exits to the northeast (Woolfe et al., 1997). As a result, most of the freshwater (and sediment) delivered to the Gulf by the large Papuan rivers tends to travel eastwards.

Data on currents within Caution Bay has been obtained from an acoustic doppler current profiler (ADCP) deployed at the proposed LNG Jetty location, with the first five months data used to model a 12-month period (GEMS, 2008). The mean hourly current speed in Caution Bay is 0.07 m/s with a maximum mean speed of 0.32 m/s (calculated as an average of the top 100 current speed records in the bay). Figure 2.03 provides an indication of the dominant patterns of tidal and wind driven currents within Caution Bay.

2.3.4 Waves

The Gulf of Papua is exposed to the local surface waves generated during the southeast trades, which propagate in the general direction of the winds but refract across shallow water towards shorelines. During the northwest monsoon, the offshore winds result in little or no swell. The seasonally averaged



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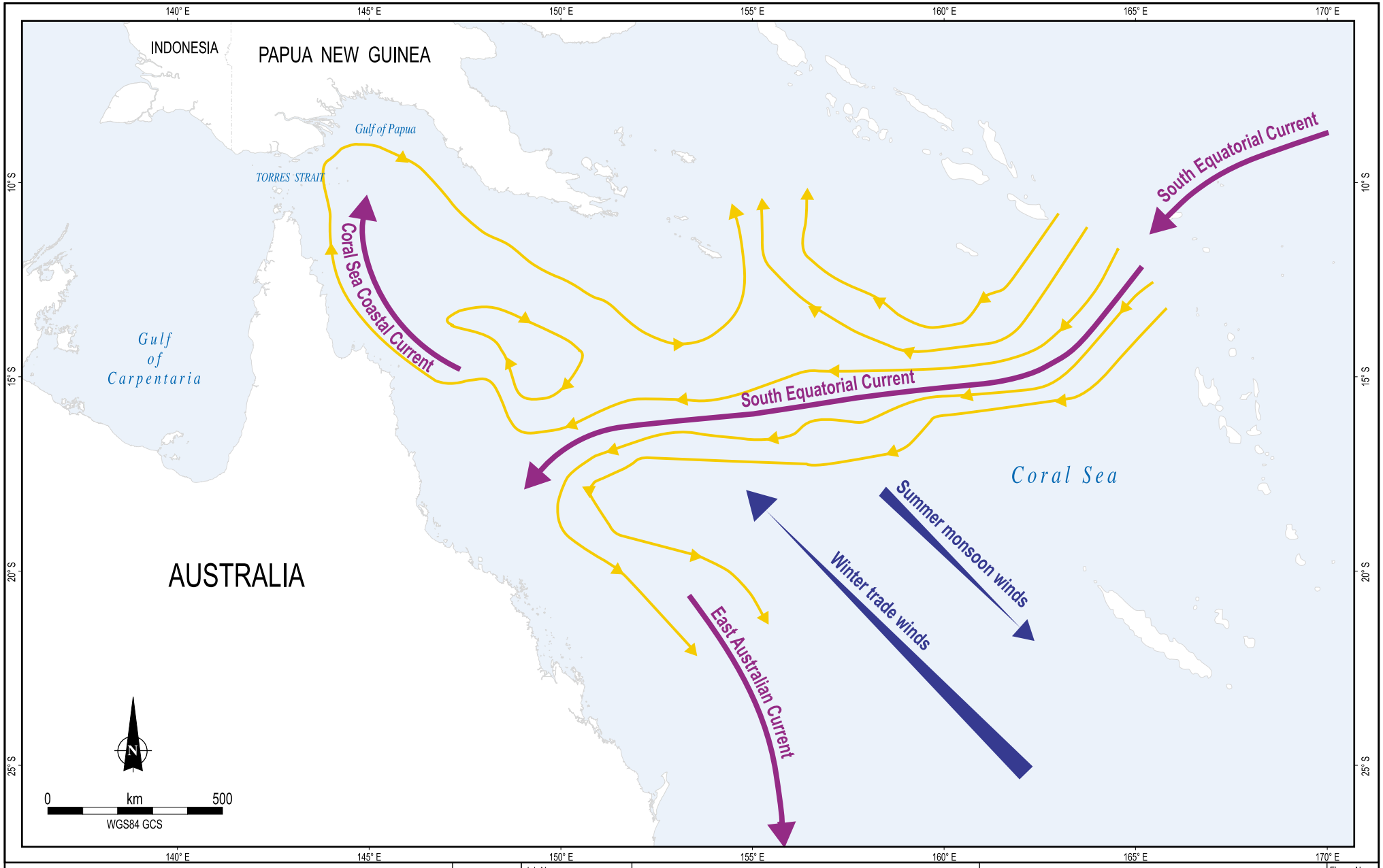
Detailed bathymetry of Caution Bay

Figure No: 2.01



Source:
Burrage et al. (1993) as cited in Woolfe et al. (1997)

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Job No: 1284

File Name: 1284_05_F02.02_HB

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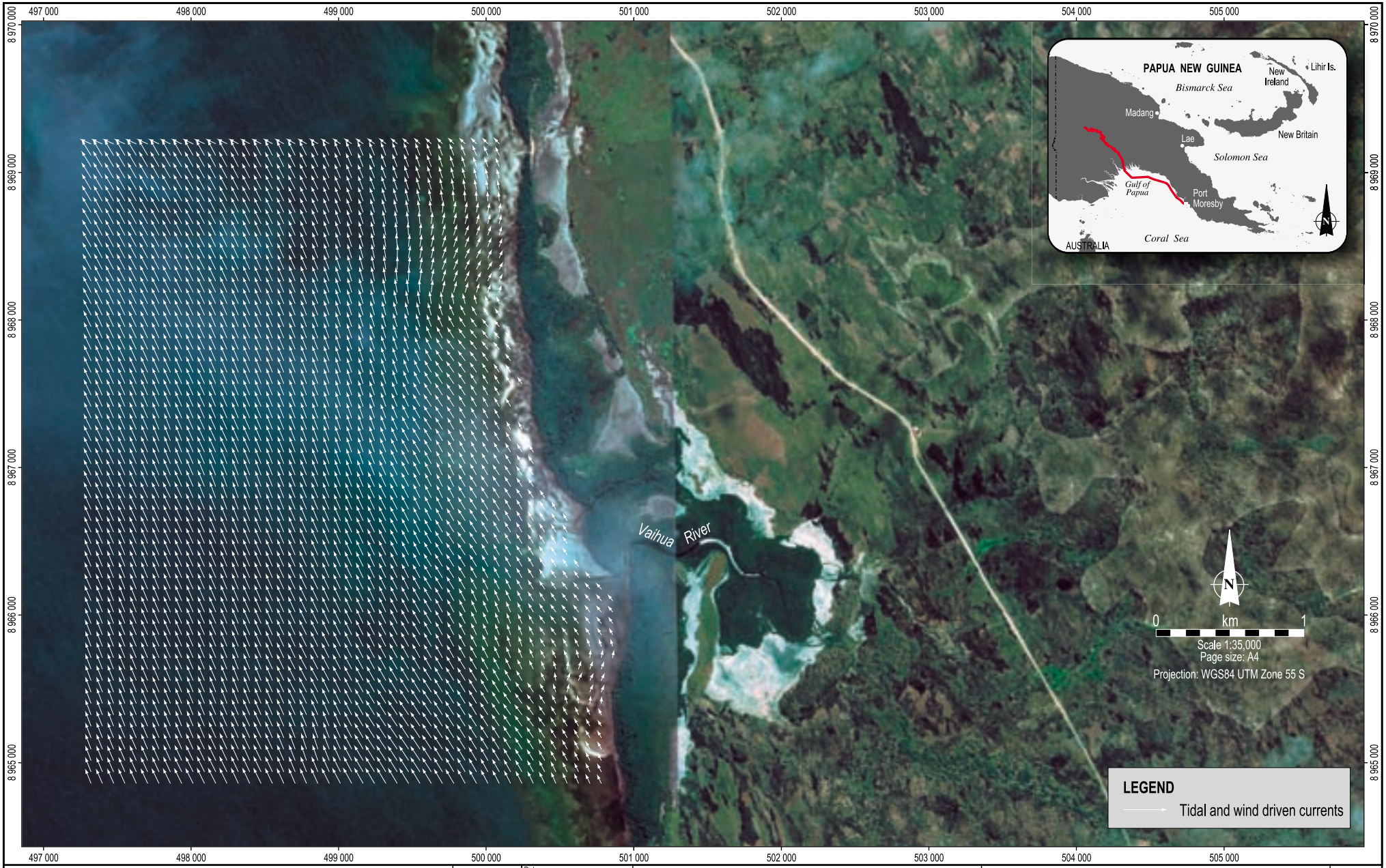
Oceanic circulation in the Gulf of Papua

Figure No: 2.02



Source:
Current data from GEMS, 2008.

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Tidal and wind driven currents

Figure No:
2.03

significant wave heights (SWHs) of 1.5 and 2.1 m occur relatively close to the coast during the southeast trades and further offshore during the northwest monsoons (Hemer et al., 2004). Within Caution Bay, the severity of the waves is somewhat mitigated by the fringing reef. Data modelled over 12 months at the proposed LNG Jetty site (using the ADCP wave recording) indicated a mean wave height of 0.42 m and a maximum wave height of 1.9 m. Wave height only exceeded 1 m for 10% of the time over the 12-month period (GEMS, 2008).

Tropical cyclones represent the extreme oceanographic conditions likely to be experienced in Caution Bay. However, the project area is north of the main cyclone belt and occurrences of such extremes are rare, with only five named cyclones in 15 years entering the Gulf of Papua. Of these Guba is the most relevant as it entered the Gulf of Papua from the southeast as a Category one cyclone and passed to the south of Port Moresby (see Figure 5.1 in GEMS, 2008). Wave recording instruments were recording during this period and the peak significant wave heights at the Caution Bay jetty site were just over 1 m, while there was only a small storm surge and peak currents reached 0.2 m/s (GEMS, 2008). A search of the tropical cyclone data base, to as far back in time as the 1950s, before satellite observations were available did not reveal any incident of cyclone genesis in the northern part of the Gulf of Papua. Table 2.02 shows the output from a theoretical model of a 990 hectopascal (hPa) storm travelling from northwest to southeast past Caution Bay, at a distance such that the strongest winds would impact near the coastline (i.e., comparable to, Cyclone Guba, in November 2007). The results described for both current and waves reflect the extreme conditions within Caution Bay.

Table 2.02 Summary of the peak wind, wave, sea level and current conditions generated in Caution Bay by the passage of a theoretical 990 hPa storm and Tropical Cyclone Guba

Parameter	Theoretical Tropical Storm	Tropical Cyclone Guba
Maximum wind speed	25 m/s	12 m/s
Maximum sea level	0.25 m	0.1 m
Maximum current speed	0.4 m/s	0.21 m/s
Maximum significant wave height	3.2 m	1 m

3 EXISTING BIOLOGICAL ENVIRONMENT

During December 2007 and April 2008, Coffey Natural Systems conducted two seasonal components of a nearshore marine characterisation study within Caution Bay. The aim of the study was to identify marine habitats, assess their current general condition and identify the potential impacts posed by the PNG LNG Project. A short follow-up survey in June 2008 focussed on specific coral bommies, identified from bathymetric data that became available after the second survey.

Sampling locations for this study were selected to represent the habitats within and surrounding the areas of the proposed facilities within Caution Bay in order to describe the status and extent of the different marine habitats locally. A number of more remote locations outside of the potential impact area were also surveyed to provide a broader area of coverage and potential reference sites as may be required for future monitoring as a condition of project approval.

3.1 Survey Methods

3.1.1 Study Timing and Personnel

Sampling events were timed so that seasonal differences could be investigated. The initial survey was conducted between 4 and 12 December 2007 at the beginning of the wet season. The purpose of this initial trip was to install the coral transect sites and sedimentation monitoring equipment, assess the diversity of coral reef fish, identify major habitat types and undertake seawater and sediment sampling.

The coral reef and fish transects were revisited during the second field survey conducted 20 April to 1 May 2008 at the beginning of the dry season. Fish diversity was re-assessed and additional habitat assessment undertaken at locations reflecting the design of the PNG LNG Project. Water and sediment samples were collected opportunistically from various locations within Caution Bay during both surveys. Additional sites were also sampled on the second survey to assist in filling in the gaps for identification of major habitat types within Caution Bay.

The two previous nearshore marine surveys undertaken were completed before detailed bathymetry data were available. Subsequently, a review of the bathymetry data revealed potential coral bommies near the proposed combined LNG Jetty / Materials Offloading Facility, shipping channel and a pipeline approach, which has subsequently been superseded by a northern approach (Figure 3.01). These bommies had not been previously investigated and could potentially pose engineering or environmental constraints. In addition, two sites were identified in the detailed bathymetry that appeared similar to the *Pavona clavus* bommie, which was discovered during the second nearshore marine survey in April 2008 (see Section 3.2.4). Therefore the final survey conducted on 25 June 2008 was to complete a visual assessment of these areas.

Coffey Natural Systems personnel travelled to Caution Bay daily from Port Moresby onboard the vessel Lauta Oroti (Plate 3.01). This vessel, along with a small dinghy, was used for the surveys.

3.1.2 Sampling Locations and Dates

The GPS coordinates for all sampling locations and the dates of sampling are listed in Tables 1 to 10 (Annex A); and the sampling locations are shown in Figure 3.02. Satellite images and navigational charts were used to select sampling locations; however, both were of reduced value without the more

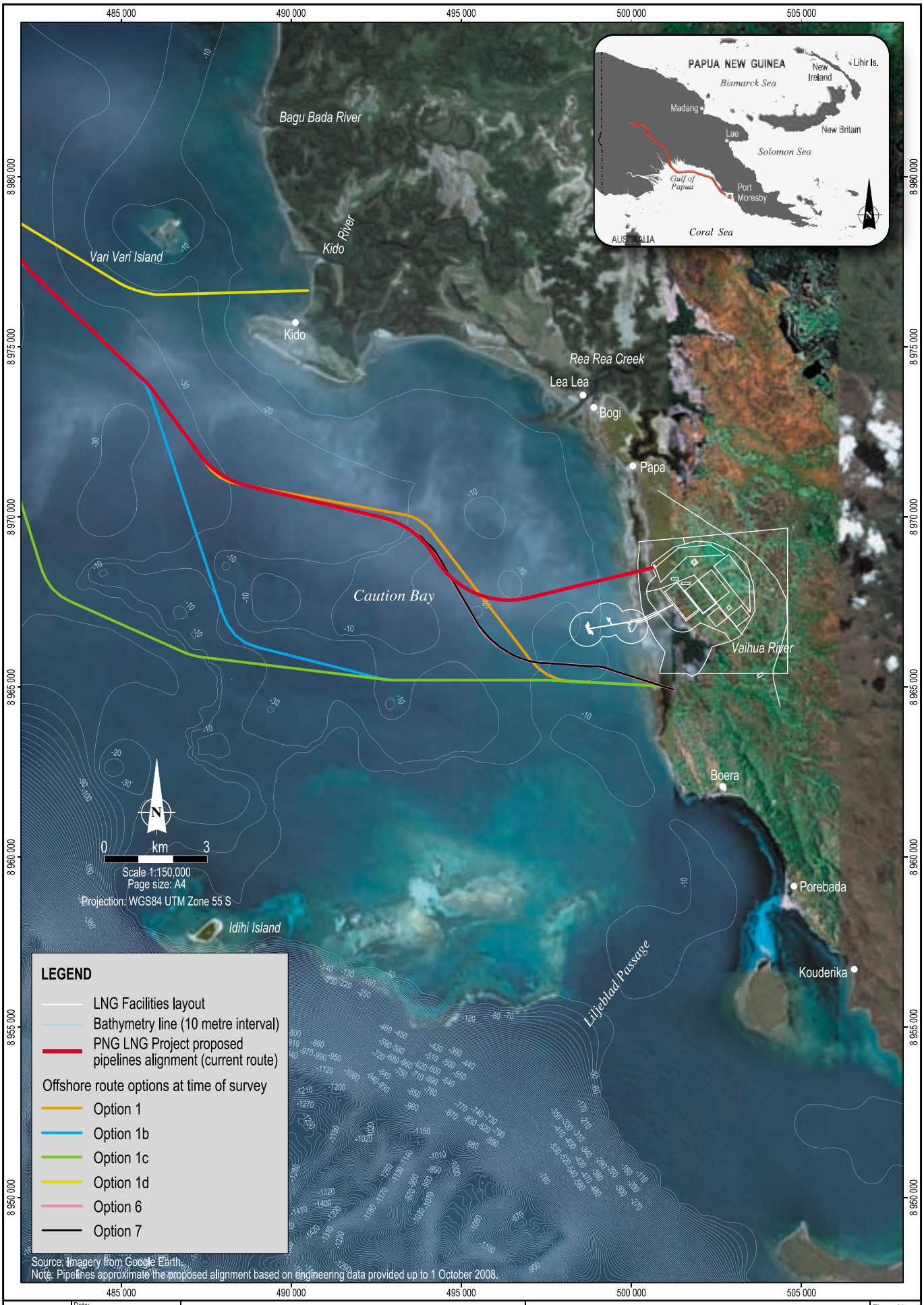

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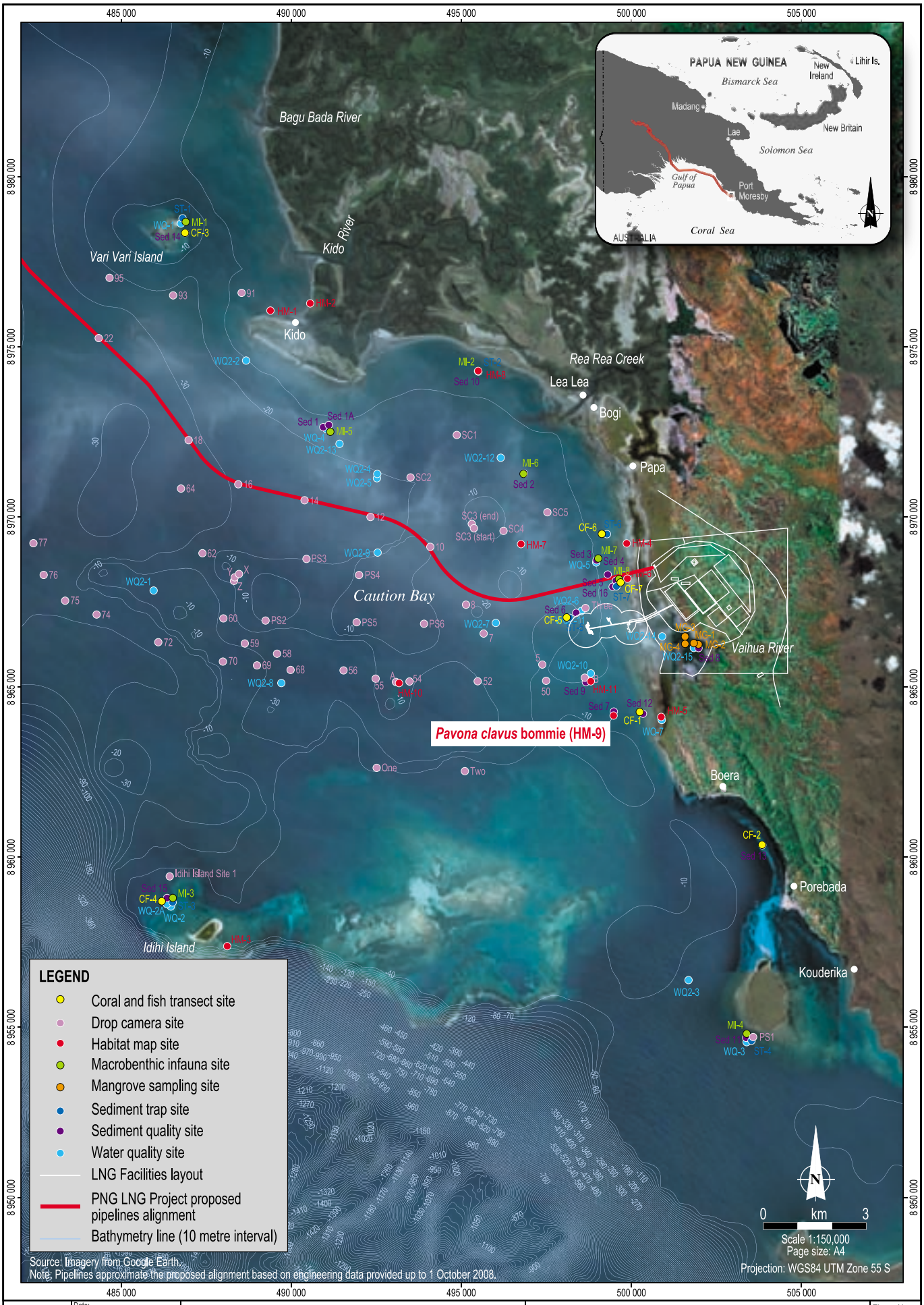
Plate 3.01
MV Lauta Oroti



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Nearshore marine sampling locations

Figure No: 3.02

detailed bathymetry data, which was collected as part of the PNG LNG Project but was not available until the very end of the second survey trip.

The areas selected for habitat characterisation were based upon several proposed offshore pipeline route alternatives, as shown in Figure 3.01. Since the completion of field surveys a final offshore pipeline route has been chosen and this route is also included on Figure 3.01.

3.1.3 Coral Census

Seven coral reef transect sites were established in Caution Bay to characterise the existing, pre-development conditions of the nearshore coral reefs. The transect locations were selected where there was a reasonably extensive cover of coral, in order to extend comparisons into the future. The details of GPS location and dates of installation are given in Table 2 of Annex A and the locations are shown in Figure 3.02.

At each transect location, two star pickets were driven into the reef substrate at a distance no less than 6 m apart to distinguish the beginning and end of the transects (Figure 3.03). Each transect was located on the reef slope just below the reef crest and orientated parallel with the reef slope to enable comparisons between different locations. The depth of the transects varied between sites and was dependent on where they were situated within the marine environment of Caution Bay (see Table 3 of Annex A). Transects were labelled with a plastic 'swing tag', and the location recorded on a GPS for future reference.

Two methods were used to quantify coral distribution and these are described below.

Visual Census

The coral reef surveys were conducted by making visual observations along each transect using the line-intercept method (AIMS, 1994), for which, divers set a waterproof tape measure between the stakes to form the transect line[1], then recorded the distance along the tape where key features were intersected (e.g., the start and end of each individual coral type). Following the AIMS (1994) methods, records were made of:

- Hard coral families and growth forms (e.g., digitate Acropora, massive Porites, encrusting Faviids).
- Other biota (e.g., soft corals, sponges and Halimeda).
- Abiota (e.g., dead coral, rubble and sand).

A photographic record of the coral transect was obtained using a high-definition digital camera in an underwater housing. The diver first photographed the swing tag to provide a reference at the start of each transect and then took photographs at approximately 0.6 m intervals along the 6 m transect with the camera held 1 to 2 m perpendicularly above the substrate, with the measuring tape framed in the centre of each photograph. Mosaics of each transect were constructed by stitching individual photographs together to provide a general overview of the structure of the coral reef community within the sampling site (Annex C).

[1] This method is consistent with the methods outlined in English et al. 1997.

Setting of reef transect

Recording coral abundance

Coral reef transect

PNG LNG	Job No: 1284	Esso Highlands Limited	Set-up and recording of reef transects	Figure No: 3.03
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Video Transects

As the 6 m transects were positioned over areas containing higher coral cover selected to provide long-term monitoring of coral condition, two additional 50-m transects at each coral transect site were set up to provide a more accurate representation of the cover of coral reef assemblages across wider areas. Each transect started at the star picket used for the 6 m visual coral transect, from which a measuring tape was laid over the reef to the appropriate distance and photographed using an underwater video camera orientated across the reef at a constant distance of 0.5 m above the seafloor. This method followed the AIMS Video Transect Analysis System (AVTAS) method developed by the Australian Institute of Marine Science (AIMS, 2004).

The AVTAS technique involved the examination of individual video frames (e.g., approximately 40 frames per 50 m transect) to identify the substrate at a number of fixed points per frame (typically 5 points). Live hard coral, live soft coral, algae, invertebrates and other substrata types such as recently dead coral, coral rubble, sand and reef substrate were recorded along the transects.

Data Analysis

Data collected from the line-intercept method was converted to percentage cover at each of the 6 m coral transect sampling sites. In addition, ecological diversity of species from different populations was calculated by the use of a biological index (Kvålseth, 1991), which offers a quantitative method in which to describe diversity within a particular community (Williams et al., 2005). They are important in providing information about a taxon's 'importance status' within its community and assist in understanding community structure.

As only one transect was installed at each coral site to provide baseline data on the coral reef assemblages, comparisons of diversity[2] of taxa across sites is difficult to determine at this stage, but the information obtained from the surveys provides a basis for future monitoring comparisons at the same sites within the coral reef community.

Diversity is the variation of taxonomic life forms within a given ecosystem and is a measure of species abundance and richness across a site. The Shannon-Weiner diversity index was used to describe the community diversity, using the following formula that takes into account both abundance and evenness of the taxa present (Magurran, 1988):

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

where H' is the value of the index, S is the number of taxa, p_i is the relative abundance of each taxa, as a proportion of individuals to the total number of individuals in the community.

[2] Main life forms rather than individual species were used in the diversity calculations.

3.1.4 Fish

Underwater visual census (UVC) and video transect methods were used to record the abundances of fish (identified to families), at each of the seven coral reef transect locations, as shown in Table 2 of Annex A.

Visual Census

The UVC method was used to estimate density and abundance of coral reef fish families, by which scuba divers recorded the numbers of fish (identified to families) whilst swimming along the 50 m transects. The locations and survey dates of the visual census were the same as for the coral reef transect surveys, which are listed in Table 2 of Annex A. Table 3 of Annex A, provides the start and finish depths in which the surveys were undertaken.

The divers recorded the number and family of each fish, and estimated the lengths of each fish and the distance from the transect to the fish (to a maximum distance of 10 m either side of the transect). Estimates of fish length were made using one centimetre size-classes for fish between one and 10 cm, two centimetre size-classes for fish between 10 and 30 cm, five centimetre size-classes for fish between 30 and 60 cm, and ten centimetre size-classes for fish over 60 cm. If fish were in a school, their number and the distance to the closest and the furthest fish was estimated.

Video Transects

Video footage of fish along the 50 m transects was taken at each site during the return swim to the start of the transect, using a digital video camera inside an underwater housing at a depth of 2 m above the reef. These videos were downloaded, copied to a DVD and archived as a permanent record.

Data Analysis

Fish density was estimated using the following formula (Kulbicki & Sarramegna, 1999):

$$D_i = (2L)^{-1} \sum (\frac{n_i}{d_i})$$

where D_i is the density of taxa *i* (fish/m^{-2}), *L* is the transect length (m), n_i is the abundance of taxa *i* and d_i is the average distance of taxa *i* from the transect (m).

Average distance for taxa *i* was calculated as follows:

$$d_i = (n_i)^{-1} \sum (n_j d_j)$$

where n_j is the number of fish of taxa *i* observed at occurrence *j*, and d_j is the distance of fish of taxa *i* from the transect at occurrence *j*.

Biomass was estimated using the following formula:

$$B_i = (2L)^{-1} \sum (\frac{w_i}{d_i})$$

where B_i is the biomass (g/m^{-2}), *L* is the transect length (m), W_i is the weight of taxa *i* (g) and d_j is the distance of fish of taxa *i* to the transect.

Weight was estimated from the average of published length–weight relationships for fish families (Froese and Pauly, 2007) using the formula:

$W = a \times L^b$

where W is the total weight of the fish (g), L is the total length of the fish (cm) and a and b are specific length and weight constants taken from databases produced by FishBase for individual species (Froese & Pauly, 2007).

3.1.5 Mangrove Communities

The mangroves around the Vaihua River, in the vicinity of the proposed LNG Plant site were characterised during the second field survey. The locations and dates of field surveys are given in Table 4 of Annex A and the visual survey locations are shown in Figure 3.02. Access to mangroves within the estuary involved using the dive tender to travel through the channels not restricted by dense mangrove populations, fallen trees or water depth. Therefore, sites were selected in areas that were easily accessible for habitat characterisation. Species of mangroves were recorded at each site where possible and for those unidentifiable on site, distinguishing features such as leaves, seedpods and flowers were collected to identify the mangrove using identification keys onboard the main research vessel. General descriptions of substrate type, animals (both terrestrial and aquatic) and other distinguishing features were also recorded.

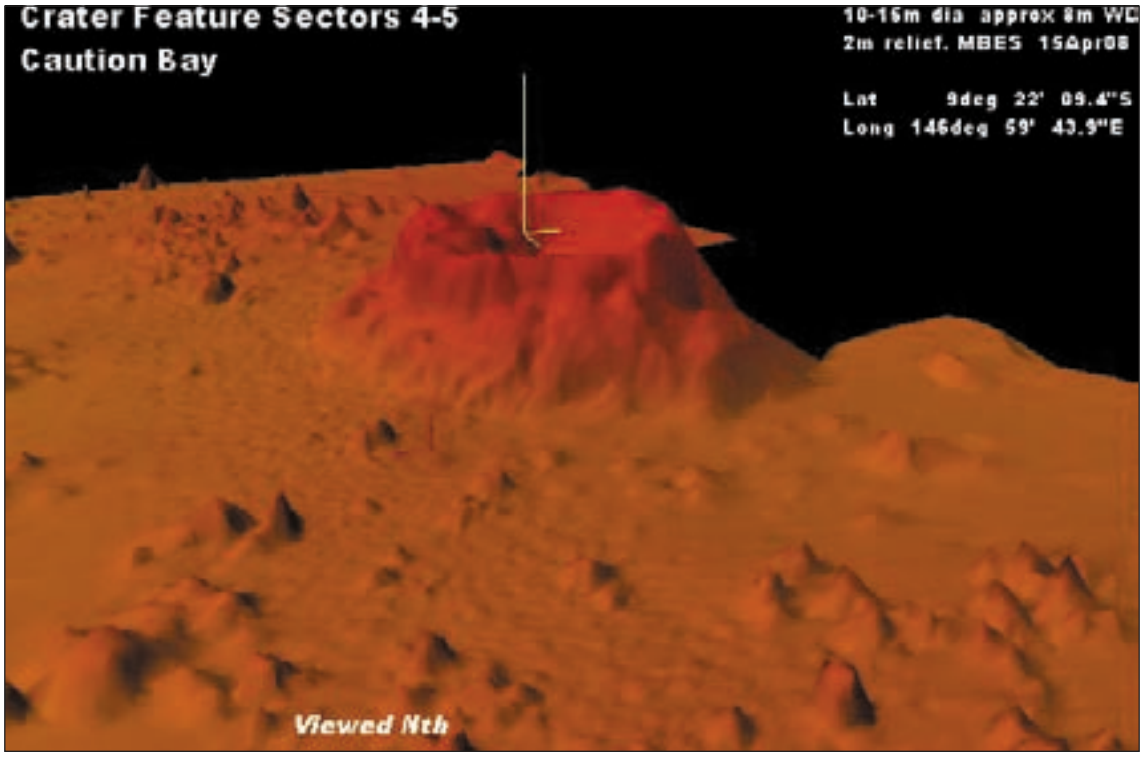
3.1.6 Habitat Map

The habitat assessment survey of the marine environment was conducted in order to identify zones of major benthic features, such as coral reefs, seagrass, subtidal sand and mangrove communities and enable assessment of the relative importance of the different habitats within Caution Bay. In addition to the coral, fish and mangrove sites investigated, eleven more locations were investigated within the vicinity of the potential project footprint. A review of satellite imagery and navigational charts of the immediate area assisted in selecting sites to classify areas of major benthic features. Table 1 of Annex A gives the locations and dates of the visual assessment surveys and the locations are shown in Figure 3.02.

At each survey location, underwater video footage, still photographs and observations were taken whilst snorkelling or scuba diving. The video footage, photos and notes were later reviewed to describe the fauna and flora inhabiting the area. The information collected in the field was used to interpret satellite imagery of the area and to construct the habitat map.

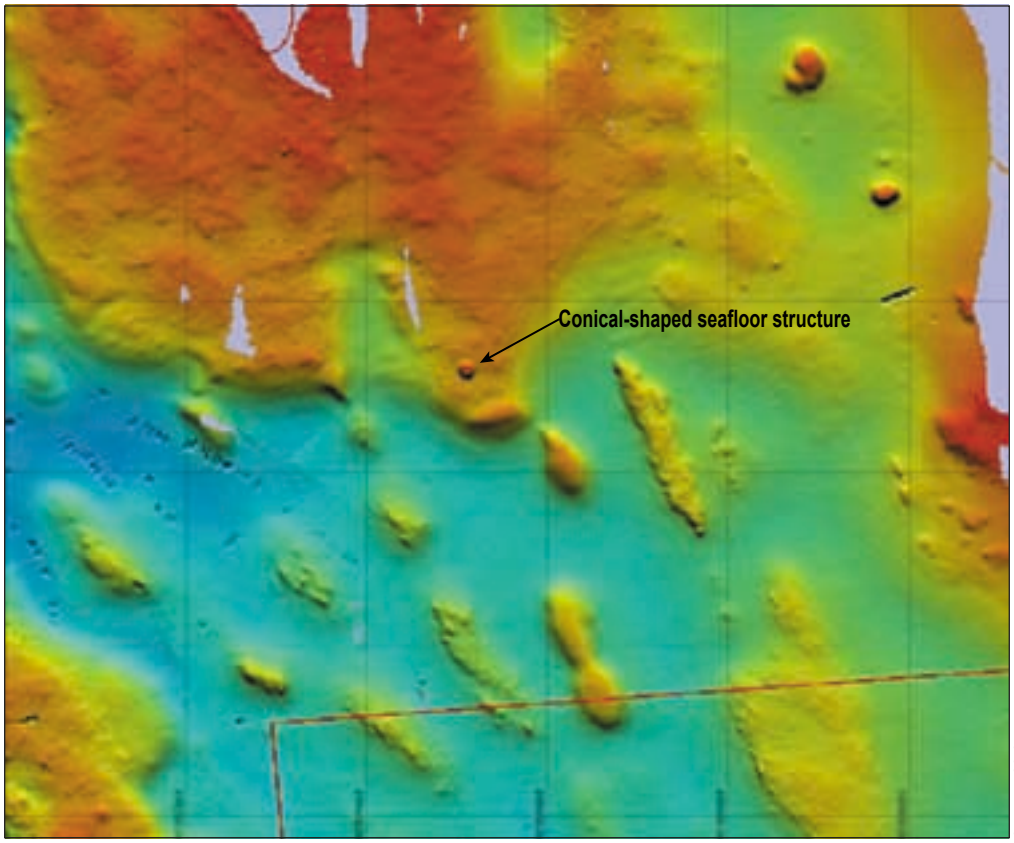
Areas of Local Significance

EGS Survey Pty (EGS) identified a small conical-shaped seafloor structure from bathymetry data of Caution Bay that was collected during a geotechnical and bathymetric survey of the offshore pipeline route (Plates 3.02 and 3.03). This structure is located approximately 1 km from the southern-most pipeline route option. EGS requested that the nearshore marine research team investigate the structure during the site visit conducted in April 2008. Digital photographs and video footage of the coral structure were taken during site investigation by the scuba divers.



Source: EGS Survey Pty

Plate 3.02
Side view of a conical-shaped seafloor structure taken from a bathymetric survey



Source: EGS Survey Pty

Plate 3.03
Aerial view of a conical-shaped seafloor structure taken from a bathymetric survey

3.1.7 Water and Sediment Quality

Water Quality Sampling

All water samples were taken directly from the bow of the small dighy, by reaching as far as possible from the boat. During the sequence of sampling, the boat was positioned with the bow facing upwind and up current, and the engine was then switched off to minimise possible contamination. Table 5 of Annex A gives the location and date of sampling events. The sampling locations are shown in Figure 3.02.

In-situ measurements of pH, conductivity, temperature and salinity were taken using a YSI Model 63 water quality meter that had been calibrated each day prior to use. The probe of the YSI meter was placed over the side of the boat directly into the water and the readings recorded.

All seawater samples for total suspended solids (TSS), nutrient and metal concentration analyses were collected directly into sample bottles, with the sampler wearing powder-free latex gloves to minimise possible contamination. Sample bottles were filled from immediately below the surface (0 to 0.5 m), to avoid both the surface microlayers at the air/water interface where contaminant concentrations may not be representative of the water column and any contaminant 'halo' that might surround the boat. The bottle cap was removed after the bottle was submerged below the water's surface.

Sediment Sampling

Sediment samples were collected opportunistically by scuba divers during the coral reef transect surveys, habitat assessment surveys and the retrieval of sediment trap samples. Details of survey work conducted are given in Table 6 of Annex A and Figure 3.02 shows the sampling locations within Caution Bay. Three sub-samples of sediment were collected to a depth of about 5 cm by taking scrapings from the seafloor with glass jars. A composite of the three samples was prepared onboard the research vessel in a stainless steel mixing bowl and a sub-sample of this was taken for laboratory analysis of physio-chemical parameters. Sediment samples, each with identification labels, were photographed, and physical descriptions of colour, texture, odour and other obvious characteristics such as the occurrence of plant matter, volcanic material and/or coral fragments were recorded.

Marine Benthic Infauna

Eight sediment samples were collected to assess the benthic infaunal assemblages within the nearshore marine environment of Caution Bay. The location and date of sampling events are given in Table 8 of Annex A, and the sampling locations are shown in Figure 3.02. Samples were collected using two 90 mm corers to a depth up to 15 cm. Macrofauna were extracted from the sediment by washing samples through a 0.5 mm-mesh sieve, then preserved in 70% ethanol solution and transported to Australia for analysis (for details see below).

Sample Preservation and Transportation

Water, sediment and macrobenthos samples were labelled with sampler's name, sample ID number, date and time of collection. Samples were refrigerated whilst held onboard the research vessel and stored in an esky surrounded by freezer blocks during transportation to Australian Laboratory Services (ALS) Laboratory Group in Brisbane for analysis of water and sediment quality. Macrobenthic fauna samples were transported to Dr John Moverley (benthic specialist taxonomist). The parameters that were determined are listed in Table 3.01.

Table 3.01 Parameters for analysis

Sample	Parameters
Seawater	- Total suspended solids (TSS). - Total metals. - Nutrients. - *In situ* parameters: pH, temperature, salinity, conductivity.
Sediment	- Particle size. - Total carbon and inorganic carbon. - Total metals in <2000 µm fraction. - Nutrients. - pH.
Infauna	- Counts and identification to lowest known taxonomic level.

Quality Assurance

The validity of the data was ensured by implementation of a quality assurance/quality control (QA/QC) program, for both the fieldwork and laboratory components of the study. This involved procedures for taking and analysing blanks, duplicates, reference materials and spiked samples. The QA/QC results are given in Annex B.

Minimisation of Contamination

The following methods were used to minimise contamination of water and sediment samples:

- Sample bottles were prepared at the analytical laboratory.
- Sample bottles and sample bags were kept in clean plastic bags and stored in eskies before and after sampling events.
- Water was collected directly into the sample bottles, thereby minimising exposure to the atmosphere.
- Powder-free disposable hand gloves were worn to minimise potential for contact with skin.
- Care was taken not to touch the internal surfaces of the bottles or tops, or otherwise contaminate the samples.

Field Quality Assurance Program

Field Blank

Field blanks were prepared during the water sampling program to monitor for possible contamination during field sampling and handling procedures. These blanks were prepared in the field using ultra-pure (milli-Q) deionised water supplied in sealed containers by ALS. This involved filling a set of sample bottles from a bulk sample of distilled deionised water in a manner as close as possible to that used for the actual sample bottles. The blanks were preserved and handled in the same way as for the sample bottles.

Field Duplicates

Duplicate samples of water from a sampling site were submitted to the laboratory for analysis to assess laboratory precision and site heterogeneity.

Laboratory Quality Assurance Program

Method Blanks

Laboratory blanks were prepared by the laboratory at a rate of at least one per 20 samples to monitor potential laboratory contamination.

Laboratory Duplicates

Intralaboratory split samples, randomly selected from the sample batch, were prepared by the laboratory at a rate of one per 10 samples to provide information on method precision and sample heterogeneity.

Laboratory Control Samples

A known, interference free matrix spiked with target analytes or certified reference material was analysed with each batch of samples to monitor method precision and accuracy independent of sample matrix.

Matrix Spikes

Matrix spikes were conducted, which entail intralaboratory split samples that are spiked with a representative set of target analytes. The purpose of this quality control parameter is to monitor potential matrix effects on analyte recoveries.

3.1.8 Sedimentation Rates

Seven sediment traps were installed in December 2007 within Caution Bay to measure sedimentation rates in the nearshore environment (see Figure 3.02). Sediment trap design is based on that developed by the Australian Institute of Marine Science (AIMS) for data collection along the Great Barrier Reef, Australia. Each trap consists of a polyvinyl chloride (PVC) collection tube, 300 mm long with a 50 mm diameter opening, which is held within a larger diameter outer tube such that the inner collection tube can be recovered and replaced at intervals. A plastic baffle is inserted at the top of the inner collection tube, which inhibits the resuspension and loss of sediment from the trap that may be caused by wave action or strong currents. The use of these baffles follows recommendations made by Hargrave and Burns (1979) and Gardner (1980).

Sedimentation rates are measured by installing a sediment trap close to the bed of the seafloor, to collect sediment settling through the water column. Typically, the total weight of the sediment collected in the traps is measured, and sedimentation rates expressed as $mg/cm^2/d$. This measurement is the total weight of the sediment that settles into the trap over the period of deployment and does not separate new sedimentation from any that has become resuspended (e.g., by wave action) following initial deposition on the seafloor.

The sedimentation traps have been designed for deployment in replicate groups, 2 m apart. Four individual traps were installed at each station in water depths of at least 5 m and were fixed approximately 1.5 m above the seafloor to star pickets driven into the benthic substrate (Plate 3.04).

Plate 3.04
Group of installed sediment traps

Plate 3.05
Crew assisting with deployment of underwater drop camera

The details of the location and the time of installation for each sediment trap are given in Table 7 of Annex A.

Recovery of the sedimentation tubes was by scuba diver and occurred at approximately 3-monthly intervals. The sedimentation tubes are capped and exchanged with a fresh tube before being brought to the surface. Once recovered, the contents are transferred into a container and rinsed to ensure that all sediment is collected.

Samples were transported to the National Analysis Laboratory in Lihir to be analysed to determine the quantity of sediments collected during the sampling period. This included analysis of the total and acid-soluble fraction, which removed carbonates, to provide an indication of the marine versus terrestrial fraction.

3.1.9 Pipeline Route Survey

Potential pipeline route options for the project within Caution Bay were investigated to determine if the routes crossed sensitive habitats or if there were any other environmental constraints. Video footage of the seafloor was undertaken with a georeferenced underwater drop camera recorder during April 2008 (Plate 3.05). The drop camera was manually lowered to approximately 0.5 to 2 m from the seafloor, until the seafloor could be clearly seen on the deck top monitor, and the site was investigated for a duration of at least two minutes, or longer if it became evident that the habitats were changing. The video footage was recorded onto digital tape using a camcorder for later reference if needed, and the real time observations from the deck viewing screen were recorded at each sampling site. The video footage was transferred to DVD and archived. Figure 3.02 shows the locations of the 52 sampling sites within Caution Bay from which video footage was collected during the field survey of April 2008, and also shows the current pipeline route alignment. This alignment was not available at the time of the surveys, however, the pipeline route options surveyed are provided in Figure 3.01. Details of the drop camera survey sites are listed in Table 9 of Annex A with detailed observations provided in Annex H.

This method was replicated during the final survey in which ten sites were investigated on 25 June 2008. These sites were represented by the following features:

- Potential *Pavona clavus* bommie (see Section 3.2.4).
- Coral bommie directly in the path of pipeline route Option 7.
- Coral bommie close to pipeline route Option 7
- Coral bommies near the proposed combined LNG Jetty / Materials Offloading Facility and turning circle.
- Coral bommies situated east of the shipping access channel.

3.2 Results and Discussion

3.2.1 Overview

Caution Bay is a shallow coastal basin, located between Porebada and Boera villages, about 20 km northwest of Port Moresby. A continuous barrier reef forms the southwestern (offshore) boundary of the bay and provides protection from ocean swells. There are natural openings in the reef to the north of Idihi Island, which effectively marks the northwestern extent of the barrier reef, and to the south

(Liljeblad Passage), which are used by small vessels to move in and out of the reef. There are a number of offshore coral bommies within Caution Bay, rising to a water depth of approximately 5 m and the southern end of the bay is characterised by shallow areas supporting patches of corals and seagrass. Two island groups are located on the boundary of Caution Bay: Vari Vari Island situated to the north is a remnant of the mainland and Idihi Island to the south, located on the barrier reef, is a coral cay.

Mangroves occur along the mainland along rivers and creek systems of Caution Bay. Rivers flowing into the Bay include the Vaihua River, Kido River and Brown River; the latter enters to the north of Redscar Bluff. Seaward of the mangroves and about 1 km offshore, there is a continuous fringing reef along the coast of caution Bay. The seafloor between the mangroves and the reef exhibits distinct zonation – including large patches of seagrass, sand, rubble and sargassum. The northern end of the bay is less protected and subject to a greater influence from ocean swells and the coastline is sandier and does not support such extensive fringing reefs. The distribution of the fringing reef within Caution Bay is shown in Figure 3.04.

There are a number of nearby villages along the coastline of Caution Bay including Kido, Lea Lea, Papa, Porebada and Boera. The people from the coastal villages rely heavily on the nearshore marine environment as a source of food, building resources and income from selling excess fish at local markets. Resource utilisation in Caution Bay is discussed in greater detail within Chapter 4 of this report.

3.2.2 Coral

Coral Census

Hard coral cover in the nearshore marine areas adjacent the proposed marine facilities, shipping access channel and offshore pipeline route ranged between 20.8% to 60.9% across the seven survey sites (Table 3.02). However, as outlined in methods, the selection of sites was not random (i.e., selected areas of higher coral cover) so does not provide an accurate guide on coral cover over the entirety of the fringing reefs. Nonetheless, the lowest abundance of coral cover (20.8%) occurred at site CF-7, located along the proposed south LNG jetty. Large areas of coral rubble and bare substrate were observed at this coral reef site which may be due to impacts associated with local villages employing dynamite fishing techniques and the exposure of the reef top during low tide to sedimentation from wave and current action. However, this site had the second highest diversity (diversity index of 1.91) with nine different types of hard corals identified along the 6 m transect (see Table 3.02). CF-7 also had the highest cover of Halimeda (calcareous green algae), which are the most abundant seaweeds in tropical habitats.

Massive *Porites* sp. corals dominate the reefs in the region, although a greater diversity (but lower cover) of *Acropora* spp. coral also occurs (see Table 3.02). *Porites* spp. accounted for between 7.7% and 87.5% of the hard coral cover at all sampling locations. Branching *Acropora* spp. coral, although usually dominant on typical tropical coral reefs, was observed infrequently during the study.

The major substrate type across all sampling sites combined was abiotic lifeforms such as dead coral, rubble and sand. Abiota attributed over 55% of total percentage substrate composition at five of the seven sampling sites. Despite protection from ocean swells, the fringing reefs in Caution Bay are still exposed to sediment mobilisation from wind-induced waves during storms and extended periods of south-east trades. The high abundance of abiotic features on the reef is not unusual but indicates the poor overall condition of the nearshore fringing reefs.

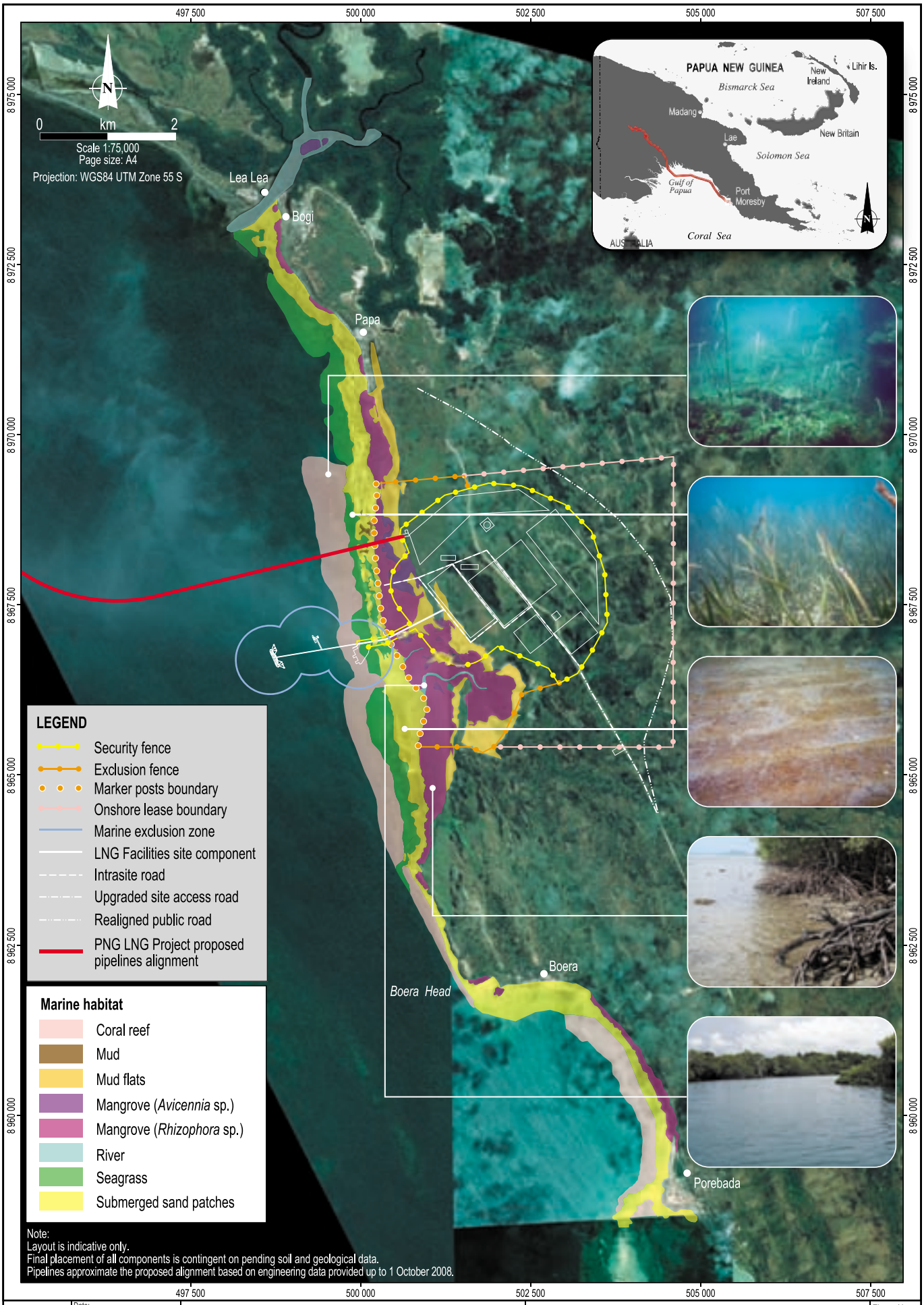


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Table 3.02 Coral reef community composition based on the 6 m coral visual census

	Site						
Lifeform	**CF-1**	**CF-2**	**CF-3**	**CF-4**	**CF-5**	**CF-6**	**CF-7**
Hard coral							
Acropora (branching)	0	4	0	0	0	0	0
Acropora (digitate)	1.5	16.1	8.2	0	0	0	2.4
Acropora (submassive)	0	0	0	7.3	0	0	0
Acropora (corymbose)	0	8.9	1.2	2.9	0	1.6	2.4
Acropora (encrusting)	0	0.8	0	6.5	1.4	0	0
Acropora (tabulate)	0	0	2.9	0	0	0	0
Porites (massive)	30.9	15.4	12.4	10.9	42.9	46.1	1.6
Porites (encrusting)	0	0	2.9	0	0	0	0
Dendrophylliia	0	0	0	0	0	0	3.2
Faviid (encrusting)	0	0	2.5	0	0	0	0.8
Faviid (massive)	0	0	6.4	4.3	5.7	0	3.2
Pectinidae (foliose)	0	0	0	0	0	3.9	1.6
Mussidae (massive)	0	0	0	0	0	0	3.2
Oculinidae	0	0	0	0	0	1.6	0
Pocillopora	2.9	0	0	0	0	7.7	2.4
Total	***35.3***	***45.2***	***36.5***	***31.9***	***50***	***60.9***	***20.8***
Other biota							
Coralline algae	0	0	0	3.6	0	0	0
Encrusting sponge	0	0	0	0	0	0	0.8
Soft coral	0	0	0	0	0	0	1.6
Sponge	0	0	0	0	14.3	0	0
Halimeda	0	0	0	0	0	18	20
Total	***0***	***0***	***0***	***3.6***	***14.3***	***18***	***22.4***
Abiotic							
Dead coral	47.1	13.7	54.7	25.4	27.1	10.2	31.2
Rubble	13.2	14.5	7.6	21.7	8.6	0	0
Sand	4.4	26.6	1.2	17.4	0	10.9	25.6
Total	***64.7***	***54.8***	***63.5***	***64.5***	***35.7***	***21.1***	***56.8***
TOTAL LIFEFORM	***100***	***100***	***100***	***100***	***100***	***100***	***100***
H' – Diversity [3]	***1.29***	***1.87***	***1.57***	***1.95***	***1.43***	***1.60***	***1.91***

[3] Where H' is the value of the Shannon-Weiner diversity index.

Although the offshore islands had a higher diversity and abundance of hard corals, and fewer abiotic features, the results in terms of percentage cover of coral appeared to under-estimate the overall visual impression at these locations, possibly because the results were from only a single 6m transect and therefore may not be a true representation of the coral reef ecosystem. Both CF-3 at Vari Vari Island (Plate 3.06) and CF-4 at Idihi Island (Plate 3.07) recorded low hard coral cover of 36.5% and 31.9% respectively. The apparent discrepancies between the coral census results and the more general visual assessment are most likely due to the effects of localalised positioning of the coral reef transect, for example, where it was difficult to install markers in areas of high abundances of hard coral. Poor visibility in December 2007 probably accounted for the sitting of the coral reef transect at CF-1 in an area of poor coral cover that was subsequently observed (in April 2008) to be adjacent to an area of relatively good condition and greater diversity of forms.

Video Transects

The structure of the coral reef sites surveyed within Caution Bay exhibited a range of different reef substrate types including live hard and soft corals, dead coral, coral rubble, algae, bare reef substrate, sand and other invertebrates (Figure 3.05). The abundance of live hard coral was highest at Vari Vari Island (CF-3), which was represented by 41.3% of the total recorded observations. The coral reef sampled at CF-2, located south of Boera village, had the second highest proportion of live hard coral. The structure of this coral reef assemblage exhibited patches of healthy coral colonies surrounded by areas of coral rubble, sand and *Sargassum*. Whilst surveying this site during the second field trip, local people were observed fishing and conducting a traditional canoe race within the surrounding inshore area. Visual observations of the coral colonies suggested that they may be important for the development of reef fish populations as many were inhabited by groups of juveniles compared to other coral reef transect sites surveyed.

Live soft corals represented a small proportion of reef substrate at all coral transect sites and ranged from 0.4% (CF-3) to 3.8% (CF-6). Soft corals generally occur in the deeper waters of fringing coral reefs which could explain their low abundance within Caution Bay as coral transect sites were conducted in water depths of 1 to 8 m (Allen & Steene, 1998). The species commonly observed within Caution Bay were the Gorgonian sea fans, *Dendronephthya* sp. and sea whips (*Junceella fragilis*).

Analyses of reef substrate type show a majority of the coral reefs surveyed within Caution Bay were dominated by abiotic categories, for which, percentage cover results ranged between 16.3% to 47.8% for all observations undertaken with the AVTAS method. As discussed in Section 3.2.2, coral reef assemblages of CF-7, located at the southern jetty option within Caution Bay, showed the highest proportion of bare reef substrate and sand substrate types of all the sites sampled.

Coral rubble was abundant at all coral reef transect sites and ranged between 2.3% (CF-7) to 43.5% (CF-5). The inshore coral reefs had higher proportions of coral rubble compared to the offshore islands of Caution Bay (Vari Vari Island and Idihi Island), which may be due to impacts associated with local villages employing dynamite fishing techniques and the exposure of the reef top during low tide to sedimentation from wave and current action. Lack of suitable substrate makes it difficult for coral communities to recolonise, and if these assemblages experience events such as dynamite fishing and wave activity on a regular basis, degradation of the ecosystem intensifies resulting in lower diversity and abundance of marine flora and fauna.

Coral cover was very poor and very patchy. The 6 m coral transects were deliberately positioned in areas of locally high coral cover to enable coral community composition to be documented. The 50 m transects were used to estimate overall coral cover at each site more accurately.

Plate 3.06
Coral diversity and cover at Vari Vari island

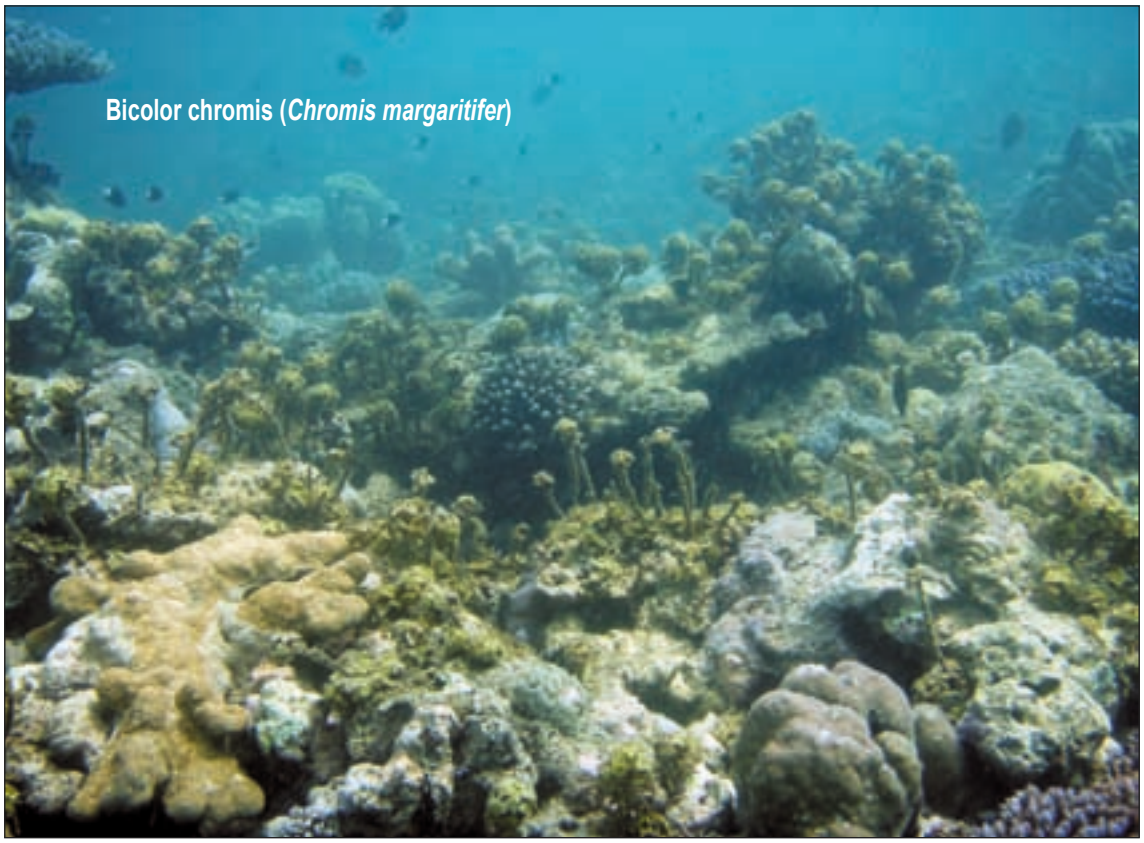
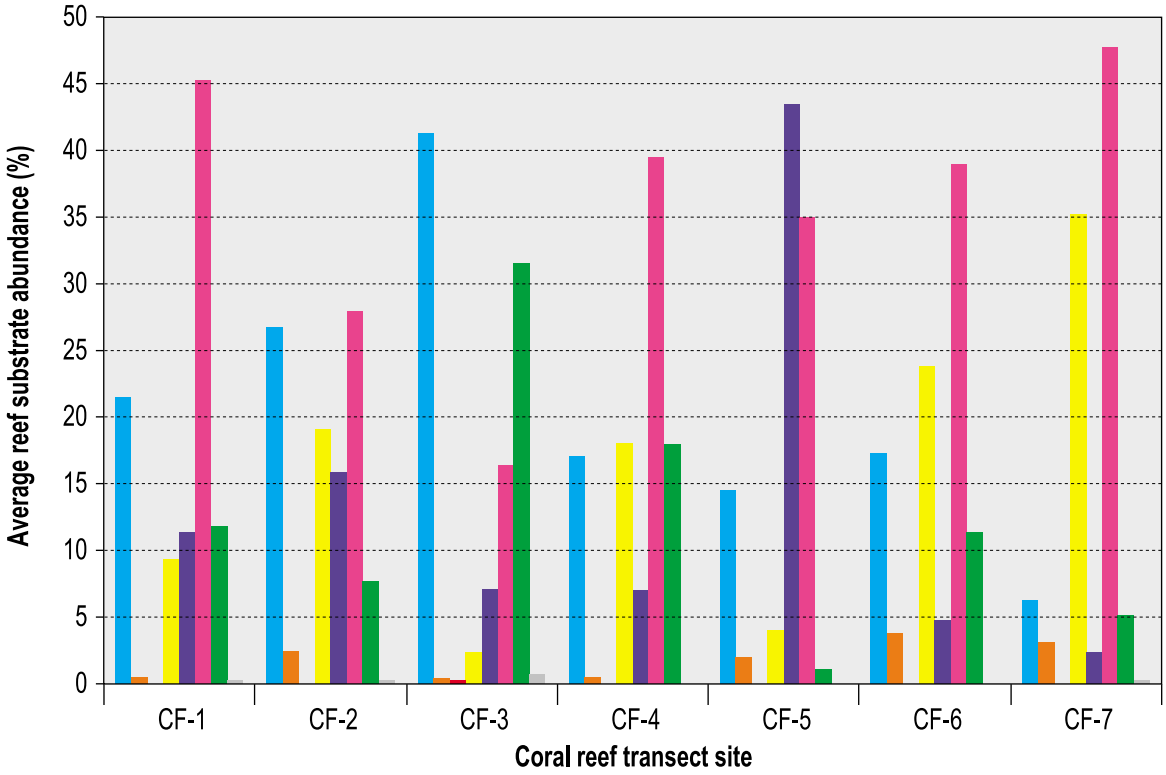
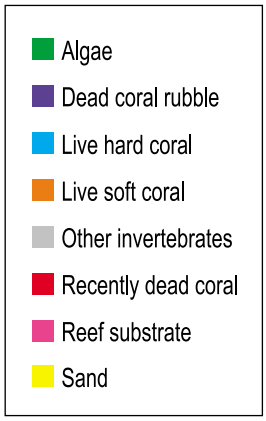


Plate 3.07
Coral diversity and cover at Idihi Island





PNG LNG	Job No: 1284	Esso Highlands Limited	Coral reef structure within Caution Bay	Figure No: 3.05
	File Name: 1284_05_F03.05_HB	PNG LNG Project		

Fringing reefs of Caution Bay supported very dense *Sargassum* cover during sampling events conducted in December. However, this cover dramatically decreased in April when coral reef transect sites were re-sampled and may be due to seasonal growth or senescence cycle of *Sargassum*. *Sargassum* shows a marked seasonal growth cycle with, in the southern hemisphere, maximum biomass achieved in late summer and senescence occurring during the cooler months (Cribb, 1990; Vuki & Price, 1994). *Sargassum* is often the dominant algae in tropical latitudes (Womersley, 1987). Competition between macroalgae and macrofauna for light, space or other resources, (Cribb, 1990), suggests that the recruitment of corals is lower in areas with high algal biomass because fleshy algae reduce areas available for the growth of coralline algae, which are known to enhance coral recruitment.

Summary

The majority of nearshore coral reefs within Caution Bay were degraded with very low coral and fish abundance. The damage has possibly been caused by extensive local dynamite fishing and subsequent storm events and other fishing practices (Plate 3.08). A number of local fishing boats and canoes were observed in Caution Bay during the study. Locals were observed actively fishing using spears, line and nets and collecting sea cucumbers for the Bech-der-mer industry within inshore coastal waters of Caution Bay. Discussions with local fisherman indicated that dynamite fishing has been undertaken in Caution Bay in recent times; however, no fresh evidence of dynamite fishing was apparent during the surveys. Most rubble was observed to be covered in algal or bacterial films indicating some time had past if the rubble was caused by dynamite fishing.

The inshore fringing reefs also contain high densities of the sea urchin *Diadema* sp. As has been observed elsewhere, the higher abundance of *Diadema* sp. may also indicate that these reefs are under higher fishing pressure than elsewhere in Caution Bay. The abundance of *Diadema* sp. is typically controlled by predatory fish and octopus and known to increase when overfishing causes a reduction in numbers of these predators (Steiner & Williams, 2006) (Plate 3.09). The grazing by *Diadema* sp. in turn adds to the reduction of coral settlement and recovery.

The offshore coral shoals and bommies also had low coral diversity and abundance, and large amounts of broken coral heads and coral rubble was commonly observed all the way to the seafloor to depths of about 15 m, suggesting that dynamite fishing was very wide spread.

The offshore islands, in comparison, supported higher coral diversity and abundance and appeared in a very healthy state, despite sustained fishing pressure, and with no evidence of damage. Fewer fishing vessels and canoes were observed in the vicinity of the offshore islands, apart from a group of approximately 40 individuals on Idihi Island who were spearing and netting to catch shark and reef fish, which they transport to the local villages for sale at the market.

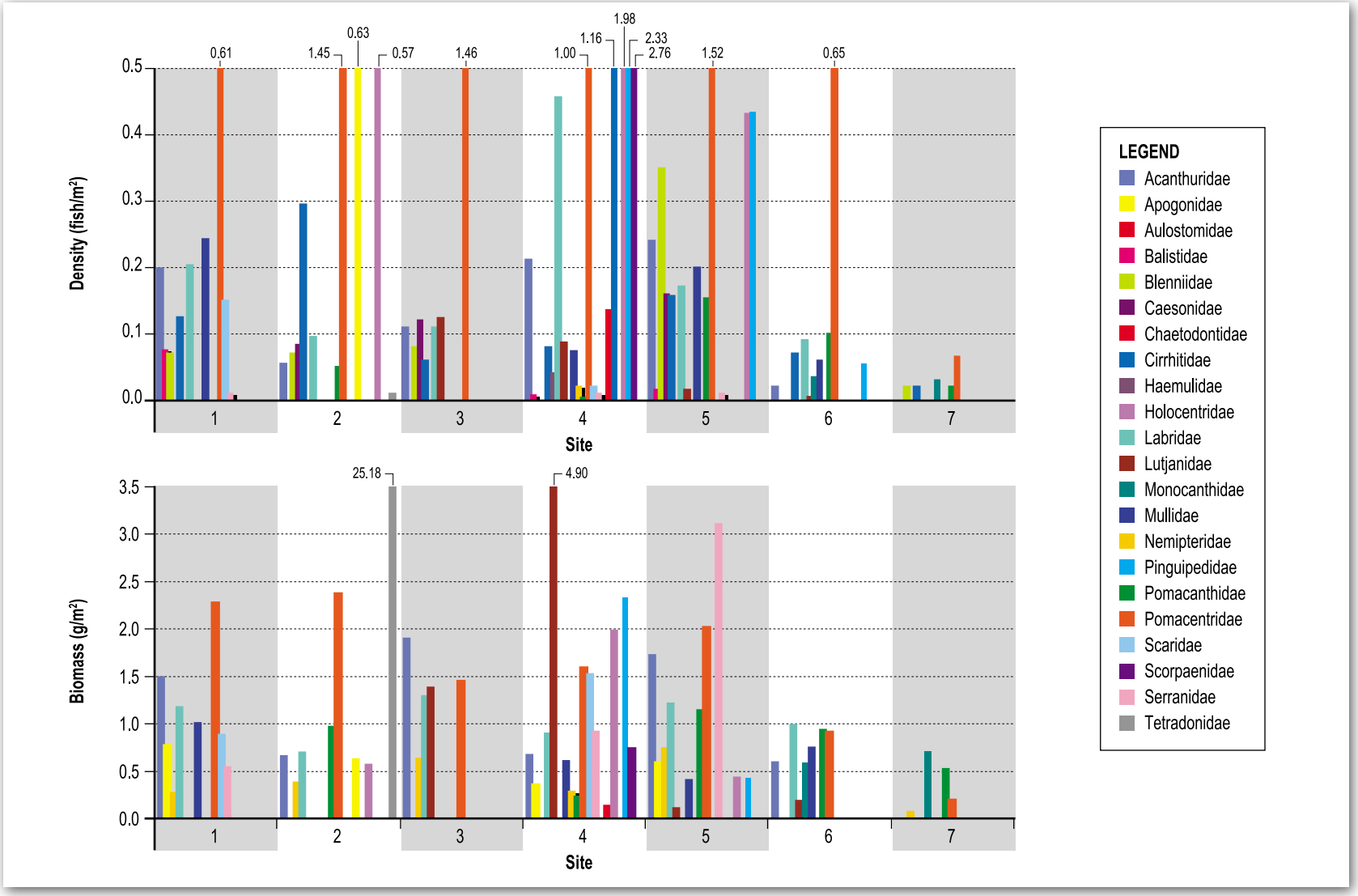
3.2.3 Fish

Underwater Visual Census

Calculations of fish density and estimates of biomass were made for each transect and then collated for each family group, from which it was possible to make comparisons between sites. Table 3.03 shows the combined density and biomass results across each sampling site for each field survey. Mean density and biomass estimates for families at each transect site are shown in Figure 3.06 and 3.07. The seasonal difference in fish abundance is marked but is most likely an artefact of the clearer water conditions encountered in April, particularly inshore, enabling divers to observe fish more effectively.

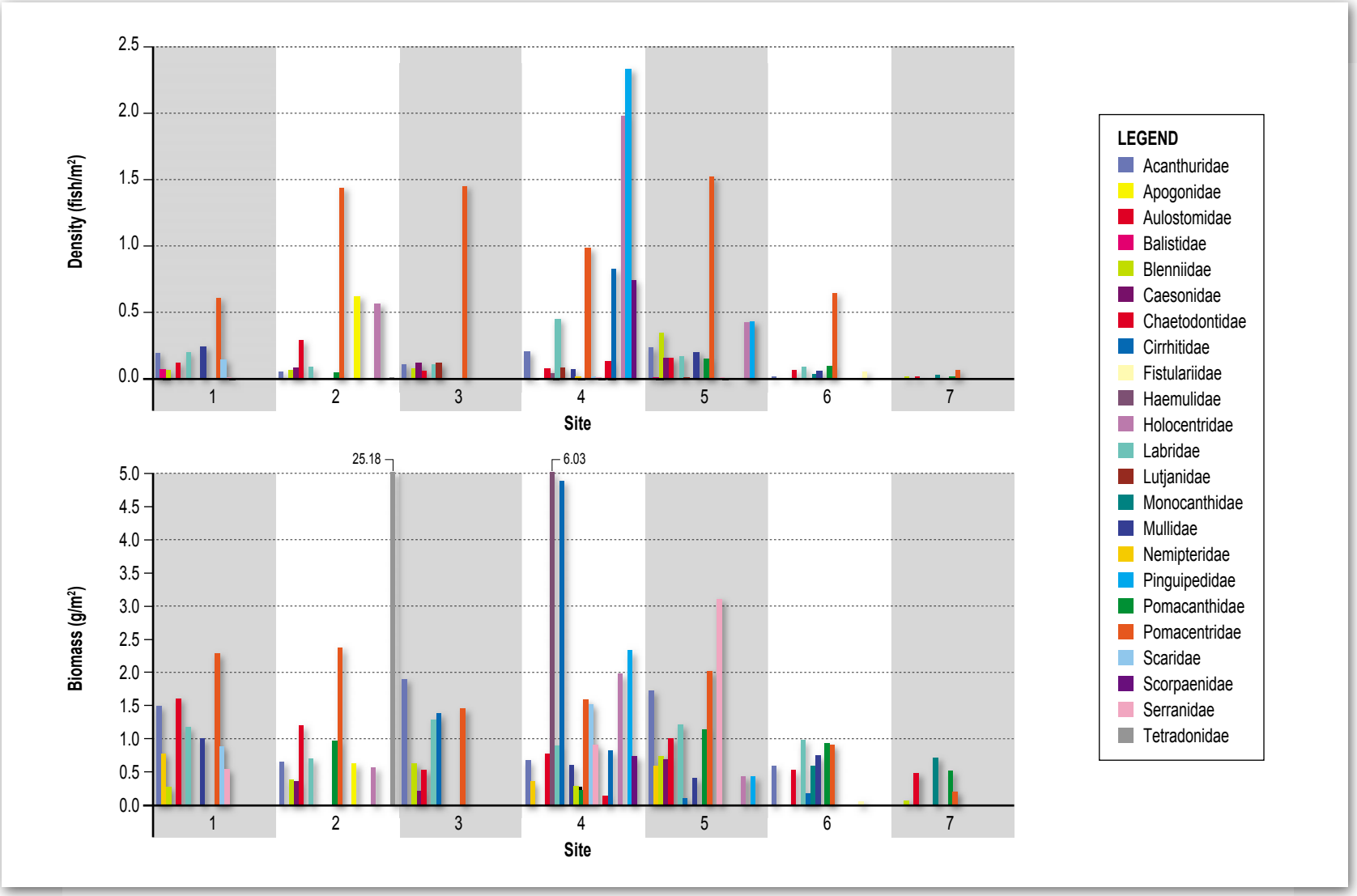
Plate 3.08
Dead coral and rubble

Plate 3.09
Sea urchins (*Diadema* spp.) in Caution Bay



PNG LNG	Job No: 1284 File Name: 1284_05_F03.06_HB	Esso Highlands Limited PNG LNG Project	Density and biomass of coral reef fish families in December 2007

Figure No: 3.06



PNG LNG	Job No: 1284	Esso Highlands Limited	Density and biomass of coral reef fish families in April 2008
	File Name: 1284_05_F03.07_HB	PNG LNG Project	Figure No: 3.07

Such marked temporal variation is less likely to represent seasonal movements, as most of the species are resident on the reef. The lowest density and biomass of reef fish of all the sampling sites was observed at site CF-7, within Caution Bay (see Table 3.03). This site also had the lowest abundance of hard coral, suggesting a direct correlation between fish and coral abundance. Sites CF-6 and CF-7, situated closest to the proposed marine facilities, had the lowest combined biomass across all sampling sites. In contrast, Site CF-4 at Idihi Island had the highest combined biomass (10.7 g/m^2 and 29.9 g/m^2 during December 2007 and April 2008 respectively) across all sampling locations. This is not unexpected, as the higher structural complexity of coral forms at Idihi Island provides shelter, food and refuge for reef fish. Larger reef fish were also present at Idihi and this may be a reason why local fishermen visit the island frequently.

Table 3.03 Fish density and biomass estimates

	December 2007							April 2008						
	Site							Site						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Density (fish/m^2)	0.1	1.3	1.3	1.3	0.3	1.4	0.03	1.7	3.2	2.1	2.3	3.2	1.1	0.2
Biomass (g/m^2)	3.0	4.8	3.6	10.7	5.4	5.6	1.0	10.0	9.7	7.4	29.9	14.5	5.5	2.0

Although identification of fish was to family level, most fish typically inhabiting coral reefs of PNG are not endemic to the area and can be found in other reefs throughout the tropical Indo-Pacific. The family Pomacentridae (damselfish) had the highest combined density across three of the seven sampling sites in December 2007 (see Figure 3.06) but re-sampling in April 2008 indicated that this family had the highest density across all sites except CF-7 (see Figure 3.07). Despite the smaller body size of damselfish compared to other reef-fish species, their biomass (combined across sites) was relatively high (4.1 g/m^2) compared to the other fish families observed in the field surveys during December 2007, with only families Acanthuridae (surgeonfish) (6.9 g/m^2) and Chaetodontidae (butterflyfish) (5.4 g/m^2) having a higher biomass measured. Biomass of damselfish in April 2008 was the highest of all species with a value of 10.8 g/m^2 recorded across all sampling sites. These results indicate how dominant damselfish are within coral reef assemblages of Caution Bay.

Reef-dependent species that rely upon the structural complexity of corals for refuge and protection were common at most sampling sites. In particular, the most common reef-dependent species included:

- Pomacentridae – *Dascyllus* sp. and *Pomacentrus* sp.
- Chaetodontidae – *Chaetodon* sp. and *Heniochus* sp.
- Acanthuridae – *Acanthurus* sp. and *Ctenochaetus* sp.

No turtles, sharks or large pelagic marine mammals were identified during the nearshore marine surveys. It would be expected that a number of reef sharks (*Carcharhinus* spp.) would have been observed during the study, as they are apex predators of coral reef ecosystems. The noted absence of sharks may also be due to fishing pressure within the bay, as shark fins were observed drying in the sun during a visit to Idihi Island, indicating sharks were caught in these offshore waters. Local fishermen have also noted that whale sharks are observed from time to time beyond the fringing reef (approximately once every two years). Opportunistic observations made by Coffey Natural Systems whilst undertaking benthic infauna sampling aboard the Pacific Conquest in March and April 2008 noted sighting dolphins in the offshore waters of Caution Bay.

Summary

The UVC surveys counted a total of 1,280 and 1,825 fish across seven sites during December 2007 and April 2008, respectively. Table 3.04 presents a summary of all recorded reef-fish families and the percentage of total observations across all sites combined. Figure 3.08 presents the percentage composition of reef fish observed across all sites. Although identification of fish was to the family level, the fish typically inhabiting coral reefs of PNG are not endemic to the area and can be found in other reefs throughout the tropical Indo-Pacific. Reef fish from the Families Chaetodontidae (butterflyfish) and Pomacentridae (damselfish) were the only groups observed at all sampling sites during both field studies. Families Labridae (wrasses) and Acanthuridae (surgeonfish) were observed at all sampling sites on at least one field survey. The larger fish targeted by fisherman, including snappers, emperors, groupers and sharks were absent or very rarely seen suggesting that fishing pressure is very high.

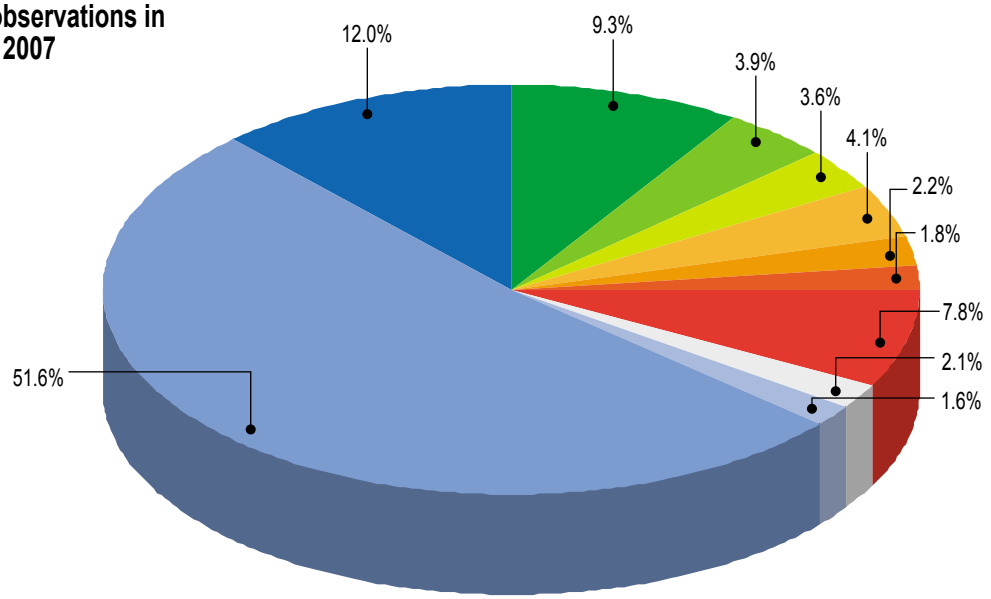
Table 3.04 Reef fish community composition

Family	% of Total Observations		Family	% of Total Observations	
	December 2007	April 2008		December 2007	April 2008
Acanthuridae (surgeonfish)	9.30	8.55	Monocanthidae (leatherjackets)	0.23	0.38
Apogonidae (cardinalfish)	0.55	2.41	Microdesnidae (dartfishes)	-	0.11
Aulostomidae (trumpet fish)	-	0.05	Mullidae (mullet)	1.80	4.49
Balistidae (triggerfish)	-	1.04	Nemipteridae (threadfin breams)	-	0.22
Blenniidae (blennies)	0.31	3.40	Parapercidae (grubfishes)	0.16	-
Caesonidae (fusiliers)	3.91	4.77	Pinguipedidae (sand perches)	-	0.55
Chaetodontidae (butterflyfish)	3.59	6.36	Pomacanthidae (angelfish)	1.56	2.36
Cirrhitidae (hawkfishes)	-	0.11	Pomacentridae (damselfish)	51.64	50.96
Fistulariidae (flutefish)	-	0.05	Scaridae (parrotfish)	0.39	1.81
Haemulidae (grunts)	-	0.22	Scolopsidae (monacle-bream)	7.81	-
Holocentridae (soldierfish)	0.39	0.77	Scorpaenidae (lionfishes)	-	0.16
Labridae (wrasse)	3.06	7.29	Serranidae (groupers)	11.95	0.22
Lutjanidae (snapper)	2.19	3.67	Tetradontidae (toadfish)	0.16	0.05

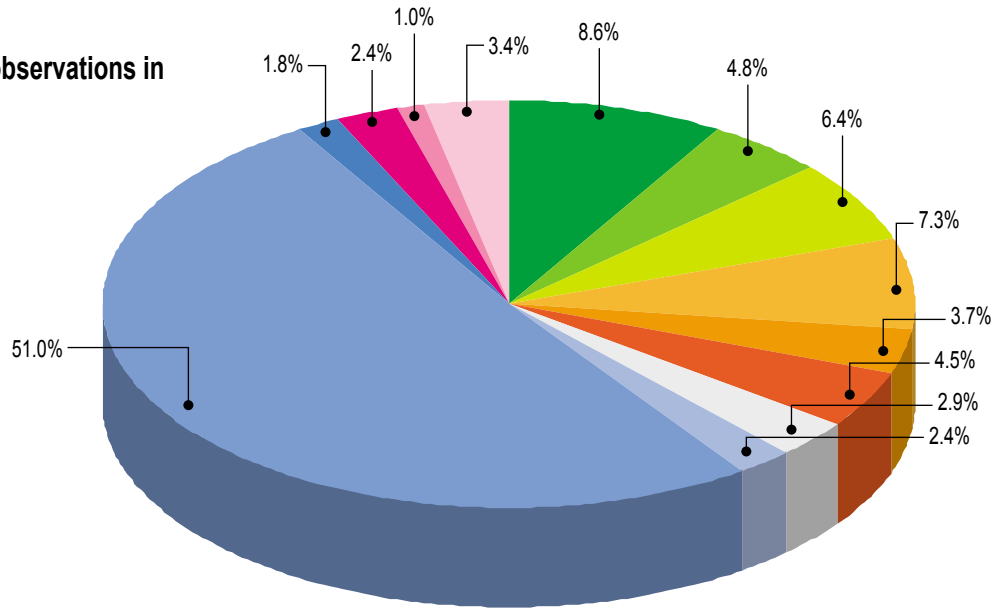
Fish from the Family Pomacentridae (damselfish) occurred in the highest abundance across all sites (51.6% and 51.0% of total observations of surveys conducted in December 2007 and April 2008 respectively). Damselfish are one of the most diverse groups of coral reef fish, with approximately 100 species occurring in Papua New Guinea (Allen & Swainston, 1993). The Humbug Dascyllus (*Dasyllus aruanua*) was frequently observed in groups above hard *Acropora* spp. coral, in which it seeks shelter and protection from predators (Plate 3.10).

Butterflyfish were common and often observed in pairs, which supports scientific studies that they have permanent lifetime bonds (Allen & Steene, 1998). Plate 3.11 shows a pair of beaked coralfish feeding on encrusting algae on an offshore coral bommie within Caution Bay. These fish represented 3.6% and 6.4% of the total reef fish observed in the December 2007 and April 2008 field studies respectively.

Reef fish observations in December 2007



Reef fish observations in April 2008



- Acanthuridae (surgeonfish)
- Apogonidae (cardinalfish)
- Balistidae (triggerfish)
- Blenniidae (blennies)
- Caesonidae (fusiliers)
- Chaetodontidae (butterflyfish)
- Labridae (wrasse)
- Lutjanidae (snapper)
- Mullidae (goatfish)
- Nemipteridae (threadfin breams)
- Other species
- Pomacanthidae (angelfish)
- Pomacentridae (damselfish)
- Serranidae (groupers)
- Scaridae (parrotfish)

PNG LNG	Job No: 1284	Esso Highlands Limited	Percentage of coral reef fish observations	Figure No: 3.08
	File Name: 1284_05_F03.08_HB	PNG LNG Project		

Plate 3.10
Cryptic damselfish on a digital Acropora coral

Plate 3.11
Butterflyfish feeding on encrusting algae

Surgeonfish (Family Acanthuridae) were frequently observed at all sites in schools. These fish graze on filamentous algae that grows on the surface of the coral colonies and were observed at all sites. Surgeonfishes were quite abundant at coral reef sites with 9.3% of all fish observed during December 2007 and 8.6% during April 2008 field studies. A number of species were observed including the Indo-Pacific bluetang (*Paracanthurus hepatus*), white-cheeked surgeonfish (*Acanthurus nigricans*) and pale-lipped surgeonfish (*Acanthurus leucoheilus*).

Wrasses (Family Labridae) are conspicuous rainbow-coloured fishes and were observed inhabiting all coral reefs surveyed within Caution Bay. Of the estimated 500 species that occur worldwide, the most commonly observed during field studies were the moon wrasse (*Thalassoma lunare*) and the cleaner wrasse (*Labroides dimidiatus*). Of the total reef fish counts at coral reef sites within Caution Bay, the family Labridae represented 4.1% of all fish observations in December 2007 and 7.3% in April 2008.

Reef predators, groupers (Serranidae), snappers (Lutjanidae) and jacks (Carangidae) appeared to be in low abundance across all sampling sites. The explanation is most likely due to the high fishing pressure exerted by local fisherman (see Chapter 4 for further details of fishing resource utilisation within Caution Bay).

The majority of observations within and outside Caution Bay were of small-sized reef fish (less than 10 cm), with smaller numbers of medium (10 to 20 cm) and large (greater than 20 cm) sized reef fish. As mentioned in Section 3.2.2, observations of coral colonies located at CF-2 suggested that they may be important for the development of reef fish populations as many were inhabited by groups of juveniles compared to other coral reef transect sites surveyed. The reefs within Caution Bay are commonly referred to as the ‘nursery reefs’ by local communities inhabiting the coastal regions of Caution Bay. Juvenile red emperor (*Lutjanus sebae*) about 20 cm in length, are often caught along the coastal reefs at depths of 10 to 15 m (Yip & Seeto, pers. com., 2008) though none was observed by the divers. Spawning grounds for coral trout, hammerhead sharks and finger mark snapper are known to occur within five coastal reefs between Boera and Papa, as juveniles are regularly caught along this region of the coast (Seeto, pers. com., 2008), however, this information was not available at the time of field surveys and therefore these spawning grounds were not investigated.

3.2.4 Nearshore Habitat Map

Overview

The survey work identified four main marine habitats (coral reef, mangrove, mud flats, seagrass and submerged sand patches) along the coastal region of Caution Bay adjacent to the proposed marine facilities. Some smaller areas of mud flats also occur along the coastline. A habitat map showing the locations of these four habitat types is presented in Figure 3.04. The habitats identified were clearly visible on the aerial imagery and ground truthed to the extent practicable; however, while the habitat descriptions are accurate, it is important to note that the areas were not extensively ground truthed and may not accurately delineate exact boundaries of the habitats identified.

Mangroves and Mud Flats

The survey identified mangroves extending almost uninterrupted along the entire coast of Caution Bay (see Figure 3.04) in the vicinity of the proposed LNG Plant site. The mangroves were observed to be extensively utilised by the local villages on a subsistence basis for fishing (spear fishing and netting), collecting crustaceans and molluscs for food and to a lesser extent as a source of building materials or

firewood (mangrove tree wood). Further discussion on the use of mangroves for subsistence is provided in the report titled *Resource Use in Caution Bay* (Coffey Natural Systems, 2008b).

The mangrove community of Caution Bay has a very simple structure and is dominated by the mangrove, *Rhizophora stylosa* (Plate 3.12). This species represented more than 90 % of all mangrove individuals present in the area, extending from the seaward margin to the start of the mud flats; a distance of approximately 300 to 900 m. Trees were typically 4 to 5 m with a maximum height of approximately 10 m. High in the intertidal zone (on the landward margin); patches of smaller grey mangrove (*Avicennia marina*) observed (Plate 3.13). Both the areas of *Rhizophora stylosa* and *Avicennia marina* were visible on the aerial imagery. Apart from these two species, only a few individuals of other species were observed including club mangrove (*Aegialitis annulata*) and yellow mangrove (*Ceriops* sp.). The complex structure of the mangrove root system is important for many ecological processes. They provide nursery habitat for many juvenile fish species and marine invertebrates, and also act as buffers of sedimentation and strong weather and act as a natural nutrient filtration system.

Sandy beaches were also observed as small patches along the southern coast in Caution Bay, in regions not supporting mangroves. The sandy sediment extended subtidally, including the inner region of the coastal fringing reef in front of the mangroves. A wide beach was also present north of Kido River and has likely built up due to sediment discharged from the nearby Vaihua River (Plate 3.14).

Supratidal mud flats were located behind the mangroves along the Vaihua River (Plate 3.15). These mud flats are barren with little mangrove or other coastal vegetation as they are only inundated infrequently.

Seagrass

Large dense seagrass meadows were observed within the shallow waters of eastern Caution Bay (Figure 3.04) generally on the flat, sandy seafloor between the mangroves and fringing reef. The seagrass communities consist of three species including *Enhalus acoroides*, *Syringodium isoetifolium*, and *Cymodocea* sp (Plate 3.16). Seagrass communities are of ecological significance as nursery habitats for prawns, lobsters, crabs, turtles, dugongs and fish, as well as aid in stabilising the substrate. While locally dense, the overall area of seagrass is not extensive and no dugong feeding trails were observed in the seagrass beds. Discussions with local people have confirmed that dugongs do not occur in Caution Bay. No seagrass was observed in deeper water seaward of the fringing reef.

Fringing Reef

As outlined in Section 3.2, the condition of the fringing reef of Caution Bay was poor, probably as a result of heavy fishing use and general sedimentation during periods of strong winds and waves, exacerbated in places by dynamite fishing. The fringing reef flat, adjacent to the seagrass bed and behind the reef crest was dominated by the brown alga, *Sargassum* sp. (Plate 3.17 and refer to Section 3.2), which is often the dominant algal species in tropical latitudes (Womersley, 1987). Much of the brown macroalgae that occurs in the tropical environments is limited to coral reef flats and slopes (Cribb, 1990; Vuki & Price, 1994), which provide a solid substrate in relatively clear water with limited grazing pressure. Macroalgal beds provide important ecological functions in shallow tropical waters such as generation of high primary and secondary production, (Schaffelke et al., 1996). They can exert physical control over other benthic fauna (River & Edmunds, 2001) and have the ability to reduce coral bleaching (Jompa & McCook, 1998). *Sargassum* may also be an effective indicator of increased nutrient inputs (Schaffelke & Klumpp, 1998). As no data exist for Caution Bay prior to the occurrence of

Plate 3.12
Dominant fringing-coast mangrove *(Rhizophora stylosa)*

Plate 3.13
Aerial roots of a grey mangrove patch *(Avicennia marina)*

Plate 3.14
Supratidal mud flats

Plate 3.15
Small patches of sandy beach along the southern coast of Caution Bay

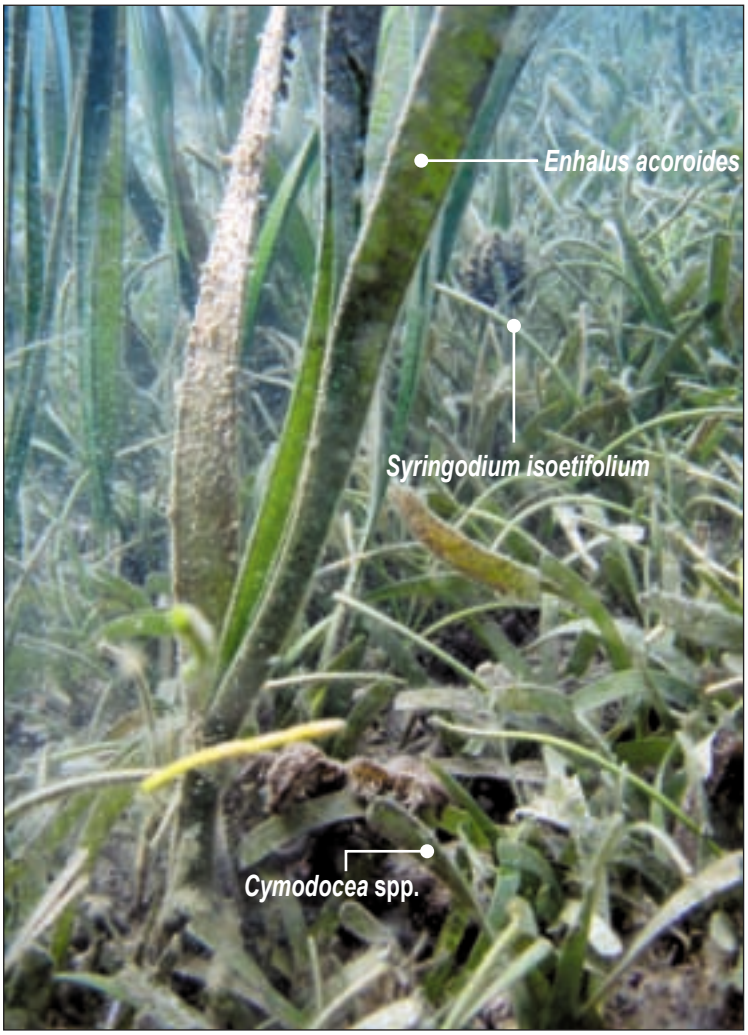


Plate 3.16
Seagrass patch containing multiple species

Plate 3.17
Reef dominated by brown algae (*Sargassum* spp.)

dynamite fishing, it is not clear if the presence of *Sargassum* on the fringing reef of Caution Bay is a result of the removal of coral through dynamite fishing or a natural phenomenon. Consultation with local villages confirms that dynamite fishing is not uncommon practice within the coastal waters, although there is no sign of recent damage at sites visited during the surveys. However, there are extensive areas of old coral rubble that may well have been caused by past dynamiting activities. See Coffey Natural Systems (2008b) for more details regarding dynamite fishing.

Brown algae, including *Sargassum*, can be adversely affected by petroleum products and may be a suitable parameter to monitor to gauge impacts from the PNG LNG Project. Petroleum products inhibit photosynthesis (North et al., 1965) and growth (Middleditch, 1984; Da Silva et al., 1997), cause structural damage (Nelson-Smith, 1972; Antrim et al., 1995), reduce algal diversity (Da Silva et al., 1997) and colonisation potential of algal spores (Reed & Lewis, 1994).

The reef slope and crest are largely free from *Sargassum* growth. This habitat is described in Section 3.2. No evidence of anchor strikes or domestic rubbish was observed during the survey at any of the habitat mapping sites.

Offshore Habitats

Caution Bay is characterised by complex bathymetry with a large number of offshore shoals and coral bommies (Plate 3.18) rising from the lagoon seafloor, which is around 15 to 20 m depth, to around 5 m (see Figure 2.01). These structures commence approximately 2 km west from the edge of the fringing reef in the central / southern region of Caution bay and extend westwards. The bathymetry of the northern end of the bay is comparatively simple, with few shallow shoals, compared with the southern end of the bay, which is dominated by shallow reef areas inshore of the barrier reef. Several of the shoals and bommies were investigated by divers and also by the use of a drop camera. One survey site corresponded with site CF-5, a coral and fish site established on one bommie offshore the proposed jetty location. The offshore coral shoals and bommies have a low coral diversity and abundance, with large amounts of broken coral heads and coral rubble to depths of approximately 15 m (Plate 3.19). In contrast, a single *Pavona clavus* coral bommie of local significance was identified near the landfall for the southern-most pipeline route option and a detailed description is available in the section below.

In between the shoals the seafloor consists of fine sands as described in Section 3.11.

Two offshore islands are located within Caution Bay: Idihi Island and Vari Vari Island (see Figure 3.04). Vari Vari Islands are situated to the north and are island remanent of the mainland that support an extensive fringing reef. Idihi Island is a coral cay, and is located to the south on the barrier reef. Idihi Island, in particular, is relatively void of dense vegetation and instead is dominated by creeping ‘dune vines’. The coral at both Vari Vari Islands and Idihi Island was in good condition with healthy coral cover and diversity observed and no veneer of sediment or signs of anthropogenic disturbance or disturbance from natural sources. This would suggest that dynamite fishing has been restricted to nearshore areas within Caution Bay.

Pavona clavus bommie

The geotechnical and bathymetric survey identified a subsea structure (see Section 3.1.6), which was surveyed by divers and identified as a very large coral of the species *Pavona clavus.* It was measured as 16.75 m in diameter and approximately 3 m in height off the bottom. *P. clavus* is a common coral with a wide distribution across the Indo-Pacific region. This species is known to grow very large, several metres in diameter, and form large mono-specific stands or reefs, as in this example. Other examples

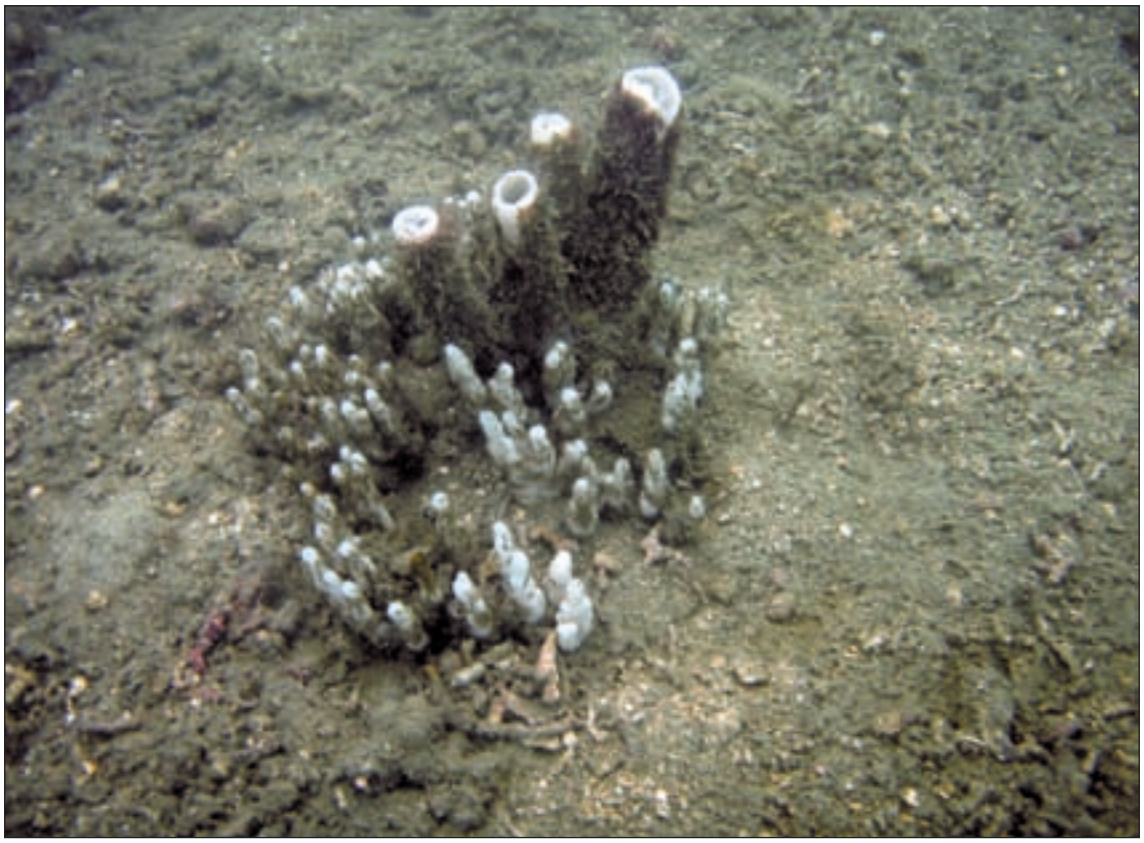


Plate 3.18
Sponge (*Haplosclerida* sp.) on southern slope of an offshore bommie

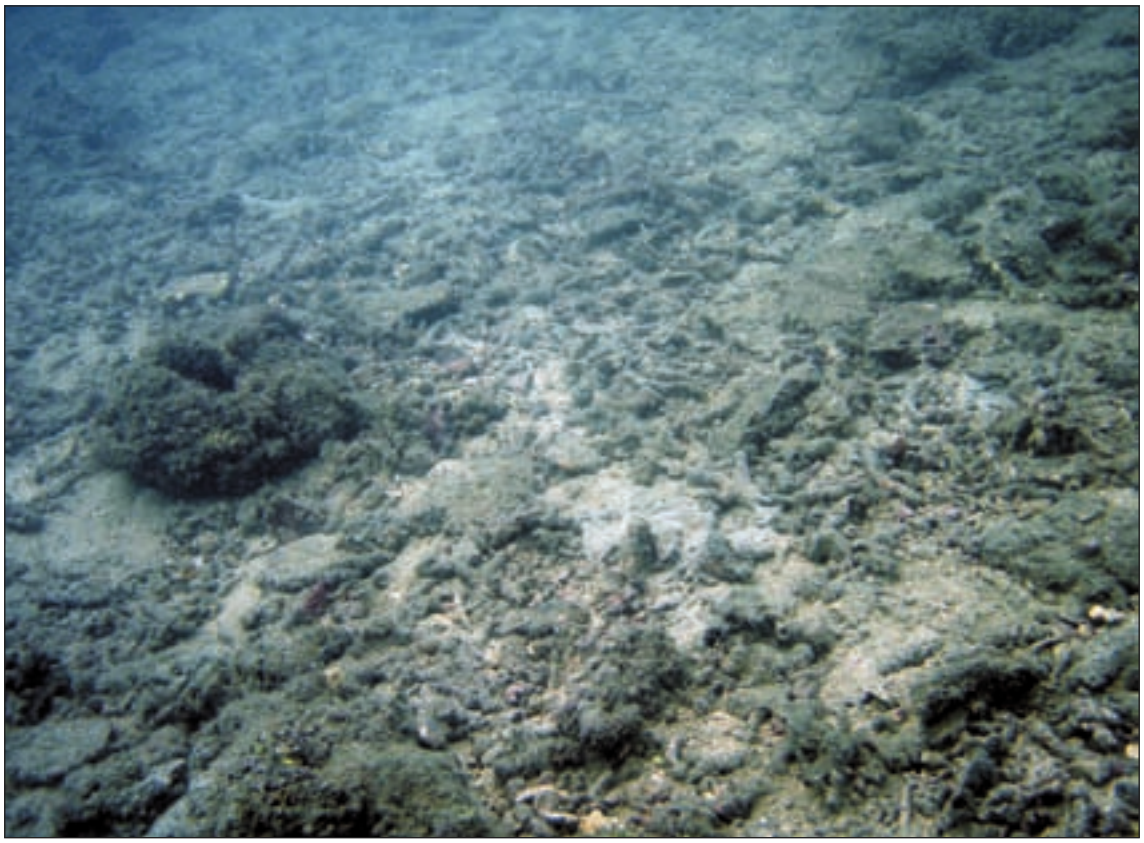


Plate 3.19
Coral rubble on an offshore bommie in Caution Bay

of very large individuals (greater than 15 m) of this species have been recorded in the literature, such as a colony from Urvina Bay, Galápagos (Benway, undated), but specimens of this size are not common.

The species has been studied extensively by paleoclimatologists and linear growth rates of 5 to 20 mm/yr are recorded in the literature (Cronin, 1999). This suggests that the coral in Caution Bay could be in excess of 150 to 300 years old based on its height above the surrounding seafloor.

Unlike most other nearshore coral reef areas of Caution Bay, the proportion of live coral cover across the bommie was very high (estimated as close to 100 %) and the condition of the coral was healthy (Plates 3.20 and 3.21). The bommie also supported very high fish densities, including large numbers of Lutjanidae (snapper), which are not as commonly sighted at other sites in Caution Bay.

The condition of the coral and abundance of fish also support the belief that the fringing reef and nearby patch reefs in Caution Bay have been extensively fished using dynamite and not the result of storm damage. Surrounding reefs, both inshore and offshore of the *P. clavus* bommie, are in very poor condition, supporting limited coral cover and low fish abundance, especially fish targeted by fisherman. This coral bommie, in contrast, supports high coral cover and fish abundance. *P. clavus* is a very fragile coral as its growth form consists of loosely cemented columns, which will fall apart if disturbed and then become easily damaged by storm and swell action.

Given the growth form of *P. clavus,* the location of the bommie between areas of degraded reef and the shallow depth (approximately 8 m), this bommie would be expected to be as sensitive to damage caused by storms and cyclones as the surrounding degraded reefs suggesting that the damage observed elsewhere is not caused by extreme ocean conditions. Rather, given the location the *P. clavus* bommie, isolated from other reefs in an area of extensive sandy seafloor where generally limited water clarity makes it difficult to locate the structure, it is possible that the bommie is not known to local fishermen, or at least has not been fished using dynamite.

Therefore this coral bommie is significant for two reasons:

- It is locally significant as it is one example of a healthy, non-degraded coral bommie observed during field surveys in the nearshore environment in Caution Bay.
- It is notable as specimens of *Pavona clavus* of this size (and age) are not common.

3.2.5 Quality Assurance Program Results: Sediment and Water Quality

Holding Time

It is difficult when working in Papua New Guinea to collect seawater samples and transport them to Australia before holding times are exceeded as they usually need to be analysed within 48 hours of collection. For water samples, all samples for pH measurement exceeded compliance holding times as did a small number of samples analysed for suspended solids, alkalinity, total mercury, ammonia and nitrite. All sediment samples collected during field studies breached holding times for analysis of moisture content and total recoverable mercury. It is therefore possible that some under-reporting of these parameters may occur; however, with the short exceedence times, this is unlikely to represent any substantial difference. All other water and sediment parameters remained within holding times.

Plate 3.20
Fish abundance on *Pavona clavus* bommie

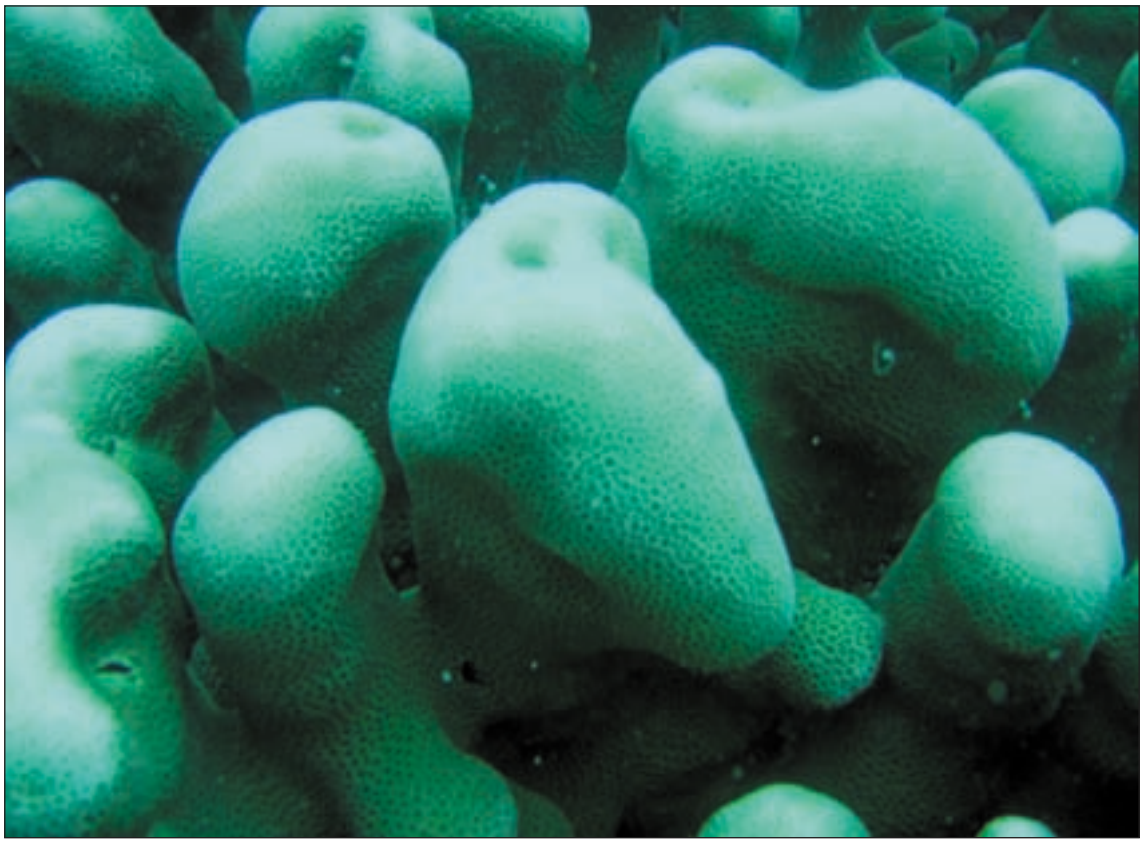


Plate 3.21
Coral structure on *Pavona clavus* bommie

Field Quality Control Samples

Results for field blanks and duplicate analyses of water samples are presented in Annex B, Tables A and B. These show acceptable results for the field quality control samples.

Laboratory Quality Assurance Results

Results for laboratory duplicates, method blank analyses and spike recoveries for sediment and water quality are shown in Annex B, Tables C to L. All laboratory quality control analyses showed acceptable results.

3.2.6 Marine Water Quality

Papua New Guinea environmental water quality guidelines for protection of marine aquatic life are provided in Schedule 1 of the PNG Environment (Water Quality Criteria) Regulation 2002. Any discharges to water associated with the project will be regulated under the PNG *Environment Act 2000* and require an Environment (Waste Discharge) Permit.

The Environmental Code of Practice (ECP) for the PNG Mining Industry (OEC, 2000) includes water quality guidelines that were based on the Australian and New Zealand Environment and Conservation Council and World Health Organization guidelines available at the time (since updated) and are voluntary, i.e., not legally enforceable.

The enforceable PNG water quality standards do not include some quality measures. Therefore, criteria based on more comprehensive scientific information are also considered relevant to the project. In 2000, revised water quality guidelines for a range of environmental values in Australia were published by the Australian and New Zealand Environment and Conservation Council, and the Agricultural and Resource Management Council of Australian and New Zealand (ANZECC/ARMCANZ, 2000). In general, these guidelines are more stringent than the PNG water quality standards and therefore have been adopted as an additional assessment framework for this report.

In summary, results of the nearshore marine water quality samples were compared with:

- Schedule 1 of the PNG Environment (Water Quality Criteria) Regulation 2002.
- ECP for the PNG Mining Industry (OEC, 2000).
- Australian and New Zealand Guideline for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000).

The adopted assessment criteria are included in the results, which are shown in Tables 3.05 and 3.06 and in Figures 3.09 to 3.14. The raw laboratory results are included in Annex E.

General Parameters

Results for parameters including conductivity, salinity, temperature, pH and nutrients are presented in Table 3.05 and shown graphically in Figure 3.09. Conductivity in the nearshore marine environment of Caution Bay ranged from 43.4 to 57.8 mS/cm. Salinity ranged from 27.8 ppt to 34.5 ppt, with the exception of one sample of 36.6 ppt at WQ2-14, which was collected at the mouth of Vaihua River over a shallow sand bank in April. The Vaihua River is more accurately described as a tidal inlet with limited freshwater inputs, mostly from surface run-off during the wet season. Values of pH ranged from 7.94, at

Table 3.05 Seawater – general water quality and nutrients

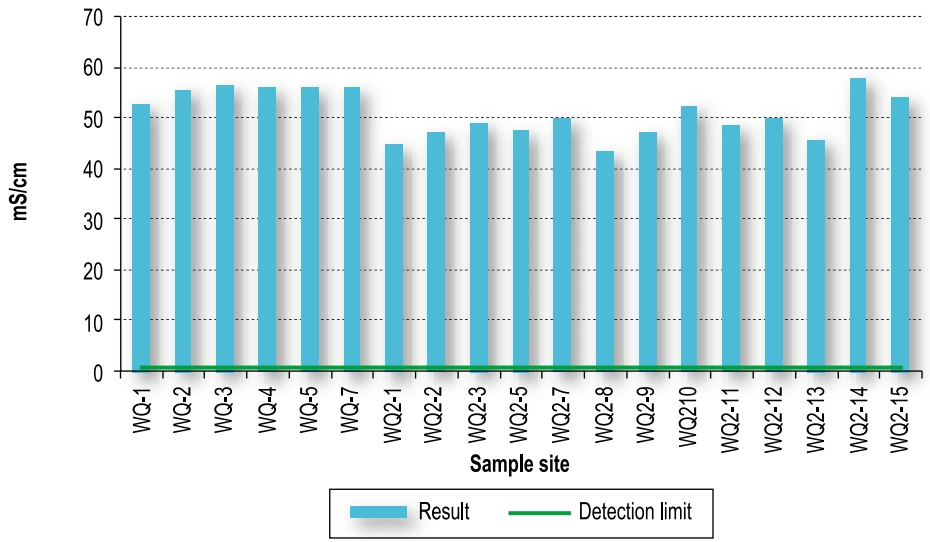
	Conductivity	Salinity	Temperature	pH	Total Suspended Solids	Nutrients				
						Ammonia as N	Nitrite plus Nitrate as N	Total Kjeldahl Nitrogen	Total Nitrogen as N	Total Phosphorus as P
Unit	mS/cm	ppt	°C	pH unit	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Detection Limit	1	-	-	0.01	1	0.01	0.01	0.1	0.1	0.01
Site										
WQ-1	52.8	31.2	30.2	8.2	3	0.041	0.011	<0.1	<0.1	<0.01
WQ-2	55.5	33.8	29.3	8.2	4	0.044	<0.01	<0.1	<0.1	<0.01
WQ-2A	55.5	33.8	29.3	8.2	5	0.045	0.016	<0.1	<0.1	<0.01
WQ-3	56.6	34.1	29.6	8.2	4	0.047	0.017	<0.1	<0.1	<0.01
WQ-4	55.9	34.3	28.6	8.2	5	0.04	<0.01	<0.1	<0.1	<0.01
WQ-5	56.1	34.4	28.8	8.2	2	0.044	<0.01	<0.1	<0.1	<0.01
WQ-7	55.9	34.5	28.3	8.2	17	0.051	0.015	<0.1	<0.1	<0.01
WQ2-1	45.0	29.2	24.8	8.1	32	0.017	0.012	0.2	0.2	0.07
WQ2-2	47.2	30.5	25.2	7.9	35	0.011	0.012	<0.1	<0.1	0.11
WQ2-3	49.2	31.5	25.9	8.1	37	0.013	<0.01	<0.1	<0.1	0.13
WQ2-4 (Duplicate)	47.5	30.4	25.8	8.1	30	0.013	<0.01	<0.1	<0.1	0.13
WQ2-5	47.5	30.4	25.8	8.1	38	0.017	0.492	0.1	0.6	0.12
WQ2-6 (Duplicate)	48.7	31.5	25.4	8.1	28	0.055	0.013	0.2	0.2	0.10
WQ2-7	50.0	32.2	25.7	8.1	68	0.018	0.011	<0.1	<0.1	0.09
WQ2-8	43.4	27.8	25.2	8.1	32	0.014	<0.01	0.1	0.1	0.07
WQ2-9	47.2	29.5	25.5	8.1	26	<0.01	<0.01	0.1	0.1	0.11
WQ2-10	52.5	34.2	25.5	8.1	41	0.02	0.022	0.1	0.1	0.10
WQ2-11	48.7	31.5	25.4	8.1	27	<0.01	<0.01	0.2	0.2	0.12
WQ2-12	50.0	32.4	25.5	8.0	41	0.011	<0.01	0.1	0.1	0.10
WQ2-13	45.6	29.6	24.9	8.1	35	0.013	0.025	0.1	0.2	0.08
WQ2-14	57.8	36.6	27.6	8.0	48	0.042	0.015	0.2	0.2	0.11
WQ2-15	54.3	33.7	26.7	7.7	32	0.041	<0.01	0.4	0.4	0.05
Guidelines										
ANZECC/ARMCA NZ	-	-	-	8-8.4	-	-	-	-	0.1	0.015
Schedule 1	-	-	No alteration >2°C	No alteration		-	45[A1]	45	-	-
PNG ECP	<5% change[B1]	<5% change[B1]	<2°C increase[B2]	<0.2 pH change[B3]	<10% change**	-	-	-	-	-

Notes: A1 = Both nitrate and nitrite. B1 = Change from seasonal mean background level. B2 = From normal temperature. B3 = Change from normal pH.

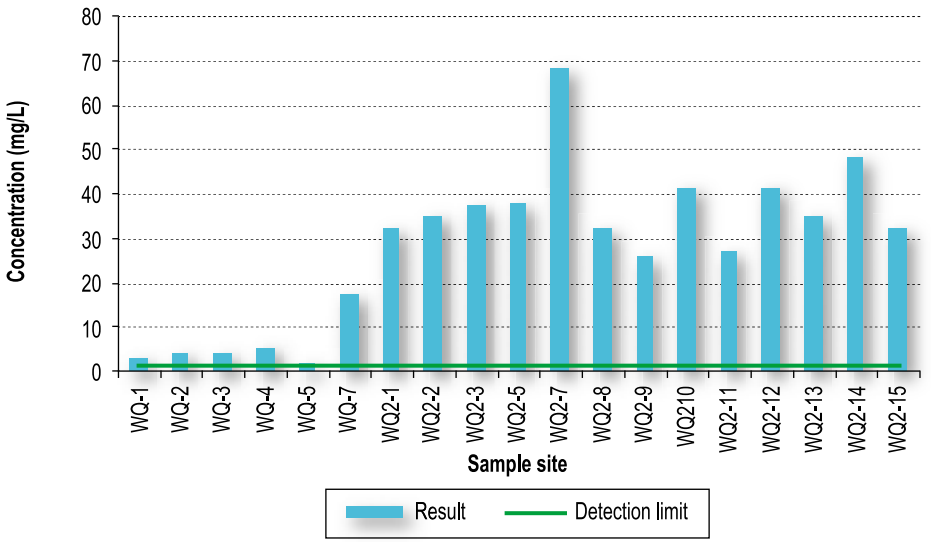
Table 3.06 Seawater – total metals

	Metal												
	Aluminum	**Silver**	**Arsenic**	**Cadmium**	**Cobalt**	**Chromium**	**Copper**	**Iron**	**Manganese**	**Nickel**	**Lead**	**Selenium**	**Zinc**
Detection Limit	0.01	0.0001	0.0005	0.0002	0.0002	0.0005	0.001	0.005	0.0005	0.0005	0.0002	0.002	0.005
Site													
WQ-1	0.02	<0.0001	0.0017	<0.0002	<0.0002	<0.0005	<0.001	0.027	0.0041	0.0006	<0.0002	<0.002	<0.005
WQ-2	<0.01	<0.0001	0.0018	<0.0002	<0.0002	<0.0005	<0.001	<0.005	0.0011	<0.0005	<0.0002	<0.002	<0.005
WQ-2A	<0.01	<0.0001	0.0017	<0.0002	<0.0002	<0.0005	<0.001	0.006	0.0014	<0.0005	<0.0002	<0.002	<0.005
WQ-3	<0.01	<0.0001	0.0018	<0.0002	<0.0002	<0.0005	<0.001	0.014	0.0014	<0.0005	<0.0002	<0.002	<0.005
WQ-4	<0.01	<0.0001	0.0018	<0.0002	<0.0002	<0.0005	<0.001	0.01	0.0013	<0.0005	<0.0002	<0.002	<0.005
WQ-5	<0.01	<0.0001	0.0018	<0.0002	<0.0002	<0.0005	<0.001	0.011	0.0016	<0.0005	<0.0002	<0.002	<0.005
WQ-7	0.01	<0.0001	0.0018	<0.0002	<0.0002	<0.0005	<0.001	0.025	0.0016	<0.0005	<0.0002	<0.002	<0.005
WQ2-1	0.02	<0.0001	0.0011	0.0003	<0.0002	<0.0005	<0.001	0.011	0.0014	<0.0005	<0.0002	<0.002	<0.005
WQ2-2	0.02	<0.0001	0.0014	<0.0002	<0.0002	<0.0005	<0.001	0.011	0.0019	<0.0005	<0.0002	<0.002	<0.005
WQ2-3	0.01	<0.0001	0.0015	<0.0002	<0.0002	<0.0005	<0.001	0.006	0.0013	<0.0005	<0.0002	<0.002	<0.005
WQ2-4 (Duplicate)	0.02	<0.0001	0.0018	<0.0002	<0.0002	<0.0005	<0.001	0.014	0.0025	<0.0005	<0.0002	<0.002	<0.005
WQ2-5	0.02	<0.0001	0.0015	<0.0002	<0.0002	<0.0005	<0.001	0.012	0.0024	<0.0005	<0.0002	<0.002	<0.005
WQ2-6 (Duplicate)	0.02	<0.0001	0.0014	<0.0002	<0.0002	<0.0005	<0.001	0.012	0.0019	<0.0005	<0.0002	<0.002	<0.005
WQ2-7	0.02	<0.0001	0.0013	<0.0002	<0.0002	<0.0005	<0.001	0.012	0.0018	<0.0005	<0.0002	<0.002	0.005
WQ2-8	0.02	<0.0001	0.0011	0.0005	<0.0002	<0.0005	<0.001	0.022	0.0028	<0.0005	<0.0002	<0.002	<0.005
WQ2-9	0.02	<0.0001	0.0012	<0.0002	<0.0002	<0.0005	<0.001	0.017	0.002	<0.0005	<0.0002	<0.002	<0.005
WQ2-10	0.01	<0.0001	0.0017	0.0003	<0.0002	<0.0005	<0.001	0.008	0.0018	<0.0005	<0.0002	<0.002	<0.005
WQ2-11	0.01	<0.0001	0.0014	<0.0002	<0.0002	<0.0005	<0.001	0.01	0.0016	<0.0005	<0.0002	<0.002	<0.005
WQ2-12	0.01	<0.0001	0.0016	<0.0002	<0.0002	<0.0005	<0.001	0.007	0.002	<0.0005	<0.0002	<0.002	0.006
WQ2-13	0.02	<0.0001	0.0013	<0.0002	<0.0002	<0.0005	<0.001	0.011	0.0018	<0.0005	<0.0002	<0.002	<0.005
WQ2-14	0.13	<0.0001	0.0018	0.0002	0.0003	<0.0005	<0.001	0.157	0.0284	0.0007	<0.0002	<0.002	<0.005
WQ2-15	0.3	<0.0001	0.0014	<0.0002	0.0007	0.0008	<0.001	0.381	0.143	0.0023	<0.0002	<0.002	<0.005
Guidelines													
ANZECC/ARMCANZ	-	0.0014	0.0055	-	0.001	0.0044	0.0013	-	-	0.07	0.0044	-	0.015
Schedule 1	-	-	0.05	0.001	-	0.01	0.03	1	2	1	0.004	0.01	5
PNG ECP	-	-	0.05	0.002	0.0009	0.05	0.005	-	0.1	0.015	0.005	0.07	0.05

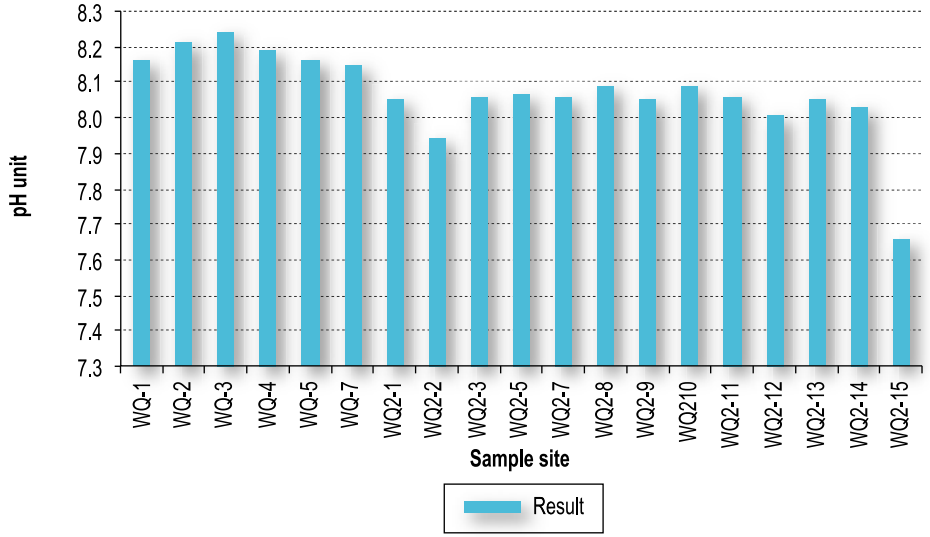
Conductivity



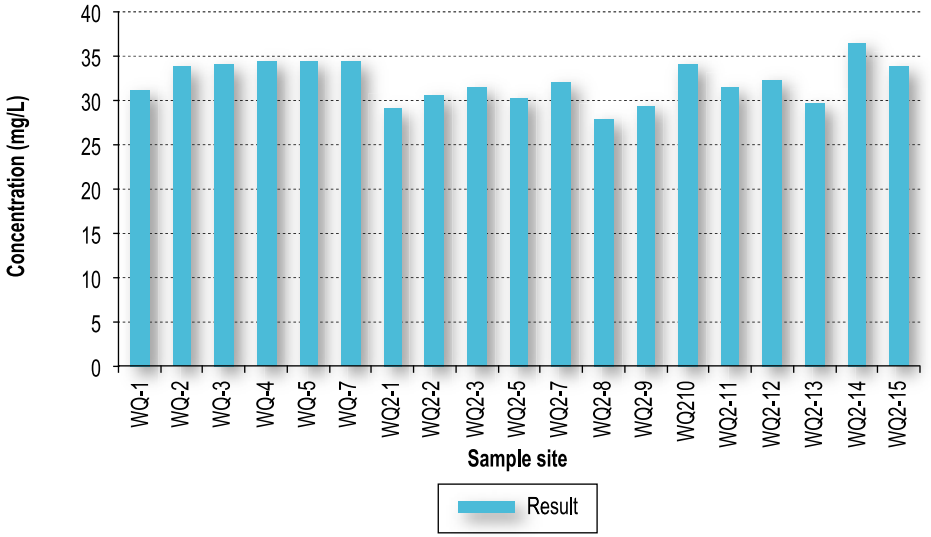
Total Suspended Sediments



pH (in-situ)



Salinity



PNG LNG	Job No: 1284	Esso Highlands Limited	Figure No: 3.09
	File Name: 1284_05_F03.09_HB	PNG LNG Project	Seawater quality – physical attributes

WQ2-2, a site located south of Redscar Head, to pH 8.24 at WQ-3, taken from the existing shipping channel on the southern side of Haidini Island. These pH values are within the expected pH range for seawater of 7.5 to 8.5 (Smith, 2006). A pH value of 7.66 was recorded at WQ2-15, a site located within the mangrove community of Vaihua River, as expected from an estuarine environment.

Total suspended solids ranged from 2 mg/L at WQ-5 to 17 mg/L at WQ-7 during the first field survey in December 2007. Concentrations recorded from samples taken during April 2008, had results ranging from 26 mg/L at WQ2-9 to 68 mg/L at WQ2-7. Concentrations of total suspended solids were higher in April than December, contrary to the higher visibility in April noted by the divers. Further investigation is required to validate these results. Sedimentation rates were recorded in settlement tubes located on the reefs for periods between December 2007 to February 2008 and February to April 2008 (see Section 3.2.8). These results show a range, possibly reflecting localised conditions, but no overall consistency across all sites over the sampling periods. At sampling sites taken during the first field survey, nutrients, including total Kjeldahl nitrogen, total nitrogen and total phosphorus, were below the analytical detection limits (Figure 3.10), while samples taken in April 2008 showed levels above the detection limits for these nutrients at a majority of the sites within Caution Bay. Ammonia concentrations observed from all sampling sites ranged from less than 0.01 to 0.055 mg/L. The concentration of ammonia in natural waters varies widely, however in unpolluted oxygenated seawater, the typical concentrations range from 0 to 0.17 mg/L (Johansson & Wedbourg, 1980). Therefore all ammonia concentrations are within the typical concentration range.

Metal Concentration

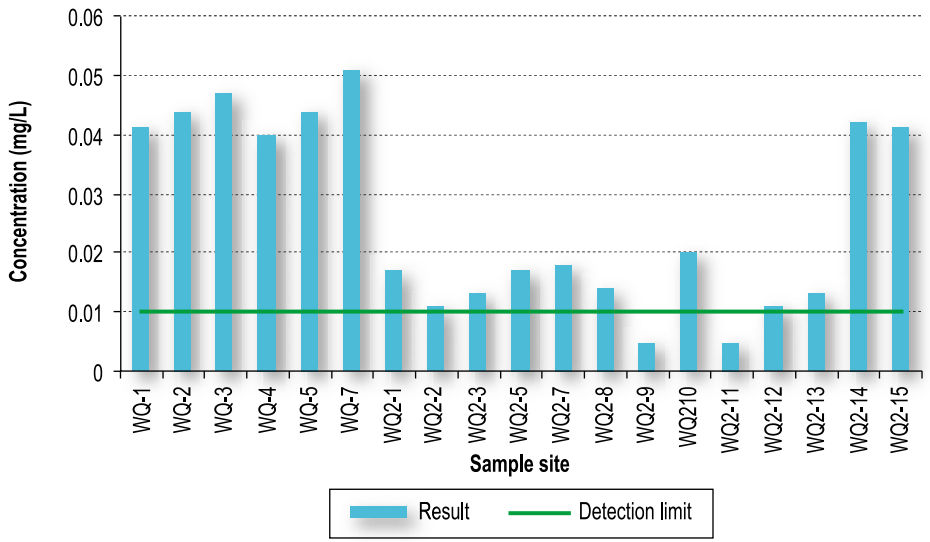
Results for total metal concentrations are shown in Table 3.06. Although there are no guidelines for total metal concentrations for the protection of marine aquatic life, the guidelines for filterable metal concentrations are used below as a broad indication of compliance[4]. Using total metal values therefore adds a level of conservatism in this assessment.

A majority of the water samples had concentrations of cobalt, chromium, copper, nickel, lead, selenium and zinc below the analytical detection limits (which were less than 0.001 mg/L for copper, less than 0.002 mg/L for cobalt, lead and selenium and less than 0.005 mg/L for chromium, nickel and zinc). The results are presented in Figures 3.11 to 3.14. Where results are below the detection limit, a value of half of the detection limit has been used in the graphs.

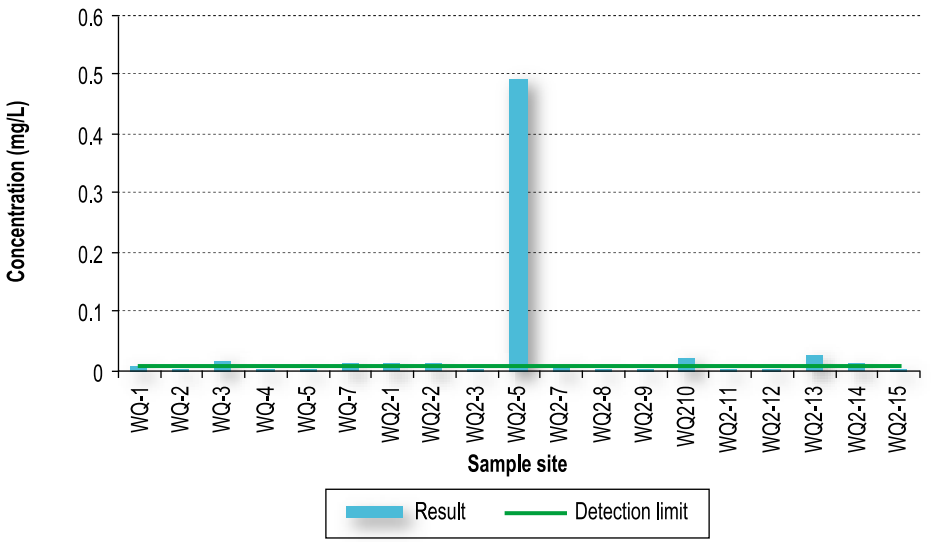
Where aluminium, iron, arsenic, cadmium, manganese and silver concentrations are above the detection limits, results were below the guidelines for the protection of marine aquatic life (Schedule 1 criteria, the ECP guidelines and ANZECC/ARMCANZ guidelines) indicating uncontaminated waters.

[4] If the total metal concentrations exceed the guidelines, it does not necessarily indicate that the filterable metal concentration will also be exceeded.

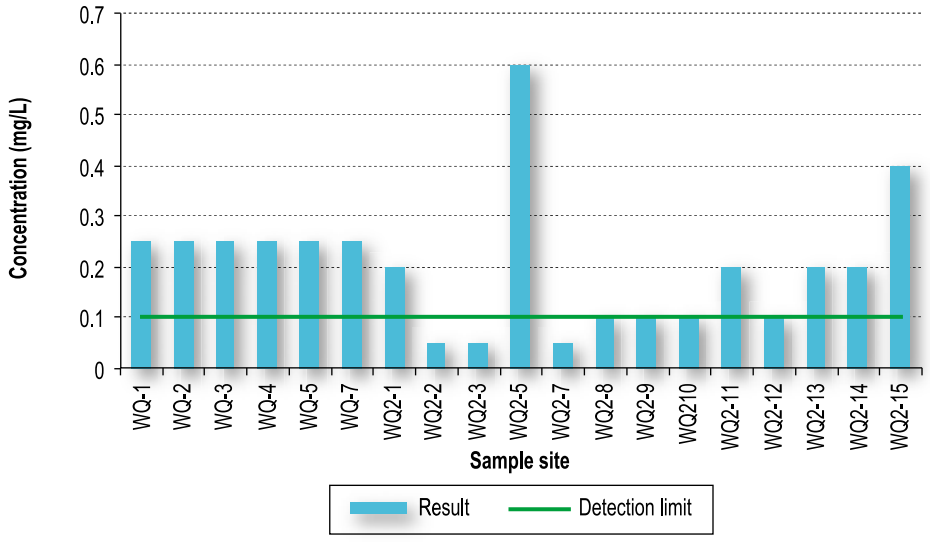
Ammonia



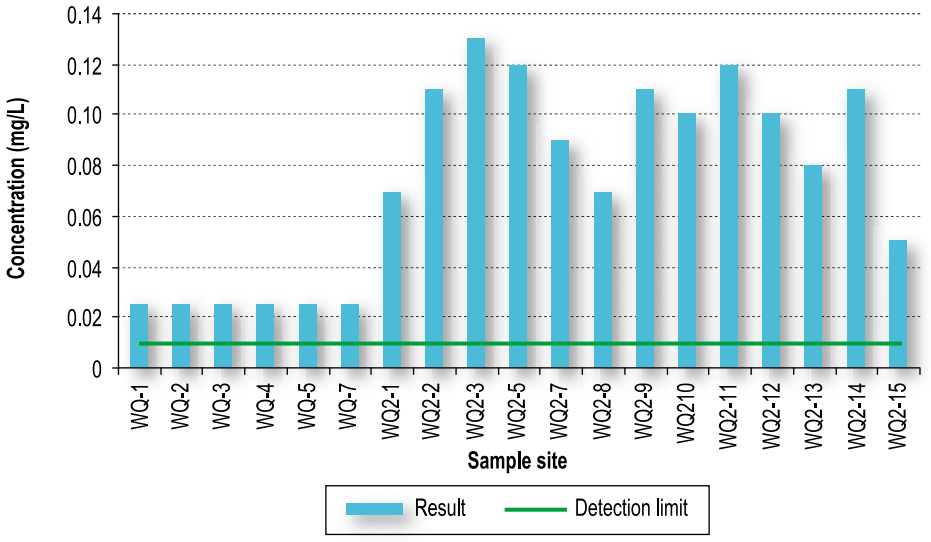
Nitrite plus Nitrate as N



Total Nitrogen



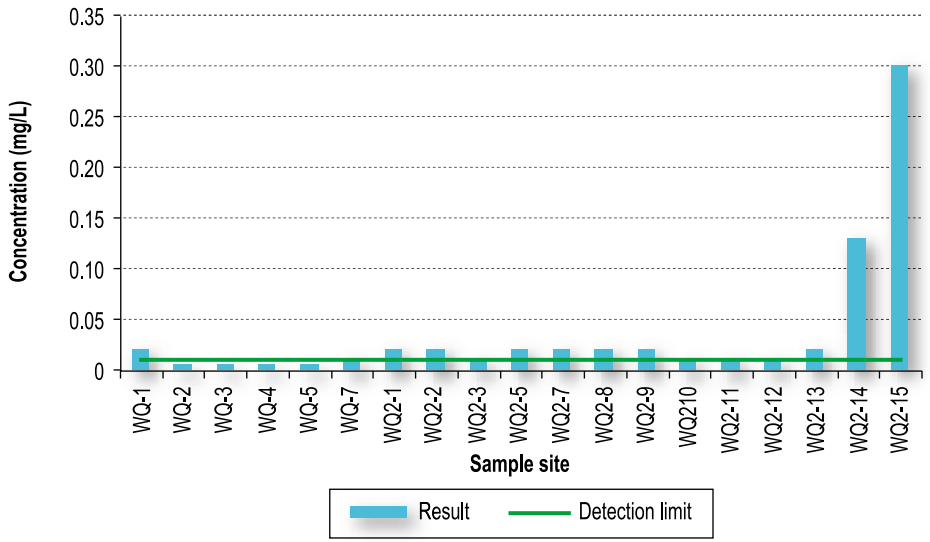
Total Phosphorus



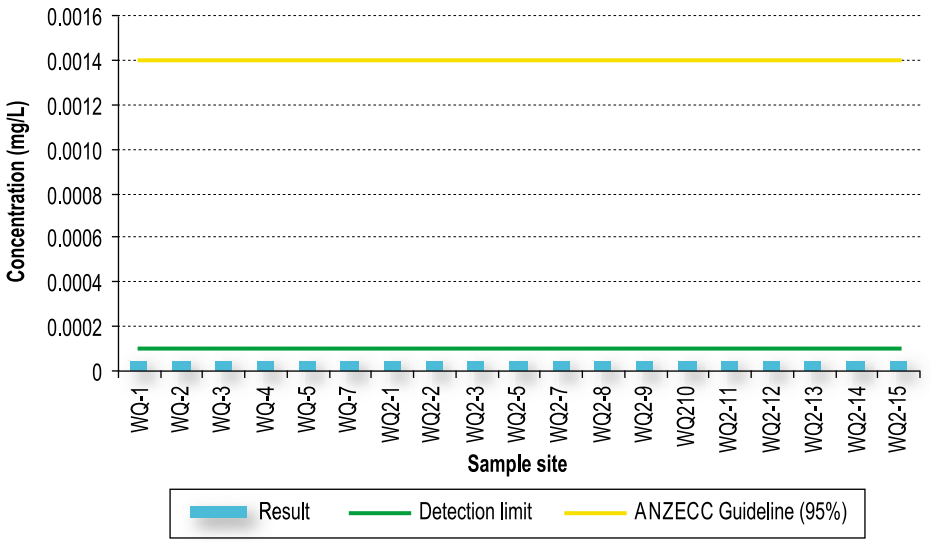
PNG LNG	Job No: 1284 File Name: 1284_05_F03.10_HB	Esso Highlands Limited PNG LNG Project	Seawater quality - ammonia, nitrite plus nitrate, total nitrogen and total phosphorus

Figure No: 3.10

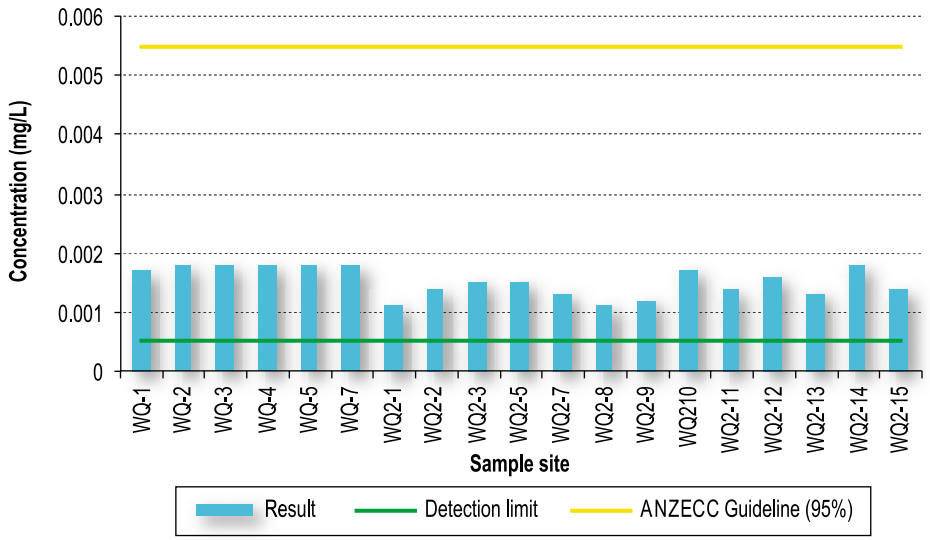
Aluminium



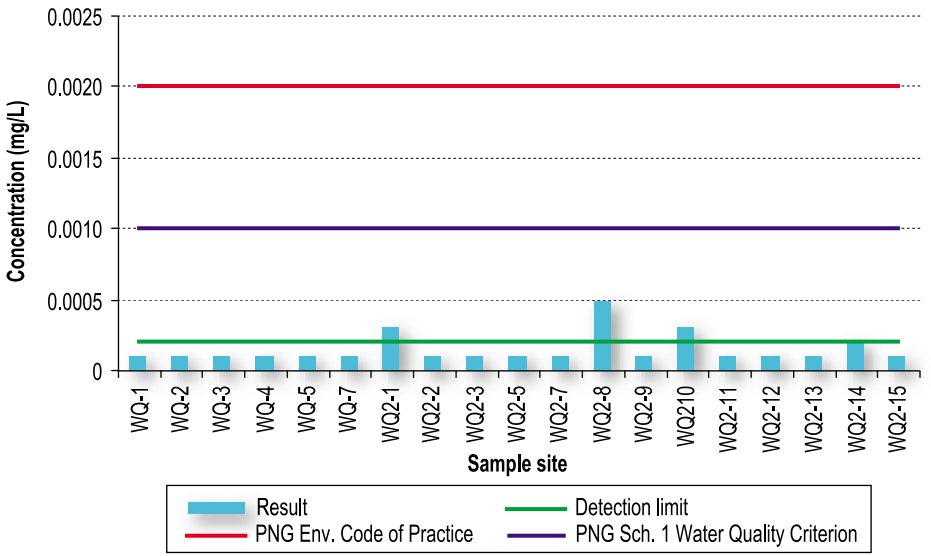
Silver



Arsenic

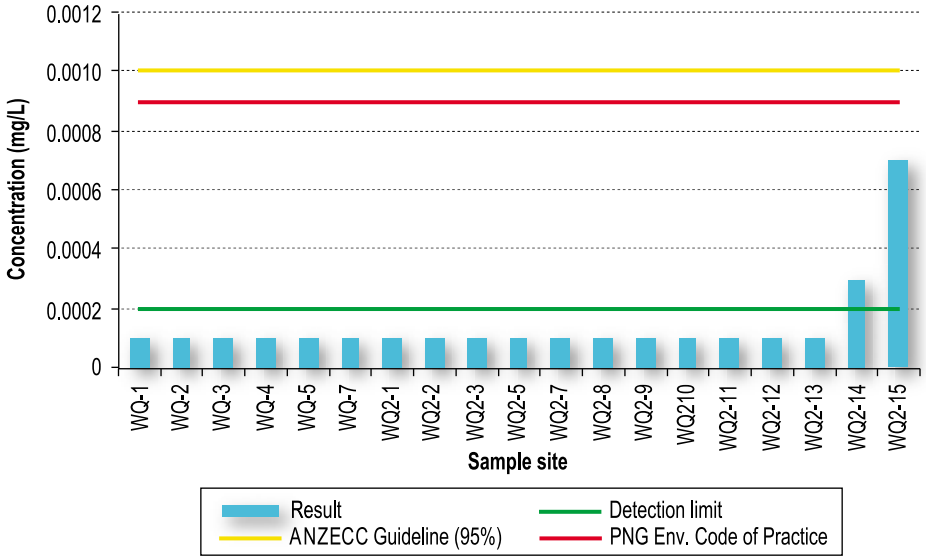


Cadmium

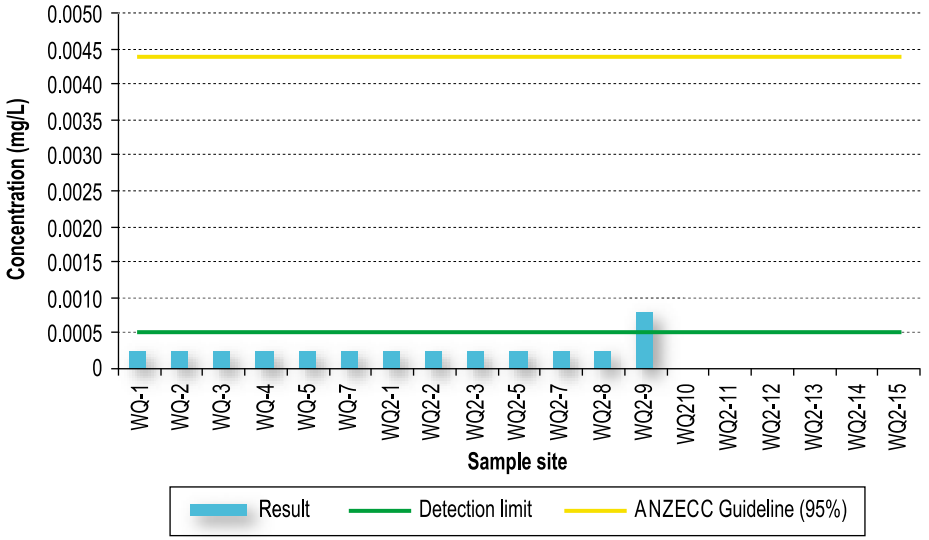


PNG LNG	Job No: 1284	Esso Highlands Limited	Figure No: 3.11
	File Name: 1284_05_F03.11_HB	PNG LNG Project	Seawater quality – aluminium, silver, arsenic and cadmium

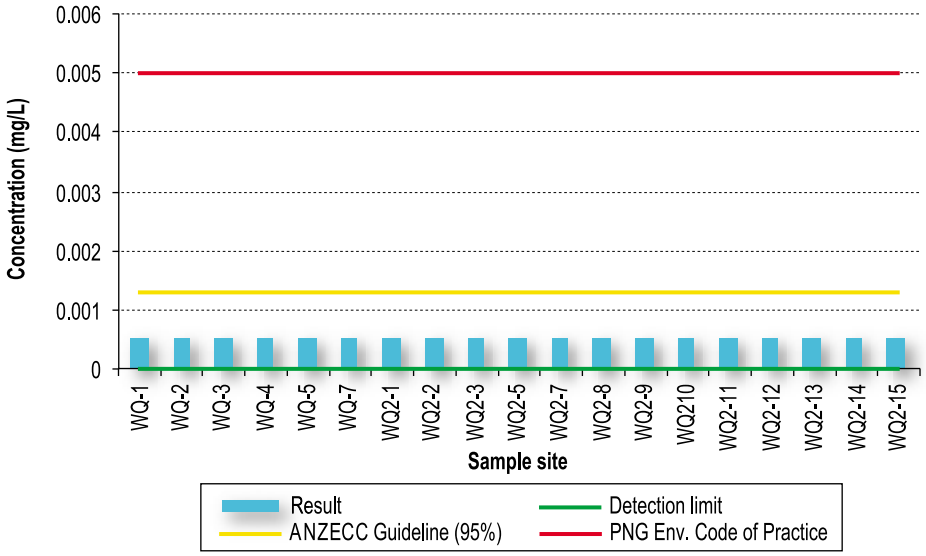
Cobalt



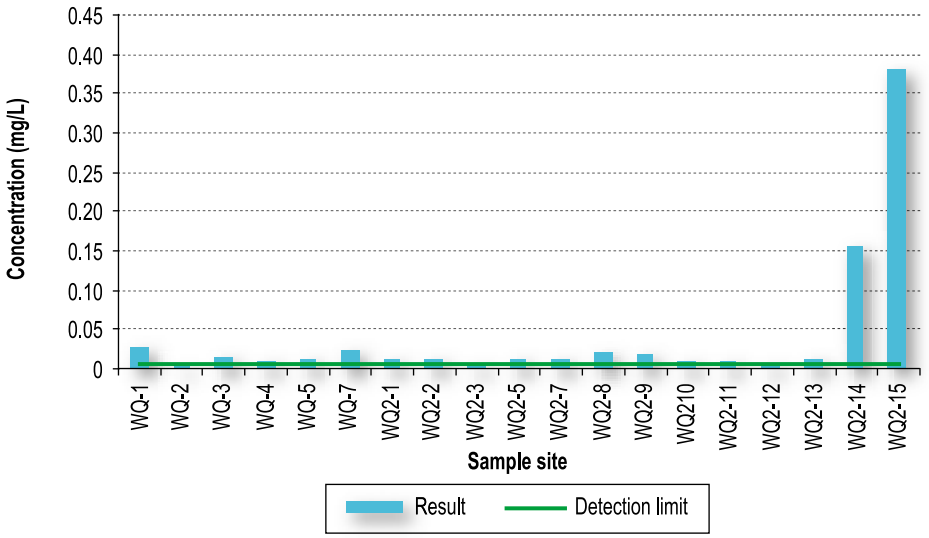
Chromium



Copper

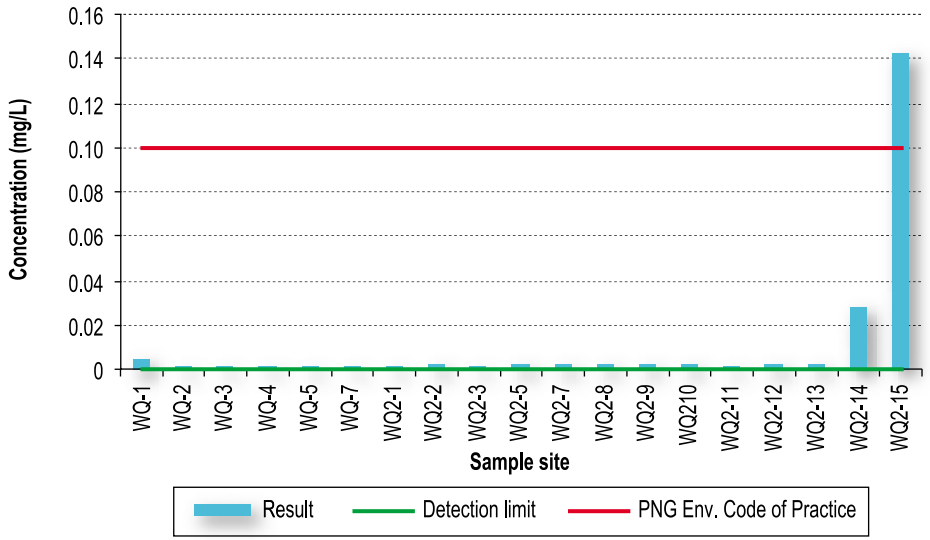


Iron

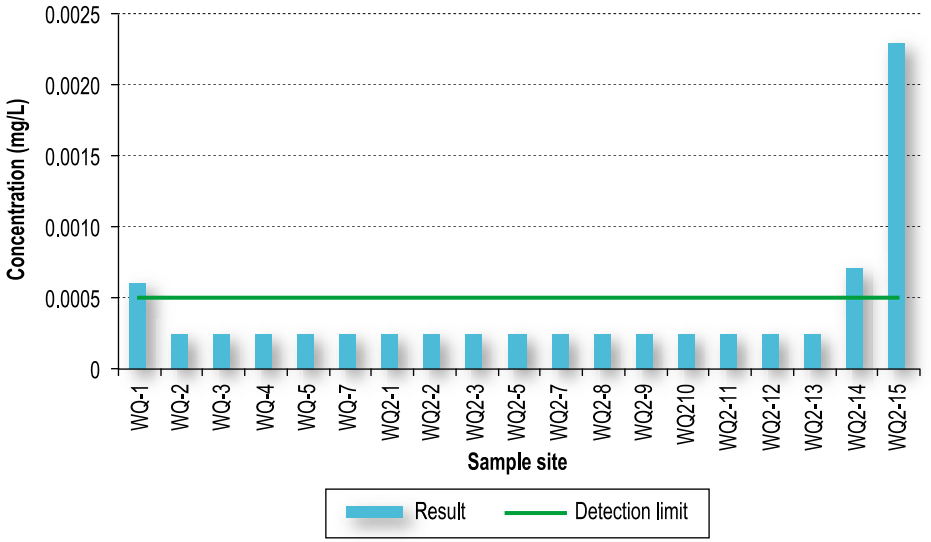


	PNG LNG	Job No: 1284 File Name: 1284_05_F03.12_HB	Esso Highlands Limited PNG LNG Project	Seawater quality - cobalt, chromium, copper and iron	Figure No: 3.12

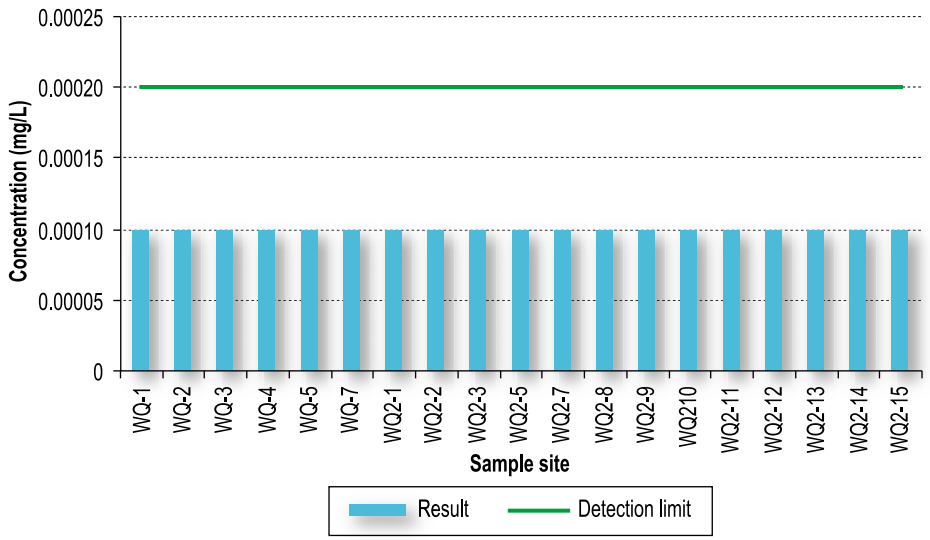
Manganese



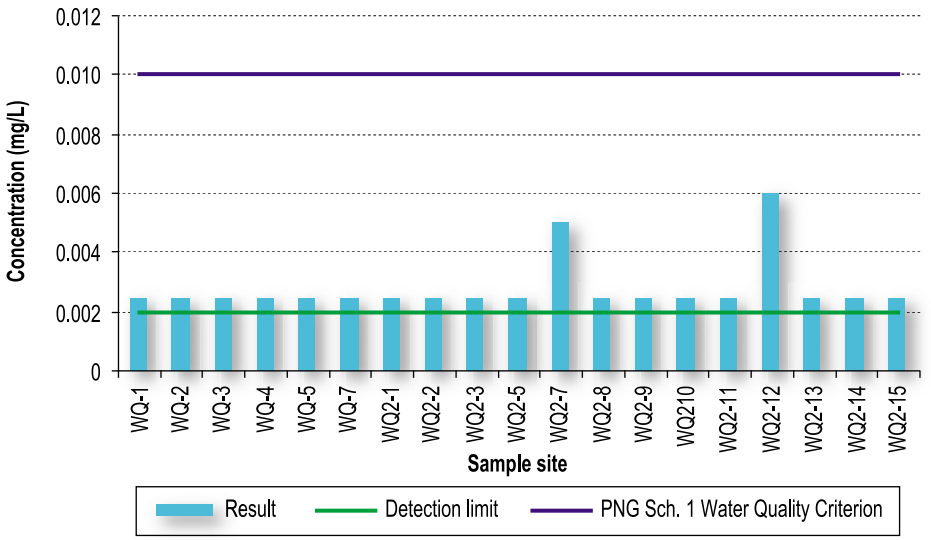
Nickel



Lead

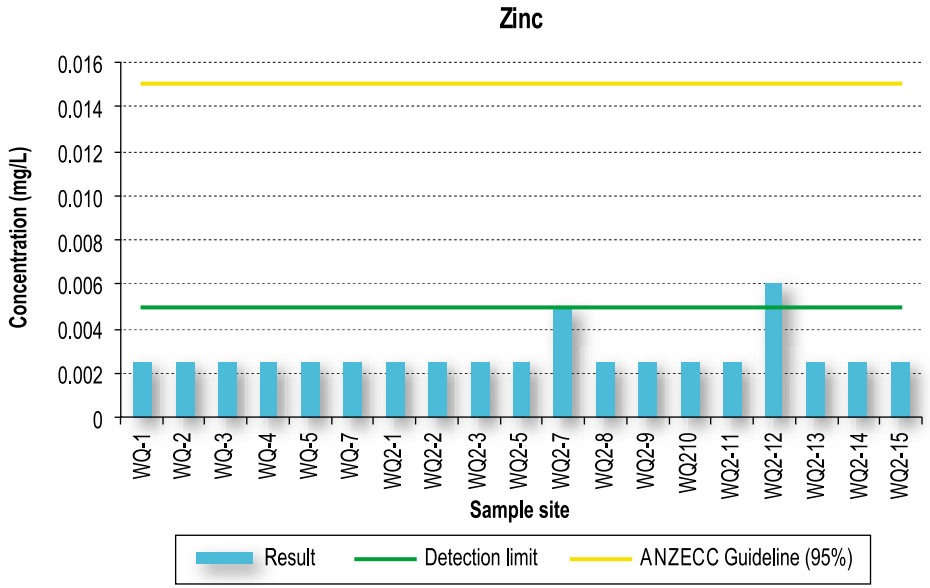


Selenium



PNG LNG	Job No: 1284 File Name: 1284_05_F03.13_HB	Esso Highlands Limited PNG LNG Project	Seawater quality - manganese, nickel, lead and selenium

Figure No: 3.13



	PNG LNG	Job No: 1284 File Name: 1284_05_F03.14_HB	Esso Highlands Limited PNG LNG Project	Seawater quality - zinc	Figure No: 3.14

3.2.7 Sediment Quality

PNG regulatory authorities have not established sediment quality guidelines. The Australian and New Zealand Guideline for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000) describe interim sediment quality guidelines (ISQG) and therefore these have been used as a comparison with the results obtained from the sediment analyses (Table 3.07). These guidelines contain two values, ISQG-low and ISQG-high, which delineate three biological effects ranges:

- Concentrations below the ISQG-low guideline represent a range where adverse biological effects on benthic biota will rarely be observed.
- Concentrations between the ISQG-low and ISQG-high guidelines represent a range where adverse biological effects on benthic biota will occasionally be observed.
- Concentrations above the ISQG-high guideline represent a range where adverse biological effects on benthic biota frequently occur.

Metal concentrations were analysed from the sub 2,000 µm fraction at all sites. Graphs of total metal concentrations of sediments sampled are given in Figures 3.15 to 3.18. Silver and cadmium concentrations in sediment samples were below the detection limit, but this limit is higher than the ISQG-low guideline and therefore determining whether the concentrations of these metals are below the low guideline is not possible. Arsenic, chromium, copper, nickel, lead and zinc metal concentrations were above the detection limit but results were below ISQG-low guidelines. There are no guidelines for aluminium, cobalt, iron, manganese or selenium. Silver concentrations in sediment sample, Sed 7, were slightly above the ISQG-low guideline. Nickel concentrations in sediment sample Sed 8, were also above the ISQG-low guideline, in contrast to other sediments analysed. Both samples however, were lower than the ISQG-high guideline.

The results for proportions of total carbon and inorganic carbon in sediment samples, along with particle size ratios, are shown in Table 3.08. The proportion of organic carbon ranged from 2.2% to 10.8%. Total inorganic carbon in sediment samples ranged from 1.17% to 10.7%. Graphs of seafloor sediment particle sizes are given in Figure 3.19A and 3.19B. Sediment samples collected from the proposed shipping channel in Caution Bay (Sed 1, 2 and 3), at Idihi Island and in the mangrove communities of Vaihua River were dominated by particle sizes below the 63 µm fraction, and between the 63 µm and 2,000 µm sediment fraction. The majority of the sediment samples collected within Caution Bay were represented by sediments between 63 µm and 2,000 µm. Approximately one-third of particle size distributions were in the greater than 2000 µm sediment fraction for samples obtained from areas dominated by coral reefs (Sed 9, 10, 12, 13 and 16), which are areas that consist mainly of coral rubble and shell debris.

Table 3.07 Sediment – metals

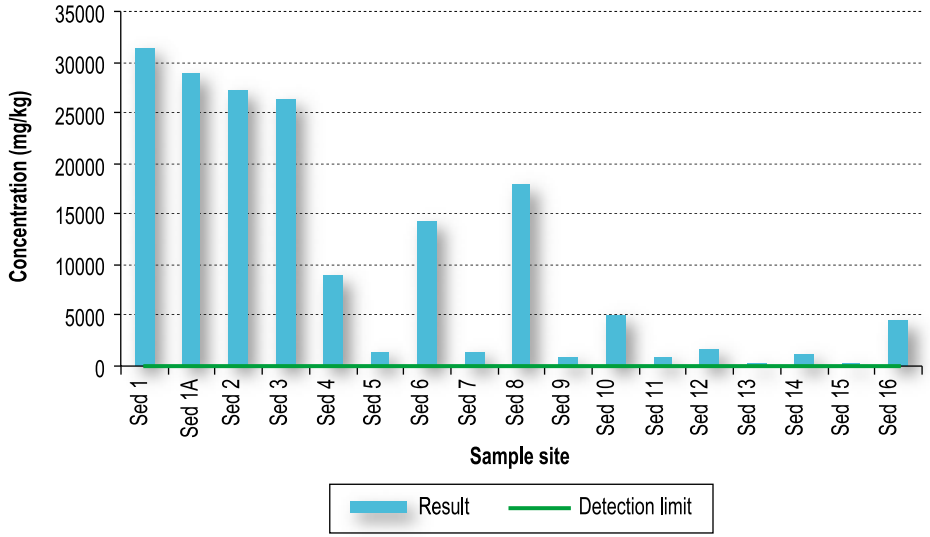
	Metal (mg/kg)*												
	Aluminum	**Silver**	**Arsenic**	**Cadmium**	**Cobalt**	**Chromium**	**Copper**	**Iron**	**Manganese**	**Nickel**	**Lead**	**Selenium**	**Zinc**
Detection Limit	50	2	5	1	2	2	5	50	5	2	5	5	5
Site													
Sed 1	31,500	<2	7	<1	10	33	38	35,200	398	20	13	<5	62
Sed 1 (Duplicate)	28,900	<2	7	<1	10	33	39	35,000	396	20	12	<5	61
Sed 2	27,200	<2	<5	<1	8	29	28	28,400	366	17	10	<5	46
Sed 3	26,300	<2	<5	<1	6	23	27	20,900	289	14	8	<5	32
Sed 4	8,930	<2	8	<1	7	20	12	21,400	309	11	6	<5	25
Sed 5	1,500	<2	<5	<1	<2	5	<5	4,270	187	<2	<5	<5	6
Sed 6	14,200	<2	7	<1	7	24	23	23,100	388	14	8	<5	41
Sed 7	1,540	<3	<5	<1	<3	5	<5	4,760	192	3	<5	<5	5
Sed 8	18,000	<2	7	<1	14	48	**67**	27,500	418	**47**	10	5	73
Sed 9	960	<2	<5	<1	<2	3	<5	2,140	147	<2	<5	<5	5
Sed 10	5,160	<2	7	<1	3	9	12	11,900	252	7	<5	<5	25
Sed 11	860	<2	<5	<1	<2	5	<5	1,350	78	<2	<5	<5	<5
Sed 12	1,760	<2	<5	<1	<2	2	20	1,370	90	<2	<5	<5	8
Sed 13	380	<2	<5	<1	<2	<2	<5	610	40	<2	<5	<5	<5
Sed 14	1,250	<2	<5	<1	<2	3	7	1,780	134	<2	<5	<5	<5
Sed 15	300	<2	<5	<1	<2	<2	5	420	56	<2	<5	<5	<5
Sed 16	4,560	<2	<5	<1	<2	4	8	3,470	112	2	<5	<5	<5
Guidelines*													
ISQG-Low	-	1	20	1.5	-	80	65	-	-	21	50	-	200
ISQG-High	-	3.7	70	10	-	370	270	-	-	52	220	-	410

Source: ANZECC/ARMCANZ (2000).

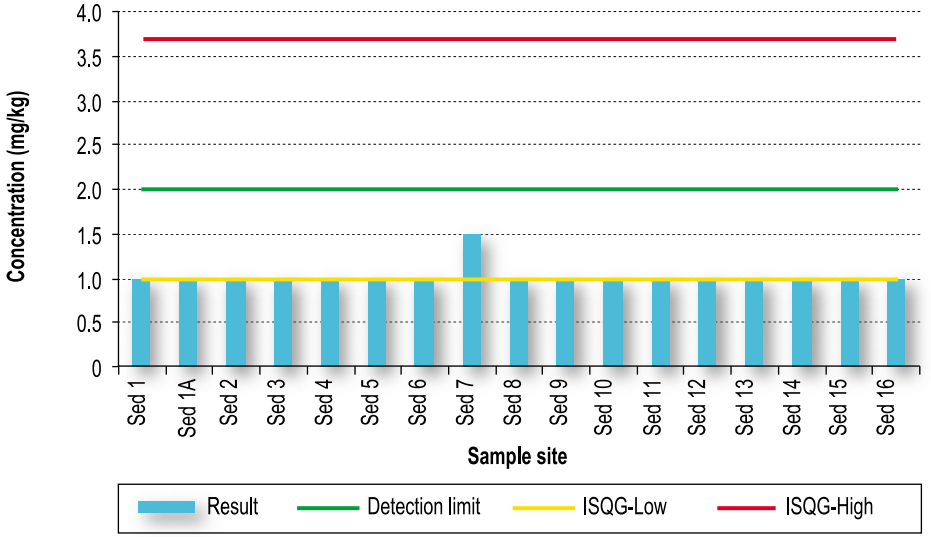
Bold text indicates concentrations above ISQG-Low. No values were above ISQG-High.

* Analyses undertaken on the less than 2,000 µm fraction.

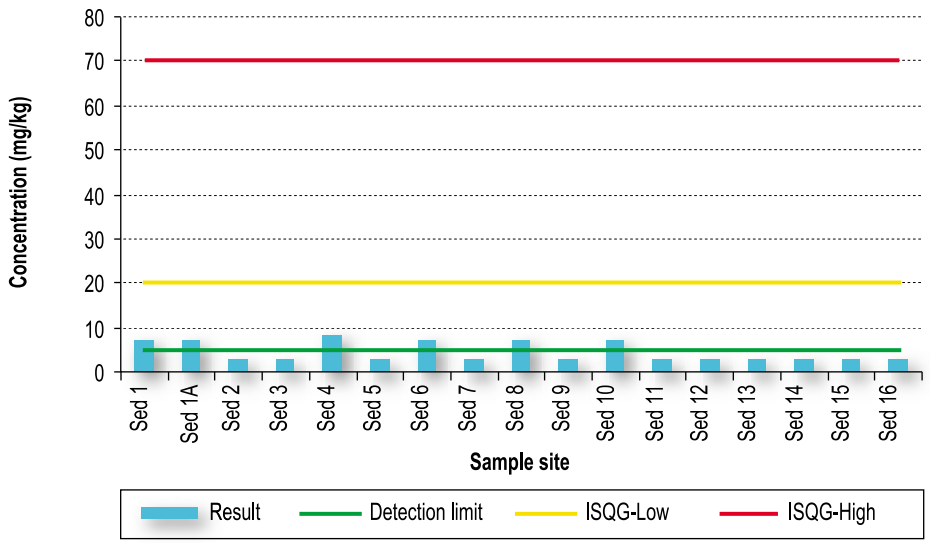
Aluminium



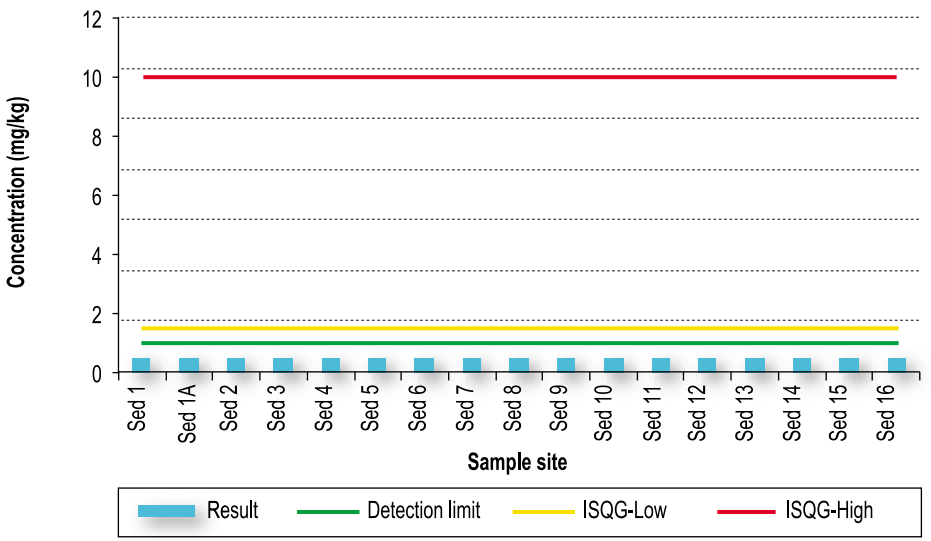
Silver



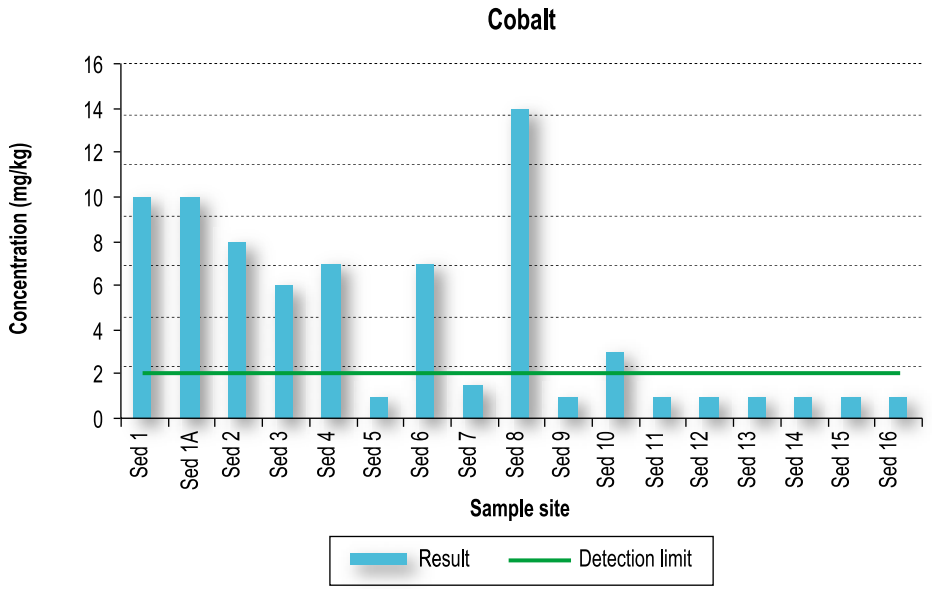
Arsenic

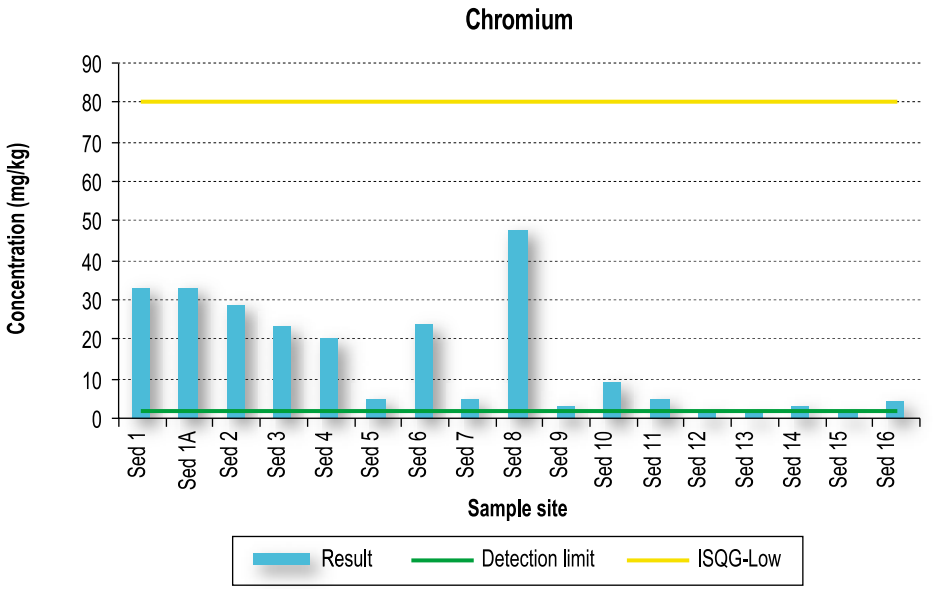


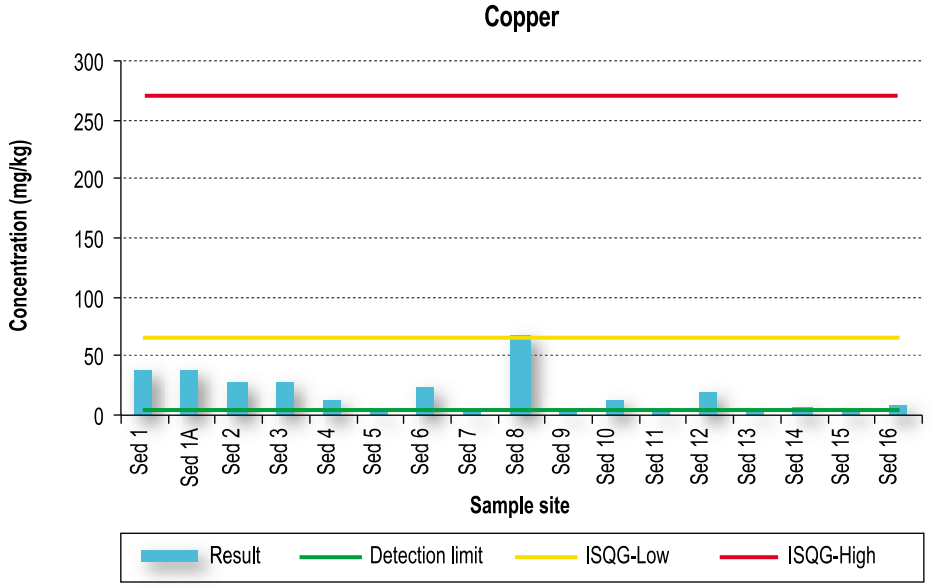
Cadmium

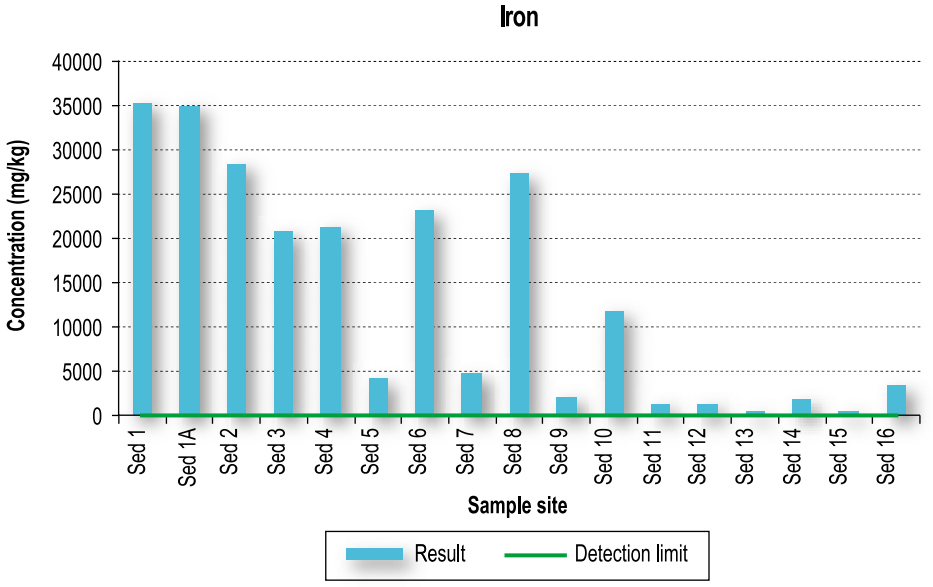


PNG LNG	Job No: 1284	Esso Highlands Limited	Figure No: 3.15
	File Name: 1284_05_F03.15_HB	PNG LNG Project	Sediment quality - aluminium, silver, arsenic and cadmium

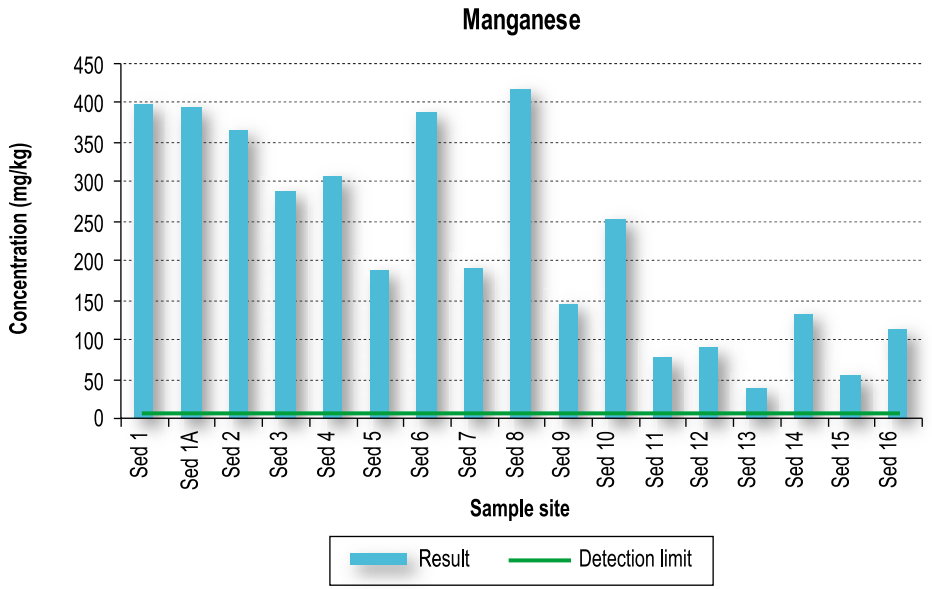


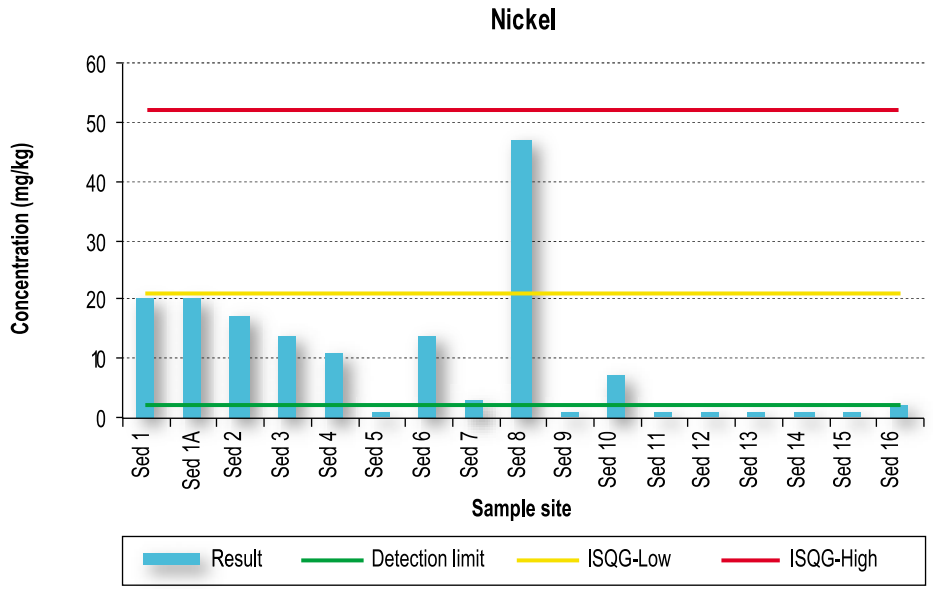


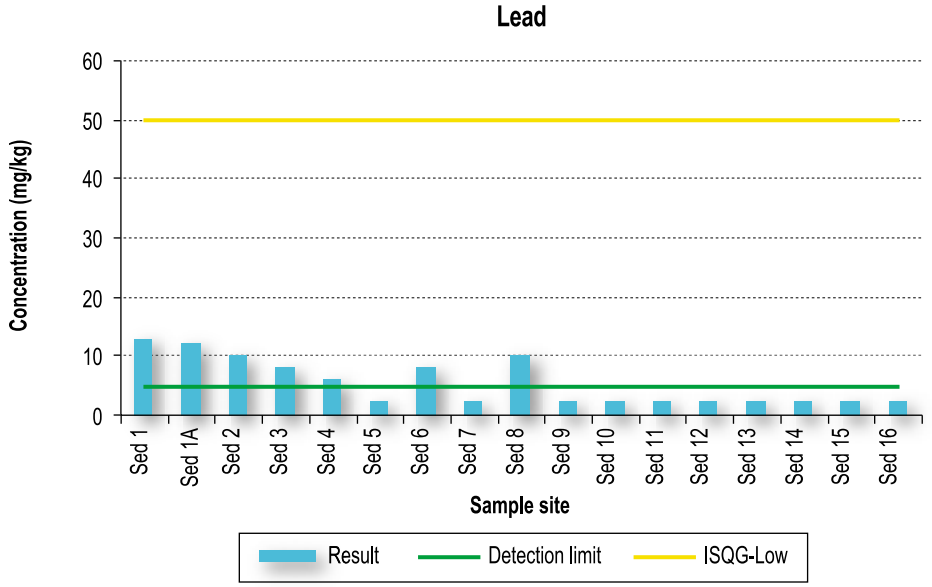


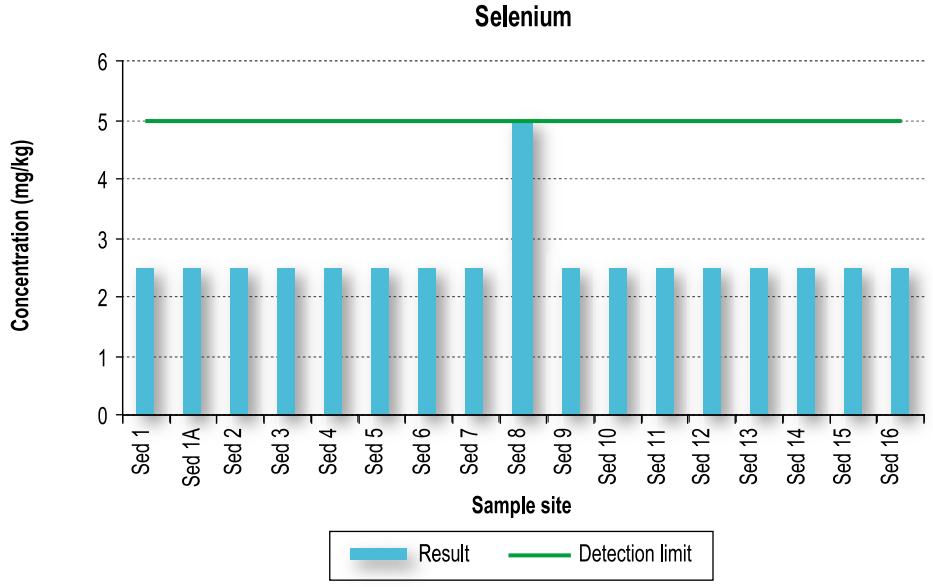


PNG LNG	Job No: 1284 File Name: 1284_05_F03.16_HB	Esso Highlands Limited PNG LNG Project	Sediment quality - cobalt, chromium, copper and iron	Figure No: 3.16

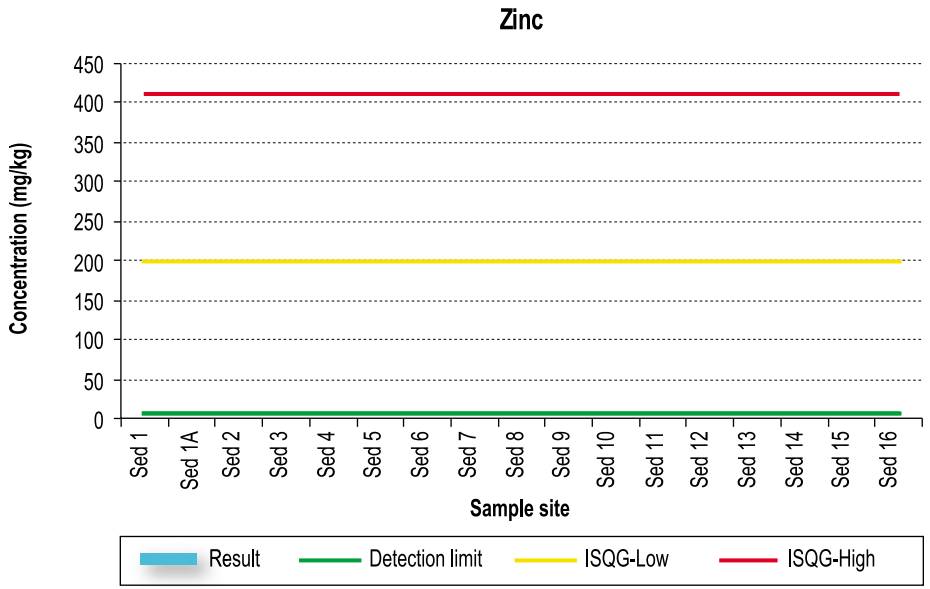








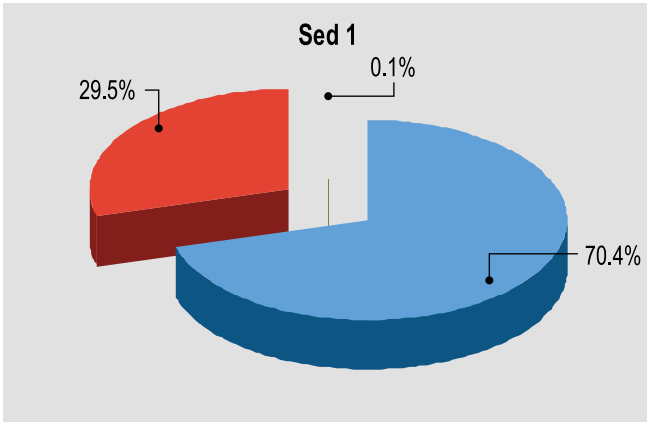
PNG LNG	Job No: 1284 File Name: 1284_05_F03.17_HB	Esso Highlands Limited PNG LNG Project	Sediment quality - manganese, nickel, lead and selenium	Figure No: 3.17

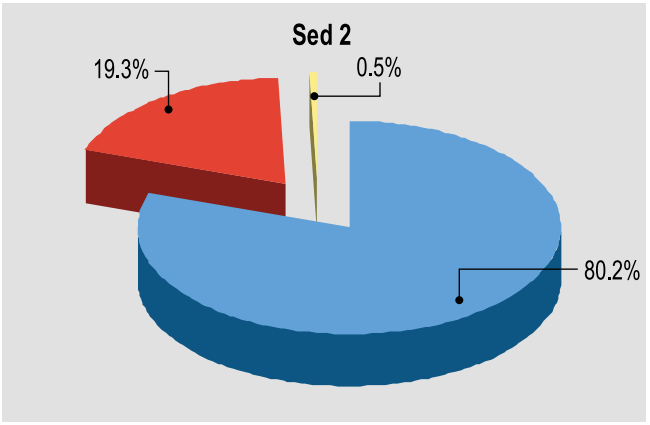


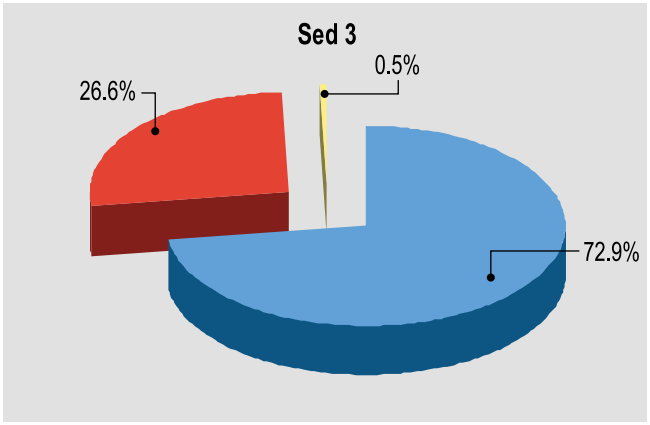
PNG LNG	Job No: 1284	Esso Highlands Limited	Sediment quality - zinc	Figure No: 3.18
	File Name: 1284_05_F03.18_HB	PNG LNG Project		

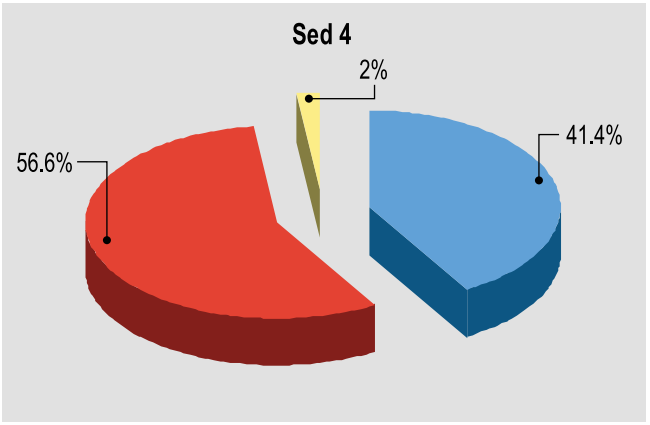
Table 3.08 Sediment – particle size, total organic carbon and total inorganic carbon

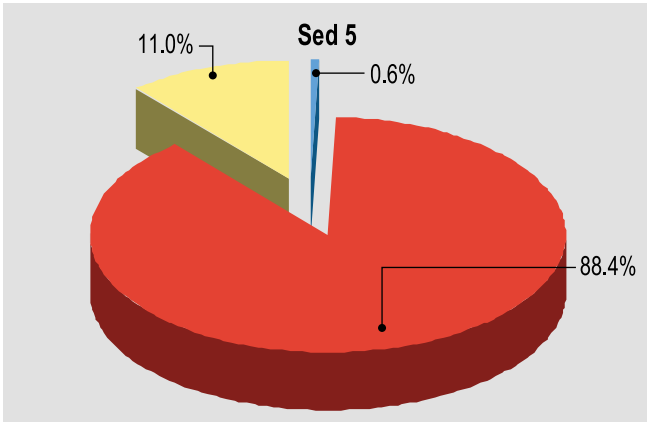
Site	Total Organic Carbon (%)	Total Inorganic Carbon (%)	Particle Size Distribution (%)		
			less than 63 µm	63 µm to 2,000 µm	greater than 2,000 µm
Sed 1	2.5	1.5	70.4	29.5	0.1
Sed 1 (Duplicate)	2.2	1.2	63.3	33.6	3.1
Sed 2	4.4	3.4	80.2	19.3	0.6
Sed 3	5.5	4.5	72.9	26.6	0.5
Sed 4	5.8	5.4	41.4	56.6	2.0
Sed 5	10.5	10.4	0.6	88.4	11.0
Sed 6	6.0	5.5	52.2	43.3	4.5
Sed 7	10.5	10.4	0.4	89.3	10.3
Sed 8	6.8	1.4	63.3	34.7	2.0
Sed 9	10.5	10.3	0.5	63.4	36.1
Sed 10	10.1	9.9	1.8	73.2	25.0
Sed 11	10.5	10.4	2.1	87.5	10.4
Sed 12	10.4	10.2	0.7	72.0	27.3
Sed 13	10.5	10.3	1.5	78.6	19.9
Sed 14	10.5	10.4	0.6	87.2	12.2
Sed 15	10.8	10.7	0.1	98.4	1.5
Sed 16	10.2	10.0	3.2	75.9	20.9

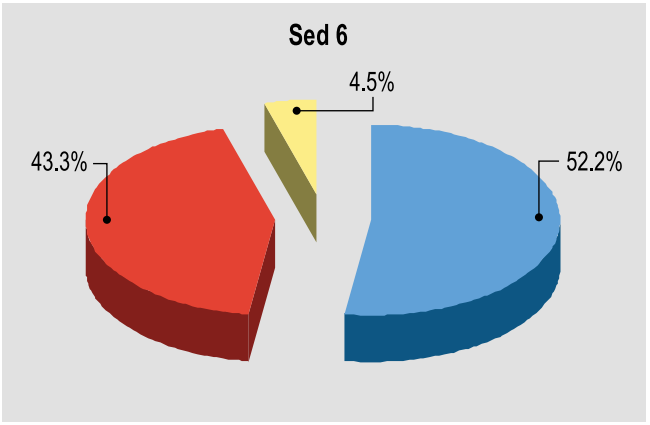


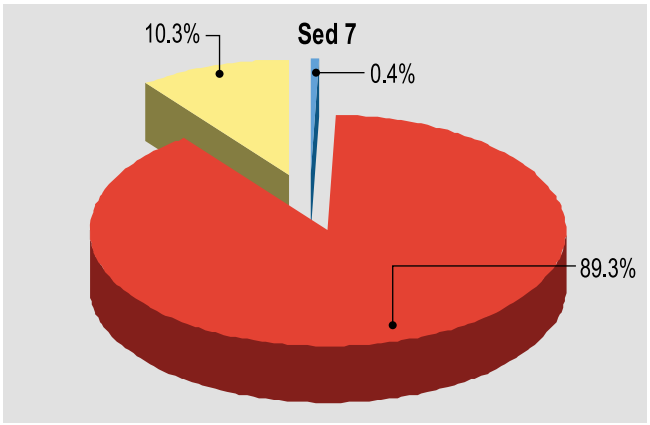


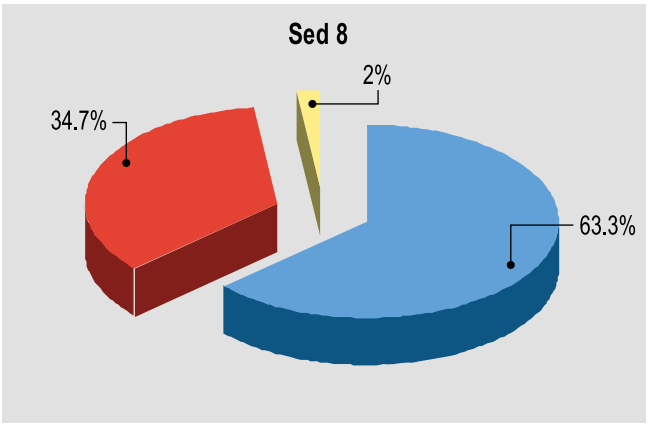






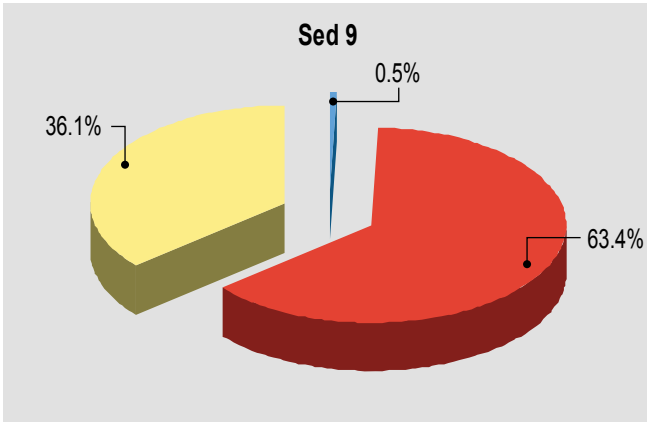


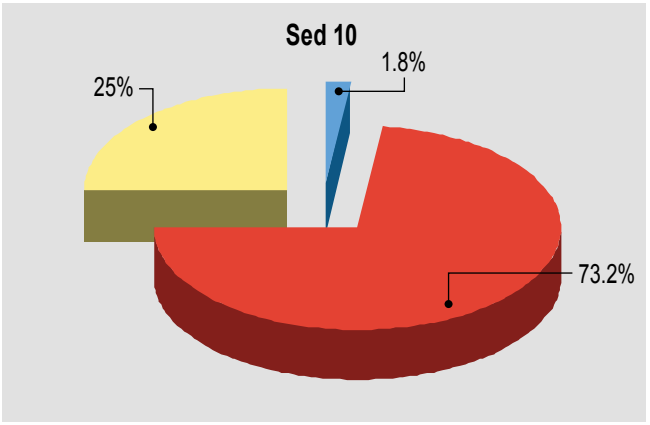


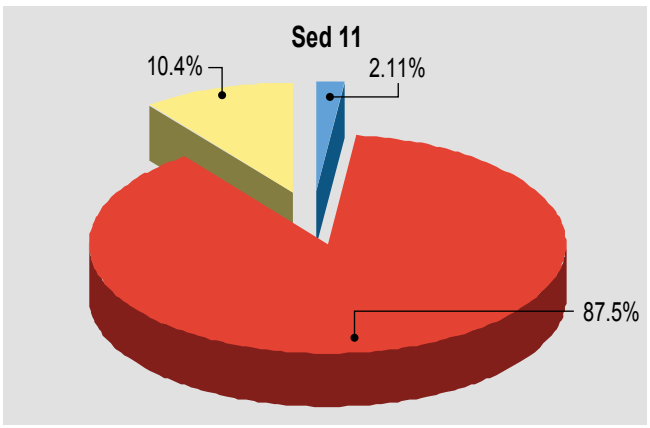


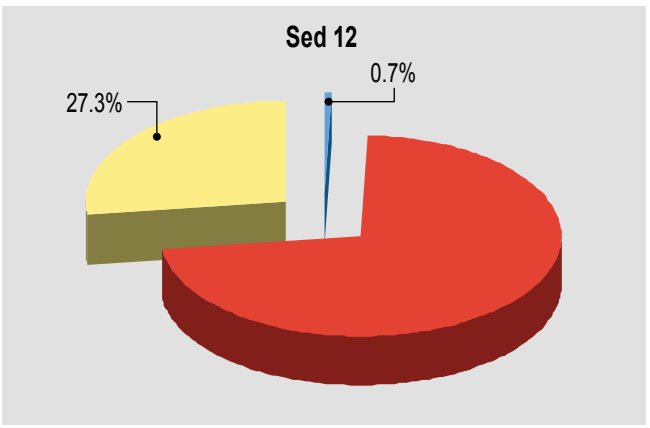
< 63 µm > 63 µm > 2000 µm

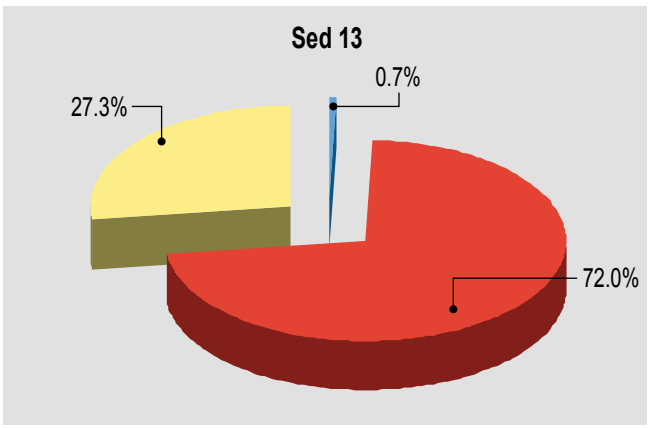
PNG LNG	Job No: 1284	Esso Highlands Limited	Figure No: 3.19A
	File Name: 1284_05_F03.19A_HB	PNG LNG Project	Seafloor sediments - particle size distribution

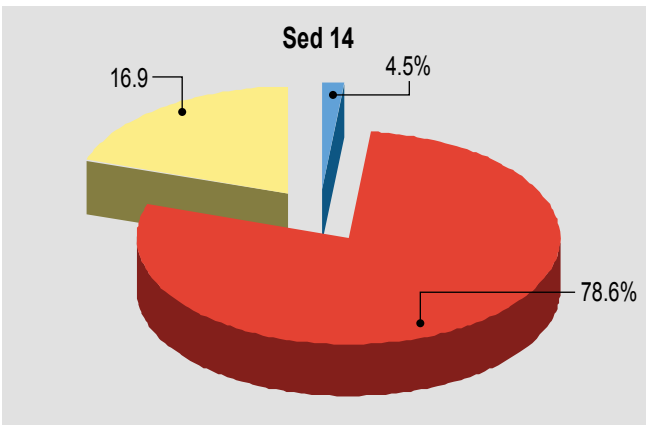


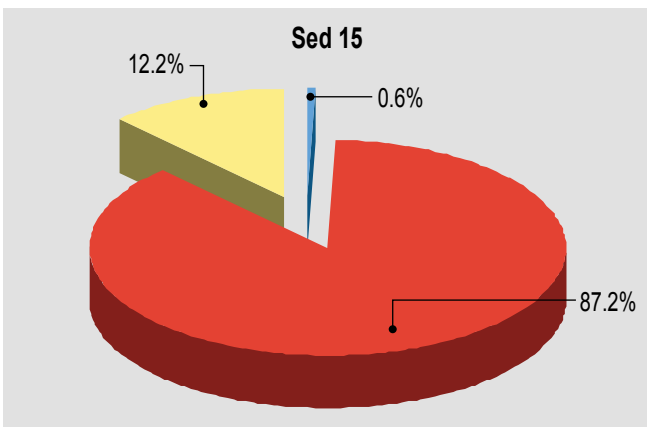


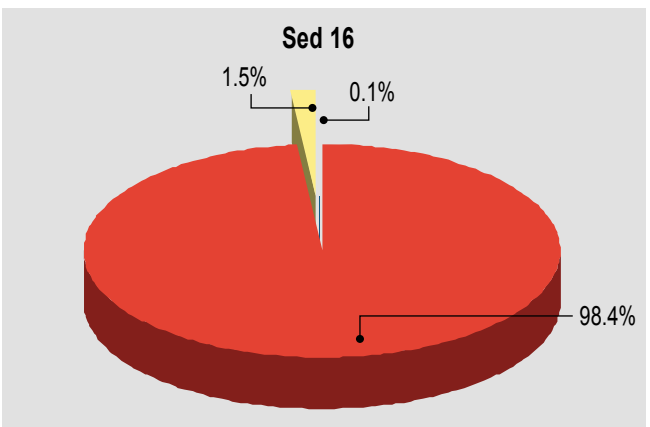












< 63 µm > 63 µm > 2000 µm

PNG LNG	Job No: 1284	Esso Highlands Limited	Figure No: 3.19B
	File Name: 1284_05_F03.19B_HB	PNG LNG Project	Seafloor sediments - particle size distribution

3.2.8 Sedimentation Rates

Sedimentation data available to date spans two deployment periods from December 2007 to February 2008 and February 2008 to April 2008. Sedimentation will be dependent on wind directions and strength, which may resuspend sediment and seasonal river flows which will introduce sediment. The sampling to date mostly covers the wet season so lower rates would be expected in the dry season. Mean sedimentation rates are presented in Table 3.09 and the raw sedimentation results are given in Annex F. Sedimentation of terrestrial origin occurred at higher rates at sediment traps located close to the eastern coastline of Caution Bay (ST-2, ST-5, ST-6 and ST-7) as in these samples, the proportion of calcium carbonate was low. Results of calcium carbonate determination are highly variable, but indicate that as much as approximately 60 to 80% of material may be of marine origin at sites located at Idihi Island, Vari Vari Island and the shipping channel on the southern side of Haidini Island.

Table 3.09 Sedimentation rates within Caution Bay

Site	December 2007 to February 2008		February 2008 to April 2008	
	Mean (mg/cm^2/day)	Standard Error	Mean (mg/cm^2/day)	Standard Error
ST-1	2.79	0.35	5.52	0.36
ST-2	4.91	0.59	5.69	1.14
ST-3	1.03	0.09	0.86	0.16
ST-4	3.92	0.09	0.10	0.03
ST-5	1.51	0.07	1.08	0.02
ST-6	29.17	6.90	4.40	1.11
ST-7	14.74	3.33	1.61	1.04

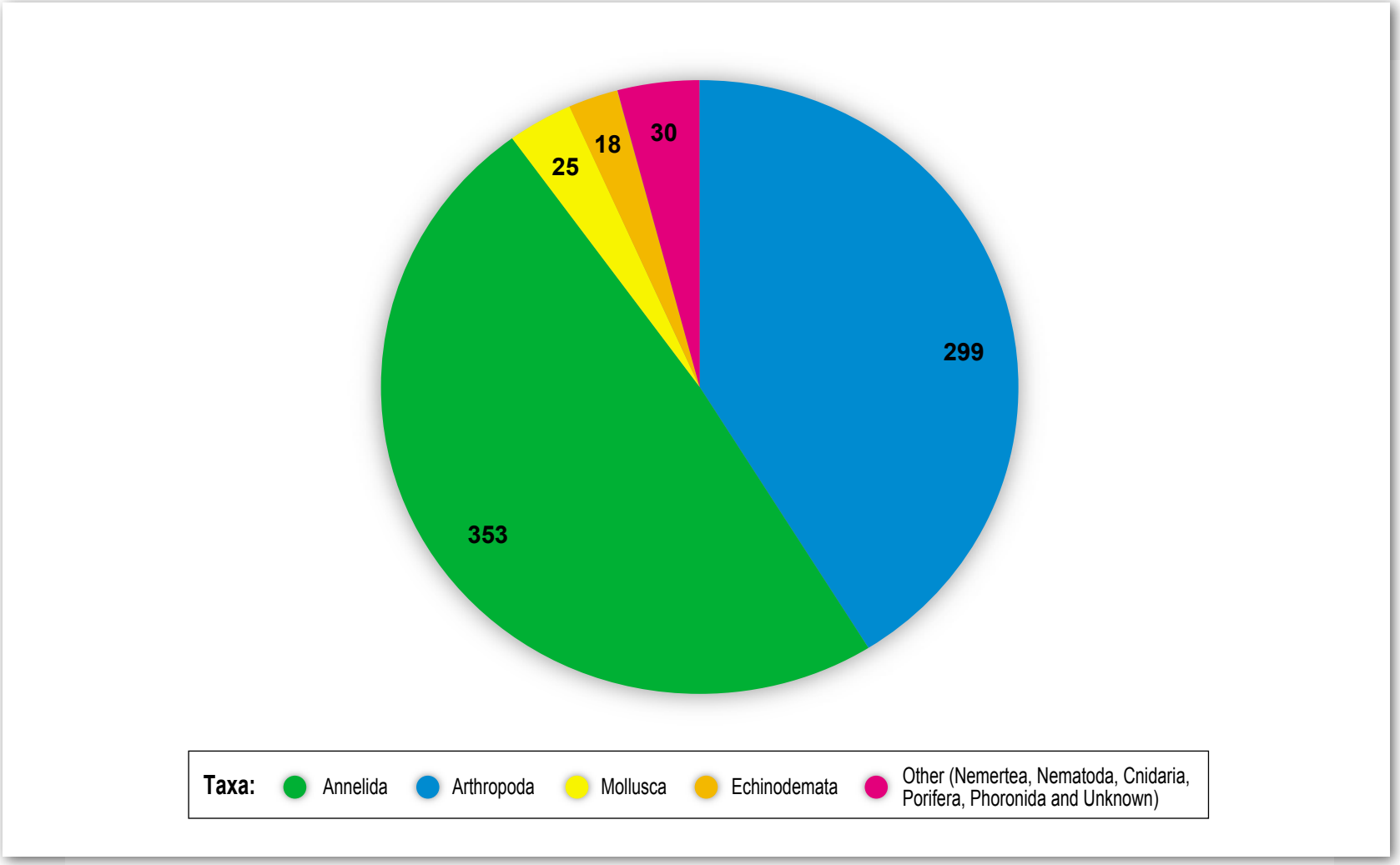
3.2.9 Marine Macrobenthic Infauna

Information presented in this section is based on a report prepared by Dr. John Moverley (Annex G). A total of 725 individuals from 68 different taxa were collected in Caution Bay across eight sampling locations, indicating a high diversity of macrobenthic fauna (Figure 3.20). The numbers of taxa varied between sampling locations, but polychaete worms and crustaceans were the dominant macrobenthic infaunal taxa of the sediment samples, which is typical of shallow water sediments.

Non-metric Multi-dimensional Scaling (NMDS) and cluster analysis observed a distinct gradient and grouped infauna into nearshore deepwater infauna, located in the shipping channel, inshore shallow water infauna and three individual sites of infauna from carbonate sand regions. While not measured, it is likely that this gradient reflects increasing sediment gradient size and decreasing organic inputs.

3.2.10 Seafloor Characterisation

Visual assessment of the nearshore seafloor of Caution Bay by drop camera enabled description of the benthic habitat along the proposed pipeline routes, in the vicinity of the nearshore marine facilities and shipping access channel. Water depths of the sampling sites along the proposed pipeline routes ranged from 4.5 to 47 m with an average of 24.5 m. In the main expanse of Caution Bay between the bommies and shoals are areas of homogenous habitats of fine sand and silts with generally sparse visible biota,



PNG LNG	Job No: 1284	Esso Highlands Limited	Marine macrobenthic infauna abundance	Figure No: 3.20
	File Name: 1284_05_F03.20_HB	PNG LNG Project		

although bioturbation (burrows and pits) evident at most sites investigated suggest biological activity of benthic infauna occurs in these areas (Plate 3.22).

Sites 5 and 7 were characterised by low visibility (see Plate 3.22), being relatively close to the eastern coastline of Caution Bay, where sediments may easily be suspended in the water column. There was little visual evidence of flora and fauna at these sites.

Sites X and Y, along pipeline option 1c (see Figure 3.01) were analysed where the proposed route appeared to cross an area where water depth suddenly reduced from approximately 35 m to between 6 and 8 m. Investigation of these sites indicated the presence of hard bottom reef substrate containing sponges, soft corals, whip corals, gorgonians, *Halimeda*, emergent fauna (tube worms, sea pens) and a diversity of fish including surgeonfish, damselfishes and wrasses. The percentage of coral cover at these sites was relatively low and the condition of the reefs was poor, consisting of large patches of coral rubble and sand (Plate 3.23).

The results of the seafloor environmental survey confirm that the predominately sandy seafloor of the proposed pipeline routes is homogenous over extensive areas within Caution Bay and therefore is not likely to be critical for route selection. The shoal areas were degraded with extensive areas of rubble, little hard coral cover, and not of high environmental value.

Site 5

Site 7

Plate 3.22 Drop camera video footage showing low visibility
due to increased suspended sediments and little visual evidence of flora and fauna

Site X

Site Y

Plate 3.23 Drop camera video footage showing small isolated coral bommies with low coral cover

4 ISSUES AND ASSESSMENT OF SIGNIFICANCE

This chapter describes the potential physical, biological and, to a lesser extent, social issues associated with the construction and operation of the marine facilities, the LNG Project Gas Pipeline (in Caution Bay only) and shipping access channel. This chapter also assesses the potential significance and magnitude of these impacts, prior to any mitigation. Potential impacts of the project on the social environment is provided in a separate report titled *Social Impact Assessment*, which is also an appendix to the PNG LNG Project EIS.

4.1 Approach to Impact Assessment

The significance of the potential impacts associated with the construction and operation of the marine facilities, LNG Project Gas Pipeline (in Caution Bay only) and shipping access channel was derived from the analysis of:

- The extent and type of change, including the timing, scale, size and duration and likelihood of the impact (magnitude).
- The sensitivity of the environment to change, including its capacity to accommodate the kinds of changes the project may bring about (sensitivity or value of resource/receptor).

4.1.1 Impact Magnitude

The magnitude of an impact reflects:

- The intensity or severity of the impact.
- How long the impact will last.
- Over what spatial extent will the impact be felt.

Criteria for assessing the magnitude of an impact are provided in Table 4.01.

Table 4.01 Magnitude of impact categories and descriptions

Category	Description
Very High	Effect likely to have large impact on population, community or ecosystem survival and health, possibly even leading to local extinction or system collapse. Impact is widespread, affecting 10 to 25% of a regional population (e.g., within all of Caution Bay). Recovery, if possible, is likely to take more than 10 years.
High	Effect likely to have severe negative impact on population, community or ecosystem survival or health. Impact is regional, affecting up to 10% of a regional population. Recovery, if possible, is likely to take from 5 to 10 years.
Medium	Effect will be detectable but not severe; populations or the areal extent of communities may be reduced but unlikely to lead to major changes to population, community or ecosystem survival or health. Impact is local, generally occurring up to 2 km from impact site. Recovery is likely to take from 2 to 5 years.

Table 4.01 Magnitude of impact categories and descriptions (cont'd)

Category	Description
Low	Effect may be detectable but is small and unlikely to have any material impact. Impact affects immediate surrounds of area of activity and extends for less than 1 km radius. Recovery is rapid - up to 2 years.
Minimal	Effect unlikely to be detectable.
Positive	Effect is likely to benefit the population, community or ecosystem.

4.1.2 Sensitivity of Resource/receptor

The sensitivity of the environmental receptor will reflect:

- Its formal status, whether by statutory or attributed conservation status, land use zoning or environmental quality standard.
- Its vulnerability to material damage or loss by the impact in question.
- Its iconic or symbolic importance to cultural value systems.

The sensitivity of the resource/receptor that may be impacted was determined from the baseline information and classified into categories based on Table 4.02.

Table 4.02 Sensitivity of resource/receptor categories and descriptions

Category	Description
Very High	A population of an ecologically or socially important species on an international level, or a site or habitat supporting such a species. A rare, threatened or vulnerable habitat or species and/or a breeding ground or feeding area that is critical to the survival of such species. Resource that provides the sole source food or income for local people.
High	A nationally designated site. A population of an ecologically or socially important species on a national level, or a site or habitat supporting such a species. Site supports 1% or more of national population. Resource upon which local people are frequently dependent for provision of food or income.
Medium	A population of an ecologically or socially important species on a regional level, or a site or habitat supporting such a species. Site supports 1% or more of regional population. Resource upon which local people are occasionally dependent for provision of food or income.
Low	Sites, populations or resources that generally enrich/maintain the local area. Resource upon which local people are rarely dependent for provision of food or income.
Minimal	No detectable ecological or social value or sensitivity.

4.1.3 Assessment of Significance

A matrix of significance was developed that combined the different definitions of magnitude of impacts with the various scales of resource or receptor sensitivity. The matrix is provided in Table 4.03, and assigns a significance of impact for each of the possible combinations between magnitude of impact and sensitivity of resource or receptor. Only the magnitude of an impact can be reduced by mitigation:

the sensitivity, as assessed, is fixed and is not changed by project activities. The resultant significance therefore reflects the reduction in magnitude that can be achieved by the proposed mitigation.

Table 4.03 Matrix of significance

Magnitude of Impact	Sensitivity of Resource/receptor				
	Very High	High	Medium	Low	Minimal
Very High	Major	Major	Major	Moderate	Minimal
High	Major	Moderate	Moderate	Minor	Minimal
Medium	Moderate	Moderate	Minor	Minor	Minimal
Low	Moderate	Minor	Minor	Minor	Minimal
Minimal	Minimal	Minimal	Minimal	Minimal	Minimal
Positive	Positive	Positive	Positive	Positive	Positive

4.2 Issues and Pre-Mitigation Impact Assessment

4.2.1 Direct Loss of Marine Habitat

Issue

The marine habitats presently in the areas that will be occupied by the combined LNG Jetty / Materials Offloading Facility will be removed or buried during construction activities. Adjacent areas will be affected by construction-induced increases in sedimentation, as described in Section 3.2.4. This will mainly affect marine habitats between the shore and 15-m water depth. Where the offshore pipeline is located, seafloor and shoreline habitats along and immediately adjacent to the route will be disturbed during construction. The types of the nearshore habitats affected include submerged and intertidal sandy substrates, fringing reefs, seagrass beds and mangroves.

Pre-Mitigation Impact Assessment

Magnitude of Impact

The extent of loss of marine habitats for the LNG Jetty / Materials Offloading Facility will be limited to the width of the causeway and its immediate vicinity. This is unavoidable but the causeway is planned to pass through a relatively narrow part of the fringing mangroves, seagrass beds and fringing reef (see Figure 3.04) that would not exceed 10% of the available habitats regionally within Caution Bay. The magnitude of impact is therefore assessed as MEDIUM (local impact generally up to 2 km from impact site).

The pipelaying activities and marine facility construction will directly disturb only a very narrow construction corridor and anchor points, and the route has been designed to avoid coral reefs and bommies. The seafloor will rapidly recover in the actively buried section of the pipeline, which includes the fringing reef and seagrass areas, and partially bury the pipeline where laid directly onto the seafloor. Based on the criteria the magnitude of impact is LOW.

Sensitivity of Resource or Receptor

The coral reef, seagrass and mangrove environments provide nursery habitat for many juvenile fish species and marine invertebrates, and also act as buffers of sedimentation and strong weather and act

as a natural nutrient filtration system. Much of the fringing reef of the affected area is degraded and sedimented but is still of subsistence importance to the local people. For these reasons, the sensitivity of the resource/receptor of marine habitats for the LNG Jetty / Materials Offloading Facility is considered as HIGH.

Generally the area disturbed by pipelaying activities is characterised by areas of homogenous habitats consisting of fine sand and silts with generally sparse visible biota although there are offshore coral bommies within the vicinity of the pipeline construction corridor that may be impacted by increases in suspended sediments. For these reasons, the sensitivity of the resource/receptor is considered as HIGH.

Assessment of Significance

Based on the criteria set out in the matrix of significance, the significance of this potential impact to the marine habitats in the vicinity of the LNG Jetty / Materials Offloading Facility and the pipeline route is assessed as MODERATE and MINOR respectively.

4.2.2 Changes to Coastal Processes and Sediment Transport

Issue

Potential changes to coastal processes and sediment transport could occur once the construction of the combined LNG Jetty / Materials Offloading Facility is complete and during the operational life of the project.

The construction of the combined LNG Jetty / Materials Offloading Facility earthen causeway will increase suspended sediments and turbidity in the areas of construction activity where the seafloor is directly disturbed, particularly where the fill is placed for the construction of the earthen causeway. The extent of sediment suspension in the water will also depend on the source and size characteristics of the material used for construction and the amount of fines contained. These construction effects are discussed in Section 4.2.3, as are the issues of sediment disturbance during dredging.

A specialist study undertaken by Global Environmental Modelling Systems (GEMS) modelled the effects of the LNG Jetty / Materials Offloading Facility on sediment transport and coastal processes (GEMS, 2008). This section provides a summary of the results. Modelling programs used to perform the analyses were GEMS 3D Coastal Ocean Model and SWAN wave model. Data inputs to the model include:

- Current data from two acoustic Doppler current profilers (ADCPs) deployed by ExxonMobil in Caution Bay in September 2007.
- Weather data from a weather station installed by ExxonMobil near Boera in February 2008.
- Detailed bathymetry data from Caution Bay collected by EGS Survey during the geotechnical and bathymetric survey of the offshore pipeline
- Sediment particle size data collected in Caution Bay by Coffey Natural Systems during nearshore marine surveys.
- Sedimentation rate data collected in Caution Bay by Coffey Natural Systems during nearshore marine surveys.

- Upwelling information (based on satellite/temperature data) interpreted by the Commonwealth Scientific and Industrial Research Organisation (CSIRO).
- Satellite tracking of 'drifters' deployed in Caution Bay by Hydrobiology Pty Ltd and Coffey Natural Systems.

The combined LNG Jetty / Materials Offloading Facility has been designed so that the earthen causeway section does not extend offshore far enough to impede the natural sediment transport and coastal processes, or cause sedimentation at the mouth of the Vaihua River. The need to shorten the earthen causeway was identified from the results of the hydrodynamic modelling study (GEMS, 2008), which found that the effects of the initially proposed LNG Jetty / Materials Offloading Facility, with its earthen causeway extending 1 km from the mangrove fringe to the 8 m depth contour would cause sedimentation and closure of the Vaihua River. This would have required some form of management to keep the Vaihua River open for the life of the project and beyond.

Shortening of the earthen causeway also improves the flushing and dilution of discharges such as reject brine discharged from the desalination process (see GEMS, 2008) but would require a once-off dredging program lasting approximately one to two months with dredge volumes in the order of 150,000 to 200,000 m^3 of spoil.

Pre-Mitigation Impact Assessment

Magnitude of Impact

The existing patterns of tidal inundation and freshwater flow between the catchments and estuaries will be maintained by the proposed design and construction of the combined LNG Jetty / Materials Offloading Facility. Similarly, the integrity and normal alongshore sediment transport processes will have stabilised. Continued monitoring will determine the need (if any) for further restorative action.

By applying the impact significance criteria outlined above, the potential magnitude of residual impact to habitat connectivity and aquatic ecology is defined as LOW.

Sensitivity of Resource or Receptor

As discussed in Section 4.2.1, the Vaihua River and adjacent mangroves are important for ecological processes and are also utilised by local communities for subsistence fishing, collection of shellfish and building supplies. Therefore the sensitivity of the resource/receptor is also considered as HIGH.

Assessment of Significance

Based on the criteria set out in the matrix of significance, the significance of this potential impact to the Vaihua River and mangrove communities in the vicinity of the LNG Jetty / Materials Offloading Facility is assessed as MINOR.

4.2.3 Increased Suspended Sediment and Sedimentation Rates

Issue

Sedimentation effects can lead to smothering of adjacent sensitive seafloor habitat, such as coral reef and seagrass, and reduce light availability within the water column. Corals and seagrass that rely on photosynthetic processes require adequate light penetration. Several activities associated with project

construction will cause increases in suspended sediment in the water column and sedimentation rates and these include the following:

- **Dredging.** Dredging activities will disturb the seafloor and stir up sediment leading to increased suspended sediment and turbidity in the water column within the immediate area and down current from the source. Some dredging of the turning basin adjacent to the LNG Jetty may be required to facilitate berthing and manoeuvring of the LNG carriers. It is considered that there is sufficient existing under-keel depth within the channel for LNG carriers to enter Caution Bay and berth at the LNG Jetty so that no dredging of the shipping channel will be required. However, dredging will be required to allow vessels to unload equipment at the shortened Materials Offloading Facility. The overall volume of material to be dredged is estimated to be between 150,000 and 200,000 m^3. Modelling of the proportion of time that total suspended sediment (TSS) values of 5 mg/l above ambient are exceeded show that much of the shoreline of Caution Bay will potentially be affected (see GEMS, 2008), although a TSS value of 5mg/l is not particularly high. Figure 4.01 shows that a predicted TSS value of 10 mg/l is exceeded from 1% to 5% of the time over an extended part (less than 10 km) of the coast of Caution Bay, but contours of exceedence between 5 and 50% of the time are within a radius of approximately 2 km from the dredging, which would impact the fringing reef for up to 1 km either side of the channel as it is dredged for the Materials Offloading Facility. The predicted TSS value of 20 mg/l is not exceeded more than 30% of the time, and the extent of the impact on fringing reef correspondingly lower (Figure 4.01).

- **Marine traffic.** Project construction shipping traffic travelling within Caution Bay will potentially cause resuspension of seafloor sediments through the generation of currents from propeller action. Suspended sediments will disperse according to particle sizes and the strength of prevailing currents.

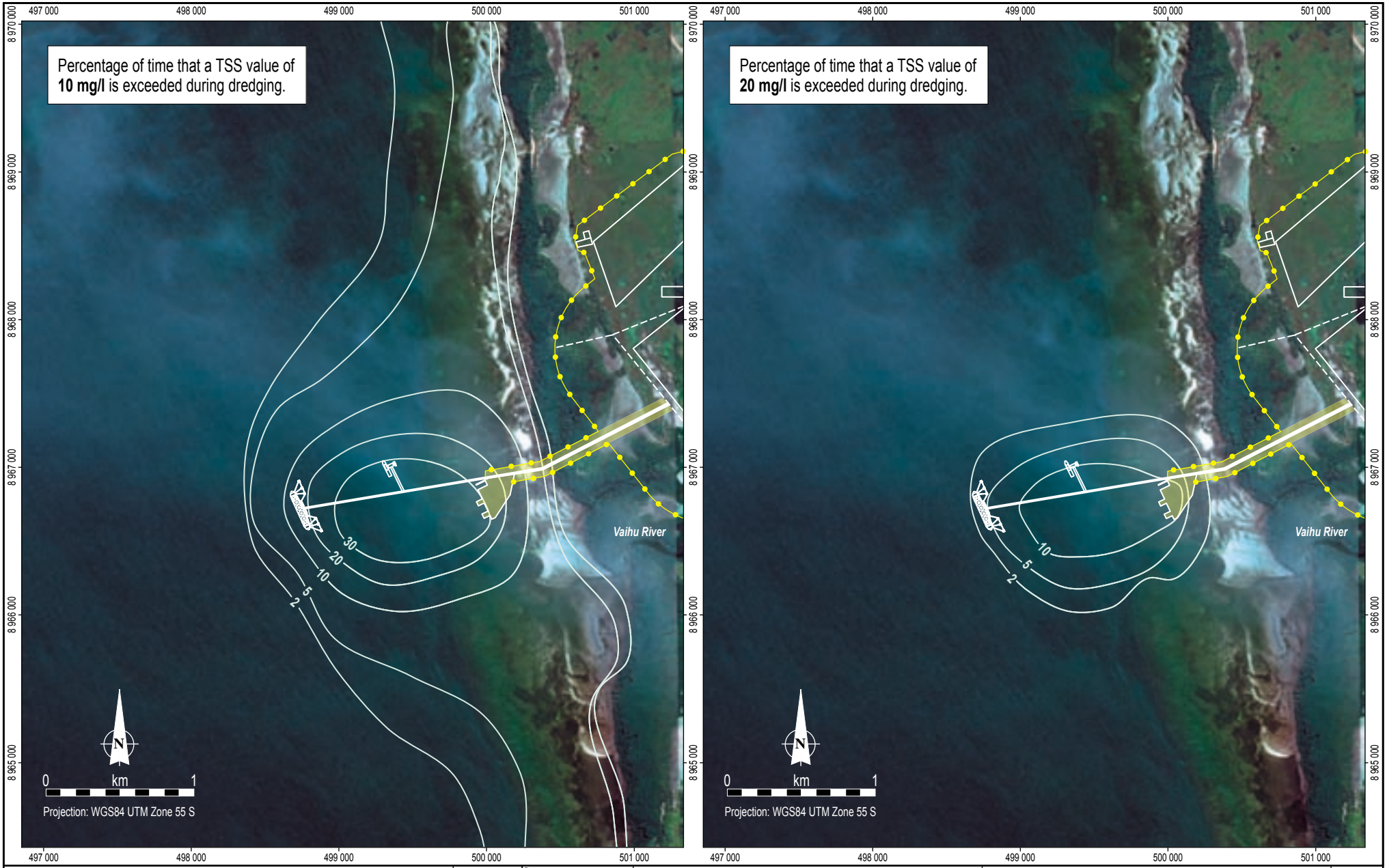
- **Construction of marine facilities and offshore pipeline.** Activities associated with the construction of the combined LNG Jetty / Materials Offloading Facility and installation of the offshore section of the gas pipeline will disturb the seafloor and stir up sediment leading to increased suspended sediment and turbidity in the water column.

Pre-Mitigation Impact Assessment

Magnitude of Impact

The extent of detectable increases in sedimentation is expected to be less than 2 km from the impact sources. The duration of the impact will be limited to the construction phase and possible maintenance dredging events.

Dredging of the approach to the earthen causeway may take two to three months, depending on the size and type of equipment selected.



Source: Sediment plume data digitised from GEMS (2008). Indicative only.

Note: Layout is indicative only.
Final placement of all components is contingent upon pending soil and geological data.

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Sediment plume modelling

Figure No: **4.01**

Offshore pipelaying is expected to progress at a rate of 1 to 3 km per day, however activities in Caution Bay are expected take longer, progressing at a rate of 300 to 720 m per day.

The marine habitats adjacent to the shipping access channel, LNG Jetty / Materials Offloading Facility and offshore pipeline includes fringing-coast mangrove, seagrass beds, coral reef communities and extensive sandy seafloors. Without any mitigation, sedimentation could affect these habitats through smothering and turbidity; and mainly on the potential extent of dredging plumes, the magnitude of impact is assessed as HIGH.

Sensitivity of Resource or Receptor

The marine habitats identified above are sensitive to changes in water quality and will be impacted by increases in suspended sediment. Therefore the sensitivity of the receptor is HIGH, as it supports species that are important on a regional level and provide food to local communities.

Assessment of Significance

Given the short temporal and localised spatial effects of the impact, the overall significance of this impact is considered to be MODERATE.

4.2.4 Disposal of Dredged Material

Issue

Disposal of the spoil will cause temporary impacts from sediment plumes in the water column and deposition on the seafloor. The dredged material is likely to consist of lagoon sand, silts and clays and it is proposed that any spoil that cannot otherwise be used is disposed to very deep water off the continental shelf (greater than 450 m) which occurs within 2 to 3 km beyond the outer barrier reef system. The environmental conditions at the deposition area at approximately 450 m depth have not been studied[5], but continental slopes, typically include valleys of sedimentary deposits with rocky outcrops between. At these water depths, marine plants and reef-building corals do not occur, as they require high light penetration that does not reach these depths. However, other forms of corals are likely to occur on areas of hard substrate, and benthic animals will inhabit areas of soft sediments.

Pre-Mitigation Impact Assessment

Magnitude of Impact

The disposal location has been selected (by the hydrodynamic model) to remove any risk of spoil affecting the barrier reef. The volume of material to be disposed will be in order of 150,000 to 200,000 m^3, and the duration of the disposal is expected to be in the order of two to three months in total, depending on the size of the dredge used and weather-induced lay days. The material is natural

[5] Prior to the decision to shorten the earthen causeway, the volume of dredge material was expected to be low (if any). Subsequent to this decision, there has not been the opportunity to undertake such work, but this will be undertaken prior to construction.

lagoon sand and silts and is unlikely to contain any contaminants (to be confirmed prior to construction), and is the same sediment that is naturally (gradually) transported from the shallow to the deep slope areas.

Based on the, short duration of dredging, expected depositional nature of the receiving area and uncontaminated nature of the material (both to be confirmed by testing prior to construction), the magnitude of impact is MEDIUM.

Sensitivity of Resource or Receptor

The location of disposal of dredged material is beyond the barrier reef in water of around 450 m depth off the continental slope. At these depths, plants and the reef-building corals do not occur as they require high light penetration that is not available in these water depths. However, other forms of corals are likely to occur on areas of hard substrate and benthic animals will inhabit areas of soft sediments. These life forms are widespread and any localised impacts from sediment smothering are likely to be reversible. Based on widespread nature of the resource at these depths, the sensitivity of the resource/receptor is LOW.

Assessment of Significance

The overall significance of this residual impact is therefore assessed as MINOR.

In the event that more extensive dredging of the channel is required to reach a shorter Materials Offloading Facility earthen causeway, requiring greater volumes of material to be disposed, investigations of the environmental characteristics of the disposal area may be required.

4.2.5 Underwater Noise

Issue

The vessels associated with construction and operations activities, including lay barges, tugs, LNG carriers and condensate carriers, will contribute to existing underwater noise levels. The lay barge is likely to use anchors but may be dynamically positioned; in which case, the underwater noise created by dynamically positioned vessels is generally greater than from other sources.

Some pile driving activities may be required for the construction of the marine facilities, and this will cause underwater noise and pressure waves that could affect fish and marine mammals. The effects of this are variable, ranging from mortality (e.g., see Hastings & Popper, 2005; Nedwell, et al., 2003) to avoidance or migration (Feist et al., 1992). However, mortality of fish has only been reported when exposed to high intensities of sound, close to the source and when restricted from moving away; and not when the fish were moved further from the source (Nedwell et al., 2003; Hastings & Popper 2005). Noise from pile driving can affect marine mammals, such as dolphins. For example to their directional hearing or by masking vocalisation frequencies and amplitude (David, 2006). Depending on intensity and frequency, this may extend several kilometres, although observed behavioural modifications may also have been due to redistribution of prey (David, 2006).

Some blasting may be required during dredging of the shipping turning circle and for the marine facilities if the dredging equipment cannot remove rocky outcrops that require removal. These sounds have the potential to interfere with the behaviour of nearby marine mammals that communicate using sound.

Pre-Mitigation Impact Assessment

Magnitude of Impact

There are numerous sources that contribute to ambient ocean noise including oceanic processes, noise from shipping activities and naturally occurring biological background noise.

The duration of the impact will be limited to the construction of offshore pipeline and LNG Jetty / Materials Offloading Facility, and the operation of LNG tankers and support vessels, which is anticipated to be every four days.

Marine animals are not likely to be exposed suddenly to high levels of underwater noise from shipping, or dredging as it is audible from great distances. The duration of sound impacts at any particular location are short, as the pipelaying progresses at 300 to 720 m per day in the approach to Caution Bay.

Some pile driving activities may be required for the construction of the marine facilities, and this will cause underwater noise and pressure waves that could affect fish and marine mammals, if suddenly exposed at close range.

Based mainly on the potential for underwater noise form pile driving to cause sudden impact,, the magnitude of impact is assessed as MEDIUM.

Sensitivity of Resource or Receptor

As discussed in Section 3.2.3, marine mammals are rarely encountered in Caution Bay. Some whale species listed as vulnerable by the IUCN are found in the Gulf of Papua, but these large species are not frequently observed to enter the nearshore environment of Caution Bay. Smaller marine mammals, such as bottlenose dolphins, occur in Caution Bay but are not listed by the IUCN. Dugongs are not reported to be present; however, species of turtles, such as green and hawksbill, do occur in Caution Bay and are listed by IUCN. Given the presence, or potential presence of IUCN-listed species, the sensitivity of the resource/receptor is HIGH.

Assessment of Significance

Based on the criteria set out in the matrix of significance, the overall significance of this potential impact is assessed as MODERATE.

4.2.6 Collision of Vessels with Marine Mammals and Other Large Marine Fauna

Issue

The presence of the pipelaying and marine facilities construction vessels and the arrival and departure of LNG carriers and condensate tankers for loading and export present some ongoing risk of disturbances to and collision with marine mammals and turtles.

Pre-Mitigation Impact Assessment

Magnitude of Impact

Even without specific mitigation measures, collisions between marine mammals and project-related vessels are unlikely to occur for the following reasons:

- The pipelaying vessel will travel at slow speeds (300 to 720 m per day in Caution Bay), i.e., animals would have to collide with the vessel, not vice versa.
- While the support vessels (tugs and supply boats) will travel at greater speeds than the pipelaying vessel, they do not move at high speed and their noise characteristics enable such species as dolphins and turtles to avoid them, as with existing levels of shipping traffic.
- Sounds associated with the pipeline installation activities should temporarily deter marine mammals from entering the immediate areas of activity (see Section 4.2.5).
- Marine mammals, with the exception of dolphins, are not commonly seen in the parts of the Caution Bay traversed by the pipeline.

Based on these reasons the magnitude of impact is MINIMAL.

Sensitivity of Resource or Receptor

As discussed in Section 3.2.3, marine mammals are rarely encountered in Caution Bay. Some whale species listed as vulnerable by the International Union for the Conservation of Nature (IUCN) (Cetacean Specialist Group, 1996a, 1996b, 1996c) are found in the Gulf of Papua, but these large species are not frequently observed to enter the nearshore environment of Caution Bay. Smaller marine mammals, such as bottlenose dolphins, occur in Caution Bay but are not listed by the IUCN. Dugongs are not reported to be present; however, species of turtles, such as green and hawksbill, do occur in Caution Bay and are listed by IUCN. Given the presence, or potential presence of IUCN-listed species, the sensitivity of the resource/receptor is HIGH.

Assessment of Significance

Based on the criteria set out in the matrix of significance, the overall significance of this potential impact is assessed as MINIMAL.

4.2.7 Effects of Lighting on Marine Fauna

Issue

The LNG Facilities will be lit for safety and security purposes during construction and operation. Increases in lighting may have an impact on the movement and migration of marine fauna inhabiting the local region. Surface lights, such as the light of the moon, are used by some marine fauna for navigation. Sea turtles navigate to and from nesting beaches by using the light of the moon, and hatchlings migrate out to sea using the same navigational technique.

Pre-Mitigation Impact Assessment

Magnitude of Impact

LNG Facilities will be illuminated 24 hours a day during construction and operations. At night, there is likely to be some direct illumination or glare from the LNG Facilities (including the marine facilities) that may be visible from Idihi Island. For this reasons, the magnitude of impact is MEDIUM.

Sensitivity of Resource or Receptor

While there are IUCN-listed species in Caution Bay, there are no beaches suitable for turtle nesting in the immediate vicinity of the proposed LNG Facilities (although turtles may nest occasionally on Idihi Island and also may feed in the coastal waters of Caution Bay). The assessment criteria in Table 4.02 determine that the sensitivity of the resource/receptor is HIGH because of the presence of IUCN-listed species within the vicinity of the project area.

Assessment of Significance

The overall significance of this residual impact is therefore assessed as MODERATE.

4.2.8 Discharge of Brine from Desalination Plant Processing

Issue

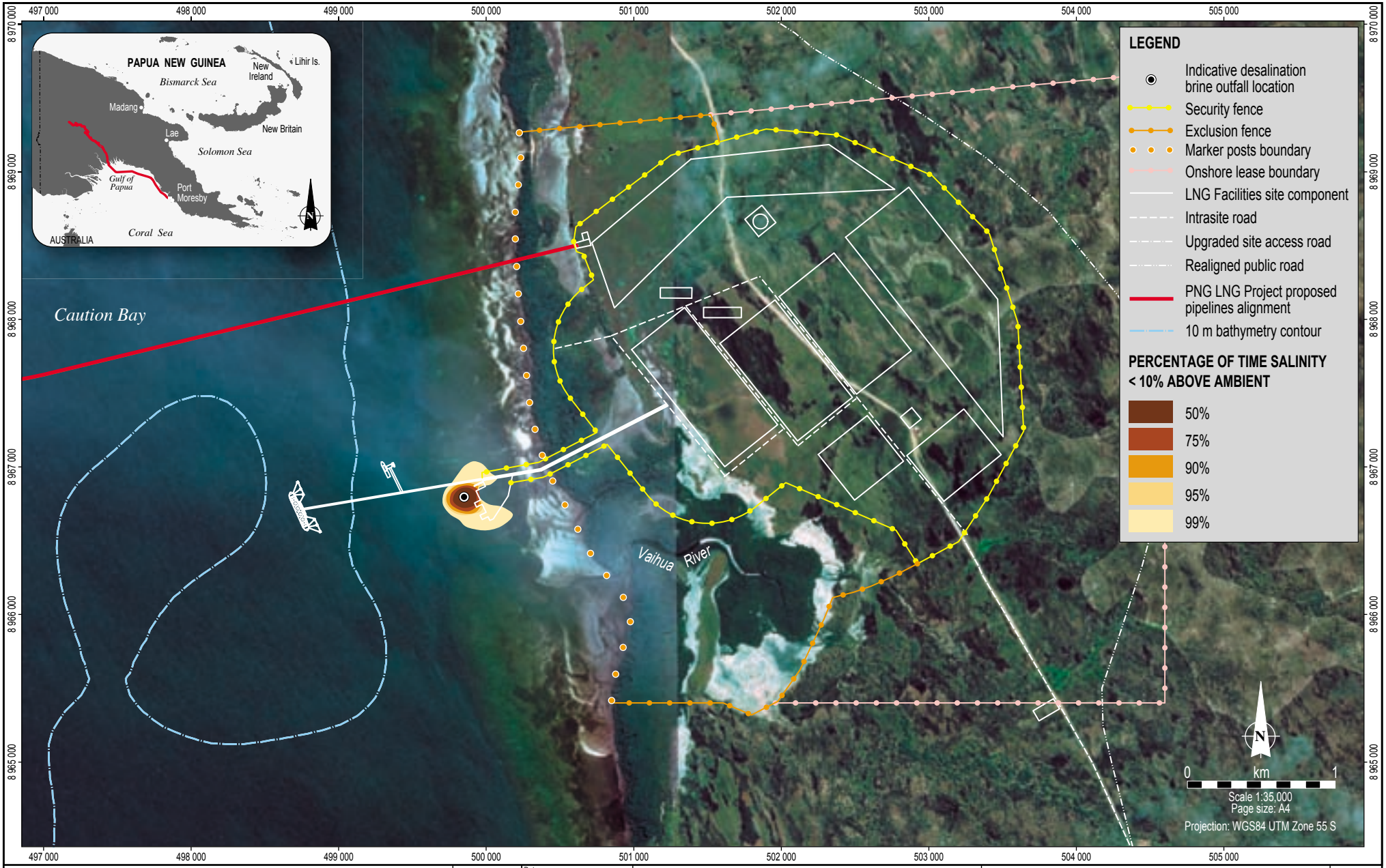
The base case for a freshwater source for the LNG Facilities site is seawater desalination. Discharge of reject brine from desalination is assessed as an ongoing operational activity, as requirements during construction will extend into the longer-term operational phase. During the early stages of construction, discharge of brine will be relatively low but will peak during years 3 and 4 at 2,500 m^3 per day, corresponding roughly to an equivalent volume of reject brine to be disposed. Initially, the discharge will be at the end of the Materials Offloading Facility but on completion of construction of the LNG jetty, discharge will be at the end of the combined LNG Jetty / Materials Offloading Facility (Figure 4.02) at a depth of approximately 12 m.

The brine discharges may have localised effects on salinity with associated effects on habitats such as seagrasses and corals, and on the fisheries in the bay. The constant discharge of reject streams with high salinity levels can be detrimental for marine life, and can cause changes to species composition and abundance in the vicinity of discharge (Lattemann & Höpner, 2008).

Pre-Mitigation Impact Assessment

Magnitude of Impact

Research findings from studies investigating the impacts of saline discharge from desalination plants are varied. No toxic effects of desalination plant seawater were recorded on amphipods, kelp spores or fertilised sea urchin eggs in laboratory experiments (Bay & Greenstein, 1992). Similarly, no significant variations in the macrobenthic community could be attributed to the brine discharges from the desalination plant inhabiting off the northwest Mediterranean coast of Spain (Raventos et al., 2006), and increased salinity was not found to affect the density, blade productivity and blade biomass of a seagrass meadow (*Thalassia testudinum*) after 6.5 months off Antigua, West Indies (Tomasko et al., 2000). In contrast, negative responses to increased salinity have been recorded for a number of marine organisms, such as zooxanthellate coral (*Stylophora pistillata*) (Ferrier-Pagés et al., 1999). A number of studies have also reported that some seagrass species are negatively impacted by increased salinity (Sadhwani et al., 2005; Fernández-Torquemada, 2004; Sánchez-Lizaso et al., 2008). For example, in one long-term study of more than six years, a shallow seagrass (*Posidonia oceanica*) bed was found to be very sensitive to increased salinity, and it was recommended that discharges of brine over such seagrass areas should not exceed 38.5 practical salinity units (psu) of salinity for more than 25% of the time or 40 psu for more than 5% of the time (Sánchez-Lizaso et al., 2008) in order to reduce adverse impacts.



Source: Sediment plume data digitised from GEMS (2008). Indicative only.
Note: Layout is indicative only.
Final placement of all components is contingent on pending soil and geological data.
Pipelines approximate the proposed alignment based on engineering data provided up to 1 October 2008.

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Brine output mixing zones (during peak discharge)

Figure No: **4.02**

Conservative estimates based on the scientific literature suggest that that benthic environments are able to tolerate an increase in salinity of between 1 to 2 psu (Høpner & Windelberg, 1996; Jenkins & Wasyl, 2005; Barron, 2006); and slightly higher levels for restricted periods for certain seagrass species (Sánchez-Lizaso et al., 2008). Generally, impacts are not detected where there is adequate flushing. The World Health Organization (WHO, 2007) suggests that a 10% increment above ambient ocean salinity is a conservative measure of aquatic life tolerance to increases in salinity.

Based on the literature, the magnitude of impact of discharge of brine over the life of the project is potentially MEDIUM.

Sensitivity of Resource or Receptor

The ecological importance of the receiving marine environment as discussed in Section 3.2.4, is that the marine communities provide nursery habitat for many juvenile fish species and marine invertebrates, and also act as buffers of sedimentation and strong weather and act as a natural nutrient filtration system. Much of the fringing reef of the affected area is degraded and sedimented but is still of subsistence importance to the local people. For these reasons, the sensitivity of the resource/receptor of marine habitats within the vicinity of the brine discharge is considered as HIGH.

Assessment of Significance

The overall significance of this residual impact is therefore assessed as MODERATE.

4.2.9 Discharge from Vessels

Issue

Discharge of sewage and other galley wastes into the coastal waters of Caution Bay has the potential to cause localised elevation of nutrients in the receiving waters, which will in turn lead to accelerated algae and plankton growth. Discharge of solids or liquid chemicals could potentially cause more serious contamination.

Pre-Mitigation Impact Assessment

Magnitude of Impact

Without adherence to MARPOL (IMO, 1973/1978) standards, or equivalent port policies and procedures), discharge of sewage and galley waste into coastal waters could adversely affect fringing reefs and seagrass areas and associated fish communities. The magnitude of impact is assessed as MEDIUM, as frequency of shipping is not high.

Sensitivity of Resource or Receptor

The sensitivity of resource/receptor is HIGH, given the proximity of reefs, seagrass and subsistence fisheries.

Assessment of Significance

Given the above assessments, the overall significance of this impact is MODERATE.

4.2.10 Discharge of Hydrotest Water

Issue

Hydrotest water, sourced from desalination, will be used in the integrity testing of the LNG tanks. It typically contains residual chemical additives such as anti-scalants and biocides. Therefore, there is potential for impact to the quality of receiving waters in Caution Bay resulting from the freshwater and traces of these chemicals.

Pre-Mitigation Impact Assessment

Magnitude of Impact

As this is effectively a once-off discharge activity that occurs only at commissioning, the effects will be temporary and localised, but without adequate flushing or treatment, magnitude of impact is assessed potentially as LOW.

Sensitivity of Resource or Receptor

The sensitivity resource/receptor is considered to be HIGH, where discharge could affect reefs or seagrass areas.

Assessment of Significance

The overall significance of this residual impact is therefore assessed as MINOR.

4.2.11 Discharge of Wastewater

Issue

Sources of wastewater that will ultimately be discharged into Caution Bay include treated sewage, other domestic water and surface runoff, which may be clean or potentially contaminated from the LNG Facilities site. There is potential for impact to the quality of receiving waters in Caution Bay resulting from the freshwater and contained nutrients and chemical contaminants.

Pre-Mitigation Impact Assessment

Magnitude of Impact

Without treatment appropriate to source of water nutrient and chemical contamination of the receiving waters is likely. However, sewage treatment plants and systems of retention/settlement ponds to treat oily water are part of the design of the facilities to manage water discharge to meet permit conditions, rather than an optional mitigation measure. On this basis, the magnitude of impact is assessed potentially as LOW.

Sensitivity of Resource or Receptor

The sensitivity resource/receptor is considered to be HIGH, where discharge could affect reefs or seagrass areas.

Assessment of Significance

The overall significance of this residual impact is therefore assessed as MINOR

4.2.12 Accidental Spillage of Hazardous Substances

Issue

Hazardous and dangerous goods that will be used on the pipelaying vessels include diesel fuel, oxyacetylene gas (for welding), solvents (for repair of corrosion coatings on the pipe), paints, hydraulic fluids, oxygen-reducing agents and X-ray sources (for radiography of pipeline welds). Accidental spillage of these substances or a large-scale spill, such as that caused by a vessel collision, could impact the marine environment. The worst-case scenario, however unlikely, would be a vessel collision resulting in the spillage of a large quantity of fuel and other hazardous substances. A spill of this size could spread a great distance from the initial spillage site and have long-term impacts to marine biota (including fishery resources), particularly if a spill were to reach coastal areas.

Pre-Mitigation Impact Assessment

Magnitude of Impact

The magnitude of impact is dependent on the volume and substance or substances that are spilled into the marine environment, and in this regard, inventories of hazardous substances will be low. The worst-case scenario, however unlikely, would be a vessel collision resulting in the spillage of a fuel and other hazardous substances. A spill of could spread a great distance from the initial spillage site to landfall and have long-term impacts to marine biota (including fishery resources), particularly if a spill were to reach coastal areas.

A spill may cause long-term impacts to marine biota and fishery resources. While, potential volumes are low and it is extremely unlikely for such an event to occur, without appropriate procedures and emergency response plans, the magnitude of impact is assessed as MEDIUM.

Sensitivity of Resource or Receptor

Habitat in Caution Bay may be impacted in the event of a large-scale spill as mangroves or corals exposed at low tide in particular are sensitive to oil smothering. People inhabiting the coastal villages would similarly be affected by spills that impact fisheries resources, as they rely on these resources for their livelihood. For these reasons, the sensitivity of resource/receptor is HIGH.

Assessment of Significance

The overall significance of this residual impact is therefore MODERATE.

4.2.13 Potential Introduction of Aquatic Pests

Issue

A potential pathway for the introduction of non-native marine flora and fauna into PNG waters is the presence of non-native organisms in ballast water discharged in waters of Caution Bay or the presence of non-native organisms on the hulls of the construction vessels, LNG carriers and condensate tankers.

Marine pests cause problems to ecosystems through competition with existing native species for resources, alteration of localised gene pools and modification of physical environments.

Pre-Mitigation Impact Assessment

Magnitude of Impact

Generally, marine animals adapted to tropical conditions have widespread distributions (many throughout the Indo-Pacific) and non-native (e.g. temperate) species are unlikely to survive, hence overall risks of new and exotic 'pests' becoming established are low. The worst examples involve transfer between northern and southern temperate areas, However, non-native marine pests can still be introduced into tropical waters and an example of this is the introduction of the black-striped mussel (*Mytilopsis sallei*) to Darwin marinas in 1999 (Marshall et al., 2003), which rapidly colonised extensive areas and became very difficult and costly to eradicate. In the unlikely event that this was to occur, the organism or organisms may spread to other parts of PNG waters) and long-term (i.e., it is often not possible to eradicate introduced marine flora and fauna). On this basis, the magnitude of impact is MEDIUM.

Sensitivity of Resource or Receptor

The susceptibility of tropical waters, such as Caution Bay, to the introduction of non-native marine flora and fauna is lower than temperate waters. Most tropical species have a wide distribution, so the risks of local introductions of species not already there or of temperate species becoming established is low. However, the sensitivity of the reefs and seagrass habitats within Caution Bay is HIGH.

Assessment of Significance

The overall significance of this potential impact is therefore MODERATE.

4.2.14 Exclusion Zone Effects on Fish Populations

Issue

The project will enforce a 500 m exclusion zone around the marine facilities for safety and security purposes (see Figure 1.02). Only authorised personnel will be allowed to access this zone. Subsistence fishing is a major source of food and income for local villages situated along the coast of Caution Bay including Papa, Lea Lea, Boera and Porebada. As such fishing pressure on resources is relatively high. The 500 m exclusion zone will act as a 'no take zone', which may increase fish stocks and provide a positive effect on fish and shellfish stocks, depending on redistribution of fishing to other areas. However, local people will be excluded from fishing or travelling within the exclusion zones around the LNG Jetty / Materials Offloading Facility. This will increase travelling times and fuel consumption for the local people who use Caution Bay to access villages north and south of the LNG Facilities site.

Pre-Mitigation Impact Assessment

Magnitude of Impact

Without mitigation, given the ongoing nature of the exclusion, the magnitude of impact perceived as a VERY HIGH impact by people whose fishing activities are directly affected.

Sensitivity of Resource or Receptor

As discussed in Section 3.2.3, most fish typically inhabiting coral reefs of PNG have a widespread distribution and can be found in other reefs throughout the tropical Indo-Pacific. However, fish are an important food resource to local communities in Caution Bay, and daily fishing is an important food-gathering activity even though fringing reefs in the area appear degraded and overfished. For these reasons, the sensitivity resource/receptor is considered to be HIGH.

Assessment of Significance

Taking the perception of affected people into consideration, the significance of this potential impact is potentially MAJOR.

4.2.15 Emissions from Shipping Operations

This will be addressed in air quality and greenhouse gas emission reports, which are appendices to the PNG LNG Project EIS.

5 RECOMMENDATIONS

The following measures are recommended to assist in the mitigation of the potential issues described in Chapter 4.

5.1 Limit Marine Habitat Disturbance

Limit marine habitat disturbance and mangrove clearing for LNG Jetty / Materials Offloading Facility construction to the area within the perimeter fence. Prohibit works from exceeding the design disturbance width and enforce boundaries through use of markers/tape and worker awareness.

5.2 Development of a Sedimentation, Erosion and Dredging Management Plan

Establish and enforce a sedimentation, erosion and dredging management plan that includes validation monitoring during key activities such as dredging activities, construction of the Materials Offoading Facility with procedures to ameliorate impacts that exceed project license conditions. Consider use of silt curtains and other good industry practice management controls when working in mangroves, particularly near the seaward extent. Use gravel core and armour rock for construction of the Materials Offloading Facility, or install impervious (geotextile) mat for soils or materials with high content of fines, Continue sediment monitoring, with scope similar to that undertaken for the EIS.

5.3 Maintain Existing Hydrodynamic Processes at Vaihua River Mouth

The length of the earthen causeway part of the LNG Jetty / Materials Offloading Facility was reduced from 1 km to 500 m offshore from the mangroves as a design change to maintain natural hydrodynamic connections between Caution Bay and the Vaihua River, and to avoid the need for any long-term restorative action to keep the river open. However, an environmental trade-off is the need for a once-off dredging program to allow shipping access to the shortened Materials Offloading Facility, which requires an 8-m water depth; this being environmentally preferable to ongoing management of the Vaihua River opening. This would require dredge volumes in the order of 150,000 to 200,000 m^3 of spoil, based on a 90-m wide, 500-m-long channel dredged to a depth of 8 m lowest astronomical tide. Means to minimise impacts of dredging are included in the recommendations set out below in Section 5.5.

5.4 Development of a Water and Sediment Quality Monitoring Program

Conduct validation monitoring and evaluation of water and sediment quality should be conducted in the vicinity of discharge points and at sensitive receptors to confirm that measured water and sediment quality parameters are within permitted environmental limits. Establish a response plan to halt or clean up impacts that exceed predicted conditions.

5.5 Manage and Reduce Sedimentation from Dredging

Adhere to Environment Australia (Commonwealth of Australia) guidelines or similar (in the anticipation of the introduction of Marine Pollution (Sea Dumping) Bill, currently under consideration by the PNG Government) with respect to dredging and disposal of dredged material (includes protocols for investigating contamination and suitability of material for disposal; alternative options for use of material; management of dredging operations; site selection).

5.6 Minimise Impacts from Elevated Salinity

Design the marine outfall of the desalination plants to disperse the brine into Caution Bay to achieve maximum flushing and compliance with the required Environment (Waste Discharge) Permit and position the outfall location at the end of the LNG Jetty and configure the outfall diffusers to maximise dispersion and dilution. Brine discharge from the desalination plant should be discharged into the marine environment at salinity concentrations as close to normal conditions as possible. Wastewater could be discharged in the vicinity of the brine outfall to assist with dilutions.

5.7 Minimise Underwater Noise Impacts on Marine Fauna

Pile-driving activities should be managed so that underwater sound increases incrementally during the construction of the LNG Jetty to allow mobile marine fauna in the vicinity the opportunity to move away before sound levels reach maximum.

5.8 Minimise Effects of Stray Light on Marine Fauna (e.g., Turtles)

Where practicable, utilise treatments for the reduction of light spill into the marine environment during construction and operation will be managed to minimise visibility of the LNG Facilities (including the marine facilities) from Idihi Island where turtles may be nesting.

5.9 Development of an Emergency Response Procedure

Establish an offshore Emergency Response Procedure appropriate to the project phase and include staff training at induction to inform workers of their responsibilities under the plan. This should include identification of all risks or sources of potential chemical and fuel spills and application of appropriate control or clean-up equipment.

5.10 Implementation of a Marine Fauna Observation Procedure

It is not practicable or necessary to conduct marine fauna observation procedures for the construction and operations activities within Caution Bay. The activities are not dissimilar from existing activities; and although the level of such activities will increase by project construction and operations, risks of causing physical injury to the species likely to be present (dolphins and the occasional turtle) are low.

5.11 Implementation of a Blasting Procedure

In the event that underwater blasting is required (e.g. for removal of bommies), a pre-blasting clearance survey should be applied to ensure no turtles are in the vicinity,

5.12 Implementation of a Marine Quarantine Plan

It is recommended that a project-wide quarantine management plan be established and enforced, which should include inspection of equipment, machinery and consumables, such as pipe and imported rock. The plan should follow International Maritime Organization requirements and industry good practice with respect to ballast water discharge and hull cleaning to prevent unintended pest introductions.

5.13 Implementation of a Marine Waste Management Plan

A marine waste management (discharges to sea) plan that will complies with MARPOL standards (prohibiting discharges within three nautical miles of the coast) and with international port policies and procedures applying for vessels within this distance should be developed and implemented.

5.14 Notification of Local People and Commercial Fishers about Construction and Operation Activities

A community awareness program should be carried out to inform inhabitants of villages situated along the coastline of Caution Bay about the construction of the pipeline and marine LNG infrastructure including likely timing and the dangers associated with approaching pipelaying vessels and LNG tankers.

Consultation should include issues such as:

- Project impacts to fishing and resources.
- Access issues and exclusion zones.
- Dynamite fishing.
- Risks from ciguatera poisoning.
- Safety aspects (traffic; burning etc.).
- Fishing restrictions on non-PNG workers.

6 SUMMARY

A summary of the potential issues associated with the construction and operation of the offshore pipeline and LNG facilities, along with a pre-mitigation impact assessment and recommendations for the project is provided as Table 6.01.

Table 6.01 Summary

Potential Issue	Pre-Mitigation Impact Assessment			Recommendation
	Magnitude of Impact	Sensitivity of Resource/receptor	Significance	
Direct loss of marine habitat (LNG Jetty / Materials Offloading Facility).	Medium	High	Moderate	Prohibit works from exceeding design disturbance width and enforce boundaries.
Direct loss of marine habitat (pipeline).	Low	High	Minor	Maintain design limits.
Changes to coastal processes and sediment transport.	Low	High	Minor	Mitigation by design already included.
Increased suspended sediment and sedimentation rates.	High	High	Moderate	Establish and enforce a sedimentation, erosion and dredging management plan; water and sediment quality monitoring program.
Disposal of dredged material.	Medium	Low	Minor	Erosion and dredging management plan.
Underwater noise.	Medium	High	Moderate	Employ noise reducing methods during construction activities.
Collision of vessels with marine mammals and other large marine fauna.	Minimal	High	Minimal	
Effects of lighting on marine fauna.	Medium	High	Moderate	Shielding as practicable to reduce night visibility.
Discharge of brine from desalination plant processing.	Medium	High	Moderate	Install outfall diffusers; discharge near wastewater outfall; water and sediment quality monitoring program.
Discharge from vessels.	Low	High	Minor	Adhere to marine waste plan that complies with MARPOL and equivalent requirements.
Discharge of hydrotest water.	Low	High	Minor	Dispersion;, treatment; discharge near brine outfall, water and sediment quality monitoring program.
Discharge of wastewater.	Low	High	Minor	Dispersion; treatment; discharge near brine outfall; water and sediment quality monitoring program.
Accidental spillage of hazardous substances.	Medium	High	Moderate	Development of an emergency response procedure.
Potential introduction of aquatic pests.	Medium	High	Moderate	Implementation of a quarantine plan.
Exclusion zone effects on fish populations.	Very High	High	Major	Consultation / compensation.
Emissions from shipping operations.				* Refer to air quality and greenhouse gas emission impact assessment reports.

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Annex A

Sampling Locations

Table 1 Habitat map sampling locations

Site	Habitat Type	Easting	Northing	Date
HM-1	Isolated coral reef colonies with sargassum	489407	8976102	06/12/2007
HM-2	Sandy substrate	490565	8976304	06/12/2007
HM-3	Coral reef	488090	8957430	07/12/2007
HM-4	Intermittent coral bommies, sandy patches, reef covered with sargassum	499844	8969254	08/12/2007
HM-5	Distinct zones of seagrass and sargassum with small coral outcrops	500898	8964080	10/12/2007
HM-6	Seagrass and coral reef	499887	8968221	10/12/2007
HM-7	Coral bommie surrounded by rubble/sandy substrate	496766	8969227	10/12/2007
HM-8	Coral reef with sand/rubble patches	495505	8974317	25/04/2008
HM-9	Isolated large *Pavona* coral bommie	499506	8964326	26/04/2008
HM-10	Sand/rubble with isolated small coral bommies	493183	8965142	28/04/2008
HM-11	Sand/rubble with isolated small coral bommies	498740	8965263	29/04/2008

Projection: WGS84 (Zone 55).

Table 2 Coral reef and fish transect surveys

Site	Easting	Northing	Date	Start and Finish Depths (m)
CF-1	500368	8964255	05/12/2007 26/04/2008	1.6 and 1.7
CF-2	503848	8960397	05/12/2007 26/04/2008	1.7 and 1.8
CF-3	486885	8978380	06/12/2007 23/04/2008	1.0 and 3.0
CF-4	486449	8958755	07/12/2007 28/04/2008	4.0 and 5.0
CF-5	498105	8967097	08/12/2007 26/04/2008	7.0 and 8.0
CF-6	499301	8969516	08/12/2007 22/04/2008	3.3 and 3.6
CF-7	499551	8968162	09/12/2007 22/04/2008	4.7 and 4.9

Projection: WGS84 (Zone 55).

Table 3 Underwater visual census surveys

Site	Start and Finish Depths (m)	Transect Length (m)
CF-1	1.6 and 1.7	50
CF-2	2.0 and 2.0	50
CF-3	1.3 and 2.7	50
CF-4	3.6 and 4.5	50
CF-5	7.0 and 11.7	50
CF-6	3.1 and 1.0	50
CF-7	3.5 and 3.7	50

Table 4 Mangrove sampling locations

Site	Easting	Northing	Date	Time	Mangrove species
MG-1	501883	8966257	29/04/2008	10:14	• Dominated by *Rhizophora* spp. • Yellow mangrove (*Ceriops* spp.)
MG-2	501877	8966267	29/04/2008	10:48	• Dominated by *Rhizophora* spp.
MG-3	501593	8966511	29/04/2008	11:05	• Myrtle mangrove (*Osbournia octodonta*)
MG-4	501593	8966311	29/04/2008	11:13	• Yellow mangrove (*Ceriops* spp.) • *Rhizophora* spp. (juveniles)

Projection: WGS84 (Zone 55).

Table 5 Water quality sampling locations

Site	Easting	Northing	Date	Time	Notes
WQ-1	486797	8978703	06/12/2007	10:13	
WQ-2	486441	8958765	07/12/2007	11:00	
WQ-2A	486441	8958765	07/12/2007	11:00	Duplicate of WQ-2
WQ-3	503440	8954722	07/12/2007	16:00	
WQ-4	491107	8972670	08/12/2007	09:15	
WQ-5	498965	8968764	08/12/2007	11:15	
WQ-7	500898	8964080	10/12/2007	15:00	
WQ-8	-	-	10/12/2007	15:00	Blank
WQ2-1	485967	8967875	30/04/2008	9:20	
WQ2-2	488679	8974633	30/04/2008	8:55	
WQ2-3	501722	8956418	30/04/2008	12:35	
WQ2-4	492541	8971268	30/04/2008	11:25	Duplicate of WQ2-5
WQ2-5	492541	8971268	30/04/2008	11:20	
WQ2-6	498536	8967273	30/04/2008	10:15	Duplicate of WQ2-11
WQ2-7	496013	8966924	30/04/2008	10:20	
WQ2-8	489732	8965155	30/04/2008	10:45	
WQ2-9	492531	8968976	30/04/2008	11:05	
WQ2-10	498787	8965392	29/04/2008	12:40	
WQ2-11	498536	8967273	30/04/2008	10:10	
WQ2-12	496191	8971778	30/04/2008	9:56	

Table 5 Water quality sampling locations (cont'd)

Site	Easting	Northing	Date	Time	Notes
WQ2-13	491434	8972170	30/04/2008	9:40	
WQ2-14	500911	8966511	29/04/2008	11:23	
WQ2-15	501883	8966257	29/04/2008	10:14	
WQ2-16	-	-	29/04/2008	15:00	Blank

Projection: WGS84 (Zone 55).

Table 6 Sediment sampling locations

Site	Easting	Northing	Date	Time	Observations
Sed 1	491106	8972670	09/12/2007	9:00	Very fine dark grey clay
Sed 1A	491106	8972670	09/12/2007	10:30	Very fine dark grey clay
Sed 2	496834	8971310	09/12/2007	11:15	Very fine dark grey clay
Sed 3	498969	8968762	08/12/07	11:10	Very fine dark grey clay
Sed 4	499331	8968320	22/04/2008	9:30	Very fine light grey mud
Sed 5	499508	8968006	22/04/2008	14:00	Very gritty, grey substrate with lots of rubble
Sed 6	498536	8967273	25/04/2008	9:00	Very fine light grey mud
Sed 7	499506	8964326	26/04/2008	11:00	Very gritty, grey substrate with lots of rubble
Sed 8	501883	8966257	29/04/2008	10:14	Thick dark grey/black mud with organic matter and very distinct sulphuric odour
Sed 9	498740	8965263	29/04/2008	13:00	Very gritty, grey substrate with lots of coral rubble
Sed 10	495505	8974317	25/04/2008	11:00	Very gritty, grey substrate with lots of coral rubble
Sed 11	503445	8954725	26/04/2008	14:30	Very fine light grey sandy substrate
Sed 12	500368	8964255	05/12/2007	10:20	Very gritty. grey substrate with lots of shells and calcium carbonate
Sed 13	503848	8960397	05/12/2007	15:45	Very gritty, grey sandy substance
Sed 14	486885	8978380	06/12/2007	10:20	Grey sandy substrate
Sed 15	486449	8958755	07/12/2007	10:30	
Sed 16	499551	8968162	10/12/2007	15:00	Very gritty, grey/brown sandy substrate

Projection: WGS84 (Zone 55).

Table 7 Sediment trap sampling locations

Site	Easting	Northing	Date	Time
ST-1	486808	8978712	06/12/2007	11:45
ST-2	495505	8974317	06/12/2007	15:32
ST-3	486441	8958765	07/12/2007	11:00
ST-4	503445	8954725	07/12/2007	16:00
ST-5	498182	8967060	08/12/2007	10:00
ST-6	499301	8969516	08/12/2007	14:00
ST-7	499551	8968162	09/12/2007	14:30

Projection: WGS84 (Zone 55).

Table 8 Marine macrobenthic sampling locations

Site	Easting	Northing	Date	Time	Infauna Sample Details
MI-1	486808	8978712	06/12/2007	11:45	3 cores collected at 7.5 m
MI-2	495505	8974317	06/12/2007	15:32	2 cores collected at 5.8 m
MI-3	486441	8958765	07/12/2007	11:00	2 cores collected at 5 m
MI-4	503445	8954725	07/12/2007	16:00	2 cores collected at 6.5 m
MI-5	491106	8972670	09/12/2007	9:00	2 cores collected at 20 m
MI-6	496834	8971310	09/12/2007	10:30	2 cores collected at 16 m
MI-7	498969	8968762	09/12/2007	11:15	2 cores collected at 12 m
MI-8	499551	8968162	10/12/2007	10:15	2 cores collected at 4 m

Projection: WGS84 (Zone 55).

Table 9 Drop camera sampling locations

Pipeline Route Option Number	Site Number	Easting	Northing	Date	Time	Depth to Seafloor (m)
6	12	492333	8790035	21/4/08	10:30	24
	14	490389	8970506	21/4/08	11:05	26
	16	488451	8970996	21/4/08	11:25	30
	18	486977	8972292	21/4/08	11:45	31
	22	484347	8975287	21/4/08	12:20	33
	26	481604	8978182	21/4/08	12:45	35
	10	494081	8969149	21/4/08	14:54	21
	8	495133	8967451	21/4/08	15:17	21
	7	495666	8966607	27/4/08	11:46	22
	5	497390	8965704	27/4/08	12:00	18
1d	91	488535	8976604	23/4/08	11:48	32
	93	486536	8976547	23/4/08	12:10	25
	95	484647	8977056	23/4/08	12:30	7
1c	79	481818	8971183	24/4/08	9:33	37
	77	482415	8969274	24/4/08	9:48	42
	76	482725	8968324	24/4/08	10:00	45
	75	483362	8967582	24/4/08	10:12	45
	74	484268	8967159	24/4/08	10:23	44
	72	486096	8966347	24/4/08	10:40	42
	70	488000	8965797	24/4/08	11:00	38
	69	488992	8965673	24/4/08	11:15	47
	68	489984	8965550	24/4/08	11:35	35
	X	488451.5	8968348.6	24/4/08	11:57	6-7
	Y	488323.4	8968145.9	24/4/08	12:10	8
1b	64	486761	8970864	24/4/08	12:33	32
	62	487379	8968962	24/4/08	12:50	32
	Z	488341.6	8968256.45	24/4/08	13:42	10

Table 9 Drop camera sampling locations (cont'd)

Pipeline Route Option Number	Site Number	Easting	Northing	Date	Time	Depth to Seafloor (m)
1b (continued)	60	488007	8967064	24/4/08	14:15	35
	59	488643	8966317	24/4/08	14:27	37
	58	489593	8966014	24/4/08	14:40	37
	56	491531	8965522	24/4/08	15:00	31
	55	492500	8965276	27/4/08	10:55	29
	54	493493	8965200	27/4/08	11:06	25
	52	495493	8965200	27/4/08	11:31	23
	50	497493	8965199	27/4/08	12:07	20
	A	493183	8965142	27/4/08	11:15	7
	B	498740	8965263	27/4/08	12:17	8
Proposed shipping access channel	SC-1	494868	8972440	25/4/08	11:53	15
	SC-2	493504	8971192	25/4/08	12:08	19
	SC-3 (start)	495374	8969711	25/4/08	12:45	10
	SC-3 (end)	495324	8969823	25/4/08		
	SC-4	496239	8969623	25/4/08	13:00	4.5
	SC-5	497525	8970173	25/4/08	13:17	14
Sensitivities between pipeline route option 1b and 6 within Pullen Shoals	PS-1	503472	8954747	27/4/08	9:18	24
	PS-2	489256	8966991	27/4/08	9:33	32
	PS-3	490443	8968805	27/4/08	9:54	20
	PS-4	492008	8968334	27/4/08	10:08	6.5
	PS-5	491929	8966928	27/4/08	10:23	7
	PS-6	493904	8966891	27/4/08	10:38	11
Additional sites south of pipeline route option 1c	Idihi Island	486428	8959471	28/4/08	10:51	12
	One	492511	8962665	28/4/08	11:37	10
	Two	495112	8962564	28/4/08	11:54	13
	Three	498638	8967307	28/4/08	14:39	4

Projection: WGS84 (Zone 55).

Table 10 Additional drop camera sampling locations taken during final field survey

Site	Easting	Northing	Depth to Seafloor (m)	Description
GA-1	499880	8964666	11	Sandy substrate with epibenthic burrows. Very small amount of live coral cover. No *P. clavus*
GA-2	499956	8964522	10	Sandy substrate with very low coral cover. School of small fish observed swimming through site. No *P. clavus*
GA-3	499633	8965444	10	Rocky outcrops containing areas of live hard coral. Green algal patches observed.
GA-4	498200	8966289	-	Raised coral bommie surrounded by coral rubble and sandy substrate with small numbers of epibenthic burrows. School of small fish observed swimming through site. Algal bed growing from rocky outcrop of the bommie.

Table 10 Additional drop camera sampling locations taken during final field survey (cont'd)

Site	Easting	Northing	Depth to Seafloor (m)	Description
GA-5	499122	8966789	12	Raised coral bommie surrounded by coral rubble and sandy substrate with small numbers of epibenthic burrows. Small percentage of live coral cover observed at the site.
GA-6	498756	8965356	8	Series of isolated coral bommies surrounded by patches of sand and coral rubble. Reef fish inhabiting the isolated bommies.
GA-7	497389	8967467	18	Sandy substrate with small numbers of burrows.
GA-8	497278	8968467	17	Small patches of large hard and soft coral colonies surrounded by sand and coral rubble.
GA-9	497156	8968967	11	Small patches of large hard coral colonies surrounded by sand and coral rubble. School of small fish observed swimming through site.
GA-10	496356	8970367	5	Very sandy substrate with small isolated coral bommies. Low percentage of coral cover.

Projection: WGS84 (Zone 55).

Annex B

Quality Assurance Program Results

QA/QC Data

Field Quality Assurance/Quality Control

Table A: Field Blank (Freshwater)

Units	Ag mg/L	Al mg/L	As mg/L	Cd mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Mn mg/L	Ni mg/L	Pb mg/L	Se mg/L	Zn mg/L
LOR	0.0001	0.01	0.0005	0.0002	0.0002	0.0005	0.001	0.005	0.0005	0.0005	0.0002	0.002	0.005
Blank - field trip 1	<0.0001	<0.01	0.0018	<0.0002	<0.0002	<0.0005	0.002	0.015	0.0015	<0.0005	<0.0002	<0.002	<0.005
Blank - field trip 2	<0.0001	<0.01	<0.0005	<0.0002	<0.0002	<0.0005	<0.001	<0.005	<0.0005	<0.0005	<0.0002	<0.002	0.006

Table B: Field Duplicate (Seawater)

Units	Ag mg/L	Al mg/L	As mg/L	Cd mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Mn mg/L	Ni mg/L	Pb mg/L	Se mg/L	Zn mg/L
LOR	0.0001	0.01	0.0005	0.0002	0.0002	0.0005	0.001	0.005	0.0005	0.0005	0.0002	0.002	0.005
WQ2A	<0.0001	<0.01	0.0017	<0.0002	<0.0002	<0.0005	<0.001	0.006	0.0014	<0.0005	<0.0002	<0.002	<0.005
WQ2-4	<0.0001	0.02	0.0018	<0.0002	<0.0002	<0.0005	<0.001	0.014	0.0025	<0.0005	<0.0002	<0.002	<0.005
WQ2-6	<0.0001	0.02	0.0014	<0.0002	<0.0002	<0.0005	<0.001	0.012	0.0019	<0.0005	<0.0002	<0.002	<0.005
RPD%													

Laboratory Quality Assurance/Quality Control

Table C: Sediment Quality - Metals Duplicates

Unit	Ag mg/kg	Al mg/kg	As mg/kg	Cd mg/kg	Co mg/kg	Cr mg/kg	Cu mg/kg	Fe mg/kg	Mn mg/kg	Ni mg/kg	Pb mg/kg	Se mg/kg	Zn mg/kg
LOR	2	50	5	1	2	2	5	50	5	2	5	5	5
Sample - field trip 1	<2	1760	<5	<1	<2	2	20	1370	90	<2	<5	<5	8
Duplicate	<2	1690	<5	<1	<2	2	<5	1370	87	<2	<5	<5	<5
RPD(%)	0.0	4.2	0.0	0.0	0.0	0.0	119.0	0.0	3.2	0.0	0.0	0.0	52.7
Recovery limits %	-	0-20	-	-	-	-	-		0-50	-	-	-	-
Sample 2 - field trip 2	<2	8930	8	<1	7	20	12	21400	309	11	6	<5	25
Duplicate 2	<2	8760	8	<1	7	20	13	21000	304	11	6	<5	24
RPD(%)	0.0	1.9	0.0	0.0	0.0	0.0	0.0	2	1.4	0.0	0.0	0.0	0.0
Recovery limit %	-	0-20	-	-	-	0-50	-	0-20	0-20	-	-	-	-

Table D: Sediment Quality - Duplicates

Unit	TOC %	TIC %
LOR	0.02	0.02
Sample - field trip 2	10.5	10.3
Duplicate	10.4	10.2
RPD(%)	1	0.6
Recovery limits %	0-20	0-20

Table E: Sediment Quality - Blank Laboratory Spike Test

	Ag	Al	As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Se	Zn	TOC	TIC
Unit	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	%
LOR	*2*	50	*5*	*1*	*2*	*2*	*5*	50	*5*	*2*	*5*	*5*	*5*	0.02	0.02
Sample	*<2*	<50	*<5*	*<1*	*<2*	*<2*	*<5*	<50	*<5*	*<2*	*<5*	*<5*	*<5*	<0.02	<0.02
Spike concentration	-	-	13.8	2.82	-	61.6	54.7	-	-	55.1	55.5	-	105	100	100
% recovery	-	-	105	98.8	-	8	108	-	-	109	106	-	107	99	100
Recovery limits %	-	-	81.1-117	81.5-112	-	91.2-115	93-119	-	-	91.4-117	86.1-113	-	87.6-118	70-130	70-130

Table F: Sediment Quality >2000µm Matrix Spike

	Ag	Al	As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Se	Zn
Unit	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Spike concentration	-	-	50	25	50	50	50	-	50	50	50	-	50
% recovery	-	-	110	103	82.1	101	91.5	-	ND	93.9	103	-	87.3
Recovery limits %	-	-	70-130	70-130	70-130	70-130	70-130	-	70-130	70-130	70-130	-	70-130

ND = Not determined.

Table G: Water Quality - Duplicates

	pH	NH_3	NO_X	TKN	Total P
Unit		mg/L	mg/L	mg/L	mg/L
LOR	0.01	0.01	0.01	0.1	0.01
Sample	8.23	<0.01	<0.01	<0.1	0.13
Duplicate	8.23	0.012	<0.01	<0.1	0.13
RPD %	0	15.7	0.0	0.0	0.0
Recovery limits %	0-20	-	-	-	0-50

Table H: Water Quality - Duplicates

Unit	Ag	Al	As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Se	Zn
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Saline water													
LOR	0.0001	0.01	0.0005	0.0002	0.0002	0.0005	0.001	-	0.0005	0.0005	0.0002	-	0.005
Sample	<0.0001	0.02	0.0011	0.0003	<0.0002	<0.0005	<0.001	-	0.0014	<0.0005	<0.0002	-	<0.005
Duplicate	<0.0001	0.02	0.0012	0.0003	<0.0002	<0.0005	<0.001	-	0.0015	<0.0005	<0.0002	-	<0.005
RPD %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	7.9	0.0	0.0	-	0
Recovery limits %	-	-	-	-	-	-	-	-	-	-	-	-	-

Table I: Water Quality - Blank Laboratory Spike Test

	pH	NH_3	NO_X	TKN	Total P
Unit		mg/L	mg/L	mg/L	mg/L
LOR	0.01	0.01	0.01	0.1	0.01
Sample	-	-	-	<0.1	<0.01
Spike concentration	7	1	0.5	10	4.42
% recovery	100	105	106	86.4	89.6
Recovery limits %	98.3-118	87.2-123	85.5-118	70-111	70.4-100

Table J: Water Quality - Blank Laboratory Spike Test

	Ag	Al	As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Se	Zn
Unit	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Saline water													
LOR	0.0001	0.01	0.0005	0.0002	0.0002	0.0005	0.001	-	0.0005	0.0005	0.0002	-	0.005
Sample	<0.0001	<0.01	<0.0005	<0.0002	<0.0002	<0.0005	<0.001	-	<0.0005	<0.0005	<0.0002	-	<0.005
Spike concentration	0.01	0.5	0.1	0.1	0.1	0.1	0.1	-	0.1	0.1	0.1	-	0.1
% recovery	88.7	96.8	96.9	87.8	94.7	97.3	92.9	-	98	94.6	98.3	-	92.6
Recovery limits %	79.4-116	78.7-121	85.3-113	79.5-105	79.3-114	78.8-115	77.6-118	-	80.2-118	78.8-112	83.4-119	-	80.7-112

Table K: Water Quality Matrix Spike - General

	NH_3	NO_X	TKN	Total P
Unit	mg/L	mg/L	mg/L	mg/L
Spike concentration	0.4	0.4	5	1
% recovery	92.7	105	111	105
Recovery limits %	70-130	70-130	70-130	70-130

Table L: Water Quality Matrix Spike - Metals

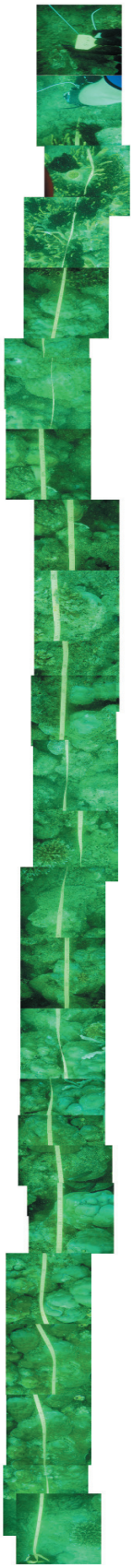
	As	Cd	Co	Cr	Cu	Mn	Ni	Pb	Zn
Unit	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Saline water									
Spike concentration	1	0.25	1	1	1	1	1	1	1
% recovery	122	98.4	121	124	120	109	118	112	115
Recovery limits %	70-130	70-130	70-130	70-130	70-130	70-130	70-130	70-130	70-130

Annex C

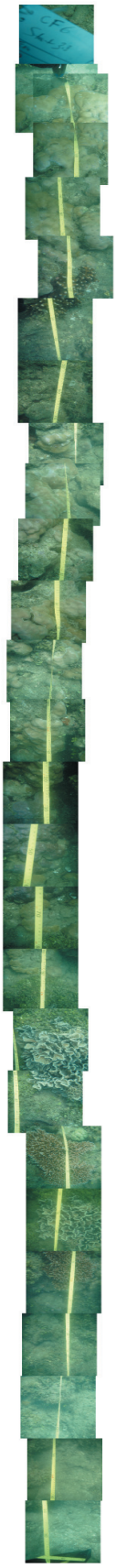
Coral Reef Transects

CT — 1 CT — 2 CT — 3 CT — 4

coffey natural systems	Job No: 1284	Esso Highlands Ltd	Esso	Coral reef transects CF—1 to CF—4	Figure No: 1A
	File Name: 1284_05_F001a_KB	PNG LNG Project			



CT — 5



CT — 6

CT — 7

coffey natural systems	Job No: 1284	Esso Highlands Ltd	Esso	Coral reef transects CF—5 to CF—7	Figure No: 1B
	File Name: 1284_05_F001b_KB	PNG LNG Project			

Annex D

Habitat Map Descriptions

Table 1 Habitat map descriptions from field survey 1 (4 to 12 December 2007)

Site	Date	Location	Description
HM-1	6/12/07	Redscar head GPS Coordinates: Zone: 55L Easting: 489407 Northing: 8976102	• Started snorkel 400 m south of village Kido. • Reef was made up of isolated bommies, lots of sargassum, reasonably diverse corals – A*cropora* and favides. • Fish – mainly gobies. • Very fish and nothing over ~6 cm. • Small fish nursery. • Locals swim in area so some foot damage.
HM-2	6/12/07	Pipeline option 1d – landfall GPS Coordinates: Zone: 55L Easting: 490565 Northing: 8976304	• Sandy bottom. High sediment load from river near Kido. • Landfall sandy beach. • Pandanus swampy land near coast with coconut trees. • Mangroves further inland near estuary.
HM-3	7/12/07	Idihi Island GPS Coordinates: Zone: 55L Easting: 488090 Northing: 8957430	• Inhabited by Porebada residents intermittently. – They have erected beach shacks in the dunes. – They catch reef fish for sale at local markets. Witnessed shark-finning practices for sale to Taiwanese and Chinese fisherman. – Fishing by spearing. – Collecting shells. – Important fishing spot for locals. – Long gill nets set. – Locals reported some turtle nesting on island – green turtles and leatherbacks. Reported that nesting occurs about this time (December). They reported eating turtle eggs occasionally. We did not see turtle tracks or nests.

Table 1 Habitat map descriptions from field survey 1 (4 to 12 December 2007) (cont'd)

Site	Date	Location	Description
HM-4	8/12/07	Pipeline route option 1b GPS Coordinates: Zone: 55L Easting: 499844 Northing: 8969254	• Snorkel started approximately 1.5 km from shore in water depth of 4-5 m. • Reef edge had intermittent bommies with sand patches and channels surrounding them. • Reef covered with *Sargassum* on the reef top frequently dominating other coral species from settling. • Fish species included a number of goat fish damselfish (yellow spotted) and few v. juvenile butterfly fish. All species except mullidae sought refuge in coral heads and rock ledges. • Appears reef had been decimated by storm events or dynamite fishing. • Anecdotal evidence of dynamite fishing from local villages all along the coast, However, the dead upturned corals with whorls and channels are consistent across whole reef, which may indicate storm event than fishing influences. • Approx 1km – 500 m from shore are large seagrass beds of multiple species. • Very few juvenile fish in seagrass. • No evidence of dugong feeding scars. • High numbers of sea urchins and tests scattered amongst battered reef. • 500 m to shore is white sand with no seagrass and only small patches of rocks. The sand runs right up to start of mangrove. • Many small *Acropora* sp, throughout reef (heads all less than 50 cm across). • Fungidae common. • Gonipora like favid present in some sections. • Coral cover low <5%. • Most corals small – porities, acopora, farads, tubinamia.
HM-5	10/12/07	Materials Offloading Facility (MOF) GPS Coordinates: Zone: 55L Easting: 500898 Northing: 8964080	• Very similar to HM-4 habitat map. • Less distinctive sandy patch close to the mangroves. • Zones of seagrass and *Sargassum* not as distinct as HM-4. Zones more mixed. • More small corals amongst the *Sargassum*. • Very low coral cover. • Very few fish species. • Patches/colonies of *Diadema* sp. sea urchins. • 3 different species of seagrass.

Table 1 Habitat map descriptions from field survey 1 (4 to 12 December 2007) (cont'd)

Site	Date	Location	Description
HM-7	10/12/07	Offshore coral bommie GPS Coordinates: Zone: 55L Easting: 496766 Northing: 8969227	• Descended to 15 m – mud/rubble. • Gradual slope – sparse featherstars, sponges and coral outcrops. • Reef started at approximately 10 m. – Gorgonian fans. – Featherstars. – Anemones. – Sponges. – Tunicates. – Posolopara. – Favids. – Mussidae. – Fungids. • Butterfly fish, anemones, morish idol, surgeon, small grubfish, nudibranch were also present. • Low coral cover (<5%).

Table 2 Habitat map descriptions from field survey 2 (20 April to 1 May 2008)

Site	Date	Location	Description	Coral Diversity	Other Marine Organism Diversity
HM-8	25/04/08	Northern Caution Bay (ST-2 site) GPS Coordinates: Zone: 55L Easting: 495505 Northing: 8974317	• One large bommie consisting of faviid colonies (Genus Favia). • Old coral reef with very low coral cover and large areas of rubble and sand. • Isolated small bommies within the area. • From the coral bommie, the reef started to slope (deeper water depth). • Locals were observed fishing when we arrived at the sampling site.	• Acropora colonies. • Soft coral (very abundant). • Whip corals (distinct patches/gardens). • Massive faviid corals. • Porities corals. • Gorgonian corals. • Brown algae (Turbinaria). • Single massive Mussidae (looks like a “brain” coral).	• Surgeon fish (quite abundant). • Clown fish (few). • Large anemones. • Butterfly fish. • Stingray. • Wrasses. • Damsel fish. • Goat fish (abundant). • Crinoids (feather stars). • Large starfish (quite abundant). • Sponges (abundant gardens – linked with coral whips). • Hydrozoa.
HM-9	26/04/08	Piri Patch, Inshore Caution Bay GPS Coordinates: Zone: 55L Easting: 499505.9 Northing: 8964326	• One extremely large single coral colony approximately 16.7m in diameter and approximately 3m high. • Located within 10m water depth (at benthic surface).	• Single *Pavona clavus* colony.	• Bommie supported very high densities of fish. • Large numbers of Lutjanidae (snapper).

Table 2 Habitat map descriptions from field survey 2 (20 April to 1 May 2008)

Site	Date	Location	Description	Coral Diversity	Other Marine Organism Diversity
HM-10	28/04/08	Area of rubble with isolated corals on pipeline route option 1c and 1b (Site A on drop camera) GPS Coordinates: Zone: 55L Easting: 493183 Northing: 8965142	• Flat area in 6-7m depth, mostly coral rubble with isolated small coral bommies - coral cover very low i.e. < 1 %. Not much sand as probably swept clean by currents.	• Isolated Porites massive bommies (< 2 m). • All other corals very small including many *Acropora* (< 10-15 cm). • Soft corals. • Sea whips and gorgonians. • Large specimen of dark green coral (looks like black coral).	• Large fan worms . • Sponges. • Crinoids. • Surgeonfish. • Goatfish in high size diversity. • Parrotfish (<10cm). • Triggerfish in high size diversity. • Damsel. • Butterfly.. • School of fusilier. • Wrasse. • Angel fish. • Lion fish.
HM-11	29/04/08	Area of rubble and sand with isolated corals on pipeline route option 1c and 1b (Site B on drop camera) GPS Coordinates: Zone: 55L Easting: 498740 Northing: 8965263	Flat area in 6 to 7 m depth, mostly sand and coral rubble with isolated small coral bommies and coral growth - coral cover very low i.e. < 5 % overall but small areas of high cover.	• Coral diversity high. • Patches with large numbers of fungids. • Massive porites. • Porites cylindrica. • *Acropora* - plates, staghorn, bottlebrush, digitate, encrusting. • *Faviids* - massive, encrusting. • Turbinaria. • Massive non-acropora/non-porities. • Large fan shaped and vase shaped sponges. • A few whip and gorgonian corals.	• Damsel fish present in high size diversity. • Large school of trevally. • Lizardfish. • Angel fish abundant. • Surgeon fish in pairs and groups rather than individuals. • Triggerfish in high size diversity - many large (>10 cm). • Butterfly. • Fusilliers. • Puffer fish (~ 5cm). • Blenny. • Lionfish exposed from coral bommies. • Goatfish present but not abundant.

Annex E

Raw Laboratory Water and Sediment Quality Results

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **EB0714862**	Page	: 1 of 8
Amendment	: **1**		
Client	: **COFFEY NATURAL SYSTEMS PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR KANE BLACKMAN	Contact	: Tim Kilmister
Address	: LEVEL 21, 12 CREEK STREET BRISBANE QLD, AUSTRALIA 4000	Address	: 32 Shand Street Stafford QLD Australia 4053
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Facsimile	: +61 07 30020444	Facsimile	: +61-7-3243 7218
Project	: ----	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 13-DEC-2007
Sampler	: ----	Issue Date	: 23-JUN-2008
Site	: ----		
		No. of samples received	: 18
Quote number	: ----	No. of samples analysed	: 18

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Cass Sealby	Senior Chemist - Acid Sulphate Soils	Inorganics
Cass Sealby	Senior Chemist - Acid Sulphate Soils	Stafford Minerals
Karen Kilmister		Inorganics
Matthew Goodwin	Senior Organic Chemist	Inorganics
Matthew Goodwin	Senior Organic Chemist	Organics
Stephen Hislop	Senior Inorganic Chemist	Inorganics

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Where moisture determination has been preformed, 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 insuffient 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 date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = Chemistry Abstract Services number
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

This batch has been amended to correct the fractional data on all samples. Due to a laboratory error weights were reported instead of percentages.

Volatile TPH/BTEX: Samples CF1 and CF2 showed poor surrogate recovery due to matrix interference. (Free water).

Analytical Results

Sub-Matrix: **SEDIMENT**				Client sample ID	SED1	SED1A	SED2	SED3	SED1 <2000um
				Client sampling date / time	08-DEC-2007 15:00	08-DEC-2007 15:00	08-DEC-2007 15:00	08-DEC-2007 15:00	08-DEC-2007 15:00
Compound	*CAS Number*	*LOR*	*Unit*		**EB0714862-006**	**EB0714862-007**	**EB0714862-008**	**EB0714862-009**	**EB0714862-015**
EA055: Moisture Content									
^ Moisture Content (dried @ 103°C)	----	1.0	%		**48.4**	**47.7**	**49.1**	**45.7**	----
EG005T: Total Metals by ICP-AES									
Aluminium	7429-90-5	50	mg/kg		----	----	----	----	**31500**
Arsenic	7440-38-2	5	mg/kg		----	----	----	----	**7**
Cadmium	7440-43-9	1	mg/kg		----	----	----	----	<1
Chromium	7440-47-3	2	mg/kg		----	----	----	----	**33**
Cobalt	7440-48-4	2	mg/kg		----	----	----	----	**10**
Copper	7440-50-8	5	mg/kg		----	----	----	----	**38**
Iron	7439-89-6	50	mg/kg		----	----	----	----	**35200**
Lead	7439-92-1	5	mg/kg		----	----	----	----	**13**
Manganese	7439-96-5	5	mg/kg		----	----	----	----	**398**
Nickel	7440-02-0	2	mg/kg		----	----	----	----	**20**
Selenium	7782-49-2	5	mg/kg		----	----	----	----	<5
Silver	7440-22-4	2	mg/kg		----	----	----	----	<2
Zinc	7440-66-6	5	mg/kg		----	----	----	----	**62**
EG035T: Total Mercury by FIMS									
Mercury	7439-97-6	0.1	mg/kg		----	----	----	----	**0.1**
EP006: Total Inorganic Carbon (TIC)									
Total Inorganic Carbon	----	0.02	%		**1.48**	**1.17**	**3.36**	**4.50**	----
EP007: Total Carbon (TC)									
Total Carbon	----	0.02	%		**2.50**	**2.20**	**4.35**	**5.46**	----
EP080/071: Total Petroleum Hydrocarbons									
C6 - C9 Fraction	----	10	mg/kg		<10	<10	<10	<10	----
C10 - C14 Fraction	----	50	mg/kg		<50	<50	<50	<50	----
C15 - C28 Fraction	----	100	mg/kg		<100	<100	<100	<100	----
C29 - C36 Fraction	----	100	mg/kg		<100	<100	<100	<100	----
GEO26: Sieving									
-63µm	----	0.01	%		**70.4**	**63.3**	**80.2**	**72.9**	----
+63µm	----	0.01	%		**29.5**	**33.6**	**19.3**	**26.6**	----
+2000µm	----	0.01	%		**0.07**	**3.09**	**0.54**	**0.48**	----
EP080S: TPH(V)/BTEX Surrogates									
1.2-Dichloroethane-D4	17060-07-0	0.1	%		**98.1**	**99.9**	**97.0**	**92.4**	----
Toluene-D8	2037-26-5	0.1	%		**94.6**	**97.6**	**92.5**	**82.9**	----
4-Bromofluorobenzene	460-00-4	0.1	%		**85.7**	**86.0**	**88.1**	**77.9**	----

Analytical Results

Sub-Matrix: **SEDIMENT**				Client sample ID	SED1A <2000um	SED2 <2000um	SED3 <2000um	----	----
				Client sampling date / time	08-DEC-2007 15:00	08-DEC-2007 15:00	08-DEC-2007 15:00	----	----
Compound	*CAS Number*	*LOR*	*Unit*		**EB0714862-016**	**EB0714862-017**	**EB0714862-018**	**----**	**----**
EG005T: Total Metals by ICP-AES									
Aluminium	7429-90-5	50	mg/kg		**28900**	**27200**	**26300**	----	----
Arsenic	7440-38-2	5	mg/kg		**7**	<5	<5	----	----
Cadmium	7440-43-9	1	mg/kg		<1	<1	<1	----	----
Chromium	7440-47-3	2	mg/kg		**33**	**29**	**23**	----	----
Cobalt	7440-48-4	2	mg/kg		**10**	**8**	**6**	----	----
Copper	7440-50-8	5	mg/kg		**39**	**28**	**27**	----	----
Iron	7439-89-6	50	mg/kg		**35000**	**28400**	**20900**	----	----
Lead	7439-92-1	5	mg/kg		**12**	**10**	**8**	----	----
Manganese	7439-96-5	5	mg/kg		**396**	**366**	**289**	----	----
Nickel	7440-02-0	2	mg/kg		**20**	**17**	**14**	----	----
Selenium	7782-49-2	5	mg/kg		<5	<5	<5	----	----
Silver	7440-22-4	2	mg/kg		<2	<2	<2	----	----
Zinc	7440-66-6	5	mg/kg		**61**	**46**	**32**	----	----
EG035T: Total Mercury by FIMS									
Mercury	7439-97-6	0.1	mg/kg		**0.1**	<0.1	<0.1	----	----

Analytical Results

Sub-Matrix: **SOIL**				Client sample ID	CF1	CF2	CF3	CF4	CF7
				Client sampling date / time	05-DEC-2007 15:00	05-DEC-2007 15:00	06-DEC-2007 15:00	07-DEC-2007 15:00	10-DEC-2007 15:00
Compound	*CAS Number*	*LOR*	*Unit*		**EB0714862-001**	**EB0714862-002**	**EB0714862-003**	**EB0714862-004**	**EB0714862-005**
EA055: Moisture Content									
^ Moisture Content (dried @ 103°C)	----	1.0	%		**34.2**	**30.6**	**27.5**	**28.0**	**32.0**
EP006: Total Inorganic Carbon (TIC)									
Total Inorganic Carbon	----	0.02	%		**10.2**	**10.3**	**10.4**	**10.7**	**10.0**
EP007: Total Carbon (TC)									
Total Carbon	----	0.02	%		**10.4**	**10.5**	**10.5**	**10.8**	**10.2**
EP080/071: Total Petroleum Hydrocarbons									
C6 - C9 Fraction	----	10	mg/kg		<10	<10	<10	<10	<10
C10 - C14 Fraction	----	50	mg/kg		<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	mg/kg		<100	<100	<100	<100	<100
C29 - C36 Fraction	----	100	mg/kg		<100	<100	<100	<100	<100
GEO26: Sieving									
-63µm	----	0.01	%		**0.66**	**1.53**	**0.55**	**0.09**	**3.24**
+63µm	----	0.01	%		**72.0**	**78.6**	**87.2**	**98.4**	**75.9**
+2000µm	----	0.01	%		**27.3**	**19.9**	**12.2**	**1.53**	**20.9**
EP080S: TPH(V)/BTEX Surrogates									
1.2-Dichloroethane-D4	17060-07-0	0.1	%		**76.0**	**76.6**	**86.9**	**104**	**102**
Toluene-D8	2037-26-5	0.1	%		**88.1**	**83.9**	**94.1**	**100**	**96.3**
4-Bromofluorobenzene	460-00-4	0.1	%		**83.7**	**84.1**	**89.5**	**92.7**	**90.2**

Analytical Results

Sub-Matrix: **SOIL**				Client sample ID	CF1 <2000um	CF2 <2000um	CF3 <2000um	CF4 <2000um	CF7 <2000um
				Client sampling date / time	05-DEC-2007 15:00	05-DEC-2007 15:00	06-DEC-2007 15:00	07-DEC-2007 15:00	10-DEC-2007 15:00
Compound	*CAS Number*	*LOR*	*Unit*		**EB0714862-010**	**EB0714862-011**	**EB0714862-012**	**EB0714862-013**	**EB0714862-014**
EG005T: Total Metals by ICP-AES									
Aluminium	7429-90-5	50	mg/kg		**1760**	**380**	**1250**	**300**	**4560**
Arsenic	7440-38-2	5	mg/kg		<5	<5	<5	<5	<5
Cadmium	7440-43-9	1	mg/kg		<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg		**2**	<2	**3**	<2	**4**
Cobalt	7440-48-4	2	mg/kg		<2	<2	<2	<2	<2
Copper	7440-50-8	5	mg/kg		**20**	<5	**7**	**5**	**8**
Iron	7439-89-6	50	mg/kg		**1370**	**610**	**1780**	**420**	**3470**
Lead	7439-92-1	5	mg/kg		<5	<5	<5	<5	<5
Manganese	7439-96-5	5	mg/kg		**90**	**40**	**134**	**56**	**112**
Nickel	7440-02-0	2	mg/kg		<2	<2	<2	<2	**2**
Selenium	7782-49-2	5	mg/kg		<5	<5	<5	<5	<5
Silver	7440-22-4	2	mg/kg		<2	<2	<2	<2	<2
Zinc	7440-66-6	5	mg/kg		**8**	<5	<5	<5	<5
EG035T: Total Mercury by FIMS									
Mercury	7439-97-6	0.1	mg/kg		<0.1	<0.1	<0.1	<0.1	<0.1

Surrogate Control Limits

Sub-Matrix: **SEDIMENT**		Recovery Limits (%)	
Compound	*CAS Number*	*Low*	*High*
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	80	121
Toluene-D8	2037-26-5	81	117
4-Bromofluorobenzene	460-00-4	74	121

Sub-Matrix: **SOIL**		Recovery Limits (%)	
Compound	*CAS Number*	*Low*	*High*
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	80	121
Toluene-D8	2037-26-5	81	117
4-Bromofluorobenzene	460-00-4	74	121

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **EB0805665**	Page	: 1 of 8
Client	: **COFFEY NATURAL SYSTEMS PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MS ANNE-MAREE GOLDMAN	Contact	: Tim Kilmister
Address	: LEVEL 21, 12 CREEK STREET BRISBANE QLD, AUSTRALIA 4000	Address	: 32 Shand Street Stafford QLD Australia 4053
E-mail	: anne-maree_goldman@coffey.com	E-mail	: Services.Brisbane@alsenviro.com
Telephone	: +61 07 30020409	Telephone	: +61-7-3243 7222
Facsimile	: +61 07 30020444	Facsimile	: +61-7-3243 7218
Project	: NSYSABTF01284AE	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 01-MAY-2008
Sampler	: Anne-Maree Goldman	Issue Date	: 30-MAY-2008
Site	: Caution Bay,PNG		
		No. of samples received	: 16
Quote number	: EN/007/08	No. of samples analysed	: 16

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Kim McCabe	Senior Inorganic Chemist	Inorganics
Matthew Goodwin	Senior Analyst	Inorganics
Matthew Goodwin	Senior Analyst	Organics
Phillip Kennedy	2IC Environmental Laboratory	Inorganics
Stephen Hislop	Senior Inorganic Chemist	Inorganics
Stephen Hislop	Senior Inorganic Chemist	Stafford Minerals

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Key : CAS Number = Chemistry Abstract Services number
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

Analytical Results

Sub-Matrix: **SEDIMENT**				Client sample ID	SED 4	SED 5	SED 6	ST-2	SED 7
				Client sampling date / time	22-APR-2008 09:30	22-APR-2008 14:00	25-APR-2008 09:00	25-APR-2008 11:00	26-APR-2008 11:00
Compound	*CAS Number*	*LOR*	*Unit*		**EB0805665-001**	**EB0805665-002**	**EB0805665-003**	**EB0805665-004**	**EB0805665-005**
EA055: Moisture Content									
^ Moisture Content (dried @ 103°C)	----	1.0	%		**34.1**	**32.4**	**46.5**	**37.7**	**33.2**
EP006: Total Inorganic Carbon (TIC)									
Total Inorganic Carbon	----	0.02	%		**5.37**	**10.4**	**5.49**	**9.92**	**10.4**
EP007: Total Carbon (TC)									
Total Carbon	----	0.02	%		**5.84**	**10.5**	**6.02**	**10.1**	**10.5**
EP080/071: Total Petroleum Hydrocarbons									
C6 - C9 Fraction	----	10	mg/kg		<10	<10	<10	<10	<10
C10 - C14 Fraction	----	50	mg/kg		<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	mg/kg		<100	<100	<100	<100	<100
C29 - C36 Fraction	----	100	mg/kg		<100	<100	<100	<100	<100
GEO26: Sieving									
-63µm	----	0.01	%		**41.4**	**0.55**	**52.2**	**1.81**	**0.44**
+63µm	----	0.01	%		**56.6**	**88.4**	**43.3**	**73.2**	**89.3**
+2000µm	----	0.01	%		**1.97**	**11.0**	**4.48**	**25.0**	**10.3**
EP080S: TPH(V)/BTEX Surrogates									
1.2-Dichloroethane-D4	17060-07-0	0.1	%		**98.2**	**94.9**	**88.4**	**93.2**	**97.3**
Toluene-D8	2037-26-5	0.1	%		**103**	**94.4**	**94.0**	**97.6**	**102**
4-Bromofluorobenzene	460-00-4	0.1	%		**95.7**	**87.3**	**86.4**	**88.7**	**91.5**

Analytical Results

Sub-Matrix: **SEDIMENT**

Compound	CAS Number	LOR	Unit	Client sample ID	ST-4	SED 8	SED 9	SED 4 <2000um	SED 5 <2000um
				Client sampling date / time	26-APR-2008 14:30	29-APR-2008 10:14	29-APR-2008 13:00	21-APR-2008 10:00	22-APR-2008 10:00
					EB0805665-006	EB0805665-007	EB0805665-008	EB0805665-009	EB0805665-010
EA055: Moisture Content									
^ Moisture Content (dried @ 103°C)	----	1.0	%		**27.6**	**60.1**	**32.9**	----	----
EG005T: Total Metals by ICP-AES									
Aluminium	7429-90-5	50	mg/kg		----	----	----	**8930**	**1500**
Arsenic	7440-38-2	5	mg/kg		----	----	----	**8**	<5
Cadmium	7440-43-9	1	mg/kg		----	----	----	<1	<1
Chromium	7440-47-3	2	mg/kg		----	----	----	**20**	**5**
Cobalt	7440-48-4	2	mg/kg		----	----	----	**7**	<2
Copper	7440-50-8	5	mg/kg		----	----	----	**12**	<5
Iron	7439-89-6	50	mg/kg		----	----	----	**21400**	**4270**
Lead	7439-92-1	5	mg/kg		----	----	----	**6**	<5
Manganese	7439-96-5	5	mg/kg		----	----	----	**309**	**187**
Nickel	7440-02-0	2	mg/kg		----	----	----	**11**	<2
Selenium	7782-49-2	5	mg/kg		----	----	----	<5	<5
Silver	7440-22-4	2	mg/kg		----	----	----	<2	<2
Zinc	7440-66-6	5	mg/kg		----	----	----	**25**	**6**
^ Sulfur as S	----	50	mg/kg		----	----	----	----	**2340**
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.1	mg/kg		----	----	----	<0.1	<0.1
EP006: Total Inorganic Carbon (TIC)									
Total Inorganic Carbon	----	0.02	%		**10.4**	**1.37**	**10.3**	----	----
EP007: Total Carbon (TC)									
Total Carbon	----	0.02	%		**10.5**	**6.80**	**10.5**	----	----
EP080/071: Total Petroleum Hydrocarbons									
C6 - C9 Fraction	----	10	mg/kg		<10	<10	<10	----	----
C10 - C14 Fraction	----	50	mg/kg		<50	<50	<50	----	----
C15 - C28 Fraction	----	100	mg/kg		<100	<100	<100	----	----
C29 - C36 Fraction	----	100	mg/kg		<100	<100	<100	----	----
GEO26: Sieving									
-63µm	----	0.01	%		**2.08**	**63.3**	**0.49**	----	----
+63µm	----	0.01	%		**87.5**	**34.7**	**63.4**	----	----
+2000µm	----	0.01	%		**10.4**	**2.04**	**36.1**	----	----
EP080S: TPH(V)/BTEX Surrogates									
1.2-Dichloroethane-D4	17060-07-0	0.1	%		**99.8**	**101**	**91.8**	----	----
Toluene-D8	2037-26-5	0.1	%		**105**	**105**	**95.7**	----	----
4-Bromofluorobenzene	460-00-4	0.1	%		**95.1**	**97.7**	**85.3**	----	----

Analytical Results

Sub-Matrix: **SEDIMENT**

Compound	CAS Number	LOR	Unit	Client sample ID	SED 6 <2000um	ST-2 <2000um	SED 7 <2000um	ST-4 <2000um	SED 8 <2000um
				Client sampling date / time	24-APR-2008 10:00	25-APR-2008 10:00	26-APR-2008 10:00	26-APR-2008 10:00	29-APR-2008 10:00
					EB0805665-011	EB0805665-012	EB0805665-013	EB0805665-014	EB0805665-015
EG005T: Total Metals by ICP-AES									
Aluminium	7429-90-5	50	mg/kg		**14200**	**5160**	**1540**	**860**	**18000**
Arsenic	7440-38-2	5	mg/kg		**7**	**7**	<5	<5	**7**
Cadmium	7440-43-9	1	mg/kg		<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg		**24**	**9**	**5**	**5**	**48**
Cobalt	7440-48-4	2	mg/kg		**7**	**3**	<3	<2	**14**
Copper	7440-50-8	5	mg/kg		**23**	**12**	<5	<5	**67**
Iron	7439-89-6	50	mg/kg		**23100**	**11900**	**4760**	**1350**	**27500**
Lead	7439-92-1	5	mg/kg		**8**	<5	<5	<5	**10**
Manganese	7439-96-5	5	mg/kg		**388**	**252**	**192**	**78**	**418**
Nickel	7440-02-0	2	mg/kg		**14**	**7**	**3**	<2	**47**
Selenium	7782-49-2	5	mg/kg		<5	<5	<5	<5	**5**
Silver	7440-22-4	2	mg/kg		<2	<2	<3	<2	<2
Zinc	7440-66-6	5	mg/kg		**41**	**25**	**5**	<5	**73**
^ Sulfur as S	----	50	mg/kg		----	**1850**	**1890**	**2170**	**3440**
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.1	mg/kg		<0.1	<0.1	<0.1	<0.1	<0.1

Analytical Results

Sub-Matrix: **SEDIMENT**				Client sample ID	**SED 9 <2000um**	----	----	----	----
				Client sampling date / time	29-APR-2008 10:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*		**EB0805665-016**	**----**	**----**	**----**	**----**
EG005T: Total Metals by ICP-AES									
Aluminium	7429-90-5	50	mg/kg		**960**	----	----	----	----
Arsenic	7440-38-2	5	mg/kg		<5	----	----	----	----
Cadmium	7440-43-9	1	mg/kg		<1	----	----	----	----
Chromium	7440-47-3	2	mg/kg		**3**	----	----	----	----
Cobalt	7440-48-4	2	mg/kg		<2	----	----	----	----
Copper	7440-50-8	5	mg/kg		<5	----	----	----	----
Iron	7439-89-6	50	mg/kg		**2140**	----	----	----	----
Lead	7439-92-1	5	mg/kg		<5	----	----	----	----
Manganese	7439-96-5	5	mg/kg		**147**	----	----	----	----
Nickel	7440-02-0	2	mg/kg		<2	----	----	----	----
Selenium	7782-49-2	5	mg/kg		<5	----	----	----	----
Silver	7440-22-4	2	mg/kg		<2	----	----	----	----
Zinc	7440-66-6	5	mg/kg		**5**	----	----	----	----
^ Sulfur as S	----	50	mg/kg		**2060**	----	----	----	----
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.1	mg/kg		<0.1	----	----	----	----

Surrogate Control Limits

Sub-Matrix: **SEDIMENT**

Compound	CAS Number	Recovery Limits (%) Low	Recovery Limits (%) High
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	80	121
Toluene-D8	2037-26-5	81	117
4-Bromofluorobenzene	460-00-4	74	121

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **EB0714863**	Page	: 1 of 8
Client	: **COFFEY NATURAL SYSTEMS PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR KANE BLACKMAN	Contact	: Tim Kilmister
Address	: LEVEL 21, 12 CREEK STREET BRISBANE QLD AUSTRALIA 4000	Address	: 32 Shand Street Stafford QLD Australia 4053
E-mail	: kane_blackman@coffee.com	E-mail	: Services.Brisbane@alsenviro.com
Telephone	: +61 07 30020400	Telephone	: +61-7-3243 7222
Facsimile	: +61 07 30020444	Facsimile	: +61-7-3243 7218
Project	: PNG LNG Project 1284	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 13-DEC-2007
Sampler	: ----	Issue Date	: 09-JAN-2008
Site	: Portion 152		
		No. of samples received	: 8
Quote number	: ----	No. of samples analysed	: 8

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Ashwini Sharma	Inorganics Co-ordinator	Inorganics
Celine Conceicao	Spectroscopist	Inorganics
Karen Kilmister		Inorganics
Matthew Goodwin	Senior Analyst	Organics
PHALAK INTHAKESONE	Organics Co-ordinator	Organics
Stephen Hislop	Senior Inorganic Chemist	Inorganics

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A Campbell Brothers Limited Company

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.

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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.

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Key : CAS Number = Chemistry Abstract Services number
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **ED093F (Dissolved Cations) & ED040F (Dissolved Anions): Sample # 8 (WQ8) has been confirmed by reanalysis.**
- **LOR for all samples raised x 5 for Total Phosphorus, Total Kjeldahl Nitrogen and Total Nitrogen due to saline matrix**
- **ORC low level metals analysis conducted by ALS Sydney, NATA accreditation no. 825, site no 10911**

Analytical Results

Sub-Matrix: **SEAWATER**				Client sample ID	WQ1	WQ2	WQ2A	WQ3	WQ4
				Client sampling date / time	06-DEC-2007 10:13	07-DEC-2007 11:00	07-DEC-2007 11:00	07-DEC-2007 16:00	08-DEC-2007 09:15
Compound	*CAS Number*	*LOR*	*Unit*		**EB0714863-001**	**EB0714863-002**	**EB0714863-003**	**EB0714863-004**	**EB0714863-005**
EA025: Suspended Solids									
^ Suspended Solids (SS)	----	1	mg/L		**3**	**4**	**5**	**4**	**5**
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L		<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L		<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		**110**	**104**	**109**	**107**	**117**
Total Alkalinity as CaCO3	----	1	mg/L		**110**	**104**	**109**	**107**	**117**
ED040F: Dissolved Major Anions									
Sulphate as SO4 2-	14808-79-8	1	mg/L		**2850**	**2770**	**2890**	**2990**	**2900**
ED045P: Chloride by PC Titrator									
Chloride	16887-00-6	1	mg/L		**21100**	**20600**	**22800**	**22300**	**21600**
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		**448**	**434**	**451**	**462**	**456**
Magnesium	7439-95-4	1	mg/L		**1400**	**1350**	**1400**	**1450**	**1420**
Sodium	7440-23-5	1	mg/L		**11300**	**10800**	**11200**	**11600**	**11400**
Potassium	7440-09-7	1	mg/L		**544**	**512**	**542**	**556**	**555**
EG035T: Total Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L		**0.0004**	**0.0001**	<0.0001	**0.0001**	<0.0001
EG093T: Total Metals in Saline Water by ORC-ICPMS									
Aluminium	7429-90-5	10	µg/L		**20**	<10	<10	<10	<10
Selenium	7782-49-2	2	µg/L		<2	<2	<2	<2	<2
Iron	7439-89-6	5	µg/L		**27**	<5	**6**	**14**	**10**
Arsenic	7440-38-2	0.5	µg/L		**1.7**	**1.8**	**1.7**	**1.8**	**1.8**
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
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		**4.1**	**1.1**	**1.4**	**1.4**	**1.3**
Nickel	7440-02-0	0.5	µg/L		**0.6**	<0.5	<0.5	<0.5	<0.5
Silver	7440-22-4	0.1	µg/L		<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	5	µg/L		<5	<5	<5	<5	<5
EK055: Ammonia as N									
Ammonia as N	7664-41-7	0.010	mg/L		**0.041**	**0.044**	**0.045**	**0.047**	**0.040**
EK059: Nitrite plus Nitrate as N (NOx)									
Nitrite + Nitrate as N	----	0.010	mg/L		**0.011**	<0.010	**0.016**	**0.017**	<0.010
EK061: Total Kjeldahl Nitrogen (TKN)									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		<0.5	<0.5	<0.5	<0.5	<0.5

Analytical Results

Sub-Matrix: **SEAWATER**

Compound	CAS Number	LOR	Unit	Client sample ID: WQ1	WQ2	WQ2A	WQ3	WQ4
				Client sampling date / time: 06-DEC-2007 10:13	07-DEC-2007 11:00	07-DEC-2007 11:00	07-DEC-2007 16:00	08-DEC-2007 09:15
				EB0714863-001	EB0714863-002	EB0714863-003	EB0714863-004	EB0714863-005
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	0.1	mg/L	<0.5	<0.5	<0.5	<0.5	<0.5
EK067: Total Phosphorus as P								
Total Phosphorus as P	----	0.01	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	**657**	**642**	**706**	**694**	**672**
^ Total Cations	----	0.01	meq/L	**643**	**617**	**641**	**663**	**648**
^ Ionic Balance	----	0.01	%	**1.13**	**1.98**	**4.84**	**2.28**	**1.80**
EP033: C1 - C4 Hydrocarbon Gases								
Methane	74-82-8	10	µg/L	<10	<10	<10	<10	<10
Ethene	74-85-1	10	µg/L	<10	<10	<10	<10	<10
Ethane	74-84-0	10	µg/L	<10	<10	<10	<10	<10
Propene	115-07-1	10	µg/L	<10	<10	<10	<10	<10
Propane	74-98-6	10	µg/L	<10	<10	<10	<10	<10
Butene	25167-67-3	20	µg/L	<20	<20	<20	<20	<20
Butane	106-97-8	20	µg/L	<20	<20	<20	<20	<20
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	----	----	<50	----	<50
C15 - C28 Fraction	----	100	µg/L	----	----	<100	----	<100
C29 - C36 Fraction	----	50	µg/L	----	----	<50	----	<50
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**99.3**	**115**	**93.9**	**103**	**96.6**
Toluene-D8	2037-26-5	0.1	%	**98.4**	**101**	**95.8**	**93.9**	**96.6**
4-Bromofluorobenzene	460-00-4	0.1	%	**94.5**	**92.4**	**113**	**93.1**	**114**

Analytical Results

Sub-Matrix: **SEAWATER**				Client sample ID	WQ5	WQ7	WQ8	----	----
				Client sampling date / time	08-DEC-2007 11:15	10-DEC-2007 15:00	10-DEC-2007 15:00	----	----
Compound	*CAS Number*	*LOR*	*Unit*		**EB0714863-006**	**EB0714863-007**	**EB0714863-008**	**----**	**----**
EA025: Suspended Solids									
^ Suspended Solids (SS)	----	1	mg/L		**2**	**17**	<1	----	----
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L		<1	<1	<1	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L		<1	<1	<1	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		**118**	**110**	**4**	----	----
Total Alkalinity as CaCO3	----	1	mg/L		**118**	**110**	**4**	----	----
ED040F: Dissolved Major Anions									
Sulphate as SO4 2-	14808-79-8	1	mg/L		**3170**	**2990**	<1	----	----
ED045P: Chloride by PC Titrator									
Chloride	16887-00-6	1	mg/L		**24200**	**23500**	<1	----	----
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		**490**	**456**	<1	----	----
Magnesium	7439-95-4	1	mg/L		**1540**	**1450**	<1	----	----
Sodium	7440-23-5	1	mg/L		**12200**	**11700**	<1	----	----
Potassium	7440-09-7	1	mg/L		**643**	**583**	<1	----	----
EG035T: Total Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L		<0.0001	<0.0001	<0.0001	----	----
EG093T: Total Metals in Saline Water by ORC-ICPMS									
Aluminium	7429-90-5	10	µg/L		<10	**10**	<10	----	----
Selenium	7782-49-2	2	µg/L		<2	<2	<2	----	----
Iron	7439-89-6	5	µg/L		**11**	**25**	**15**	----	----
Arsenic	7440-38-2	0.5	µg/L		**1.8**	**1.8**	**1.8**	----	----
Cadmium	7440-43-9	0.2	µg/L		<0.2	<0.2	<0.2	----	----
Chromium	7440-47-3	0.5	µg/L		<0.5	<0.5	<0.5	----	----
Cobalt	7440-48-4	0.2	µg/L		<0.2	<0.2	<0.2	----	----
Copper	7440-50-8	1	µg/L		<1	<1	**2**	----	----
Lead	7439-92-1	0.2	µg/L		<0.2	<0.2	<0.2	----	----
Manganese	7439-96-5	0.5	µg/L		**1.6**	**1.6**	**1.5**	----	----
Nickel	7440-02-0	0.5	µg/L		<0.5	<0.5	<0.5	----	----
Silver	7440-22-4	0.1	µg/L		<0.1	<0.1	<0.1	----	----
Zinc	7440-66-6	5	µg/L		<5	<5	<5	----	----
EK055: Ammonia as N									
Ammonia as N	7664-41-7	0.010	mg/L		**0.044**	**0.051**	**0.031**	----	----
EK059: Nitrite plus Nitrate as N (NOx)									
Nitrite + Nitrate as N	----	0.010	mg/L		<0.010	**0.015**	<0.010	----	----
EK061: Total Kjeldahl Nitrogen (TKN)									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		<0.5	<0.5	<0.5	----	----

Analytical Results

Sub-Matrix: **SEAWATER**				Client sample ID	WQ5	WQ7	WQ8	----	----
				Client sampling date / time	08-DEC-2007 11:15	10-DEC-2007 15:00	10-DEC-2007 15:00	----	----
Compound	*CAS Number*	*LOR*	*Unit*		**EB0714863-006**	**EB0714863-007**	**EB0714863-008**	**----**	**----**
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	0.1	mg/L		<0.5	<0.5	<0.5	----	----
EK067: Total Phosphorus as P									
Total Phosphorus as P	----	0.01	mg/L		<0.05	<0.05	<0.05	----	----
EN055: Ionic Balance									
^ Total Anions	----	0.01	meq/L		**752**	**728**	**0.08**	----	----
^ Total Cations	----	0.01	meq/L		**699**	**666**	**0.10**	----	----
^ Ionic Balance	----	0.01	%		**3.67**	**4.46**	----	----	----
EP033: C1 - C4 Hydrocarbon Gases									
Methane	74-82-8	10	µg/L		<10	<10	<10	----	----
Ethene	74-85-1	10	µg/L		<10	<10	<10	----	----
Ethane	74-84-0	10	µg/L		<10	<10	<10	----	----
Propene	115-07-1	10	µg/L		<10	<10	<10	----	----
Propane	74-98-6	10	µg/L		<10	<10	<10	----	----
Butene	25167-67-3	20	µg/L		<20	<20	<20	----	----
Butane	106-97-8	20	µg/L		<20	<20	<20	----	----
EP080/071: Total Petroleum Hydrocarbons									
C6 - C9 Fraction	----	20	µg/L		<20	<20	<20	----	----
C10 - C14 Fraction	----	50	µg/L		<50	<50	<50	----	----
C15 - C28 Fraction	----	100	µg/L		<100	<100	<100	----	----
C29 - C36 Fraction	----	50	µg/L		<50	<50	<80	----	----
EP080S: TPH(V)/BTEX Surrogates									
1.2-Dichloroethane-D4	17060-07-0	0.1	%		**93.4**	**107**	**88.6**	----	----
Toluene-D8	2037-26-5	0.1	%		**94.2**	**93.8**	**94.9**	----	----
4-Bromofluorobenzene	460-00-4	0.1	%		**112**	**116**	**110**	----	----

Surrogate Control Limits

Sub-Matrix: **SEAWATER**		Recovery Limits (%)	
Compound	*CAS Number*	*Low*	*High*
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	80	120
Toluene-D8	2037-26-5	88	110
4-Bromofluorobenzene	460-00-4	86	115

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **EB0805659**	Page	: 1 of 12
Amendment	: **1**		
Client	: **COFFEY NATURAL SYSTEMS PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MS ANNE-MAREE GOLDMAN	Contact	: Tim Kilmister
Address	: LEVEL 21, 12 CREEK STREET BRISBANE QLD, AUSTRALIA 4000	Address	: 32 Shand Street Stafford QLD Australia 4053
E-mail	: anne-maree_goldman@coffey.com	E-mail	: Services.Brisbane@alsenviro.com
Telephone	: +61 07 30020409	Telephone	: +61-7-3243 7222
Facsimile	: +61 07 30020444	Facsimile	: +61-7-3243 7218
Project	: NSYSABTF01284AE	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 01-MAY-2008
Sampler	: Anne-Maree Goldman	Issue Date	: 29-MAY-2008
Site	: Caution Bay,PNG		
		No. of samples received	: 16
Quote number	: EN/007/08	No. of samples analysed	: 16

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

NATA Accredited Laboratory 825

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Accredited for compliance with ISO/IEC 17025.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Ashwini Sharma	Laboratory Manager	Inorganics
Celine Conceicao	Spectroscopist	Inorganics
Kim McCabe	Senior Inorganic Chemist	Inorganics
Matthew Goodwin	Senior Analyst	Organics
PHALAK INTHAKESONE	Organics Co-ordinator	Organics
Stephen Hislop	Senior Inorganic Chemist	Inorganics

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Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient 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 date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = Chemistry Abstract Services number
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **EG093 T: Positive Zinc result for batch EB0805659-016 has been confirmed by re-analysis.**
- **Semivolatile TPH: For samples WQ2-1 and WQ2-11 insufficient sample has been provided for standard analysis. Where applicable LOR values have been adjusted accordingly.**

Analytical Results

Sub-Matrix: WATER				Client sample ID	WQ2-1	WQ2-2	WQ2-3	WQ2-4	WQ2-5
				Client sampling date / time	30-APR-2008 09:20	30-APR-2008 08:55	30-APR-2008 12:35	30-APR-2008 11:25	30-APR-2008 11:20
Compound	CAS Number	LOR	Unit		EB0805659-001	EB0805659-002	EB0805659-003	EB0805659-004	EB0805659-005
EA005: pH									
pH Value	----	0.01	pH Unit		8.16	8.29	8.24	8.25	8.25
EA025: Suspended Solids									
^ Suspended Solids (SS)	----	1	mg/L		32	35	37	30	38
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L		<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L		<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		110	111	112	110	110
Total Alkalinity as CaCO3	----	1	mg/L		110	111	112	110	110
ED040F: Dissolved Major Anions									
Sulphate as SO4 2-	14808-79-8	1	mg/L		2200	2300	2360	2460	2460
ED045P: Chloride by PC Titrator									
Chloride	16887-00-6	1	mg/L		15600	15500	16200	16200	16900
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		342	353	357	377	374
Magnesium	7439-95-4	1	mg/L		1090	1130	1150	1200	1190
Sodium	7440-23-5	1	mg/L		8530	8780	8940	9520	9180
Potassium	7440-09-7	1	mg/L		419	444	448	470	468
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EG093T: Total Metals in Saline Water by ORC-ICPMS									
Aluminium	7429-90-5	10	µg/L		20	20	10	20	20
Selenium	7782-49-2	2	µg/L		<2	<2	<2	<2	<2
Iron	7439-89-6	5	µg/L		11	11	6	14	12
Arsenic	7440-38-2	0.5	µg/L		1.1	1.4	1.5	1.8	1.5
Cadmium	7440-43-9	0.2	µg/L		0.3	<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
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		1.4	1.9	1.3	2.5	2.4
Nickel	7440-02-0	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5
Silver	7440-22-4	0.1	µg/L		<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	5	µg/L		<5	<5	<5	<5	<5
EK055: Ammonia as N									
Ammonia as N	7664-41-7	0.010	mg/L		0.017	0.011	0.013	0.013	0.017
EK059: Nitrite plus Nitrate as N (NOx)									
Nitrite + Nitrate as N	----	0.010	mg/L		0.012	0.012	<0.010	<0.010	0.492

Analytical Results

Sub-Matrix: **WATER**				Client sample ID	WQ2-1	WQ2-2	WQ2-3	WQ2-4	WQ2-5
				Client sampling date / time	30-APR-2008 09:20	30-APR-2008 08:55	30-APR-2008 12:35	30-APR-2008 11:25	30-APR-2008 11:20
Compound	*CAS Number*	*LOR*	*Unit*		**EB0805659-001**	**EB0805659-002**	**EB0805659-003**	**EB0805659-004**	**EB0805659-005**
EK061: Total Kjeldahl Nitrogen (TKN)									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		**0.2**	<0.1	<0.1	<0.1	**0.1**
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	0.1	mg/L		**0.2**	<0.1	<0.1	<0.1	**0.6**
EK067: Total Phosphorus as P									
Total Phosphorus as P	----	0.01	mg/L		**0.07**	**0.11**	**0.13**	**0.13**	**0.12**
EN055: Ionic Balance									
^ Total Anions	----	0.01	meq/L		**490**	**488**	**509**	**510**	**530**
^ Total Cations	----	0.01	meq/L		**488**	**504**	**513**	**543**	**528**
^ Ionic Balance	----	0.01	%		**0.14**	**1.62**	**0.36**	**3.18**	**0.17**
EP033: C1 - C4 Hydrocarbon Gases									
Methane	74-82-8	10	µg/L		<10	<10	<10	<10	<10
Ethene	74-85-1	10	µg/L		<10	<10	<10	<10	<10
Ethane	74-84-0	10	µg/L		<10	<10	<10	<10	<10
Propene	115-07-1	10	µg/L		<10	<10	<10	<10	<10
Propane	74-98-6	10	µg/L		<10	<10	<10	<10	<10
Butene	25167-67-3	20	µg/L		<20	<20	<20	<20	<20
Butane	106-97-8	20	µg/L		<20	<20	<20	<20	<20
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		<60	<50	<50	<50	<50
EP080S: TPH(V)/BTEX Surrogates									
1.2-Dichloroethane-D4	17060-07-0	0.1	%		**103**	**105**	**122**	**111**	**106**
Toluene-D8	2037-26-5	0.1	%		**99.1**	**96.3**	**110**	**98.3**	**93.2**
4-Bromofluorobenzene	460-00-4	0.1	%		**102**	**105**	**121**	**110**	**102**

Analytical Results

Sub-Matrix: WATER				Client sample ID	WQ2-6	WQ2-7	WQ2-8	WQ2-9	WQ2-10
				Client sampling date / time	30-APR-2008 10:15	30-APR-2008 10:20	30-APR-2008 10:45	30-APR-2008 11:05	29-APR-2008 12:40
Compound	CAS Number	LOR	Unit		EB0805659-006	EB0805659-007	EB0805659-008	EB0805659-009	EB0805659-010
EA005: pH									
pH Value	----	0.01	pH Unit		8.27	8.23	8.33	8.95	7.92
EA025: Suspended Solids									
^ Suspended Solids (SS)	----	1	mg/L		28	68	32	26	41
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L		<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L		<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		110	109	110	107	111
Total Alkalinity as CaCO3	----	1	mg/L		110	109	110	107	111
ED040F: Dissolved Major Anions									
Sulphate as SO4 2-	14808-79-8	1	mg/L		2440	2430	2090	2240	2540
ED045P: Chloride by PC Titrator									
Chloride	16887-00-6	1	mg/L		16200	16600	14200	15300	17500
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		378	371	317	344	387
Magnesium	7439-95-4	1	mg/L		1200	1180	1010	1110	1240
Sodium	7440-23-5	1	mg/L		9430	9350	7970	8640	9860
Potassium	7440-09-7	1	mg/L		474	459	377	423	498
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EG093T: Total Metals in Saline Water by ORC-ICPMS									
Aluminium	7429-90-5	10	µg/L		20	20	20	20	10
Selenium	7782-49-2	2	µg/L		<2	<2	<2	<2	<2
Iron	7439-89-6	5	µg/L		12	12	22	17	8
Arsenic	7440-38-2	0.5	µg/L		1.4	1.3	1.1	1.2	1.7
Cadmium	7440-43-9	0.2	µg/L		<0.2	<0.2	0.5	<0.2	0.3
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
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		1.9	1.8	2.8	2.0	1.8
Nickel	7440-02-0	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5
Silver	7440-22-4	0.1	µg/L		<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	5	µg/L		<5	5	<5	<5	<5
EK055: Ammonia as N									
Ammonia as N	7664-41-7	0.010	mg/L		0.055	0.018	0.014	<0.010	0.020
EK059: Nitrite plus Nitrate as N (NOx)									
Nitrite + Nitrate as N	----	0.010	mg/L		0.013	0.011	<0.010	<0.010	0.022

Analytical Results

Sub-Matrix: **WATER**				Client sample ID	WQ2-6	WQ2-7	WQ2-8	WQ2-9	WQ2-10
				Client sampling date / time	30-APR-2008 10:15	30-APR-2008 10:20	30-APR-2008 10:45	30-APR-2008 11:05	29-APR-2008 12:40
Compound	*CAS Number*	*LOR*	*Unit*		**EB0805659-006**	**EB0805659-007**	**EB0805659-008**	**EB0805659-009**	**EB0805659-010**
EK061: Total Kjeldahl Nitrogen (TKN)									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		**0.2**	<0.1	**0.1**	**0.1**	**0.1**
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	0.1	mg/L		**0.2**	<0.1	**0.1**	**0.1**	**0.1**
EK067: Total Phosphorus as P									
Total Phosphorus as P	----	0.01	mg/L		**0.10**	**0.09**	**0.07**	**0.11**	**0.10**
EN055: Ionic Balance									
^ Total Anions	----	0.01	meq/L		**509**	**521**	**446**	**480**	**550**
^ Total Cations	----	0.01	meq/L		**540**	**534**	**456**	**495**	**563**
^ Ionic Balance	----	0.01	%		**2.88**	**1.18**	**1.05**	**1.54**	**1.17**
EP033: C1 - C4 Hydrocarbon Gases									
Methane	74-82-8	10	µg/L		<10	<10	<10	<10	<10
Ethene	74-85-1	10	µg/L		<10	<10	<10	<10	<10
Ethane	74-84-0	10	µg/L		<10	<10	<10	<10	<10
Propene	115-07-1	10	µg/L		<10	<10	<10	<10	<10
Propane	74-98-6	10	µg/L		<10	<10	<10	<10	<10
Butene	25167-67-3	20	µg/L		<20	<20	<20	<20	<20
Butane	106-97-8	20	µg/L		<20	<20	<20	<20	<20
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
EP080S: TPH(V)/BTEX Surrogates									
1.2-Dichloroethane-D4	17060-07-0	0.1	%		**127**	**88.0**	**114**	**116**	**117**
Toluene-D8	2037-26-5	0.1	%		**110**	**99.1**	**94.8**	**96.2**	**99.8**
4-Bromofluorobenzene	460-00-4	0.1	%		**122**	**111**	**109**	**111**	**115**

Analytical Results

Sub-Matrix: WATER				Client sample ID	WQ2-11	WQ2-12	WQ2-13	WQ2-14	WQ2-15
				Client sampling date / time	30-APR-2008 10:10	30-APR-2008 09:56	30-APR-2008 09:40	29-APR-2008 11:23	29-APR-2008 10:14
Compound	CAS Number	LOR	Unit		EB0805659-011	EB0805659-012	EB0805659-013	EB0805659-014	EB0805659-015
EA005: pH									
pH Value	----	0.01	pH Unit		8.23	8.23	8.30	8.07	8.00
EA025: Suspended Solids									
^ Suspended Solids (SS)	----	1	mg/L		27	41	35	48	32
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L		<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L		<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		108	110	108	134	250
Total Alkalinity as CaCO3	----	1	mg/L		108	110	108	134	250
ED040F: Dissolved Major Anions									
Sulphate as SO4 2-	14808-79-8	1	mg/L		2460	2490	2270	2960	1780
ED045P: Chloride by PC Titrator									
Chloride	16887-00-6	1	mg/L		16300	16600	15500	18800	12000
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		376	385	353	452	283
Magnesium	7439-95-4	1	mg/L		1210	1200	1110	1450	844
Sodium	7440-23-5	1	mg/L		9450	9680	8880	11300	6240
Potassium	7440-09-7	1	mg/L		478	486	427	575	281
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EG093T: Total Metals in Saline Water by ORC-ICPMS									
Aluminium	7429-90-5	10	µg/L		10	10	20	130	300
Selenium	7782-49-2	2	µg/L		<2	<2	<2	<2	<2
Iron	7439-89-6	5	µg/L		10	7	11	157	381
Arsenic	7440-38-2	0.5	µg/L		1.4	1.6	1.3	1.8	1.4
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	0.8
Cobalt	7440-48-4	0.2	µg/L		<0.2	<0.2	<0.2	0.3	0.7
Copper	7440-50-8	1	µg/L		<1	<1	<1	<1	<1
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		1.6	2.0	1.8	28.4	143
Nickel	7440-02-0	0.5	µg/L		<0.5	<0.5	<0.5	0.7	2.3
Silver	7440-22-4	0.1	µg/L		<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	5	µg/L		<5	6	<5	<5	<5
EK055: Ammonia as N									
Ammonia as N	7664-41-7	0.010	mg/L		<0.010	0.011	0.013	0.042	0.041
EK059: Nitrite plus Nitrate as N (NOx)									
Nitrite + Nitrate as N	----	0.010	mg/L		<0.010	<0.010	0.025	0.015	<0.010

Analytical Results

Sub-Matrix: **WATER**				Client sample ID	WQ2-11	WQ2-12	WQ2-13	WQ2-14	WQ2-15
				Client sampling date / time	30-APR-2008 10:10	30-APR-2008 09:56	30-APR-2008 09:40	29-APR-2008 11:23	29-APR-2008 10:14
Compound	*CAS Number*	*LOR*	*Unit*		**EB0805659-011**	**EB0805659-012**	**EB0805659-013**	**EB0805659-014**	**EB0805659-015**
EK061: Total Kjeldahl Nitrogen (TKN)									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		**0.2**	**0.1**	**0.1**	**0.2**	**0.4**
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	0.1	mg/L		**0.2**	**0.1**	**0.2**	**0.2**	**0.4**
EK067: Total Phosphorus as P									
Total Phosphorus as P	----	0.01	mg/L		**0.12**	**0.10**	**0.08**	**0.11**	**0.05**
EN055: Ionic Balance									
^ Total Anions	----	0.01	meq/L		**514**	**524**	**486**	**595**	**380**
^ Total Cations	----	0.01	meq/L		**542**	**552**	**506**	**647**	**362**
^ Ionic Balance	----	0.01	%		**2.64**	**2.59**	**2.06**	**4.18**	**2.41**
EP033: C1 - C4 Hydrocarbon Gases									
Methane	74-82-8	10	µg/L		<10	<10	<10	<10	<10
Ethene	74-85-1	10	µg/L		<10	<10	<10	<10	<10
Ethane	74-84-0	10	µg/L		<10	<10	<10	<10	<10
Propene	115-07-1	10	µg/L		<10	<10	<10	<10	<10
Propane	74-98-6	10	µg/L		<10	<10	<10	<10	<10
Butene	25167-67-3	20	µg/L		<20	<20	<20	<20	<20
Butane	106-97-8	20	µg/L		<20	<20	<20	<20	<20
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		<60	<50	<50	<50	<50
EP080S: TPH(V)/BTEX Surrogates									
1.2-Dichloroethane-D4	17060-07-0	0.1	%		**124**	**113**	**116**	**86.6**	**84.4**
Toluene-D8	2037-26-5	0.1	%		**104**	**93.4**	**92.8**	**101**	**104**
4-Bromofluorobenzene	460-00-4	0.1	%		**117**	**105**	**103**	**109**	**110**

Analytical Results

Sub-Matrix: **WATER**				Client sample ID	**WQ2-16**	----	----	----	----
				Client sampling date / time	30-APR-2008 15:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*		**EB0805659-016**	**----**	**----**	**----**	**----**
EA005: pH									
pH Value	----	0.01	pH Unit		**9.20**	----	----	----	----
EA025: Suspended Solids									
^ Suspended Solids (SS)	----	1	mg/L		**6**	----	----	----	----
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L		<1	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L		<1	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		**2**	----	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L		**2**	----	----	----	----
ED040F: Dissolved Major Anions									
Sulphate as SO4 2-	14808-79-8	1	mg/L		**2**	----	----	----	----
ED045P: Chloride by PC Titrator									
Chloride	16887-00-6	1	mg/L		**7**	----	----	----	----
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		<1	----	----	----	----
Magnesium	7439-95-4	1	mg/L		<1	----	----	----	----
Sodium	7440-23-5	1	mg/L		**1**	----	----	----	----
Potassium	7440-09-7	1	mg/L		<1	----	----	----	----
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L		<0.0001	----	----	----	----
EG093T: Total Metals in Saline Water by ORC-ICPMS									
Aluminium	7429-90-5	10	µg/L		<10	----	----	----	----
Selenium	7782-49-2	2	µg/L		<2	----	----	----	----
Iron	7439-89-6	5	µg/L		<5	----	----	----	----
Arsenic	7440-38-2	0.5	µg/L		<0.5	----	----	----	----
Cadmium	7440-43-9	0.2	µg/L		<0.2	----	----	----	----
Chromium	7440-47-3	0.5	µg/L		<0.5	----	----	----	----
Cobalt	7440-48-4	0.2	µg/L		<0.2	----	----	----	----
Copper	7440-50-8	1	µg/L		<1	----	----	----	----
Lead	7439-92-1	0.2	µg/L		<0.2	----	----	----	----
Manganese	7439-96-5	0.5	µg/L		<0.5	----	----	----	----
Nickel	7440-02-0	0.5	µg/L		<0.5	----	----	----	----
Silver	7440-22-4	0.1	µg/L		<0.1	----	----	----	----
Zinc	7440-66-6	5	µg/L		**6**	----	----	----	----
EK055: Ammonia as N									
Ammonia as N	7664-41-7	0.010	mg/L		<0.010	----	----	----	----
EK059: Nitrite plus Nitrate as N (NOx)									
Nitrite + Nitrate as N	----	0.010	mg/L		<0.010	----	----	----	----

Analytical Results

Sub-Matrix: **WATER**				Client sample ID	WQ2-16	----	----	----	----
				Client sampling date / time	30-APR-2008 15:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*		**EB0805659-016**	**----**	**----**	**----**	**----**
EK061: Total Kjeldahl Nitrogen (TKN)									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		<0.1	----	----	----	----
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	0.1	mg/L		<0.1	----	----	----	----
EK067: Total Phosphorus as P									
Total Phosphorus as P	----	0.01	mg/L		<0.01	----	----	----	----
EN055: Ionic Balance									
^ Total Anions	----	0.01	meq/L		**0.26**	----	----	----	----
^ Total Cations	----	0.01	meq/L		**0.06**	----	----	----	----
EP033: C1 - C4 Hydrocarbon Gases									
Methane	74-82-8	10	µg/L		<10	----	----	----	----
Ethene	74-85-1	10	µg/L		<10	----	----	----	----
Ethane	74-84-0	10	µg/L		<10	----	----	----	----
Propene	115-07-1	10	µg/L		<10	----	----	----	----
Propane	74-98-6	10	µg/L		<10	----	----	----	----
Butene	25167-67-3	20	µg/L		<20	----	----	----	----
Butane	106-97-8	20	µg/L		<20	----	----	----	----
EP080/071: Total Petroleum Hydrocarbons									
C6 - C9 Fraction	----	20	µg/L		<20	----	----	----	----
C10 - C14 Fraction	----	50	µg/L		<50	----	----	----	----
C15 - C28 Fraction	----	100	µg/L		<100	----	----	----	----
C29 - C36 Fraction	----	50	µg/L		<50	----	----	----	----
EP080S: TPH(V)/BTEX Surrogates									
1.2-Dichloroethane-D4	17060-07-0	0.1	%		**119**	----	----	----	----
Toluene-D8	2037-26-5	0.1	%		**105**	----	----	----	----
4-Bromofluorobenzene	460-00-4	0.1	%		**116**	----	----	----	----

Surrogate Control Limits

Sub-Matrix: **WATER**		Recovery Limits (%)	
Compound	*CAS Number*	*Low*	*High*
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	80	120
Toluene-D8	2037-26-5	88	110
4-Bromofluorobenzene	460-00-4	86	115

Annex F

Raw Sedimentation Results

Table 1 Site locations and deployment dates

Site	Location		1st Deployment		2nd Deployment	
	Northing*	Easting*	Date Installed	Date Recovered	Date Installed	Date Recovered
1	8978712	486808	7/12/11	17/02/12	16/02/08	23/04/08
2	8974317	495505	7/12/11	14/02/12	13/02/08	25/04/08
3	8958765	486441	8/12/11	19/02/12	18/02/08	28/04/08
4	8954725	503445	8/12/11	14/02/12	13/02/08	26/04/08
5	8967060	498182	9/12/11	16/02/12	15/02/08	26/04/08
6	8969516	499301	9/12/11	16/02/12	15/02/08	22/04/08
7	8968162	499551	10/12/11	16/02/12	15/02/08	22/04/08

*Coordinates are in WGS84 (Zone 55)

Table 2 Sedimentation rate raw data - 1st deployment

Site	Replicate	Determination of Sedimentation Weight				Acid Digestion - % Carbonate							Sedimentation Rate			
		Volume of Sample (mL)	Initial Filter WT (g) [A]	Filter WT (g) after drying @ 105oC [B]	WT (g) of Sed [C] [C]=[B]-[A]	Sed port'n [C] WT (g) used for Digest'n [D]	Initial WT (g) of filter paper [E]	WT (g) of filter after drying at 105oC [F]	WT (g) of non-Carbonate [G] [G]=[F]-[E]	Adj. WT (g) non-Carbonate [H] [H]=[C]*[G]/[D]	WT (g) of Carbonate [I] [I]=[C]-[H]	Per cent Carbonate = [I]/[C] x 100	Total Rate (g/day)	Total Rate (mg/cm2/day)	% carbonate	Non CaCO3 Rate (mg/cm2/day)
1	1	1030	4.31	15.30	10.99	1.77	0.67	1.48	0.81	5.05	5.94	54.04	0.15	7.19	54.0	3.30
	2	1110	4.67	15.05	10.38	1.44	0.67	1.25	0.58	4.19	6.18	59.58	0.14	6.79	59.6	2.74
	3	1180	4.57	16.47	11.90	1.48	0.66	1.29	0.62	5.01	6.89	57.89	0.17	7.78	57.9	3.28
	4	1315	4.81	13.00	8.19	1.65	0.66	1.23	0.56	2.79	5.41	66.00	0.11	5.36	66.0	1.82
2	1	1230	4.66	15.54	10.88	1.85	0.61	2.06	1.45	8.52	2.36	21.70	0.16	7.39	21.7	5.79
	2	1510	4.74	10.82	6.07	1.98	0.67	2.20	1.54	4.70	1.37	22.63	0.09	4.12	22.6	3.19
	3	1100	4.84	15.55	10.71	1.53	0.67	1.84	1.17	8.18	2.54	23.68	0.15	7.28	23.7	5.55
	4	1380	4.66	14.87	10.21	1.72	0.67	1.94	1.27	7.55	2.66	26.03	0.15	6.93	26.0	5.13
3	1	1090	4.30	15.98	11.68	1.80	0.67	0.93	0.26	1.67	10.01	85.69	0.16	7.54	85.7	1.08
	2	1500	4.60	14.17	9.57	1.88	0.66	0.96	0.30	1.50	8.07	84.34	0.13	6.17	84.3	0.97
	3	1460	4.52	15.17	10.65	1.72	0.68	0.88	0.20	1.25	9.40	88.28	0.15	6.87	88.3	0.80
	4	1450	4.81	16.81	12.00	1.78	0.67	0.96	0.29	1.94	10.05	83.79	0.16	7.74	83.8	1.25
4	1	1040	4.52	21.90	17.38	1.72	0.67	1.21	0.54	5.45	11.93	68.66	0.25	11.95	68.7	3.74
	2	970	4.85	21.27	16.42	1.80	0.67	1.28	0.61	5.55	10.87	66.18	0.24	11.29	66.2	3.82
	3	1090	4.93	23.91	18.98	1.59	0.67	1.15	0.48	5.76	13.22	69.65	0.28	13.05	69.6	3.96
	4	820	4.81	23.39	18.58	1.62	0.67	1.19	0.53	6.03	12.55	67.53	0.27	12.77	67.5	4.15
5	1	1430	4.94	9.06	4.13	1.53	0.67	1.60	0.93	2.51	1.61	39.08	0.06	2.81	39.1	1.71
	2	1330	4.94	8.41	3.48	1.67	0.67	1.71	1.04	2.17	1.31	37.66	0.05	2.37	37.7	1.48
	3	1145	4.38	7.72	3.34	1.54	0.67	1.61	0.94	2.02	1.32	39.40	0.05	2.28	39.4	1.38
	4	1080	4.61	8.19	3.58	1.70	0.67	1.70	1.03	2.16	1.42	39.56	0.05	2.44	39.6	1.47
6	1	1400	4.78	109.20	104.42	1.60	0.68	1.41	0.73	47.67	56.75	54.35	1.51	71.27	54.4	32.53
	2	1190	4.45	125.35	120.90	1.92	0.67	1.59	0.91	57.52	63.38	52.42	1.75	82.52	52.4	39.26
	3	700	4.65	114.49	109.84	1.88	0.67	1.57	0.90	52.72	57.11	52.00	1.59	74.97	52.0	35.99
	4	1150	4.78	30.49	25.71	1.86	0.67	1.62	0.94	13.03	12.68	49.33	0.37	17.55	49.3	8.89
7	1	1150	4.74	34.66	29.92	1.89	0.67	1.57	0.90	14.25	15.66	52.35	0.44	20.60	52.4	9.81
	2	1290	4.39	55.75	51.35	1.65	0.67	1.48	0.82	25.30	26.05	50.73	0.75	35.35	50.7	17.42
	3	670	4.45	28.37	23.91	1.80	0.68	1.65	0.97	12.83	11.08	46.34	0.35	16.46	46.3	8.83
	4	880	4.51	69.54	65.03	1.87	0.66	1.62	0.96	33.26	31.77	48.85	0.95	44.77	48.8	22.90

Table 3 Sedimentation rate raw data - 2nd deployment

Site	Replicate	Determination of Sedimentation Weight				Acid Digestion - % Carbonate							Sedimentation Rate			
		Volume of Sample (mL)	Initial Filter WT (g) [A]	Filter WT (g) after drying @ 105oC [B]	WT (g) of Sed [C] [C]=[B]-[A]	Sed port'n [C] WT (g) used for Digest'n [D]	Initial WT (g) of filter paper [E]	WT (g) of filter after drying at 105oC [F]	WT (g) of non-Carbonate [G] [G]=[F]-[E]	Adj. WT (g) non-Carbonate [H] [H]=[C]*[G]/[D]	WT (g) of Carbonate [I] [I]=[C]-[H]	Per cent Carbonate = [I]/[C] x 100	Total Rate (g/day)	Total Rate (mg/cm2/day)	% carbonate	Non CaCO3 Rate (mg/cm2/day)
1	1	660	1.29	16.72	15.43	15.43	9.94	18.74	8.80	8.80	6.63	42.96	0.23	10.85	42.96	6.19
	2	700	1.29	14.59	13.30	13.30	9.79	16.19	6.41	6.41	6.90	51.84	0.20	9.36	51.84	4.51
	3	700	1.29	14.33	13.05	13.05	9.69	17.53	7.84	7.84	5.21	39.94	0.19	9.18	39.94	5.51
	4	750	1.29	15.34	14.05	14.05	9.35	17.67	8.32	8.32	5.74	40.81	0.21	9.89	40.81	5.85
2	1	760	1.24	13.49	12.24	12.24	10.17	18.84	8.67	8.67	3.57	29.18	0.17	8.01	29.18	5.67
	2	750	1.25	6.21	4.96	4.96	9.10	12.95	3.85	3.85	1.11	22.34	0.07	3.25	22.34	2.52
	3	700	1.19	16.18	15.00	15.00	13.64	25.50	11.86	11.86	3.14	20.93	0.21	9.82	20.93	7.76
	4	750	1.20	16.00	14.80	14.80	8.31	18.70	10.39	10.39	4.41	29.79	0.21	9.68	29.79	6.80
3	1	650	1.25	7.06	5.81	5.81	9.25	10.36	1.11	1.11	4.70	80.91	0.08	3.91	80.91	0.75
	2	590	1.25	7.48	6.23	6.23	9.73	11.73	2.00	2.00	4.23	67.88	0.09	4.19	67.88	1.35
	3	600	1.19	6.42	5.24	5.24	9.73	10.78	1.05	1.05	4.19	79.98	0.07	3.52	79.98	0.71
	4	620	1.21	6.63	5.42	5.42	9.29	10.27	0.98	0.98	4.44	81.91	0.08	3.65	81.91	0.66
4	1	610	1.26	1.45	0.19	0.19	9.98	10.02	0.04	0.04	0.15	77.87	0.00	0.12	77.87	0.03
	2	650	1.23	2.90	1.67	1.67	9.71	10.00	0.30	0.30	1.38	82.34	0.02	1.08	82.34	0.19
	3	600	1.19	1.89	0.70	0.70	13.58	13.74	0.16	0.16	0.54	76.64	0.01	0.45	76.64	0.11
	4	590	1.19	1.74	0.54	0.54	9.15	9.27	0.12	0.12	0.42	77.67	0.01	0.35	77.67	0.08
5	1	690	1.26	3.92	2.67	2.67	9.06	10.73	1.67	1.67	0.99	37.28	0.04	1.77	37.28	1.11
	2	660	1.22	3.84	2.62	2.62	9.73	11.34	1.61	1.61	1.01	38.55	0.04	1.74	38.55	1.07
	3	650	1.19	3.66	2.47	2.47	9.09	10.61	1.52	1.52	0.95	38.34	0.03	1.64	38.34	1.01
	4	570	1.20	3.88	2.68	2.68	13.69	15.38	1.68	1.68	1.00	37.18	0.04	1.78	37.18	1.12
6	1	700	1.25	16.25	15.00	15.00	9.94	15.15	5.21	5.21	9.79	65.28	0.22	10.55	65.28	3.66
	2	710	1.22	18.87	17.65	17.65	9.53	20.50	10.97	10.97	6.68	37.84	0.26	12.42	37.84	7.72
	3	640	1.18	12.79	11.61	11.61	9.74	14.05	4.31	4.31	7.30	62.85	0.17	8.17	62.85	3.03
	4	570	1.19	12.79	11.60	11.60	12.70	17.23	4.53	4.53	7.07	60.91	0.17	8.16	60.91	3.19
7	1	630	1.25	1.93	0.68	0.68	12.59	12.98	0.38	0.38	0.30	43.69	0.01	0.48	43.69	0.27
	2	650	1.22	5.66	4.43	4.43	13.87	16.16	2.29	2.29	2.14	48.36	0.07	3.12	48.36	1.61
	3	650	1.18	14.70	13.52	13.52	9.29	15.76	6.48	6.48	7.04	52.08	0.20	9.51	52.08	4.56
	4	650	1.19	1.38	0.19	0.19	13.61	13.65	0.03	0.03	0.16	82.85	0.00	0.14	82.85	0.02

Annex G

Marine Macrobenthic Infauna Analysis

MACROFAUNA ANALYSIS OF COFFEY PNG SURVEY MACROBENTHIC SAMPLES COLLECTED DECEMBER 2007

REPORT TO
COFFEY CONSULTING PTY LTD

DR. JOHN MOVERLEY

JANUARY 24 2008

TABLE OF CONTENTS

1 EXECUTIVE SUMMARY

Eight macrofauna samples were collected from an unknown location in Papua New Guinea (PNG) by Coffey Consulting Pty Ltd. These samples were shipped to ALS in Brisbane then transferred to Dr John Moverley in Melbourne to extract the macrofauna, and count the animals present.

Macrofauna were identified to the lowest possible taxonomic level Dr Moverley could achieve without referral to reference material. The material has been retained and lower level taxonomic identifications can be undertaken if required.

Sediments were shell debris, medium grained sand and coral rubble. Organic content ranged from high to above expected and mostly consisted of seagrass particles with some pieces of leaf blades being 30 mm long. These large pieces usually had many bryozoan colonies associated with them. These have not been included in the counting because they were considered to be fouling organisms that had arisen in the seagrass beds and not where the samples were collected.

The samples were rich in crustaceans and polychaete worms. Numbers of molluscs were very low considering the numbers of polychaetes and crustaceans collected and probably indicate that it is not a “typical” benthic habitat.

2 INTRODUCTION

A survey of deep-sea marine sediments off the Papua New Guinea province of Madang was undertaken by ENESAR Consulting Pty Ltd. Sediment samples containing macrofauna were preserved in the field with 70 % ethanol and shipped to ALS in Brisbane. The macrofauna samples were then forwarded to Melbourne. As well as being preserved the samples were kept refrigerated in line with the protocols for other samples that had been collected and shipped at the same time.

The macrofauna in the samples were extracted by Dr Moverley using standard procedures.

3 METHODOLOGY

On arrival in Melbourne samples were washed through a 0.5 mm mesh sieve and placed in a fresh solution of 75% ethanol / tap water.

Sediments were shell debris, medium grained sand and coral rubble. Organic content ranged from high to above expected and mostly consisted of seagrass particles with some pieces of leaf blades being 30 mm long. These large pieces usually had many bryozoan colonies associated with them. These have not been included in the counting because they were considered to be fouling organisms that had arisen in the seagrass beds and not where the samples were collected.

At the time of sorting, the samples were again washed through a 0.5 mm sieve. The material was placed into a sorting tray and the organic material and other light material washed off by agitating the sample and pouring off the floating material. This was sorted under a dissecting microscope. The denser material that was retained in the tray was sorted separately under a dissecting microscope.

Any animals found in the samples were placed in vials. Separate vials were used for the common phyla (crustacea, worms and molluscs) and another vial for the other animals.

After all eight samples had been sorted the sets of vials for each phylum were identified together. This ensured that identifications were identical across all eight samples so that if a taxon is not recorded in a sample then it was absent and has not been included at a higher taxonomic level.

Identification and counts were made under a dissecting microscope. Identifications were to the lowest taxonomic level that Dr Moverley could make without use of reference material. This has resulted in some taxa containing multiple species and others only one species. Species level identifications could be made in the future if required.

4 RESULTS

Counts are presented in Appendix A.

Seven hundred and twenty five animals were recovered, and even at the high level of taxonomic identifications used, it is apparent there is very high diversity exists with 68 different taxa being identified.

Many taxa appear to be numerically dominant in samples from one site and absent or in low numbers in samples from other sites. This is common in

samples that have been collected from a range of environments, over a wide area or a range of depths.

The samples were dominated by polychaete worms and crustaceans. The number of molluscs recovered was exceptionally low compared to other macrofauna samples worked on at this laboratory.

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APPENDIX A

MACROFAUNA NUMBERS

Table B1 Macrofauna Numbers of

	STATION NUMBER							
Taxa	Stn 1	Stn 2	Stn 3	Stn 4	CF 7	Sed 3	Sed 2	Sed 1
Sponge			2					
Anthozoa	1		1				1	1
Hydrozoa	1		1					
Nematode							1	
Nemertean		1		2	2	2	1	3
Oligochaete	1				2			
Polychaete		7		1	2	2	1	
Capitellidae		18			15		2	1
Cirratulidae		4		2	2	2	2	
Cossuridae				1		2	1	4
Dorvilleidae				1	1		2	
Eunicidae	1				2	2	1	
Glyceridae					2		1	
Lumbrineridae	2	2		2	6	3	2	1
Magelonidae				4		2	2	6
Nephtyidae	2			3		1	1	1
Nereididae	2	1						1
Onuphidae		1						
Opheliidae	1	6		8	1			
Pectinariidae	4						1	
Pilargidae				1		1		1
Poecilochaetidae					1		1	
Scalibregmatidae		2				1	1	
Sigalionidae	2							
Spionidae		8	8	28	42	13	9	10
Sternaidae						6		
Syllidae		2	1	1	2	1		
Terebellidae		1		2	2			
Trichobranchidae				1				
Crustaceans								
Harpacticoidea	2	7			2			
Leptostracan						1	1	
Cumacea	4	7	1			6	11	
Ostracoda	4	7		1	2	1	5	1
Apseudidae	1	4			7	6	6	8
Tanaidae		5	1	7	2	2	3	
Pagurapseudidae					1		9	
Isopoda			1					
Anthuridae		2			1			
Asellota		1						

	STATION NUMBER							
Taxa	Stn 1	Stn 2	Stn 3	Stn 4	CF 7	Sed 3	Sed 2	Sed 1
Gnathiidae		2						2
Amphipoda	1	7			2		6	
Caprellidea		1						
Ampeliscidae		3			1		2	
Corophiidae		32	2		6	1	3	5
Paracorophium		3	1		4		1	3
Melitidae	2	5	1			5	35	22
Oedicerotidae			1					
Phoxocephalidae	1	1	11	1	2	3	3	6
Platyischnopidae			5					
Decapodia			1	1	1			
Caridea			2				1	
Alpheidae			1					
Ogyrides delli						1		
Galatheidae			2	1				
Brachyura	1							1
Leucosiidae				1	1			
Pycnogonids			16					
Bivalves	2	3		1	1	1		1
Solenidae	1			2				
Gastropods	5	1	2			1		1
Nassarius	1							
Dentalium	1			1				
Phoronids						1		3
Ophiuroid	1	5		2	5			
Echinoidea	1				2			
Holothuroid		1			1			
Unknown Worm					2	3		1
TOTAL NUMBER	45	150	61	75	125	70	116	83

Annex H

Detailed Observations – Pipeline Route Survey

Pipeline Route Option Number	Site Number	Easting	Northing	Date	Time	Depth to Seafloor (m)	Description
6	12	492333	8790035	21/4/08	10:30	24	flat muddy bottom, lots of burrows, something swam away from the site (need to determine what it is)
	14	490389	8970506	21/4/08	11:05	26	flat muddy bottom, lots of burrows
	16	488451	8970996	21/4/08	11:25	30	flat muddy bottom, lots of burrows
	18	486977	8972292	21/4/08	11:45	31	flat muddy bottom, lots of burrows
	22	484347	8975287	21/4/08	12:20	33	flat muddy bottom, lots of burrows
	26	481604	8978182	21/4/08	12:45	35	flat muddy bottom, lots of burrows
	10	494081	8969149	21/4/08	14:54	21	flat muddy bottom, lots of burrows
	8	495133	8967451	21/4/08	15:17	21	flat muddy bottom, lots of burrows
1d	91	488535	8976604	23/4/08	11:48	32	flat muddy bottom, lots of burrows
	93	486536	8976547	23/4/08	12:10	25	flat muddy bottom, lots of burrows
	95	484647	8977056	23/4/08	12:30	7	flat muddy bottom, lots of burrows
1c	79	481818	8971183	24/4/08	9:33	37	flat muddy bottom with patches of shelly grit, clear visibility, lots of burrows, couple of ripples and possibly a sea tulip present
	77	482415	8969274	24/4/08	9:48	42	flat muddy bottom with not as many burrows, clear visibility
	76	482725	8968324	24/4/08	10:00	45	flat muddy bottom with lots of burrows, clear visibility, patches of 10-12 burrows together (maybe colonies), big burrows and lots of little ones
	75	483362	8967582	24/4/08	10:12	45	flat muddy bottom, small patches of burrows (heaps) followed by areas with only a few burrows
	74	484268	8967159	24/4/08	10:23	44	flat muddy bottom with lots of burrows, clear visibility, burrows clumped together like other sites
	72	486096	8966347	24/4/08	10:40	42	flat muddy bottom with lots of burrows, clear visibility, burrows clumped together less than other sites, more sediment in the water, darker film on the substrate
	70	488000	8965797	24/4/08	11:00	38	flat muddy bottom with burrows, some sediment suspension
1c	69	488992	8965673	24/4/08	11:15	47	flat muddy bottom, burrows are scarce, something sticking up out of the burrow, fewer and smaller burrows
	68	489984	8965550	24/4/08	11:35	35	flat muddy bottom with burrows, leaf, tube worm (?), lots of patches
	X	488451.5	8968348.6	24/4/08	11:57	6-7	coral rubble, several sponges, small boulders, rock coming up with coral, 3 fish (including surgeon?)
	Y	488323.4	8968145.9	24/4/08	12:10	8	small fish, coral rubble, volcanic boulders (?), sand patches, surgeon fish, small patches of encrusting coral, whip coral, tube worm, wrasse

Pipeline Route Option Number	Site Number	Easting	Northing	Date	Time	Depth to Seafloor (m)	Description
1b	64	486761	8970864	24/4/08	12:33	32	flat sandy bottom, absence of emergent fauna, sparse burrows, little animal in the first burrow
	62	487379	8968962	24/4/08	12:50	32	flat sandy bottom, worm sticking out of burrow
	Z	488341.6	8968256.45	24/4/08	13:42	10	igneous rock, rubble, small quantity of coral, whip coral (or old branch)
	60	488007	8967064	24/4/08	14:15	35	flat sandy bottom
	59	488643	8966317	24/4/08	14:27	37	flat sandy bottom
	58	489593	8966014	24/4/08	14:40	37	flat sandy bottom
	56	491531	8965522	24/4/08	15:00	31	flat sandy bottom
Proposed Shipping Access Channel	SC1	494868	8972440	25/4/08	11:53	15	flat muddy bottom with brown film, large burrows, visibility clearer than yesterday, leaf
	SC2	493504	8971192	25/4/08	12:08	19	flat muddy bottom with lots of burrows, brown film on benthic surface, bits of dead shell, leaf, snail trails (?)
Proposed Shipping Access Channel (continued)	SC3 (start)	495374	8969711	25/4/08	12:45	10	rubble substrate, big clumps of coral rubble, low cover of live coral present (sea whips, gorgonian, acropora and soft corals), fish swimming through the area (not reef fish), no burrows, mound area, surgeon and butterfly fish observed, moving into sandy substrate
	SC3 (end)	495324	8969823	25/4/08	-	-	-
	SC4	496239	8969623	25/4/08	13:00	4.5	coral rubble bottom, fish, whip seaweed, mainly dead coral, feather star, hard rock substrate, many schools of, damsel fish (?)
	SC5	497525	8970173	25/4/08	13:17	14	flat sandy muddy bottom with lots of burrows and brown bacterial mat (generally means muddy rather than sandy), tubes (?), visibility lower than previous sites, sea pen observed (?)
Sensitivities between pipeline route option 1b and 6	PS1	503472	8954747	27/4/08	9:18	24	rubble bottom (open bottom), live coral everywhere (fungiids?), turbineraria (?), soft corals, halimeda, gets shallower
	PS2	489256	8966991	27/4/08	9:33	32	sandy muddy flat bottom with lots of burrows, some sort of trails (snails?), something on the benthic surface
	PS3	490443	8968805	27/4/08	9:54	20	sandy muddy flat bottom with lots of burrows, something tall sticking out of the seafloor
	PS4	492008	8968334	27/4/08	10:08	6.5	rubble bottom, fish, surgeon fish (?), live coral (acropora?), moving into sand and getting deeper
	PS5	491929	8966928	27/4/08	10:23	7	rubble bottom, very low live coral cover (acropora, porities), fish, large coral bommie, live encrusting coral, surgeon fish, moving towards sandy area
Sensitivities between pipeline route option 1b and 6	PS6	493904	8966891	27/4/08	10:38	11	rubble bottom, fish, surgeon fish, very low percentage of live coral cover, whip coral, clam (?), coral bommie, fan coral (gorgonian), getting deeper and moving into sand

Pipeline Route Option Number	Site Number	Easting	Northing	Date	Time	Depth to Seafloor (m)	Description
1b PURPLE	55	492500	8965276	27/4/08	10:55	29	flat muddy bottom with lots of burrows
	54	493493	8965200	27/4/08	11:06	25	flat muddy bottom with lots of burrows, something lying on the seafloor
	52	495493	8965200	27/4/08	11:31	23	flat muddy bottom with lots of burrows
	50	497493	8965199	27/4/08	12:07	20	flat muddy bottom with scarce burrows, better visibility than #7
	A	493183	8965142	27/4/08	11:15	7	rubble bottom, live coral (acropora), surgeon fish, getting shallower
	B	498740	8965263	27/4/08	12:17	8	moving from sand to rubble (edge of the reef), live coral, fish, whip coral, soft coral/sponge (?), surgeon fish
6 RED	7	495666	8966607	27/4/08	11:46	22	flat muddy bottom, clouds of sediment
	5	497390	8965704	27/4/08	12:00	18	flat muddy bottom with lots of burrows, water very dirty
Additional sites south of the pipeline route option 1c	Idihi Island Site 1	486428	8959471	28/4/08	10:51	12	edge of the reef, fishes, live coral (medium to high coral cover), broken coral rubble, fusilliers fish, moved up to 3m water depth, coral bommies
	One	492511	8962665	28/4/08	11:37	10	reef, fishes (angel, fusilliers, wrasse, surgeon), medium live coral cover (soft, staghorn/acropora), rubble, moving into sand with burrows
	Two	495112	8962564	28/4/08	11:54	13	sandy bottom with occassional coral rubble, live coral (acropora plates, staghorn, soft, fan, whip), skinny sponges, fish (surgeon, bream), moving into sand and getting deeper
Additional sites south of the pipeline route option 1c	Three	498638	8967307	28/4/08	14:39	4	seagrass (stringy) or seaweed, sandy bottom, similar to a fringing reef, fishes, sargassum, damsel fishes, occassional live coral but not much dead coral, lots of shrimp mounds, very shallow, protected