Hydrobiology

PNG LNG Project: LNG Facilities

Aquatic Fauna Impact Assessment

October 2008

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EXECUTIVE SUMMARY

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.

The 'downstream' segment of this project describes the project components from the Omati landfall in the Gulf of Papua, to the LNG Facility in an area known as Portion 152, near Port Moresby. Portion 152 is located within the Konebada Petroleum Park, an area proposed for development of various petroleum industry infrastructure. This report deals with freshwater and estuarine environments in Portion 152 only.

The objectives of this study were to:

- Review any existing data and collect new baseline data that will assist with characterising aquatic fauna and habitats occurring in, and adjacent to, the areas potentially affected by the project;

- Identify significant species, including known rare species and those previously undescribed, occurring in and adjacent to the areas potentially affected by the project;

- Use the above information to predict potential impacts, based on likelihood of impact, relative exposure to the impact by rare or undescribed species and the sensitivity of particular species or their critical habitats to impacts potentially associated with the project; and

- Put forward recommendations that will aid in mitigating potential impacts.

The freshwater environment can be described as a dry-tropical environment and there are three catchments represented in the project area: Vaihua River, North Vaihua River and Karuka Creek (known locally as Kauka Creek), which itself is a tributary of Mokeke Creek. Dry conditions predominate in Portion 152 and at the time of sampling, many watercourses were dry and freshwater habitats existed as remnant, isolated pools. The freshwater fauna of the project area consisted of just four species of fish and two species of prawn. Some sites had no species recorded.

There are two estuaries of interest in the project area: the estuary of the Vaihua River and a small estuary associated with North Vaihua River. During the predominantly dry conditions, freshwater input to the estuaries is negligible and the estuaries exist as coastal tidal inlets. Aquatic fauna in the estuaries was considerably more diverse than the freshwater habitats, and a total of 30 species of fish and 5 species of macrocrustacea (including the mud crab) were recorded. Local people were observed to collect aquatic resources from the estuaries and no resource utilisation was observed in the freshwater environment.

The aquatic species recorded in this study are common and widespread throughout southern Papua New Guinea. No rare or threatened species were recorded.

The potential impacts of the development of the LNG Facility are assessed herein. The area identified for direct construction works is located within the North Vaihua River catchment, a relatively small catchment compared to the Vaihua River catchment to the south and Karuka River catchment to the northeast. This fact minimises the exposure of the aquatic habitats to the development activities. Furthermore, the predominance of dry conditions in the area creates an opportunity for construction (the phase of highest potential impact) to be carried out with relatively low potential for impacts related to erosion and runoff. The LNG Facility construction site is separated from estuaries by vegetation buffers and the project is expected to have little influence on estuaries. The potential impacts to estuaries from the on-land elements of the project arise from sediment/pollutants/spills in freshwater construction areas being transported downstream. However, the predominance of dry conditions and lack of connectivity between these two environments for most of the time dictates that this likelihood is very low.

The main potential source of impact to estuaries arises from the construction of the combined materials offloading facility/LNG Jetty. At the time of writing, modelling has shown that the presence of the materials offloading facility and LNG jetty (a solid structure in the current design) has the potential to alter near-shore hydrological processes and thus longshore sediment transport processes. This has the potential to cause sediment accretion on the south side of the jetty, possibly leading to blockage of the estuary mouth. At the time of writing, a number of engineering solutions are being investigated by the proponent and a commitment has been made to ensure that the final design of the facility will not cause significant sediment accretion and estuary blockage.

The Portion 152 area has a long history of anthropogenic disturbance and generally, the freshwater environments adjacent to the road corridor and proposed construction sites are considered to be non-pristine and of lower environmental value than the habitats further towards the headwaters of the two river systems. However, there are processes that are believed to be important for the maintenance of ecosystem functioning in Portion 152. The key ecological processes considered to relevant to this project are:

1. The occurrence of dry-weather freshwater refuges, in the form of isolated pools, that are vulnerable to water quality or direct impacts as there is negligible flushing capacity and no opportunity for mobile fauna to relocate should impacts occur.

2. Sporadic wet conditions that are believed to trigger breeding, movement and redistribution of freshwater species through the system and contribute freshwater flows to the estuary. This process is vulnerable to the creation of flow blockages/re-routing and structures that may create a barrier to the fish movement.

With adequate mitigations in place, impacts to these ecosystem processes are expected to be very low.

PNG LNG Project: DOWNSTREAM

Aquatic Fauna Impact Assessment

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1 INTRODUCTION

1.1 Background

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 1-1 shows a schematic of facilities and pipelines:

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;
    - 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.

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.

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.

This report deals with the LNG Facilities area only. A summary of the project components associated with the LNG Facilities area are:

- LNG Plant within an area known as Portion 152;
- Pipelaying from the ocean landfall to connect with the LNG Plant;
- LNG 'Offsite' infrastructure including LNG and condensate tanks, flare and Materials Offloading Facility;
- LNG Jetty, linking the LNG Plant with the export berths;
- Export berth, at the terminal end of the LNG Jetty where tankers will load LNG;
- Condensate berth, located along on the LNG Jetty;
- Associated infrastructure, including staff camp, offices, waste management systems and new roads.

The present report deals only with the components of the project related to the LNG Facilities (see Figure 2-1) and road upgrades, and not the area associated with the coastal environment of the Omati River Landfall in the Gulf of Papua. Coffey Natural Systems contracted Hydrobiology to undertake aquatic ecological studies for the LNG Facilities area to inform an aquatic fauna impact assessment and the present report is designated as

Hydrobiology 2008b. The upstream aquatic fauna report is Hydrobiology 2008a. Hydrobiology was also contracted to undertake baseline water and sediment quality sampling in the LNG Facilities area, which will not be covered in this report, but presented in a separate volume (Hydrobiology 2008d).

1.2 Objectives

The objectives of this study were to:

- Review any existing data and collect new baseline data that will assist with characterising aquatic fauna and habitats occurring in, and adjacent to, the watercourses potentially affected by the project;
- Identify significant species, including known rare species and those previously undescribed, occurring in and adjacent to the watercourses potentially affected by the project;
- Use the above information to predict potential impacts, based on likelihood of impact, relative exposure to the impact of rare or undescribed species and the sensitivity of particular species or their critical habitats to impacts potentially associated with the project; and
- Put forward recommendations that will aid in mitigating potential impacts.

There is a freshwater component and an estuarine component to this study. For the estuarine component, Hydrobiology's brief excluded intertidal mangrove habitats and organisms. Therefore, within the estuary, this report deals with habitats and organisms residing within the estuary channel up to the mangrove fringe.

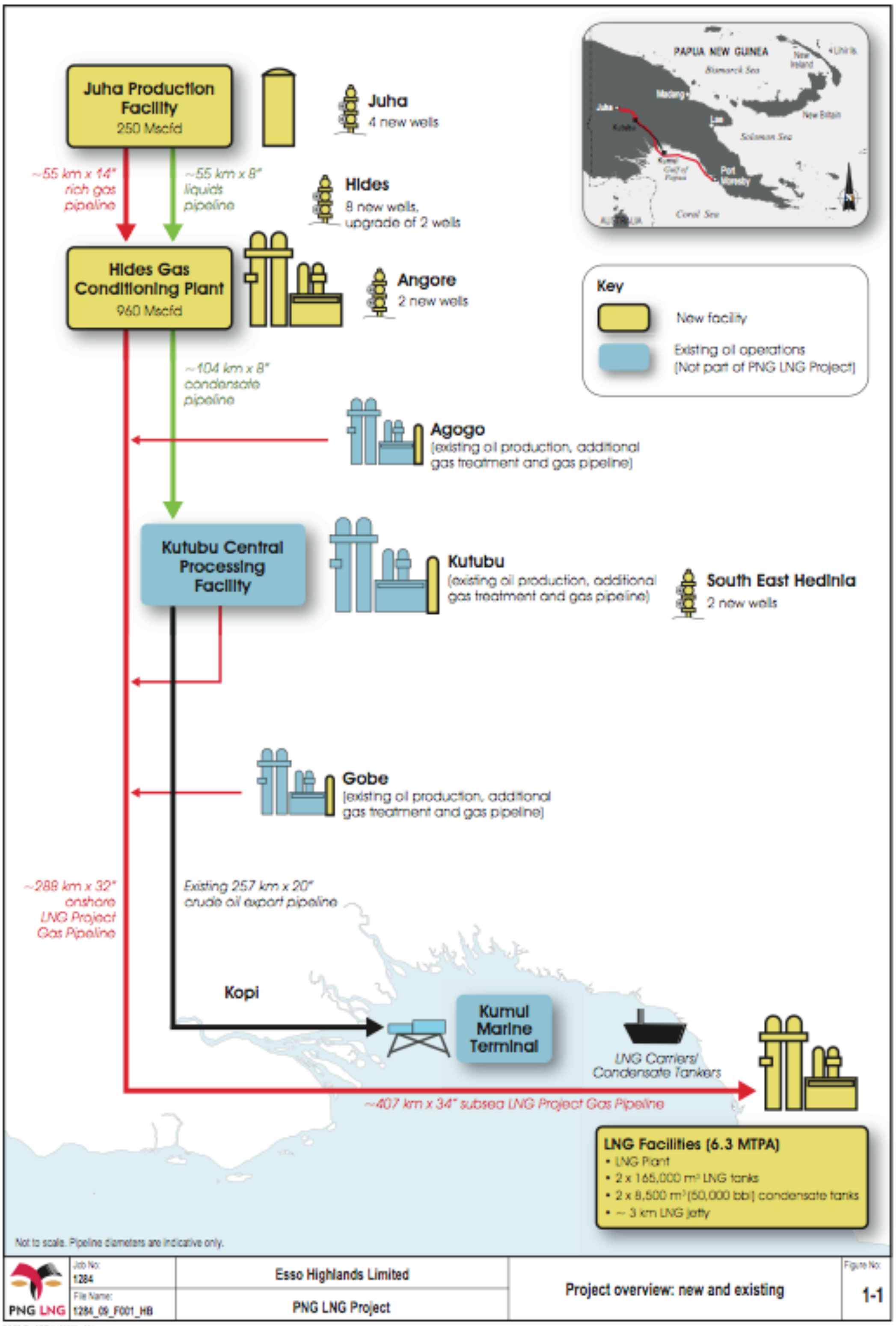


Figure 1-1 Project overview - new and existing

2 METHODS

2.1 Study Sites

Sites for this study comprised estuarine habitats and freshwater habitats in the LNG Facilities area and surrounding environs. Figure 2-1 shows the location of sampling sites in each of these study areas. GPS coordinates for sampling sites are listed in Table 2-1.

Estuary sites were located in the estuary of the Vaihua River, North Vaihua River estuary and Karuka Creek (known locally as 'Kauka Creek') estuary. For the Vaihua and North Vaihua estuaries, access was via boat, which travelled from Port Moresby Harbour to Caution Bay. The team then entered the estuaries via dinghy. This provided some difficulty as at the time of sampling there were low tides in the middle of the day. Further, at the time of sampling, the region was having 'spring tides' (high tides very high and low tides very low). This meant that broad, exposed sandbars appeared at the entrance to the estuaries on low tide, making the sea-entrance to the estuaries unnavigable by dinghy for about 2 hours either side of the low tide. The Karuka Creek estuary was accessed by banana boat from the village of Lea Lea. Lea Lea is located inside the mouth of the estuary and so access was unhindered by tides. Freshwater sites were accessed by vehicle.

Table 2-1 Sampling site coordinates

Site	Location	Location (UTM, 55L)	
		East	North
VAI1	North Vaihua Estuary	501107	8967002
VAI2	North Vaihua Estuary	500699	8966722
VAI3	Vaihua River Estuary	502042	8965996
VAI4	Vaihua River Estuary	501172	8966478
VAI5	Vaihua River (freshwater)	507069	8964504
VAI6	Vaihua River (freshwater)	504611	8963354
VAI7	Vaihua River (freshwater)	503128	8966700
VAI8	North Vaihua River (freshwater)	501646	8968618
KAR1	Karuka Creek Estuary	500461	8972942
KAR2	Karuka Creek Estuary	499910	8974226
KAR3	Karuka Creek (freshwater)	504985	8968896
KAR4	Karuka Creek (freshwater)	504818	8967738
KAR5	Karuka Creek (freshwater)	502969	8971092

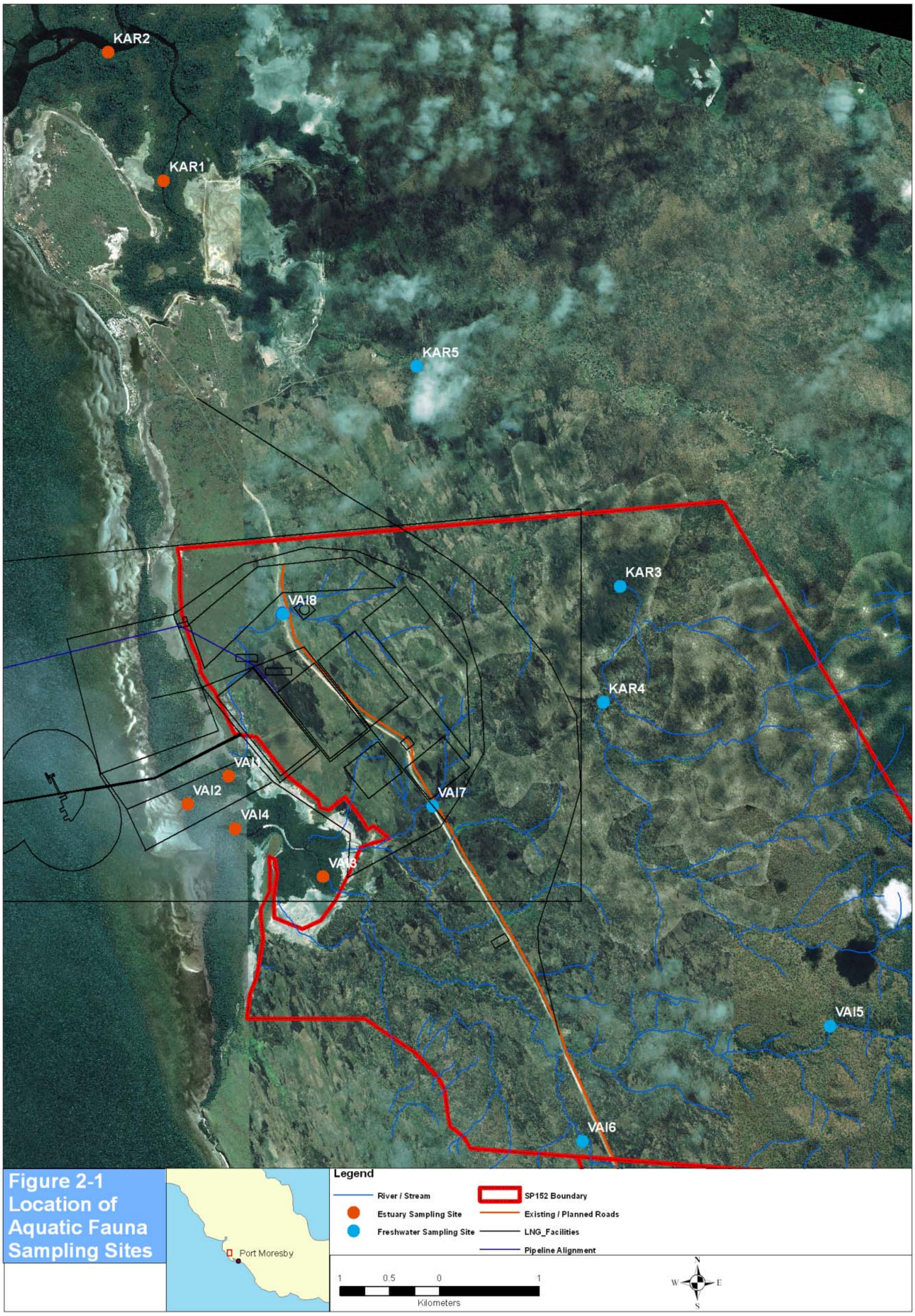


Figure 2-1 Location of aquatic fauna sampling sites

Table 2-2 lists the sampling methods used at each site and these methods are described in more detail in Sections 2.2 and 2.3. Methods used in this study were based on standard industry practice for aquatic fauna sampling in Australia and were similar to those shown to be successful in other studies of PNG aquatic fauna undertaken by Hydrobiology over some 20 years. In addition to the aquatic fauna sampling, a water and sediment sampling study was undertaken concurrently. The water and sediment sampling program will be discussed in a separate report (Hydrobiology 2008d).

Sampling was conducted from 30 May to 8 June 2008.

Table 2-2 Sampling methods employed at each site

Area	Site	Habitat	Fish Sampling	Macroinvertebrates	Water/ Sediment Sampling
North Vaihua Estuary	VAI1	Mangrove-lined estuary	Gill nets, fyke nets	Van Veen grab and sieving to 500 µm	Yes
North Vaihua Estuary	VAI2	Mangrove-lined estuary	Gill nets, fyke nets	Van Veen grab and sieving to 500 µm	Yes
Vaihua River Estuary	VAI3	Mangrove-lined estuary	Gill nets, fyke nets	Van Veen grab and sieving to 500 µm	Yes
Vaihua River Estuary	VAI4	Mangrove-lined estuary	Gill nets, fyke nets	Van Veen grab and sieving to 500 µm	Yes
Vaihua River (freshwater)	VAI5	Freshwater pool	Visual observation	No	Yes
Vaihua River (freshwater)	VAI6	Freshwater pool	Electrofishing/seine net	No	Yes
Vaihua River (freshwater)	VAI7	Freshwater pool	Electrofishing/seine net	No	No
North Vaihua River (freshwater)	VAI8	Freshwater pool	Visual observation	No	No
Karuka Creek Estuary	KAR1	Mangrove-lined estuary	Gill nets, fyke nets	Van Veen grab and sieving to 500 µm	Yes
Karuka Creek Estuary	KAR2	Mangrove-lined estuary	Gill nets, fyke nets	Van Veen grab and sieving to 500 µm	Yes
Karuka Creek (freshwater)	KAR3	Freshwater pool	Electrofishing/seine net	No	Yes
Karuka Creek (freshwater)	KAR4	Freshwater pool	Electrofishing/seine net	No	Yes
Karuka Creek (freshwater)	KAR5	Freshwater pool	Electrofishing/seine net	No	Yes

2.2 Fish

2.2.1 Netting

Plate 2-1 shows netting methods used to sample fishes. In the estuaries, gill nets of various sizes were deployed overnight. The sizes used were 15 mm, 25 mm, 35 mm and 40 mm (stretched mesh) each 10 m long and 2 m high. Gill nets 15 m long, consisting of three 5 m long panels of different mesh size (75 mm, 100 mm and 175 mm) were also set overnight. Fyke nets were also set at each estuary site overnight. The nets contained 500 mm diameter hoops with wings at the entrance, with a mesh of 5 mm (stretched mesh). The fyke nets were deployed among the mangrove fringes at low tide and the nets were submerged at high tide, with fishes and other fauna being channelled into the nets and captured.

In freshwater habitats, organisms were sampled by electrofishing (see Section 2.2.2) and seine netting. Electrofishing was not successful in habitats encountered, due to very low conductivity waters. Seine netting was an effective method in these habitats. The seine net was 5 m in length, 1.2 m in height, with a mesh size of 12 mm (stretched mesh). The seine net was used by two operators hauling the net through pools. Where pools were large, multiple hauls were completed until no additional species were recorded. As such, seine netting was not standardised.

a) Gill netting

b) Seine netting

c) Fyke net installation – low tide

d). Fyke net recovery – high tide

Plate 2-1 Netting methods employed to sample fishes

2.2.2 Electrofishing

Electrofishing was used in an attempt to sample fishes and macrocrustaceans from freshwater pools (see Plate 2-2). The instrument used for this study was a NIWA model EFM-300 backpack electrofisher, able to output pulsed DC current over a range of voltages up to 600 V and a wide variety of pulse frequencies and waveforms. The instrument was found to be ineffective in the pool habitat encountered, due to the very low conductivity waters encountered.

These habitats were sampled effectively using seine nets and visual observation as alternatives to electrofishing.

Plate 2-2 Electrofishing

2.2.3 Sample Processing

Fish and macrocrustacean specimens were identified to species level of taxonomic classification in the field where possible. Where the species name could not be determined, representative specimens were fixed in 10% formalin for 2-4 days, transferred to 70% ethanol and shipped to the office of Hydrobiology in Brisbane for identification. Detailed specimen photographs were also taken of each species.

Specimens were measured (fork length or total length for fish and carapace length for macrocrustaceans) and weighed using electronic scales (to the nearest 0.1 g up to 500 g and the nearest 1 g between 500 and 5000 g).

2.3 Macroinvertebrates

Macroinvertebrates were sampled by collecting sediments at estuary sites using a Van Veen grab sampler (Plate 2-3). Sediment was then sieved through a 500 µm sieve and the entire contents of each sample immediately preserved in 70% ethanol. Three replicate grab samples were collected at each site.

Plate 2-3 Macroinvertebrate sampling

Macroinvertebrate samples were delivered to Ecowise Environmental (Brisbane) for processing. The samples were emptied into sorting trays and all macroinvertebrate contents were removed. Specimens were identified to the family level of taxonomic classification and enumerated.

Macroinvertebrate data are presented here to provide baseline information. Data were analysed using multivariate analysis (PRIMER software) to rapidly examine between-estuary and between-site differences. Community data were analysed by constructing Bray-Curtis similarity matrices (4^{th}-root transformed data) and similarities between samples were plotted using multi-dimensional scaling plots (MDS plots). Briefly, these plots map samples such that samples with a high degree of similarity are positioned closely together while dissimilar samples are positioned further apart.

2.4 Study Limitations

This study was conducted during a time when dry conditions prevailed in the area and freshwater reaches were not flowing. This limited the effectiveness of freshwater sampling techniques and thus the assessment of freshwater communities.

Electrofishing was not successful in freshwater reaches. Although seine netting provided a suitable alternative method, the limited area of freshwater habitat precluded standardisation and replication of seine net sampling.

The limited area of freshwater habitat also precluded the ability to conduct standardised, replicated freshwater macroinvertebrate sampling. Therefore, no freshwater macroinvertebrate sampling was undertaken.

While these study limitations may have resulted in an under-estimate of the diversity and abundance of freshwater species, these issues would not considered to significantly alter the findings of the impact assessment presented herein. Follow-up studies to confirm this are recommended in Section 6.1.

3 DESCRIPTION OF AQUATIC HABITATS AND COMMUNITIES

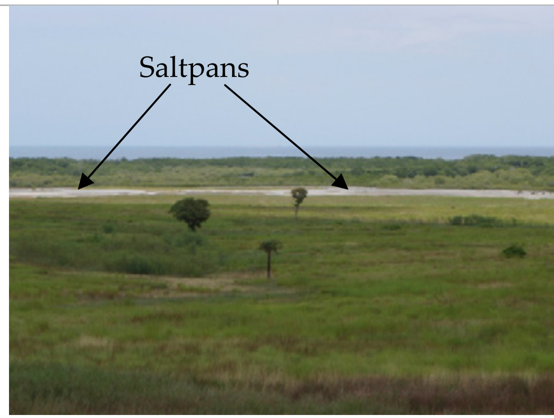
3.1 Aquatic Environments of the Project Area

There were three major types of aquatic environments encountered in the Portion 152 study area:

- Mangrove-lined estuaries;
- Episodically inundated saltpans landward of the mangroves; and
- Freshwater streams or remnant pools.

Table 3-1 summarises the key attributes of these habitat types. Saltpans were not sampled in this study.

Table 3-1 Aquatic environments of the Portion 152 project area

Habitat Type	Catchment	Aquatic Environment Features	Example Photographs	
Mangrove-lined estuaries	Lower reaches of Vaihua River, North Vaihua River and Karuka Creek	• Estuarine waters, tidal flow. • Mangrove fringe. • Substrate primarily sand near the mouths, grading to soft mud upstream.	 *Vaihua River mouth*	 *Typical upstream reach*
Saltpans	Interspersed landward of mangroves	• Episodically inundated by high tides, particularly spring tides. • Fringed by saltmarsh vegetation.	 	

Freshwater streams and pools	Vaihua River and Karuka/Mokeke creek systems	• Dry depressions. • Remnant stagnant pools. • Streams with flow.	 *Remnant pool in Vaihua River*	 *Flowing reach of Karuka Creek*

3.2 Fishes and Macrocrustaceans

No previous studies of the freshwater and estuarine aquatic fauna have been undertaken at the site. DES (2007) undertook an Initial Environmental Assessment of the Konebada Petroleum Park area, and concluded that marine resources are utilised heavily by local populations and that the freshwater environment is unlikely to harbour any species of significance. The findings of the current study concur with these findings.

3.2.1 Estuaries

Sampling in estuary habitats resulted in the collection of 30 fish species and 5 species of macrocrustacea (Table 3-2). These species are widespread and typical of mangrove-lined estuaries. All of the species collected are wide-ranging and most species were common to the Vaihua River, North Vaihua River and Karuka Creek estuaries.

Table 3-2 Mangrove species

Common Name	Species Name	Family Name
FISH		
Estuarine glass perchlet	*Ambassis macrocanthus*	Ambassidae
Estuary cardinalfish	*Apogon hyalosoma*	Apogonidae
Longtom	*Strongylura krefftii*	Belonidae
Bigeye trevally	*Caranx sexfaciatus*	Carangidae
Mangrove whipray	*Himantura granulata*	Dasyatidae
Ambon gudgeon	*Butis amboinensis*	Eleotridae
Ebony gudgeon	*Eleotris melanosoma*	Eleotridae
New Guinea herring	*Thryssa scratchleyi*	Engraulididae
Estuary cod	*Epinephelus coioides*	Epinephelidae
Largetooth ponyfish	*Gazza minuta*	Gerridae
Threadfin silver biddy	*Gerres filamentosus*	Gerridae
Goby	*Goby sp.1*	Gobiidae
Goby	*Goby sp.2*	Gobiidae
Goby	*Goby sp.3*	Gobiidae
Goby	*Goby sp.4*	Gobiidae
Goby	*Goby sp.5*	Gobiidae
Goby	*Goby sp.6*	Gobiidae
Goby	*Goby sp.8*	Gobiidae
Fly River garfish	*Zenarchopterus novaeguineae*	Hemiramphidae
Mangrove jack	*Lutjanus argentimaculatus*	Lutjanidae
Fingermark bream	*Lutjanus johnii*	Lutjanidae
Oxeye herring	*Megalops cyprinoides*	Megalopidae
Mullet	*Valamugil buchanani*	Mugilidae
Striped threadfin	*Polydactylus plebius*	Polynemidae
Scat	*Scatophagus argus*	Scatophagidae
Vermiculated spinefoot	*Siganus vermiculatus*	Siganidae
Barracuda	*Sphyraena barracuda*	Sphyraenidae
Pufferfish	*Arothron manillensis*	Tetraodontidae
Pufferfish	*Arothron reticularis*	Tetraodontidae
Archerfish	*Toxotes jaculartrix*	Toxotidae
MACROCRUSTACEANS		
Prawn	*Macrobrachium sp.1*	Palemonidae
Prawn	*Macrobrachium sp.2*	Palemonidae
Prawn	*Macrobrachium sp.3*	Palemonidae

Mudcrab	*Scylla serrata*	Portunidae
Ghost shrimp	*Thalassinidean*	Unidentified

Many of the fishes sampled were juveniles of coastal marine species and this observation is consistent with the widely held notion that estuaries provide important nursery habitat for coastal species (Robertson and Duke 1990; Blaber et al. 1995; Laegdsgaard and Johnson 1995). Adults and juveniles of estuarine specialists were also recorded.

There were very few large-bodied predators collected in this study. Single specimens of mangrove jack (*Lutjanus argentimaculatus*) and estuary cod (*Epinephelus coioides*) were the only large predators recorded. This may be a reflection of the relatively low sampling effort, but may also indicate some local fishing pressure on the large-bodied fish. Indeed, during this study, local people were observed to be intensively fishing, using large gill nets in all three estuaries visited in this study.

3.2.2 Freshwater

Sampling at freshwater sites resulted in the collection of four species of fish and two species of prawns (Table 3-3). These species are common to southern PNG and catches were very small (see Section 3.2.3).

Table 3-3 Freshwater species

Common Name	Species Name	Family Name
FISH		
Tilapia	*Oreochromis mossambica*	Cichlidae
Snakehead gudgeon	*Ophieleotris aporos*	Eleotridae
Papua rainbowfish	*Melanotaenia papuae*	Melanotaenidae
Goby	*Goby sp.7*	Gobiidae
MACROCRUSTACEANS		
Prawn	*Macrobrachium sp.3*	Palemonidae
Prawn	*Macrobrachium lar*	Palemonidae

Tilapia, native to Africa, was introduced to Papua New Guinea in the 1950's and has become established through many areas, either through natural dispersal or through intentional translocation by people. There have been no coordinated studies of the impacts of the introduction of this species to the native fauna.

Most of these freshwater species are amphidromous. That is, they breed in freshwater, probably cued by flushing flows in this environment. Eggs are transported downstream into estuaries and juveniles migrate back upstream to freshwater. Therefore, it is possible that in the wet season, higher abundance of freshwater species or a higher number of species (migrating into freshwater from the estuarine habitats) may occur in freshwater habitats.

3.2.3 Abundance and Biomass

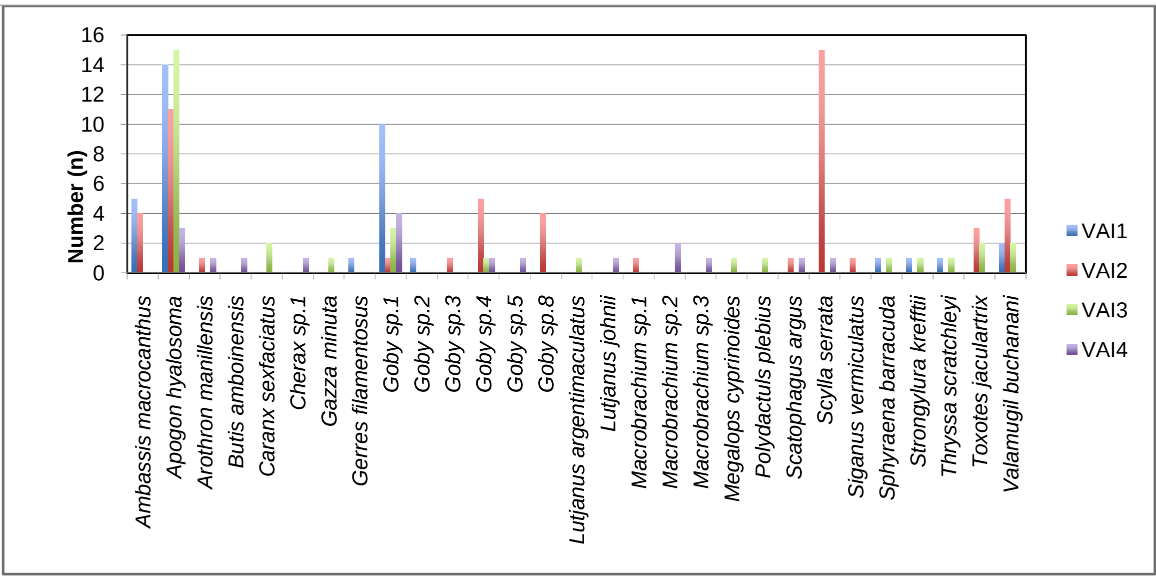
3.2.3.1 Estuaries

Vaihua and North Vaihua Estuaries

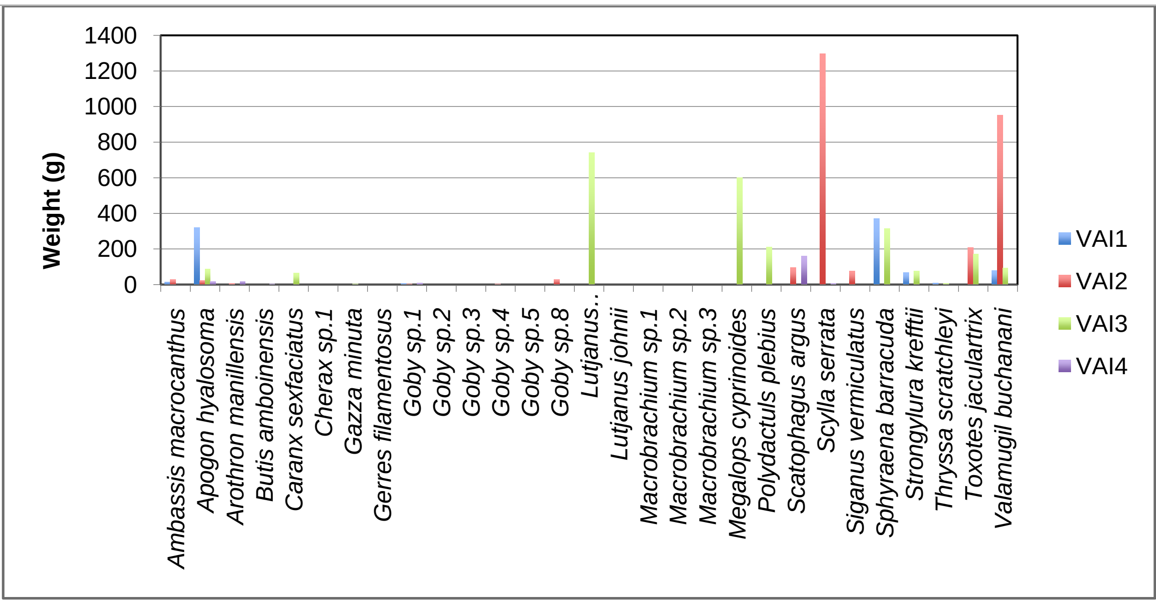
Most species collected in these estuary habitats were recorded in low numbers (Figure 3-1). The estuary cardinalfish (*Apogon hyalosoma*) was the most abundant fish species at most sites. The mudcrab (*Scylla serrata*) was the most abundant species at VAI2. Similar sampling effort was made at each site.

Biomass was very low for most species. Overall, biomass in the Vaihua estuary was dominated by mullet (*Valamugil buchanani*), followed closely by mudcrab. Single records of the large-bodied fish, mangrove jack (*Lutjanus argentimaculatus*) and oxeye herring (*Megalops cyprinoides*) contributed disproportionately high biomass to the catch at VAI3.

Raw abundance and biomass data are given in Appendix 1.



a). Abundance at Vaihua and North Vaihua estuary sites



b). Biomass at Vaihua and North Vaihua estuary sites

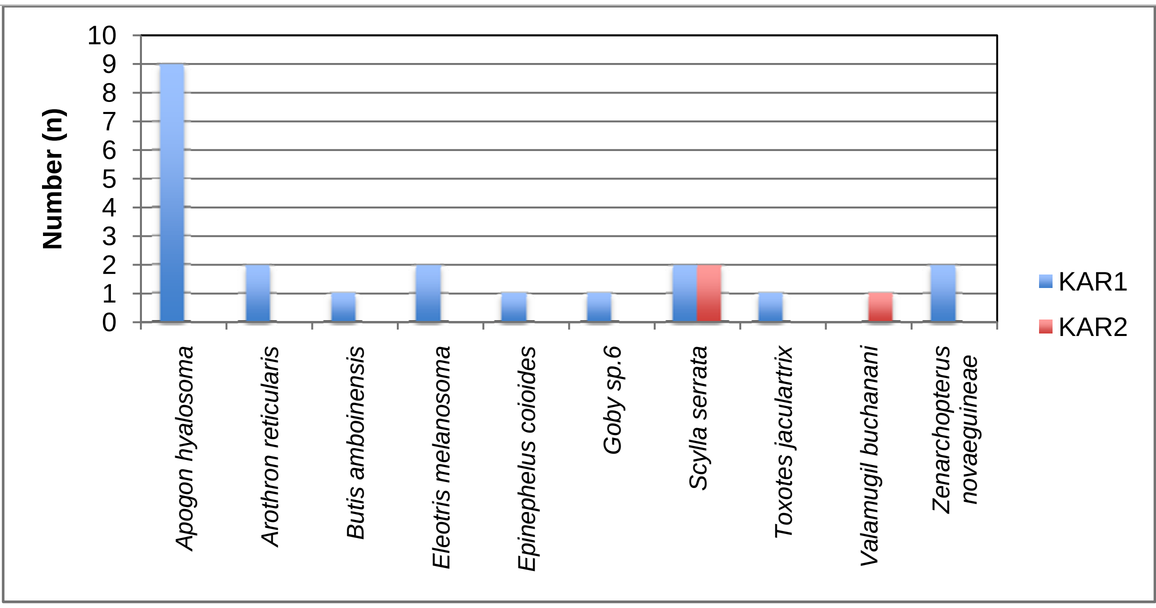
Figure 3-1 Abundance and biomass at Vaihua and North Vaihua estuary

Karuka Estuary

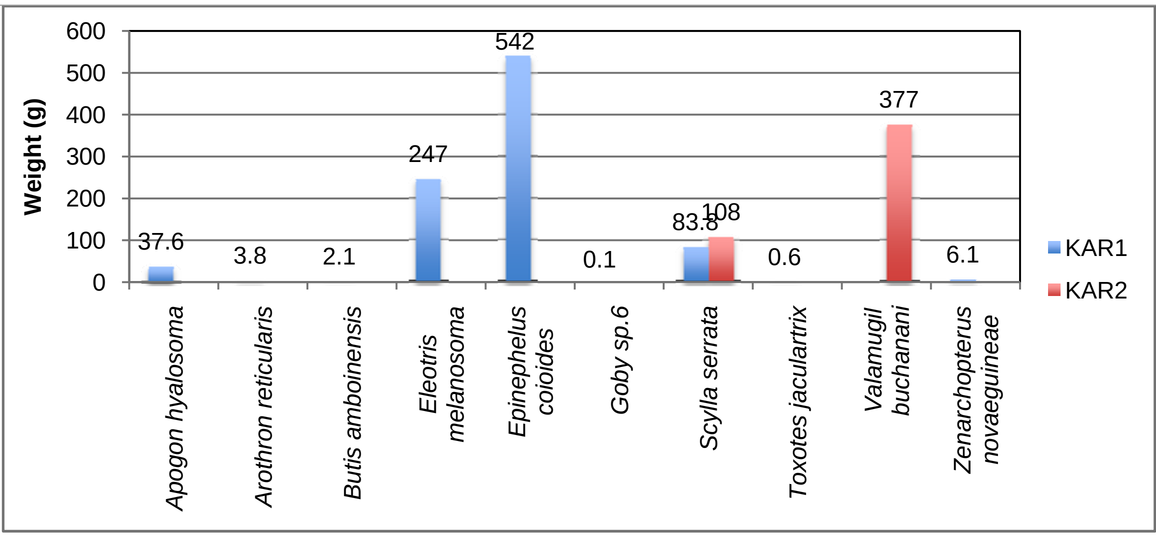
Similar to Vaihua estuary sites, catches in Karuka estuary were numerically dominated by estuary cardinalfish *Apogon hyalosoma* (Figure 3-2). Generally, catches were low and many species represented by single specimens.

A single specimen of a large estuary cod (*Epinephelus coioides*) was recorded at KAR1 and this specimen dominated the biomass.

Raw abundance and biomass data for Karuka estuary is given in Appendix 1.



a). Abundance at Karuka estuary sites



b). Biomass at Karuka estuary sites

Figure 3-2 Abundance and biomass at Karuka estuary

3.2.3.2 Freshwater

Freshwater sites recorded very small catches (Table 3-4). Sampling methods employed in this study were successful in catching fishes and prawns at most sites. However, at some sites, low conductivities reducing the effectiveness of electrofishing or constricted habitat areas (very constricted shallow pools) reducing the effectiveness of netting. At such sites, visual observations were the only successful method of recording fishes and prawns.

Four species of fish and two species of prawn were identified, in low numbers, in freshwater sites. No fishes or prawns were recorded from VAI6 and VAI7. Karuka Creek sites recorded more species (5) than Vaihua River sites (2).

Table 3-4 Abundance and biomass at freshwater sites

Species Name		Site							
Common Name	**Data**	**KAR3**	**KAR4**	**KAR5**	**VAI5**	**VAI6**	**VAI7**	**VAI8**	**Total**
Goby sp.7	Number	3							3
Goby	Weight (g)	-							-
Macrobrachium lar	Number								Vis
Prawn	Weight (g)				Vis obs			Vis obs	obs
Macrobrachium sp.3	Number								Vis
Prawn	Weight (g)			Vis obs					obs
Melanotaenia papuae	Number	14	1						15+
Papuan rainbowfish	Weight (g)	9.1	4.9	Vis obs					14+
Opieleotris aporos	Number								Vis
Snakehead gudgeon	Weight (g)			Vis obs	Vis obs			Vis Obs	obs
Oreochromis mossambica	Number	15							15+
Tilapia	Weight (g)	-		Vis obs					-
Total Number		**32**	**1**	**Vis**	**Vis**	**NC**	**NC**	**Vis**	
Total Weight		**-**	**4.9**	obs	obs			obs	

Footnote: NC = No catch. Vis obs = species identified by visual observation only.

3.3 Macroinvertebrates

Raw abundance data are given in Appendix 2. Figure 3-3 shows an MDS plot of samples, coloured-coded by estuary. There was considerable variability between samples, with no distinct groupings, suggesting no clear differences in the macroinvertebrate communities between estuaries.

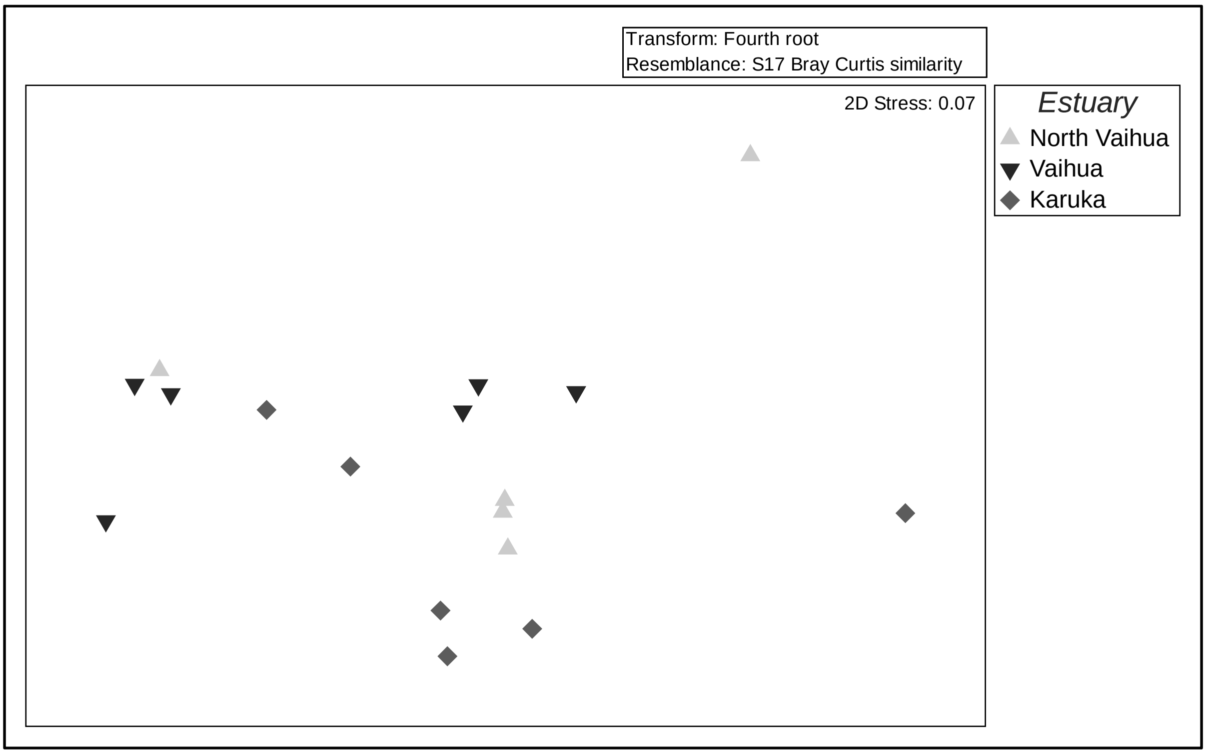


Figure 3-3 MDS plot of macroinvertebrate sample similarity among the three estuaries

An analysis of sample similarity was also performed on the basis of position within the estuary; 'upstream' samples located as far upstream as navigable in the estuary and 'downstream' sites located near the estuary mouth. Upstream to downstream gradients in macroinvertebrate community diversity and abundance are common in estuaries (Boesch 1977; Platell and Potter 1996; Schlacher and Wooldridge 1996) and this appears to be the case in the Portion 152 estuaries, with a high degree of similarity (grouping) among downstream sites, with this group being distinct from upstream sites (see Figure 3-4).

While it is useful to document these pre-existing patterns in the baseline condition, the greatest value of these data will be to provide a benchmark against which future monitoring results can be compared.

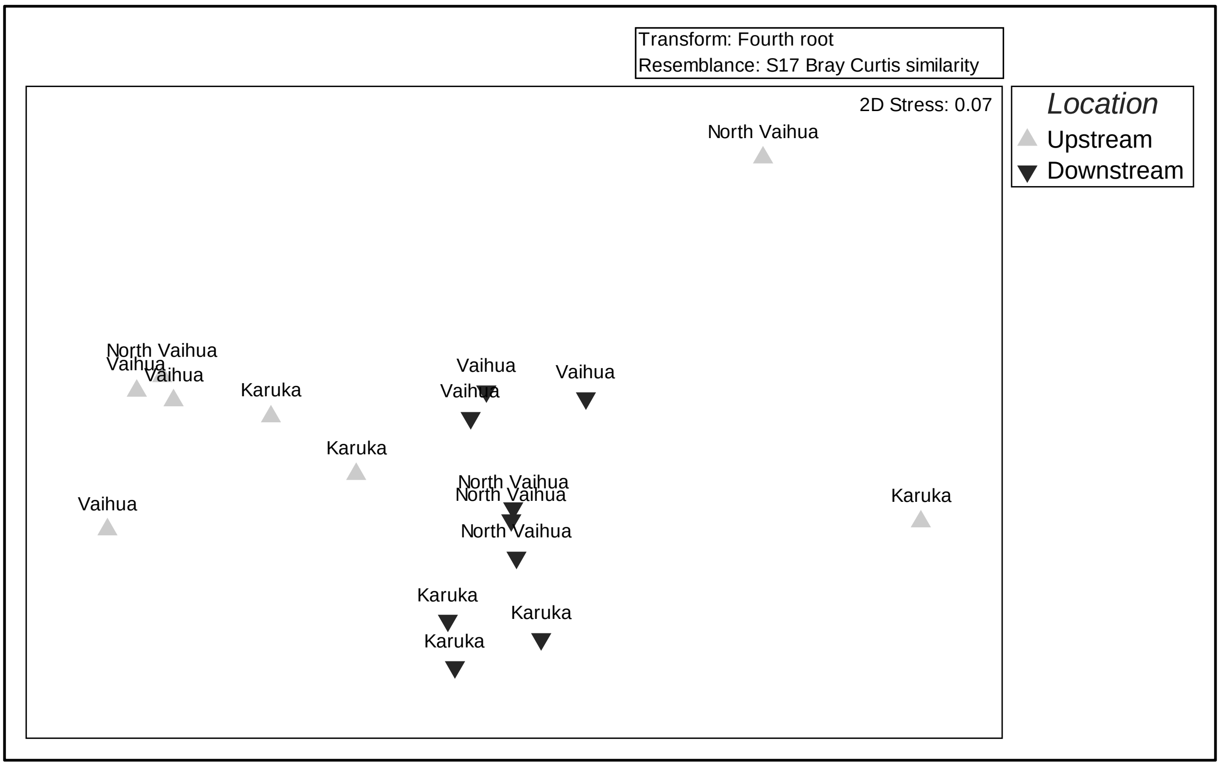


Figure 3-4 MDS plot of macroinvertebrate sample similarity among 'upstream' sites and 'downstream' sites

3.4 Connectivity and Ecosystem Processes

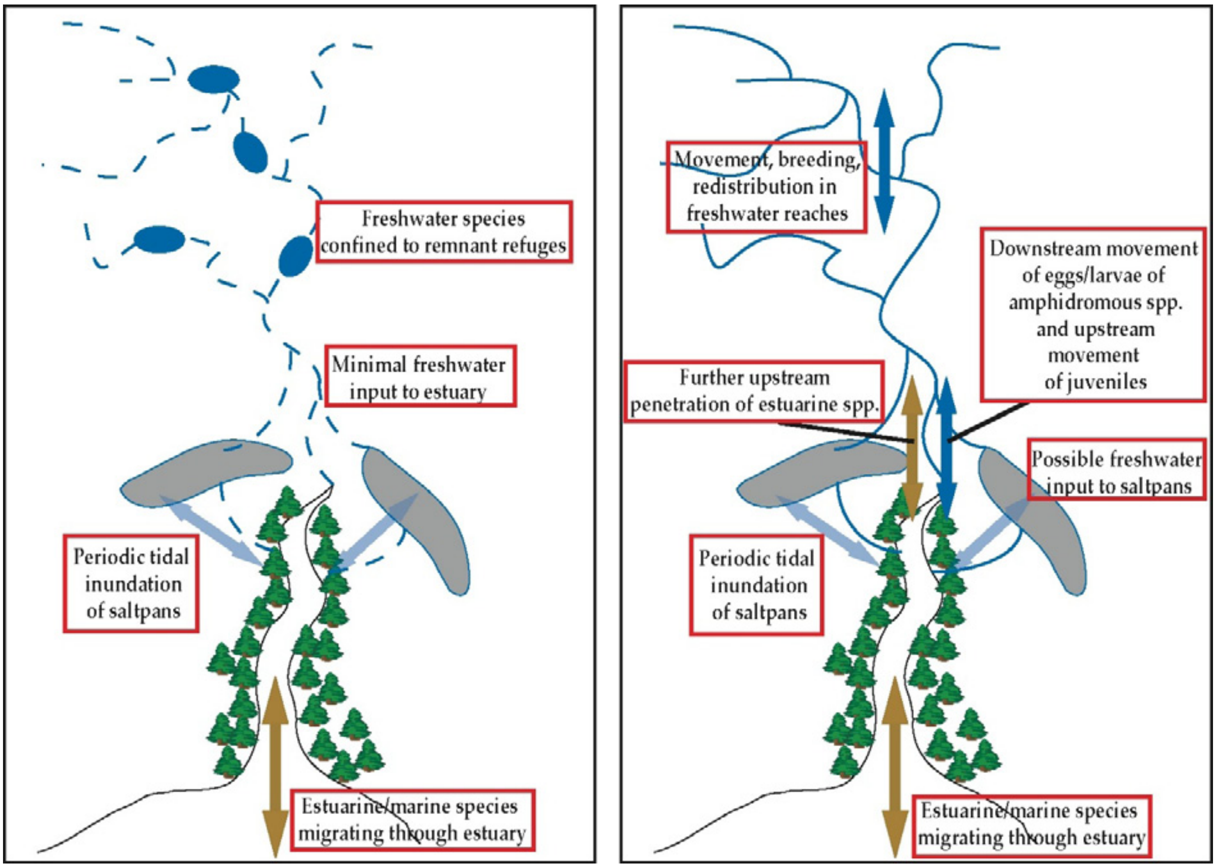
This study has shown that estuaries support the highest abundance and diversity of aquatic biota in the Portion 152 area and that freshwater habitats in Portion 152 support low abundance and diversity. The estuaries are more productive than the freshwater environments and appear to be more heavily utilised by local people for resources. Evidence of mangrove wood collection was observed (see Plate 3-1) and local people were observed fishing by gill-netting and spearfishing in estuaries daily.

Plate 3-1 Evidence of mangrove wood harvesting in Vaihua estuary

Estuaries are generally highly variable environments with respect to fish populations. At various times, estuary fish populations may be comprised of a mixture of estuarine specialists, juveniles of coastal marine species and migrating 'freshwater' species.

Although there is nothing remarkable about the freshwater or estuarine habitats in Portion 152, it is important to understand the ecosystem processes controlling these environments because, within the context of Portion 152, these are the aquatic environments present that may be exposed to impacts.

Portion 152 is a dry-tropical environment, with long periods of dry conditions and short sporadic wet conditions. It is believed that the freshwater and estuarine environments function differently under these two conditions. It is also believed that the aquatic communities occurring in freshwater and estuarine habitats will be different under these two conditions. A conceptual diagram of the dry-condition and wet-condition functioning is shown in Figure 3-5.



a). Dry Conditions *b). Wet Conditions*

Figure 3-5 Conceptual diagram of ecosystem functioning under dry and wet conditions

During dry conditions (Figure 3-5a), estuarine and coastal marine species utilise the estuarine habitat, and there is no (or very little) freshwater connection. The upstream reaches of the estuary were found to be hyper-saline in this study (see Hydrobiology 2008d). At these times, as experienced during the present study, the freshwater environment exists as a series of remnant, largely disconnected, pools. These pools are dry-period 'refuges' for aquatic fauna and there is minimal opportunity for dispersal or movement between freshwater habitats. Under these dry conditions, there may be periodic tidal inundation of the saltpans.

At the onset of wet conditions (Figure 3-5b), it is hypothesised that connectivity is restored between the freshwater habitats and the estuary. In other dry-tropical environments, the onset of wet conditions triggers breeding and dispersal of freshwater species. As described in Section 3.2.2, most of the freshwater species recorded are amphidromous[1]. Therefore, at the onset of wet conditions, the aquatic fauna occurring in estuaries could be expected to include some 'freshwater' species. Penetration of 'estuarine' species further upstream could also be expected. It is also expected that there would be some freshwater flow into saltpans during these wet conditions. During these wet times there is expected to be a 'flushing' of

[1] Breeding in freshwater, eggs transported downstream, estuarine larval stage and juveniles migrating back upstream to freshwater.

the freshwater habitats and freshwater species are expected to breed and re-distribute. This can be envisaged as a re-setting of the freshwater environment such that, when dry conditions return, there has been some replenishment of freshwater populations and water quality.

These ecosystem processes need to be maintained in order to maintain the aquatic populations in the freshwater environments and in order to maintain biodiversity values in estuaries. As such, there are differing environmental sensitivities at different times and the impact assessment (Section 4) will deal with the following general principles:

- During dry conditions, dry-weather 'refuges' (freshwater pools) are sensitive to water quality impacts;
- During wet conditions, connectivity between freshwater and the estuary is important for maintaining ecosystem processes.

4 IMPACT ASSESSMENT

4.1 Impact Categorisation

Potential impacts associated with the project will differ between the construction phase and the operation phase. The impact assessment deals with the varying spatial and temporal scales of impacts, with due consideration to the differing sensitivities and resilience in the receiving environments of the project area. Mitigation measures may ameliorate some of the potential impacts and impacts that still remain possible after mitigation are termed 'residual impacts'. The following impact assessment considers possible impacts without mitigation and outlines possible mitigations measures, and potential residual impacts. While this assessment is based on field data collection in the receiving environment, the assessment of potential impacts necessarily involves professional judgement, based on our understanding of the project development and many years of collective experience assessing such projects in Papua New Guinea and other dry-tropical environments.

The impact assessment has been carried out for the two aquatic habitat types in the project area: estuaries and freshwater.

The impact assessment involved five steps:

1. Characterisation of the range of aquatic habitat types, fauna and flora likely to occur in the project area, the conservation significance of these and their sensitivities (baseline characterisation outline in Section 3);
2. Identification of construction and operation activities to be carried out and assessment of how these may interact with aquatic ecosystems;
3. Identification of potential impacts associated with these activities;
4. Implementation of a procedure for rating risk that provides a consistent and transparent way of assessing the stresses associated with development activities and their potential effects on receptors; and
5. Recommendation of mitigation measures to address the potential impacts and predict the extent to which they are expected to reduce the impacts.

4.1.1 Construction Phase

The general activities of the construction phase that could potentially impact aquatic ecosystems are:

- Construction of watercourse crossings associated with road realignments and upgrades;
- Construction of the LNG Facility and associated infrastructure;
- Construction of the combined Materials Offloading Facility/Jetty; and

- Construction of the LNG pipeline landfall.

Specific activities associated with each of these, which are relevant to this impact assessment, are outlined below.

4.1.1.1 Road Realignment and Upgrade

The development of the LNG Facility at Portion 152 will require only minor road works. Access to the site is via an existing public road. This road will be improved and widened in some areas and will be diverted around the proposed site (Figure 4-1). Within the facility site itself, a number of minor project roads will be constructed.

These roads will cross, or run adjacent to, watercourses at various locations and the potential impacts to freshwater (and potentially estuarine) watercourses include:

- Physical impacts to riparian habitat;
- Increased sediment mobilisation to watercourses;
- Accidental fuel/oil spills into watercourses; and
- Restricting fish movement/freshwater-estuarine connectivity (e.g. flow diversion during construction, culverts etc.).

4.1.1.2 LNG Facility Construction

The location of the proposed LNG Facilities site is shown in Figure 4-1. Construction will involve land clearing, earthworks, the construction of camps and the installation of the various required infrastructure (see Plate 4-1 and Plate 4-2). The LNG Facilities site is located in an area with few freshwater drainages (see Figure 4-1) and the drainages that are present have small catchments (compared to the drainages in the more southern sections of Portion 152) and are ephemeral in nature.

The potential impacts of the construction of the LNG Facility include:

- Physical impacts to riparian habitat;
- Physical impacts to watercourse channels. Watercourses running through the LNG Facilities site will be totally rerouted to ensure appropriate site drainage and no provisions for restoring aquatic habitat will be made;
- Increased sediment mobilisation to watercourses; and
- Accidental fuel/oil spills into watercourses.

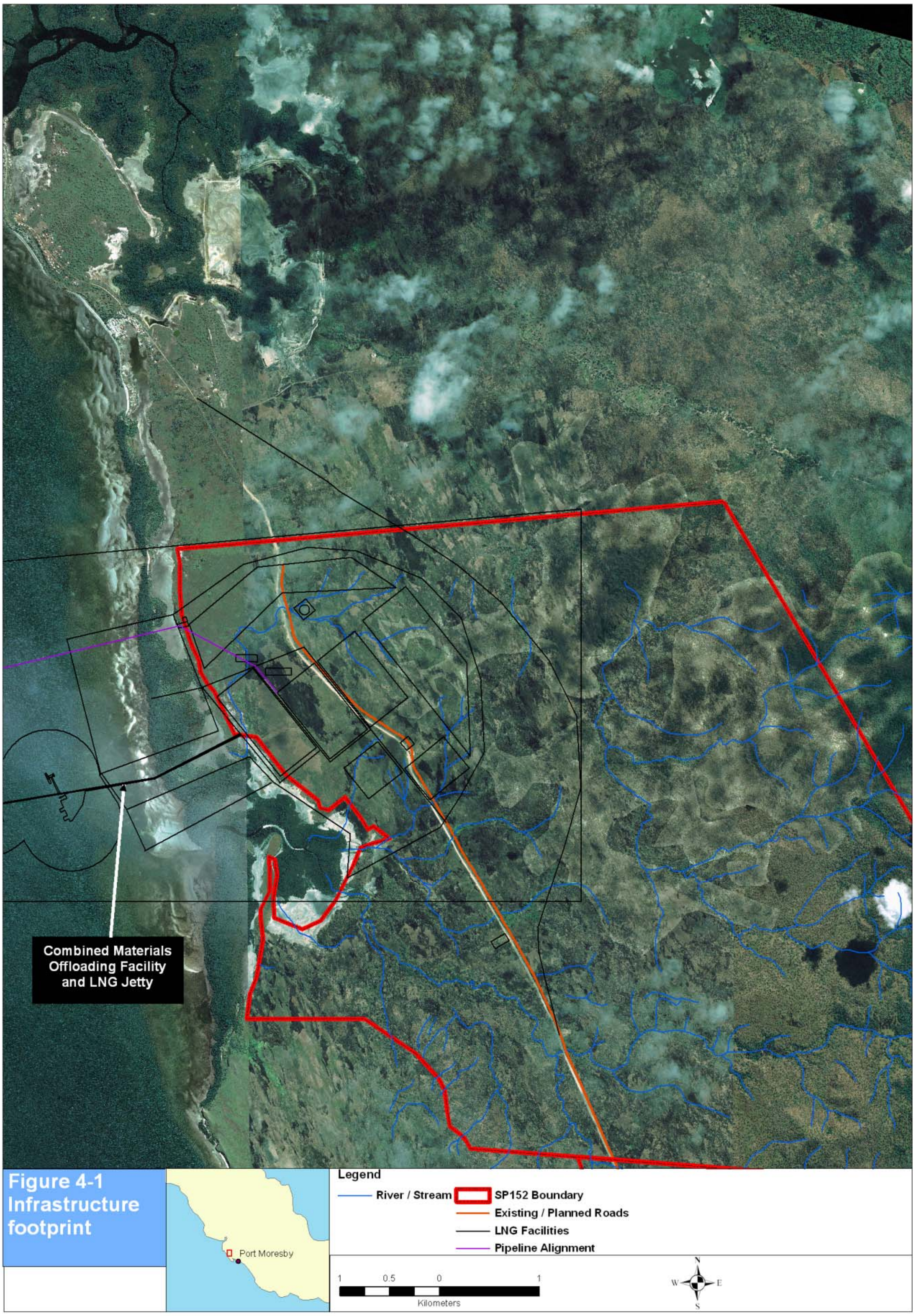


Figure 4-1 Location of LNG Facility infrastructure

Source: KBR, JGC, Worley Parsons (2007).

Plate 4-1 Example of roads and other earthworks from a similar LNG Facility construction site

Source: KBR, JGC, Worley Parsons (2007).

Plate 4-2 Example of a similar LNG Facility construction site

4.1.1.3 Jetty Construction

A combined Materials Offloading Facility and LNG Jetty will be constructed to transfer LNG from the plant to ships and to transport materials to the site. This combined jetty will be an earthen causeway 105 m wide and some 400 m long.

The potential impacts of the construction of the LNG Jetty, at the landward extent, include:

- Physical impacts to estuarine/mangrove habitat;
- Increased sediment mobilisation to estuaries; and
- Accidental fuel/oil spills into estuaries.

The marine components of the aquatic environment are not covered in this report.

4.1.1.4 LNG Pipeline Landfall Construction

The LNG pipeline will make landfall to the north of the LNG Facility (see Figure 4-1). A narrow pipeline easement will be constructed between the landfall and the LNG Facility. The pipeline easement will represent a narrow corridor through a relatively narrow mangrove/estuarine zone. A winch spread, occupying an area of some 5,250 m^2 will be located landward of the pipeline landfall.

Potential impacts of the construction of the LNG pipeline landfall include:

- Physical impacts to estuarine habitat;
- Increased sediment mobilisation to estuaries; and
- Accidental fuel/oil spills into estuaries.

4.1.2 Operation Phase

The general activities of the operation phase that could potentially impact aquatic ecosystems are:

- The management of waste collection facilities (e.g. separation pits, sumps and retention ponds draining industrial facilities);
- The transport, processing, and conditioning of LNG;
- Alterations to coastal hydrology and sedimentation processes due the presence of the Materials Offloading Facillity and LNG Jetty, leading to potential siltation of the mouth of the Vaihua Estuary;
- The use and maintenance of road infrastructure;

- The transport and storage of a range of chemical compounds (mainly hydrocarbons); and

- The movement of support staff (and potentially non-support staff) into and out of the project area.

At the time of writing, modelling had revealed that the placement of the solid causeway of the combined Materials Offloading Facility and LNG Jetty had the potential to disrupt coastal longshore current flow, the influence of wave action and thus, coastal sediment transport and deposition (David Gwyther pers. com.). Modelling showed that with the current configuration, there is a risk of sedimentation on the south side of the jetty structure and a risk of sediment build-up near the Vaihua River mouth causing 'closure' of the estuary. At the time of writing, engineering options were being investigated to prevent this from occurring. Options under examination include alterations to the design, dimensions and placement of the facility. It is understood that engineering modifications will remove the risk of siltation of the Vaihua River mouth. Therefore, the potential impacts of this occurring are not assessed here.

4.1.3 Summary of Potential Impacts

The potential impacts identified during construction and operation fall into three broad categories:

- Potential impacts to physical aquatic habitat (direct impacts to habitats and indirect impact to fauna and flora);

- Potential impacts to water quality (indirect impact to fauna and flora)[2]; and

- Potential impacts to biological communities/processes (direct impact to fauna and flora).

Table 4-1 shows which impact could be associated with each activity and project phase. As indicated in Table 4-1, the majority of impacts are associated with the construction phase and this class of impacts are either unavoidable or more difficult to control (e.g. fugitive sediment). Potential impacts associated with the operations phase relate mainly to accidents or issues that are more easily managed and controlled.

[2] Impacts to water quality are not assessed in this report. Water quality impacts are presented in a separate volume.

Table 4-1 Potential impacts

Potential Impact		Activity: Roads	Activity: LNG Facility	Activity: Materials Offloading/LNG Jetty	Activity: LNG pipeline landfall
Impacts to Physical Habitat	Reduction / modification to riparian habitat	C	C	C	C
	Sediment	C	C	C,O	C
Impacts to Biological Communities/Processes	Sediment	C	C	C	C
	Introduction of exotic species	C,O	C,O		
	Restricting to fish movement/freshwater-estuarine connectivity	C,O			

Note: C = Construction Phase, O = Operation Phase

4.1.3.1 Assumptions and Exclusions

Water Quality

No assessment of potential impacts to water quality is given in this report as this is presented in a separate report.

Shipping Oil/Fuel Spills

This report will not deal with the potential for shipping oil/fuel spills. Although such events have the potential to impact estuarine environment, this will be handled in the marine impact assessment.

Shipping-Related Introduction of Exotic Species

An assessment is made of the potential impacts of exotic species. For the estuarine environment, the primary risk of exotic species arises from the accidental introduction of species from shipping. As this is an issue specific to marine/shipping operations, a detailed assessment of the potential impacts of exotic species spread by shipping is not made, although some discussion about the issue is given.

Hydrotest Water for LNG Tank

Hydrotesting for the LNG Facility areas will be required for the LNG tanks only as hydrotesting of the pipeline will occur at the Omati River Landfall end of the pipe.

Hydrotest water will be supplied from a desalination unit. If hydrotest water is discharged to watercourses in the Portion 152 area, the issue will be one of potential water quality impacts, which are not assessed in this report. Similarly, no assessment of the potential hydrological impacts of water discharge is made here.

Fishing Pressure

It is assumed that the on-site rules and guidelines of the LNG Facility will prohibit fishing by employees. Therefore, it is assumed that there will be no increases in fishing pressure in the project area directly attributable to the development of the project, and potential impacts of increased fishing pressure are not assessed here.

4.1.3.2 Impacts to Physical Habitat

Impacts to physical habitats may arise due to:

- Direct physical damage/reduction/modification to riparian habitat; and
- Sediment mobilisation.

Riparian Habitat Modification

Riparian habitat is a key component of aquatic ecosystems, providing stream shading, structural habitat (e.g. tree root habitat), stream bank stabilisation and detrital food sources. Some riparian vegetation will need to be cleared during construction of roads, the LNG Facility, the landfall LNG pipeline and the landward extent of the jetty.

Sediment Mobilisation

The generalised effects of sediment on aquatic habitats and organisms were outlined in previous EIS documents produced for the previous gas project (NSR 1998, DBA 2005) and these will not be repeated in total here. In summary, the effects of sediment to habitats can be described as:

- Increased sedimentation, causing smothering or in-filling of fine-scale habitat, such as interstitial spaces. This may also alter detrital carbon cycling processes; and
- Increased suspended solids concentration, causing scouring of fine-scale habitat structure, such as egg-laying surfaces, and diminished primary production by plants.

Construction-related earthworks have the potential to expose soils to rainfall, potentially leading to fugitive sediment being delivered to watercourses in runoff. Construction activities within watercourses (e.g. the construction of road crossing culverts) also have the potential to mobilise sediment to the system. Much of this potential could be avoided if such construction activities were completed during dry periods, when many of the freshwater drainages in the project area are not flowing.

Where such activities occur in muddy estuarine habitats (i.e., in mangrove habitat), sediment mobilisation is expected to be more difficult to control than in the freshwater environment.

While estuaries at the site are naturally muddy/turbid environments, some short-term, localised elevation in sediment input may be expected.

4.1.3.3 Impacts to Biological Communities

Impacts to biological communities may arise due to:

- Sediment;
- The introduction of exotic species; and
- Restricting fish movement or freshwater-estuarine connectivity.

Sediment

In addition to the potential effects of sediment to physical habitat outlined above, sediment can have direct and indirect effects to fauna and flora itself. The generalised effects of sediment to fauna and flora have been described in EIS documentation for the previous gas project and will not be repeated in total here (NSR 1998, DBA 2005). The potential effects can be summarised as follows:

- Impacts to food resources:
    - Scouring or smothering of fine benthic structure and food resources;
    - Reduced primary production due to decreased light penetration;
- Impacts to fauna:
    - Abrasion of fine body integuments;
    - Scouring or smothering of egg masses or larvae;
    - Reduced success of visual-based predatory or reproductive behaviours;

The potential impacts of sediment are of most concern during the construction phase. Earthworks adjacent to watercourses and stream crossings are likely to be the most important causes of sediment mobilisation. Unlike the upstream component of the study (Hydrobiology 2008a), the mitigating factor in Portion 152 is the predominance of dry conditions that will allow sediment to be managed more effectively. In addition, in the LNG Facility area, the area to be disturbed is relatively small and there are few direct intersections with watercourses.

Introduction of exotic species

Introductions of noxious weeds and/or exotic species could have impacts on the region's indigenous fauna. In the case of fishes, this is only of relevance to the freshwater environment as there are no estuarine noxious fish species known in this area. In the case of invertebrates, the introduction of evasive species related to shipping activities has been well-documented for ports in Australia and around the world. Some of these invertebrate species could colonise the estuaries. The potential for the introduction of species related to the shipping activities will not be detailed in this report as it is a marine/shipping issue.

Introductions could be accidental (e.g. washing down machinery covered with noxious weed plant debris or seed stock) or intentional (e.g. release of fish into waterways for fishing). It is pertinent to note that the baseline surveys in Portion 152 recorded the occurrence of an introduced freshwater fish species, the tilapia (*Oreochromis mossambica*). This species was introduced by the PNG Government in the 1950s and has become widespread throughout the country. There have also been other intentional fish introductions in PNG, although none of these were into lowland habitats around Port Moresby. These introduced species may come to inhabit Portion 152 through natural dispersal or intentional translocations, but the project should aim to not accelerate this process.

Barriers to fish movement and freshwater-estuarine connectivity

As described in Section 4, the maintenance of viable freshwater fish populations and the maintenance of ecosystem process in this area is dependent on linkages between freshwater habitats and linkage between freshwater and the estuaries (see Figure 3-5).

The topography of the study area is primarily flat. In this mainly dry landscape, freshwater channels exist where there are only minor depressions through the landscape. Deeper depressions become isolated pools in the dry season. This is relevant to the management of channel-crossing constructions because alterations to the fine-scale landscape structure has the potential to re-route or isolate water flows at the onset of the wet season, thus potentially limiting the movement of fishes. An example of this concept exists in the Vaihua River, where the freshwater channels drain out of the Portion 152 area into a flat saltpan strip, before connecting through fine feeder channels to the estuary (Figure 4-2). In dry conditions, these feeder channels are maintained by groundwater seepage (P. Howe, SKM, pers. com.). While this groundwater seepage may be sufficient to keep the feeder-channels moist, they are unlikely to provide sufficient water quantity for fish movement. Connectivity of the freshwater and estuarine aquatic systems is believed to be restored via such feeder channels at times when there is high rainfall and surfacewater flow (which is also expected to be the time of maximal freshwater fish movement, breeding and dispersal).

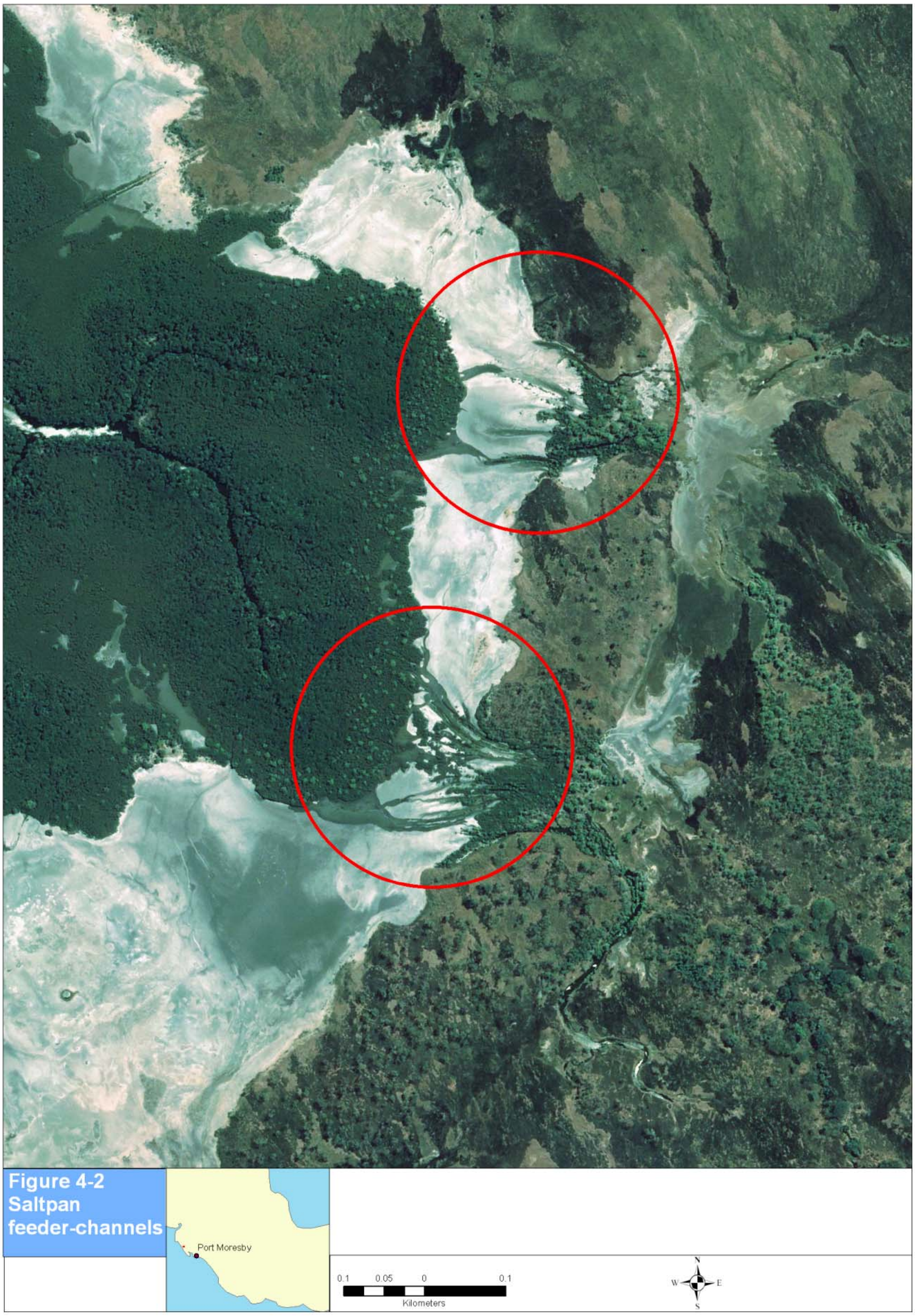


Figure 4-2 Saltpan feeder-channels between the freshwater and estuarine reaches of the Vaihua River

4.2 Impact Assessment Method

A semi-quantitative, risk-ranking method was applied to evaluate the risks to aquatic biota associated with the various potential impacts identified in Section 5.1. Definitions of consequence and likelihood have been tailored to the aquatic environment and the nature of potential impacts likely to be associated with this project. Definitions of scale and duration used to define consequence have been made consistent with those used in the previous EIS (Enesar, 2005). The impact assessment method used clearly documents the decisions taken to arrive at an impact rating, while also taking into consideration the elements of confidence surrounding each prediction.

The risk assessment method used in Enesar (2005) outlined whether the severity of potential impacts would be expected to stay the same, increase or diminish over time. This information has been incorporated into the method adopted for this study. The steps involved in the impact assessment are outlined below.

The risk rating categories defined in this impact assessment are:

- **Insignificant:** the risk associated with a potential impact is negligible and **will not** have an influence on any decision regarding the proposed activity/impact mechanism;

- **Very Low**: the risk associated with the potential impact is very small and **should not** have any influence on any decision regarding the proposed activity/impact mechanism;

- **Low**: the risk associated with the potential impact is small and **may not** have any influence on any decision regarding the proposed activity/impact mechanism;

- **Medium**: the risk associated with the potential impact is moderate and **should** influence decisions regarding the proposed activity/impact mechanism;

- **High**: the risk associated with the potential impact **will be** high and **will** influence decisions regarding the proposed activity/impact mechanism;

- **Very High**: the risk associated with the potential impact is **very** high and **will** influence decisions regarding the proposed activity/impact mechanism. Alternatives should be sought to the proposed activity or additional mitigation measures applied.

The risk associated with a given impact is a product of the consequences of that impact and the likelihood of that impact occurring. There are several key components that underpin the consequences associated with a given impact. These are spatial extent, temporal extent and the severity of the impact. Step 1 of the risk assessment decision framework used for this study was to rate the consequence of a given impact based on the explicit definitions provided in the consequence rating table (Table 4-2). The consequence rating for a given impact is determined by adding the scores for extent, severity and duration in the consequence rating table (Table 4-2) and cross-referencing that score with consequence ratings in the second consequence rating (Table 4-3).

Table 4-2 Consequence rating table number 1

Rating	Definition of Rating	Score
A. Extent – ***the area in which the impact will be experienced***		
None		0
Site	Immediate watercourse within 2 km downstream of an impact location	1
Local	2 km to 10 km downstream (reach/tributary scale)	2
Regional	Greater than 10 km downstream (river system/catchment) scale	3
B. Severity – ***the magnitude of the impact in relation to the sensitivities of the receiving environment***		
None	Unlikely to be detectable	0
Low	Detectable but small and not ecologically significant	1
Moderate	Abundance and distribution altered, but no major impacts on population survival or ecosystem function	2
High	Significant impacts on populations, communities and ecosystem functioning, possibly resulting in population extinctions or irreversible changes to ecosystem health and functioning	3
C. Duration – ***the timeframe over which the impact will be experienced***		
None		0
Short-term	Residual impacts lasting < 1 year	1
Medium-term	Residual impacts lasting between 1 and 5 years	2
Long-term	Residual impacts lasting longer than 5 years	3
Combined Score		
Consequence Rating	**From Consequence Rating Table #2**	

Table 4-3 Consequence rating table number 2

Combined Score (A+B+C)	**0-2**	**3-4**	**5**	**6**	**7**	**8-9**
Consequence Rating	Not significant	Very Low	Low	Medium	High	Very

The next step is to outline the likelihood of the impact occurring based on clear definitions of probability provided in the likelihood rating table (Table 4-4).

Table 4-4 Likelihood rating table

Probability – ***the likelihood of an impact occurring***	
Improbable	< 10% chance of occurring
Possible	11 to 50% chance of occurring
Probable	51 to 90% chance of occurring
Definite	> 90% chance of occurring

To determine the significance rating for risk associated with an impact, consequence and likelihood 'scores' were cross-referenced (Table 4-5).

Table 4-5 Significance rating table

Significance Rating	**Consequence**		**Probability**
Insignificant	Very Low Very Low	+ +	Improbable Possible
Very Low	Very Low Very Low Low Low	+ + + +	Probable Definite Improbable Possible
Low	Low Low Medium Medium	+ + + +	Probable Definite Improbable Possible
High	High High Very High Very High	+ + + +	Probable Definite Improbable Possible
Very High	Very High Very High	+ +	Probable Definite

The next step was to define the status of the impact (i.e. whether the impact is deleterious or beneficial). Next, the impact was categorised according to whether it was expected to increase (I), diminish (D) or stay the same (S) over time. Finally, a confidence rating (high, medium or low) was applied to the predictions made in the risk rating.

These steps culminated in a final impact assessment table (Table 4-6). To clearly illustrate the effect that mitigation measures could have in reducing the impact, the table was complete under the scenarios of with and without mitigation in place.

Table 4-6 Example impact assessment table

Impact	Mitigation	Extent	Severity	Duration	Consequence	Probability	Significance	Status	Confidence
	Without	Local (2)	Mod (2)	Short (1)	Low	Probable	Low	Neg (D)	High
	With	Site (1)	Low (1)	Short (1)	Very low	Possible	Insignificant	Neg (D)	High

4.3 Freshwater

4.3.1 Existing Impacts

The entire Portion 152 area has a long history of anthropogenic influence. The area has been used for cattle grazing for some 40 years and local people regularly burn-off in the area. Environmental values of the freshwater habitats are lowest in the immediate vicinity of the main road. There is refuse (see Plate 4-3) and stagnation at the road crossing sites and little high-value aquatic habitat and riparian cover. Further towards the southeast, closer to the hills and headwaters of the Vaihua River (site VAI5), environmental values are higher although species diversity and abundance is still low.

Plate 4-3 Freshwater drainage of the Vaihua River at road crossing

4.3.2 Sensitivities

Fish species encountered during the baseline survey are widely distributed in the region and Papua New Guinea. No rare or endemic species were recorded. Freshwater fishes encountered in pools the study area endure the dry season in the pools and presumably tolerate declining water quality over the dry season, and thus are considered to be 'hardy'. This is a common trait among fish species in the dry-tropics and in other areas; fishes are known to tolerate low oxygen levels, and low food supplies. However, during these dry times, the pools represent isolated 'refuges' in an otherwise dry environment. Isolated pools have minimal flushing capacity and the organisms have no opportunity for behavioural avoidance of intolerable conditions, so there is likely to be sensitivity to pollutants or other additional stress during dry periods.

As outlined in Section 4, the onset of the wet season and restored flow and connectivity in other dry-tropical environments usually marks the onset of migration, breeding and re-distribution and this is expected to be the case in Portion 152. Therefore, during the wet season, the fauna is likely to be sensitive to barriers to breeding/migration behaviours, such as diverted channels or blocked/impassable road crossings.

Generally, it is acknowledged that species adapted to clear-water habitats are more sensitive to sediment impact than those adapted for life in large turbid rivers. The freshwater reaches of the streams in Portion 152 are generally clear water, while the estuarine reaches are generally turbid environments. Therefore, freshwater species are generally expected to be more sensitive to sediment than estuarine species, a sensitivity that is exacerbated by the limited opportunity for freshwater species to behaviourally avoid intolerable conditions.

4.3.3 Impact Assessment

4.3.3.1 Impacts to physical habitat

Issues to be addressed

Impacts to riparian vegetation and habitat structure will be confined to the stream banks where the newly constructed roads, pipeline landfall RoW or other facility construction works intersect watercourses. Many of the freshwater watercourses have low-value riparian zones with little fish habitat structure or shading (Plate 4-4). In the lower reaches of freshwater watercourses, pandanus trees on the banks of some watercourses have most potential to provide some higher-value aquatic habitat. Some sites may have riparian zones of higher ecological value, although more pristine riparian zones were only identified in this study in the far southeastern section of the study area near the headwaters or the Vaihua River and no construction will occur in these areas.

Plate 4-4 Typical Vaihua River watercourse at the road crossing

The flow-on effects of physical habitat damage are expected to be negligible and not ecologically significant. Areas immediately adjacent to the crossing works will provide adequate habitat for organisms to relocate to, although it must be recognised that in some areas, pools are separated by dry riverbed and so the potential for relocation is limited in some circumstances.

Physical habitat could be potentially impacted by the mobilisation of sediment from watercourse crossing construction activities. Given the minimal flow through these watercourses, the potential for dispersal of sediments, and potential downstream impact, is low.

A hydrology and sediment report for the Portion 152 area (Hydrobiology 2008f) showed that under a modelled high-flow scenario, the construction of roads in the Vaihua River catchment is expected mobilise a small amount of sediment to the aquatic system (some 3% of the system's transport capacity). This suggests that the potential for smothering of benthic habitats by sediment is very low.

Given the modified nature of the existing habitats, and the fact that many crossing points may actually be dry during construction, the potential sediment-related impacts to habitats are expected to be insignificant.

Mitigation

Recommended measures to mitigate impacts to physical habitat in freshwater environments are listed in Table 4-7.

Table 4-7 Mitigation measures – physical habitat impacts – freshwater

Potential Impact	Proposed Mitigation Measures
Removal of riparian vegetation and modification of bank structure	• Limit the extent of riparian vegetation cleared where practical. • Fine-scale selection of crossing site to avoid particularly large/established riparian vegetation and complex bank habitat structure. • Where practical, stabilise and re-vegetate cleared banks.
Sediment	• Limit the extent of terrestrial and riparian vegetation cleared where practical. • Use good industry practice sediment controls when working within a watercourse that has flowing water. • Avoid stockpiling side-cast and topsoil materials close to waterways if rainfall and water-flows are predicted. • Good industry practice management of sediment runoff from stockpiles and cleared areas around watercourses (e.g. the use of vegetative screens, sediment traps, bunds). • Where practicable, time major earthworks to coincide with dry periods.

Impact Assessment

Table 4-8 provides a summary of the impact assessment for potential impacts to physical habitat in freshwater environments. In this table, risk ratings are provided for circumstances with and without the recommended mitigation measures in place. While the predicted risk ratings are very low even with no mitigations in place, proposed mitigation measures are expected to reduce the risk of impacts to physical habitats to a negligible level.

Table 4-8 Impact assessment - physical habitat impacts – freshwater

Impact	Mitigation	Extent	Severity	Duration	Consequence	Probability	Significance	Status	Confidence
Removal riparian vegetation and modification of bank structure	Without	Site (1)	Low (1)	Short (1)	Very low	Definite	Very Low	Negative (S)	High
	With	Site (1)	None (0)	None (0)	Not significant	Probable	Insignificant	Negative (S)	High
Sediment	Without	Local (2)	Low (1)	Short (1)	Very Low	Probably	Very Low	Negative (D)	High
	With	Site (1)	None (0)	Short (1)	Not significant	Possible	Insignificant	Negative (D)	High

4.3.3.2 Impacts to biological communities

Issues to be addressed

Sediment has the potential to impact biological communities as suspended sediment or via the processes of sedimentation (depositing of sediment onto substrate). The ways in which sediment can affect biological communities are summarised above and were outlined in the previous Gas Project EIS (Enesar 2005; DBA 2005). Sediment impacts typically cause chronic effects when the magnitude or duration of exposure exceeds tolerance limits for organisms. The potential impacts of sediment are described by a magnitude multiplied by duration relationship and most organisms are tolerant of short episodes of high sediment loads, or longer episodes of low-level sediment increases. Sediment impacts typically cause a re-distribution of mobile organisms away from the impacted area. Sessile organisms unable to avoid the impacted area may be killed in extreme circumstances.

The construction of watercourse crossings, and the construction of other project facilities have the potential to increase sediment input to watercourses. This effect would be greatest during the construction period if earthworks result in exposure of sediment to rainfall and when rehabilitation measures have not yet been put into place. Thus, such effects are expected to be short-lived for the most part. For watercourse crossings, there may be longer-duration pulses of low-level input of sediment because the crossings structures will likely be maintained as a cleared corridor and not revegetated and thus potentially exposed to erosion at a low level throughout construction and operations. Obviously, the predominance of dry conditions significantly reduces the potential for sediment to be mobilised downstream.

Hydrobiology (2008f) showed that the construction of roads in the Vaihua River catchment is expected to contribute and additional 4% to the total potential total suspended sediment (TSS) (<125 µm fraction of the sediment load[3]) of the system under a modelled high-flow scenario. This is a very small increase in potential TSS and biological impacts associated with this are expected to be insignificant with mitigations in place.

Introductions of aquatic pest species will be controlled by the development of a weed and pest management plan. The risk of spread of exotic species is considered low, with suitable controls.

Mitigation

As described above, the maintenance of connectivity between the freshwater and estuarine environment is important during times of flow. The construction of road or pipeline easement crossings has the potential to pose a barrier to that connectivity if the crossing;

- Causes a diversion or pooling of water around the crossing;
- Creates a 'step-up' that is impassable by fish and other animals; or

[3] The <125µm fraction of the TSS load is the fine-sediment fraction and regarded as the fraction of most relevance to potential impacts to organisms.

- Involves the installation of long pipe culverts that funnel the flow to create high velocities or create conditions of light or substrate that are unsuitable for fish and other animals.

The creation of fish-passage barriers in Australia has been found to be responsible for altering distribution of fishes in upstream habitats. Good industry practice design of watercourse crossings[4] (see Cotterell 1998; Witheridge 2002; Fairfull and Witheridge 2003) will avoid the creation of barriers or alterations to water flow.

Mitigation measures to minimise impacts to biological communities in freshwater habitats are given in Table 4-9.

Table 4-9 Mitigation measures - impacts to biological communities - freshwater

Potential Impact	Proposed Mitigation Measures
Sediment	• All sediment-related mitigation measures outlined above
Introduction of exotic species	• Educate workers about potential impacts of deliberate translocation of fish species. • Develop a weed and pest management plan.
Barriers to fish movement and freshwater-estuarine connectivity	• Reinstate watercourse channels after construction of crossings or, design appropriate diversions. • At crossings, if culverts are required, select large, wide box-type culverts or similar in preference to long, narrow pipe culverts. • Complete watercourse crossing construction during dry conditions as far as practical. • Avoid fine feeder-channels in the saltpan environment (see Figure 5-2).

Impact Assessment

Table 4-10 provides a summary of the impact assessment for potential impacts to biological communities in freshwater environments.

[4] Such as New South Wales Department of Primary Industries Policy and Guidelines for Fish Friendly Waterway Crossings and Queensland Department of Primary Industries Guidelines for design of stream crossings.

Table 4-10 Impact assessment – impacts to biological communities - freshwater

Impact	Mitigation	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Increased Sediment Mobilisation	Without	Site (1)	Moderate (2)	Short (1)	Very low	Probable	Very low	Negative (D)	High
	With	None (0)	None (0)	None (0)	Not significant	Improbable	Insignificant	Negative (D)	High
Introduction of exotic species	Without	Regional (3)	Moderate (2)	Long (3)	Very high	Improbable	High	Negative (I)	Low
	With	None (0)	None (0)	None (0)	Not significant	Improbable	Insignificant	Negative (I)	Low
Barriers to fish movement and freshwater-estuarine connectivity	Without	Regional (3)	High (3)	Long (3)	Very high	Possible	High	Negative (I)	Low
	With	None (0)	None (0)	None (0)	Not significant	Improbable	Insignificant	Negative (I)	Low

4.4 Estuaries

4.4.1 Existing Impacts

Observations made during this study suggest that the estuaries are utilised for aquatic resources to a much higher level than the freshwater environment. At the time of sampling, spring tides were encountered and this was known to be a time of good fishing. Harvesting of mud crabs, fishing and extraction of mangrove wood are some of the pressures existing in the estuaries. The degree to which landuse practices within Portion 152 have impacted the estuaries is unknown. However, it would be reasonable to expect that agriculture and burning in the catchment may have resulted in non-pristine conditions in the estuaries.

4.4.2 Sensitivities

Estuaries are naturally depositional/turbid environments and many of the organisms inhabiting estuaries are considered to be relatively tolerant of sediment. The sensitivities of the estuaries within, and downstream of, the project area are considered to be mostly related to sensitivities to mangroves. Mangroves provide important habitat structure in the estuaries and regulate depositional processes and coastal erosion (waves).

Estuaries generally have high flushing capacity, although the upstream reaches of estuaries sampled in this study had hyper-saline conditions (see Hydrobiology 2008d). This may suggest that flushing and water turn-over in the far upstream estuarine reaches is reduced, thus indicating that there is some potential for freshwater-derived sediment or pollutants delivered to these areas to become trapped/concentrated.

Estuaries in the project area recorded considerably higher biomass and diversity than the freshwater environment and are considered, for the purposes of this impact assessment, to be a more ‘sensitive’ receiving environment. The high level of resource use in estuaries also dictates that the estuaries will come under closer scrutiny from stakeholders.

As described above, connectivity between estuaries and freshwater is believed to be a key ecosystem process in this area. Therefore, the estuaries, and aquatic environment in general, is sensitive to the modification of the ability for water, fish and other organisms to move between the freshwater and estuarine environment in wet conditions.

4.4.3 Impact Assessment

The project has minimal direct interaction with the estuarine environment (see Figure 4-1). Potential impacts to estuaries arise from the downstream transport of sediment, spills or other issues in the freshwater environment (e.g. disruption of flow connectivity) being transported downstream into estuaries. The dry conditions that predominate in Portion 152 and the ephemeral nature of most of the freshwater watercourses will limit the potential for potential impacts in the upstream environment to affect the estuaries. The estuaries under consideration in this assessment are the Vaihua and North Vaihua estuaries (see Figure 2-1).

4.4.3.1 Impacts to Physical Habitat

Issues to be addressed

The construction of the combined Materials Offloading Facility/LNG Jetty will involve the clearing of a swath 105 m wide through the mangrove fringe, for a distance of some 400 m (see Figure 4-1. The LNG pipeline easement, to the north of the jetty, will require clearing of a narrower swath, approximately 25 m wide, through a narrow band of mangroves (approximately 200 m wide). The LNG pipeline easement will not interact with estuary channels at all as the mangroves at the landfall site represent a coastal fringe only and there is no permanent estuarine feature in the vicinity. The jetty construction will take place some 800 m north of the Vaihua River estuary and some 400 m north of the North Vaihua estuary (see Plate 4-1). Therefore, it is considered unlikely that impacts to the physical habitat structure at the construction sites will have an impact on these two main estuary features. It is believed that any potential sediment mobilisation generated from the construction site in the mangroves will be trapped by the mangrove system existing between the construction site and the estuaries.

Construction activities related to the LNG Facility are located inland from the saltpans and to the north of the estuaries. Sediment mobilised from the on-land construction activities has the potential to enter the estuary and potentially impact physical habitats through deposition. However, it is believed that this will be unlikely because there are significant landscape buffers between the LNG Facility and the estuary (terrestrial vegetation, mangroves and saltpans). Further, the predominance of dry conditions is expected to limit the transport of construction-derived erosion or turbid runoff into the estuary.

It is reasonable to expect that sediment mobilisation could cause a nearshore turbid plume when construction activities reach the seaward extent of the jetty. This turbid water may enter the estuaries due to tidal water movement or wind and wave action. The effects of this potential source of sediment to the coastal marine environment is not assessed in this report. For the estuarine environment, this potential sediment influx is expected to be very minor and not have a detectable or significant impact on physical habitats.

Mitigation

The location of the LNG Jetty and the LNG pipeline ROW some distance from the estuaries is the main mitigating factor. Further, the location of the LNG Facility landward of the estuaries, separated from the estuaries by saltpans, terrestrial vegetation and mangroves dictates that any fugitive sediment generated at the LNG Facility site is highly unlikely to affect the estuaries. Addition mitigations that could be considered are given in Table 4-11.

Table 4-11 Mitigation measures – physical habitat impacts – estuaries

Potential Impact	Proposed Mitigation Measures
Removal riparian vegetation and modification of bank structure	• No additional mitigations – Jetty and Pipeline landfall not intersecting with estuary banks.
Sediment	• Use silt curtains and other good industry practice management controls when working in mangroves, particularly near the seaward extent.

Note: This impact assessment does not assess the impacts to mangrove trees themselves, only the mangroves in terms of their habitat value to estuarine aquatic organisms.

Impact Assessment

An assessment of potential impacts to physical habitats in estuaries is given in Table 4-12.

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Table 4-12 Impact assessment – impacts to physical habitat - estuaries

Impact	Mitigation	Extent	Severity	Duration	Consequence	Probability	Significance	Status	Confidence
Reduced riparian vegetation, modified habitat structure	Without	Site (1)	None (0)	Short (1)	Not Significant	Improbable	Insignificant	Negative (S)	High
	With	Site (1)	None (0)	None (0)	Not Significant	Improbable	Insignificant	Negative (S)	High
Increased sediment	Without	Site (1)	Low (1)	Short (1)	Very Low	Possible	Insignificant	Negative (D)	High
	With	Site (1)	None (0)	None (0)	Not Significant	Improbable	Insignificant	Negative (D)	High

4.4.3.2 Impacts to Biological Communities

Issues to be addressed

Estuarine species are generally considered to be relatively sediment tolerant as estuaries are generally turbid environment, particularly in their seaward extents. As described above, the potential for sediment to enter estuarine reaches is considered very low. Therefore, sediment-related impacts are considered unlikely.

The connectivity between estuaries and freshwater habitats at times of freshwater flow is believed to be important for the ecological functioning of both environments, as described above. Construction of barriers to fish movement or blockage of that connectivity has the potential to adversely affect estuarine biological communities.

At the time of writing, modelling has shown that the presence of the materials offloading facility and LNG jetty (a solid structure in the current design) has the potential to alter near-shore hydrological processes and thus longshore sediment transport processes. This could potentially cause sediment accretion on the south side of the jetty, possibly leading to sediment accumulation at the mouth of the Vaihua River estuary and blocking of the estuary mouth. At the time of writing, a number of engineering solutions are being investigated by the proponent. The commitment has been made that the jetty will be designed and engineered such that it will not affect nearshore sedimentation and will not cause sediment accretion at the estuary mouth (David Gywther, Coffey Natural Systems, pers. comm.). Therefore, the potential impact of sediment deposition at the estuary mouth and the potential impact of estuary blockage are not considered further in this assessment.

Mitigation

Mitigation measures are given in Table 4-13.

Table 4-13 Mitigation measures - impacts to biological communities - estuaries

Potential Impact	Proposed Mitigation Measures
Sediment	• All sediment-related mitigation measures outlined above. • Community environmental awareness training about the sensitivity of mangroves and provide alternatives to mangrove wood harvesting.
Introduction of exotic species	• Educate workers about potential impacts of deliberate introduction of fish species. • Establish a weed and pest management plan. • Install appropriate washdown points in the project area to clean vehicles and equipment.
Barriers to fish movement and freshwater-estuarine connectivity	• All on-land mitigations described in Table 4-9.

Impact Assessment

An assessment of potential impacts to biological communities in estuaries is given in Table 4-14.

Table 4-14 Impact assessment – impacts to biological communities - estuaries

Impact	Mitigation	Extent	Severity	Duration	Consequence	Probability	Significance	Status	Confidence
Increased sediment	Without	Site (1)	Low (1)	Short (1)	Very Low	Possible	Insignificant	Negative (D)	High
	With	None (0)	None (0)	Short (1)	Not Significant	Improbable	Insignificant	Negative (D)	High
Introduction of exotic species	Without	Regional (3)	Moderate (2)	Long (3)	Very High	Improbable	High	Negative (I)	Low
	With	None (0)	None (0)	None (0)	Not Significant	Improbable	Insignificant	Negative (I)	Low
Barriers to fish movement and freshwater-estuarine connectivity	Without	Local (2)	Low (1)	Long (3)	Medium	Improbable	Low	Negative (I)	Low
	With	None (0)	None (0)	None (0)	Not Significant	Improbable	Insignificant	Negative (I)	Low

5 SUMMARY OF RECOMMENDED MITIGATION MEASURES

A summary of the mitigation measures recommended in this report, and the potential impact that these measures are mitigating, is given in Table 5-1. The component of the environment in which these mitigations will have a beneficial effect is indicated.

Table 5-1 Summary of proposed mitigation measures

Impact	Mitigation Measures
Removal of Riparian Vegetation and Modification of Bank Structure	Limit the extent of riparian vegetation cleared where practical.
	Fine-scale selection of crossing site to avoid particularly large/established riparian vegetation and complex bank habitat structure.
	Where practical, stabilise and re-vegetate cleared banks.
Sediment	Where practicable, time major earthworks to coincide with dry periods.
	Develop a sediment and erosion control plan.
	Limit the extent of terrestrial and riparian vegetation cleared where practical.
	Use good industry practice sediment controls when working within a watercourse that has flowing water.
	Avoid stockpiling side-cast and topsoil materials close to waterways if rainfall and water-flows are predicted.
	Community environmental awareness training about the sensitivity of mangroves and provide alternatives to mangrove wood harvesting.
Barriers to fish movement and freshwater-estuarine connectivity	Good industry practice design and installation of watercourse crossing structures.
	Reinstate watercourse channels after construction of crossings or, design appropriate diversions.
	At crossings, if culverts are required, select large, wide box-type culverts or similar in preference to long, narrow pipe culverts.
	Avoid construction works in fine feeder-channels in the saltpan environment (see Figure 4-2).
Introduction and spread of exotic species	Develop a weed and pest management plan.
	Educate workers about potential impacts of deliberate translocation of fish species.
Nutrient Enrichment	Develop a wastewater management plan.
Accidental spill of fuels, oils and other chemicals	Implement rigorous vehicle and construction management/testing procedures when machinery is required to enter watercourses or riparian zones.
	Develop and implement procedures for the appropriate handling, transport, storage and disposal of materials including fuels, lubricating oils, and other chemicals stored or used on site.
	Provide appropriate spill response equipment and training at construction sites, and at fuel storage and handling facilities.
	Develop and implement good industry practice management procedures for the demobilisation of construction crews, machinery and hydrocarbons.
	If drilling is to take place, implement a drilling fluid management plan.

Footnote: Mitigation measures in grey cells are mitigations to ameliorate potential water quality impacts. While water quality impacts are not assessed in this report, these mitigation measures are listed here because apart from sediment, these are the potential water quality impacts of most relevance to potential impacts to biological communities.

6 RECOMMENDED STUDIES, MANAGEMENT AND MONITORING

6.1 Additional Studies

It is recommended that, prior to construction, a freshwater aquatic fauna sampling event is conducted to coincide with a time of high rainfall and freshwater flows. This sampling exercise should also include a round of high-flow water quality baseline sampling. Together, these two studies will provide valuable baseline data, while also confirming the assumptions made in this report with respect to the ecological values of the freshwater environment and connectivity between freshwater and estuarine habitats.

6.2 Management

This impact assessment has suggests that the impacts of the development of the LNG Facilities area on freshwater and estuarine habitats will be very low. In particular, the predominance of dry conditions creates an opportunity to carry out construction (the time of highest potential impact) during these conditions, thus minimising the potential for sediment-related impacts in freshwater and estuarine habitats. Other factors, including the non-pristine nature of the freshwater and estuarine habitats and the sighting of the LNG Facility outside major catchment influences, also reduce the potential for aquatic impacts.

There are two ecological principals that are believed to prevail in the dry and wet conditions:

1. **Dry conditions (the predominant scenario):** Freshwater fauna restricted to remnant pools. Therefore, protection of water quality in pools is important. Estuaries operate as tidal inlets with little or no freshwater input.

2. **Wet conditions:** Flow returns to streams and connectivity with estuary restored. This represents a time of potential increased impacts from sediment runoff etc., but also higher flushing/buffering capacity in the freshwater environment. During these times, maintaining connectivity is important.

Therefore, the two over-arching management recommendations are:

1. As far as practicable, aim to complete construction activities during predicted dry conditions.

2. Maintain flow connectivity and fish passage in wet conditions by installing appropriate watercourse-crossing structures and by rehabilitating and reinstating drainage and feeder-channels if these are affected.

The construction phase of the project is considered to represent higher potential for aquatic impacts than the operations phase as the former involves clearing of vegetation, earthworks, large numbers of personnel and heavy use of machinery. During the operations phase, the main potential for impact arises from accidental spillages, which are easier to plan for and control.

6.3 Monitoring

It is recommended that monitoring take place after construction, targeted during wet conditions. This monitoring exercise would aim to sample both freshwater and estuarine habitats, but with a focus of freshwater, with the primary aim of confirming the maintenance of connectivity and fish movement. It is envisaged that water quality monitoring for a range of parameters would be required as part of the license requirements of the project and this monitoring would also serve to monitor for potential sediment/pollutant impacts and thus used to confirm the predictions of water quality impacts in this assessment.

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Appendix 1 Fish Catch Data

Estuary Sites

Species Name Common Name	Data	Site						Total
		KAR1	KAR2	VAI1	VAI2	VAI3	VAI4	
Ambassis macrocanthus	Number			5	4			9
Estuarine glass perchlet	Weight (g)			14.8	27.6			42.4
Apogon hyalosoma	Number	9		14	11	15	3	52
Estuary cardinalfish	Weight (g)	37.6		319.5	24.1	87.2	15.8	484.2
Arothron manillensis	Number				1		1	2
Pufferfish	Weight (g)				5.5		17.2	22.7
Arothron reticularis	Number	2						2
Pufferfish	Weight (g)	3.8						3.8
Butis amboinensis	Number	1					1	2
Ambon gudgeon	Weight (g)	2.1					3.4	5.5
Caranx sexfaciatus	Number					2		2
Bigeye trevally	Weight (g)					63.8		63.8
Cherax sp.1	Number						1	1
Yabby	Weight (g)						<0.1	
Eleotris melanosoma	Number	2						2
Ebony gudgeon	Weight (g)	247						247
Epinephelus coioides	Number	1						1
Estuary cod	Weight (g)	542						542
Gazza minuta	Number					1		1
Largetooth ponyfish	Weight (g)					3.6		3.6
Gerres filamentosus	Number			1				1
Threadfin silver biddy	Weight (g)			1.4				1.4
Goby sp.1	Number			10	1	3	4	18
Goby	Weight (g)			6.9	3.6	1.1	7.5	19.1
Goby sp.2	Number			1				1
Goby	Weight (g)			1.1				1.1
Goby sp.3	Number				1			1
Goby	Weight (g)				<0.1			
Goby sp.4	Number				5	1	1	7
Goby	Weight (g)				4.5	<0.1	<0.1	>4.5
Goby sp.5	Number						1	1
Goby	Weight (g)						0.8	0.8
Goby sp.6	Number	1						1
Goby	Weight (g)	<0.1						<0.1
Goby sp.8	Number				4			4
Goby	Weight (g)				28.3			28.3
Himantura granulata	Number			1				1
Mangrove whipray	Weight (g)			Unweighed				
Lutjanus argentimaculatus	Number					1		1
Mangrove jack	Weight (g)					740		740
Lutjanus johnii	Number						1	1
Fingermark bream	Weight (g)						Unweighed	-
Macrobrachium sp.1	Number				1			1
Prawn	Weight (g)				0			0

Macrobrachium sp.2	Number						2	2
Prawn	Weight (g)						0.5	0.5
Macrobrachium sp.3	Number						1	1
Prawn	Weight (g)						Unweighed	
Megalops cyprinoides	Number					1		1
Oxeye herring	Weight (g)					602		602
Polydactuls plebius	Number					1		1
Striped threadfin	Weight (g)					212		212
Scatophagus argus	Number				1		1	2
Scat	Weight (g)				96		161	257
Scylla serrata	Number	2	2		15		1	20
Mudcrab	Weight (g)	83.8	108		1297.5		5.2	1494.5
Siganus vermiculatus	Number				1			1
Vermiculated spinefoot	Weight (g)				76			76
Sphyraena barracuda	Number			1		1		2
Barracuda	Weight (g)			370		315		685
Strongylura krefftii	Number			1		1		2
Longtom	Weight (g)			67		77		144
Thryssa scratchleyi	Number			1		1		2
New Guinea herring	Weight (g)			8		5.6		13.6
Toxotes jaculartrix	Number	1			3	2		6
Archerfish	Weight (g)	0.6			207	172		379.6
Valamugil buchanani	Number		1	2	5	2		10
Mullet	Weight (g)		377	78	953	92.4		1500.4
Zenarchopterus novaeguineae	Number	2						2
Fly River garfish	Weight (g)	6.1						6.1
Total Number		**20**	**3**	**36**	**53**	**32**	**18**	**177**
Total Weight		**923**	**485**	**866.7**	**2723.1**	**2371.7**	**211.4**	**7594.9**

Note: Weights given are total weights of all specimens at each site

Freshwater Sites

Species Name Common Name	Data	Site KAR3	KAR4	KAR5	VAI5	VAI6	VAI7	VAI8	Total
Goby sp.7	Number	3							3
Goby	Weight (g)	Unweighed							-
Macrobrachium lar	Number				Vis			Vis	Vis
Prawn	Weight (g)				obs			obs	obs
Macrobrachium sp.3	Number			Vis					Vis
Prawn	Weight (g)			obs					obs
Melanotaenia papuae	Number	14	1	Vis					15+
Papuan rainbowfish	Weight (g)	9.1	4.9	obs					14+
Opieleotris aporos	Number			Vis	Vis			Vis	Vis
Snakehead gudgeon	Weight (g)			obs	obs			obs	obs
Oreochromis mossambica	Number	15		Vis					15+
Tilapia	Weight (g)	Unweighed		obs					-
Total Number		**32**	**1**	**Vis**	**Vis**	**NO**	**NO**	**Vis**	
Total Weight		**-**	**4.9**	**obs**	**obs**	**CATCH**	**CATCH**	**obs**	

Note: Weights given are total weights of all specimens at each site

Appendix 2 Macroinvertebrate Raw Data

Date Sampled		31-May-08			31-May-08			03-Jun-08			03-Jun-08			04-Jun-08			05-Jun-08		
Site		VAI 1			VAI 2			VAI 3			VAI 4			KAR 1			KAR 2		
Replicate		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Major Taxon	**Family**																		
NEMATODA					1	1	3				5	5		1			2	4	
NEMERTEA							1												
OLIGOCHAETA	Tubificidae	31	16		21	26	4	1	4	3	2	9		5	7			9	2
POLYCHAETA	Amphinomidae				9	12	4						1				10	66	29
	?Ampharetidae(damag)																		1
	Capitellidae				4	2	3				1	1		2			2	2	
	Cirratulidae					4												11	1
	Cossuridae					2	11										1	10	6
	Eunicidae										1							1	
	Glyceridae									1	1	3	1	2			1	9	2
	Lumbrinereidae						1										1		
	Maldanidae																1		2
	Nephtyidae				2	2	4					1		2	1			15	4
	Nereididae					1							1					3	
	Paraonidae						2											17	1
	Phyllodocidae						1										1	1	
	Spionidae				16	13	28							1			4	22	26
	Sternasapidae																	2	5
	Syllidae				3		3											11	6
	Terebellidae																	1	
OSTRACODA					9	11	6				14	14	56				5		3
CUMACEA	Leuconidae			1	4	1	6				6	6	44						
TANAIDACEA	Apseudidae							1					1				2		
	Tanaidae																1		2
AMPHIPODA	Talitridae					1													
	Unid. (damaged)							1									1		1
ISOPODA	Oniscidae					1													
CARIDEA	Alpheidae											1							
	Ogyrididae												1						
	Processidae																		1
	Unid. (damaged)											1							
THALASSINIDEA	Unid. (damaged)																		1
ANOMURA	Diogenidae						2										1		
BRACHYURA	Ocypodidae																		2
BIVALVIA	Arcidae					1												1	
	Galaeommatidae				5	8	2				2	2	2	1	2		4	7	4
	Lucinidae				2	1	1										2		1
	Mactridae						1										3		
	Solemyidae				1														
	Tellinidae										2	1							
GASTROPODA	Cerithiopsidae					1													
	Epitoniidae						2												
	Nassariidae										1	1	1					1	
	Neritidae																1		
	Retussidae				3		1										1		
	Trochidae				4	1	3					5	3			2			
	Vitrinellidae						1				1								
BRANCHIOPODA	Lingulidae																	3	
OPHIUROIDEA	Unid. (damaged)																6		1
	Total Abundance	**31**	**16**	**1**	**84**	**89**	**90**	**3**	**4**	**4**	**36**	**50**	**111**	**14**	**10**	**2**	**50**	**196**	**101**
	Number of taxa	**1**	**1**	**1**	**14**	**18**	**22**	**3**	**1**	**2**	**11**	**13**	**10**	**7**	**3**	**1**	**20**	**20**	**21**