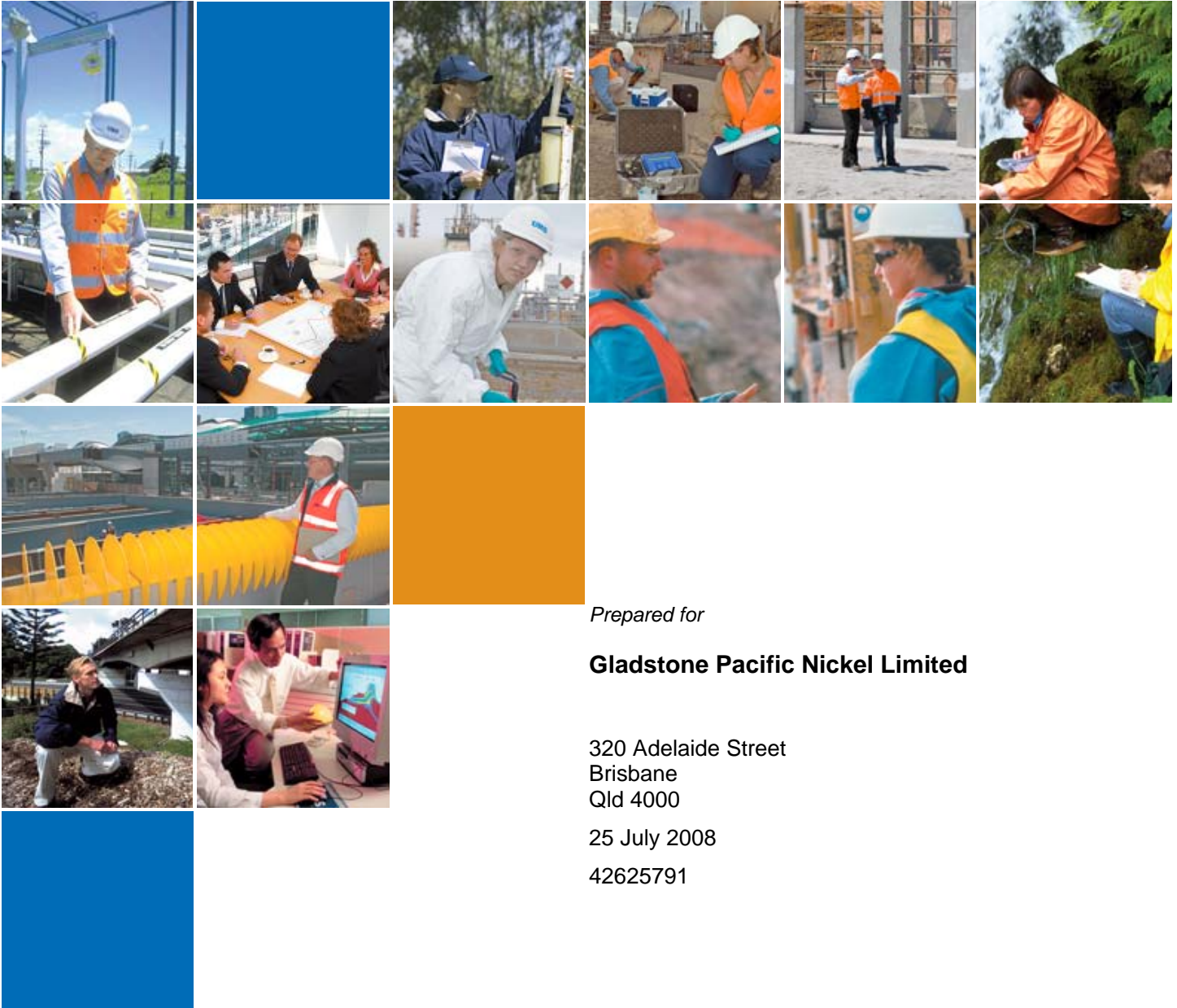


REPORT

Gladstone Pacific Nickel Refinery Environmental Assessment of Treated Water Discharge to Port Curtis



Prepared for

Gladstone Pacific Nickel Limited

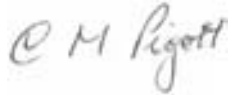
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Date: 25 July 2008
Reference: Environmental Assessment of
Status: Treated Water Discharge at
Port Curtis
FINAL

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Appendices

- A GPN Advection Dispersion Modelling Report
- B Marine Environment Reports

Executive Summary

Gladstone Pacific Nickel Ltd (GPNL) is proposing to build and operate a nickel/cobalt refinery at Gladstone, Queensland. Operation of the refinery will result in the discharge of treated refinery water to Port Curtis at Clinton Wharf at the RG Tanna coal terminal. The discharge will be via diffuser which will consist of a perforated pipe laid on the seabed. There will be one diffuser for each of the proposed two stages of the refinery.

The treated water will be piped from the refinery to a dilution pump pit. Seawater will be mixed with this water in the pit at a dilution ratio of 10:1 seawater to treated water and then discharged to Port Curtis. During periods when the ambient tidal velocity is low (half an hour either side of tide change over, or "slack water") the dilution ratio will be increased to 20:1.

Gladstone Port is Queensland's largest multi-commodity port which moves over 30% of the state's exports. Nevertheless, Port Curtis has important ecological values and is located within the Great Barrier Reef World Heritage Area. At the northern end of Port Curtis is The Narrows which is part of the Mackay/Capricorn Marine Park (a Queensland marine park). The Narrows is also listed in the National Estate Register. In addition, Port Curtis is listed in the Directory of Important Wetlands in Australia.

This report presents the findings of an assessment of the impact of the refinery's proposed treated water discharge on Port Curtis. The assessment was based on the application of the following dispersion models which predicted the effects of the refinery's discharge on the water quality and ecology of the receiving environment:

- Far-field model which assessed impacts throughout the whole of Port Curtis beyond the initial mixing zone.
- Near-field models which assessed impacts in the mixing zone in the immediate vicinity of the diffusers.

Impacts were assessed by comparing the modelled water quality concentrations with water quality objectives for each of the contaminants in the discharge. The objectives were set at levels below which there would be no significant effect on local marine flora, fauna or human health, and by extension, on the local recreational and commercial fishing activities.

The results of the far-field modelling showed that all water quality objectives would be met at all modelled locations throughout Port Curtis for both stages of the refinery.

The near-field modelling showed that water quality objectives will be met within very short distances of the diffusers. There will be small areas within the core of the effluent plume where concentrations will be in excess of the water quality objectives for a short time. However these concentrations are not representative of bulk (or even 'typical') downstream concentrations and do not occur throughout the entire water column.

Contaminants in the discharge are in dissolved form and will not settle out to contaminate the sediment of Port Curtis. The possible exception to this is manganese which may oxidise after some time and form insoluble particles of MnO₂. GPNL retained CSIRO and Central Queensland University researchers to investigate the potential behaviour of manganese. The results indicated:

- Manganese oxidises very slowly and is hindered by efficient tidal mixing.
- Manganese oxides from the refinery discharge are less toxic than dissolved manganese.
- If the oxides adsorb other metals in the seawater, it may have a beneficial effect on marine organisms in the water column due to reduced bioavailability of these metals.

On the basis of the model results it can be concluded that the refinery's discharge to Port Curtis will have no significant effect on the area's water quality or marine ecology.

Executive Summary

GPNL is committed to implementing a comprehensive monitoring program which will include the water quality and flow rates of the refinery discharge, toxicity assessment of the discharge, and near-field and far-field effects.

GPNL has sponsored several Port Curtis monitoring programs through the Port Curtis Integrated Monitoring Program (PCIMP) in order to gather vital baseline conditions. In addition, GPNL has recently committed to continue with this research and has added a specific sponsorship of a PhD student to study the behaviour of metals in Port Curtis over a period of 2-3 years.

Gladstone Pacific Nickel Ltd (ACN 104 261 887) (GPNL) is proposing to build and operate a nickel/cobalt refinery. The project, known as the Gladstone Nickel Project (GNP) consists of a high pressure acid leach plant and metals plant (collectively called the refinery) with supporting facilities to be located at Gladstone, Queensland (refer Figure 1-1).

The refinery site will be approximately 8 km west of the Gladstone central business district, and will be located at the intersection of Hanson and Reid Roads in the Yarwun Precinct of the Queensland Government Gladstone State Development Area (Figure 1-2). It will be divided into two stages; Stage 1 producing 63,000 tonnes per annum of nickel metal, and Stage 2 producing 126,000 tonnes per annum of nickel metal.

The refinery will process ores from a nickel laterite mine near Marlborough, approximately 180 km north-west of Gladstone, together with nickel laterite ores imported from the south-west Pacific region. Residue from the refinery process will be pumped to a residue storage facility (RSF) to be located at Aldoga 12 km south-west of the refinery.

The locations of the key project components are shown on Figure 1-3.

Following removal in the refinery of metals for recovery as nickel and cobalt products, the leach liquor will be combined with solid residues from the leach plant and neutralised and treated before being pumped to the RSF for long term storage. The solid residue will be thickened in the RSF thickener before being discharged to the RSF. Liquor separated in the RSF thickener and liquor decanted from the RSF will be combined in return liquor tanks and pumped back to the refinery. Some of the liquor will be re-used in the refinery and the balance will be discharged to Port Curtis. Optimum treatment of the residue and neutralised liquor is subject to ongoing analysis of treatment options and chemical analysis.

This report details the arrangements for discharge of the treated water to Port Curtis, and assesses the impacts of that discharge.

1.1 Treatment Process Prior to Discharge

The treatment of the barren liquor takes place in the final neutralisation step of the refinery process. This treatment is to neutralise residual acid in the barren solution and washed counter-current decantation (CCD) underflow slurry and precipitate residual metals from solution. To ensure any soluble chromium is removed, the CCD underflow slurry is first contacted with hydrogen sulphide (H_2S) to reduce hexavalent chromium (Cr^{6+}) (if present) to trivalent chromium (Cr^{3+}), which then precipitates when the slurry is neutralised. Excess barren solution is mixed in and neutralised with the reduced slurry to precipitate residual traces of heavy metals. Limestone is added to neutralise acid and then lime slurry is added to ensure that adequate precipitation of the heavy metals is achieved. Precipitation of soluble manganese is enhanced by controlled oxidation using a mixture of air and sulfur dioxide (SO_2/air).

Neutralisation with limestone is only effective up to pH 5; to further increase the pH, lime is required. Conventional neutralisation for minimising the presence of dissolved heavy metals is achieved at a pH of 8.5 to 9 and is less effective than using SO_2/air and requires a substantial addition of lime. The SO_2/air process selected can remove the equivalent manganese from solution more efficiently and at a lower pH.

However, there are limitations to the extent to which the discharged water quality can be improved further.

- Excess addition of SO_2 / air in an effort to further reduce manganese levels is likely to result in re-leaching of chromium, nickel, cobalt and iron back into solution.

Section 1

Introduction

- Increasing the pH above 9 with lime may be beneficial, but
 - As the pH increases above 6.5, a significant quantity of magnesium will precipitate. Magnesium is not considered to be a significant marine contaminant due to its natural abundance, thus its precipitation is not essential. The additional quantity of precipitate would increase slurry handling requirements and reduce the overall storage capacity of the RSF.
 - Higher lime demand would increase the overall cost of reagents, the demand for limestone (from which the lime is produced) and CO₂ generated based on increased fuel consumption and decomposition of the carbonate.

GPNL is considering modifying the current process design to improve the process efficiency by treating the barren solution independently from the residue as this could overcome some of the issues raised above. Also GPNL is very interested in the possibility of synergies with the local aluminium industry as discussed below.

Alternative treatment technologies have been considered but are not viable for the following reasons:

- Ion removal from barren liquor by micro-filtration or reverse osmosis would result in substantially higher energy consumption and operating cost.
- Dedicated evaporation pond for neutralised barren liquor requires considerable real estate due to the quantities involved and maintaining efficient evaporation with a limited depth of water.
- Ion exchange for the removal of manganese from leach residue solutions is still a developing and unproven technology.
- Desalination via evaporative methods has a high capital cost associated with the materials of construction and high energy requirements with associated environmental impact.
- Any of these processes would produce a concentrated brine which would require separate treatment and disposal.

1.2 Synergies in Gladstone

At the inception of the GNP it was identified that there could be a significant synergy between GNP and the nearby aluminium industry. The nature and characteristics of each of the two industries' residues and associated liquors suggest that mobile dissolved contaminants could be removed and that there could be increased water recycling and reduced quantities of solid residue.

In preliminary discussions with aluminium industry stakeholders the concepts of: 1) combining GNP residue with alkaline red mud residue; or 2) utilising GNP's high magnesium liquor to replace seawater for alkaline red mud residue neutralisation appeared to be received with interest. However development of these concepts will not proceed before the GNP receives an external go ahead (environmental approvals) and an internal green light (commercial funding).

1.3 Report Structure

The report has the following structure:

- 2) Background- Provides an overview of the evolution of options that have been investigated.
- 3) Proposed Water Discharge Configuration- Provides details on the proposed configuration of the treated water discharge to Port Curtis.

Introduction


Section 1


- 4) Existing Environment- Describes the potentially impacted environment prior to any impact by this project.
- 5) Development of Water Quality Objectives- Discusses suitable water quality objectives for this project.
- 6) Dispersion Modelling- Outlines the modelling undertaken to assess the potential impacts.
- 7) Assessment of Potential Impacts- Discusses the impacts of the refinery's discharge on the marine environment of Port Curtis.
- 8) Proposed Ongoing Studies and Monitoring- Outlines the studies and monitoring requirements proposed.

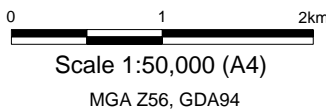
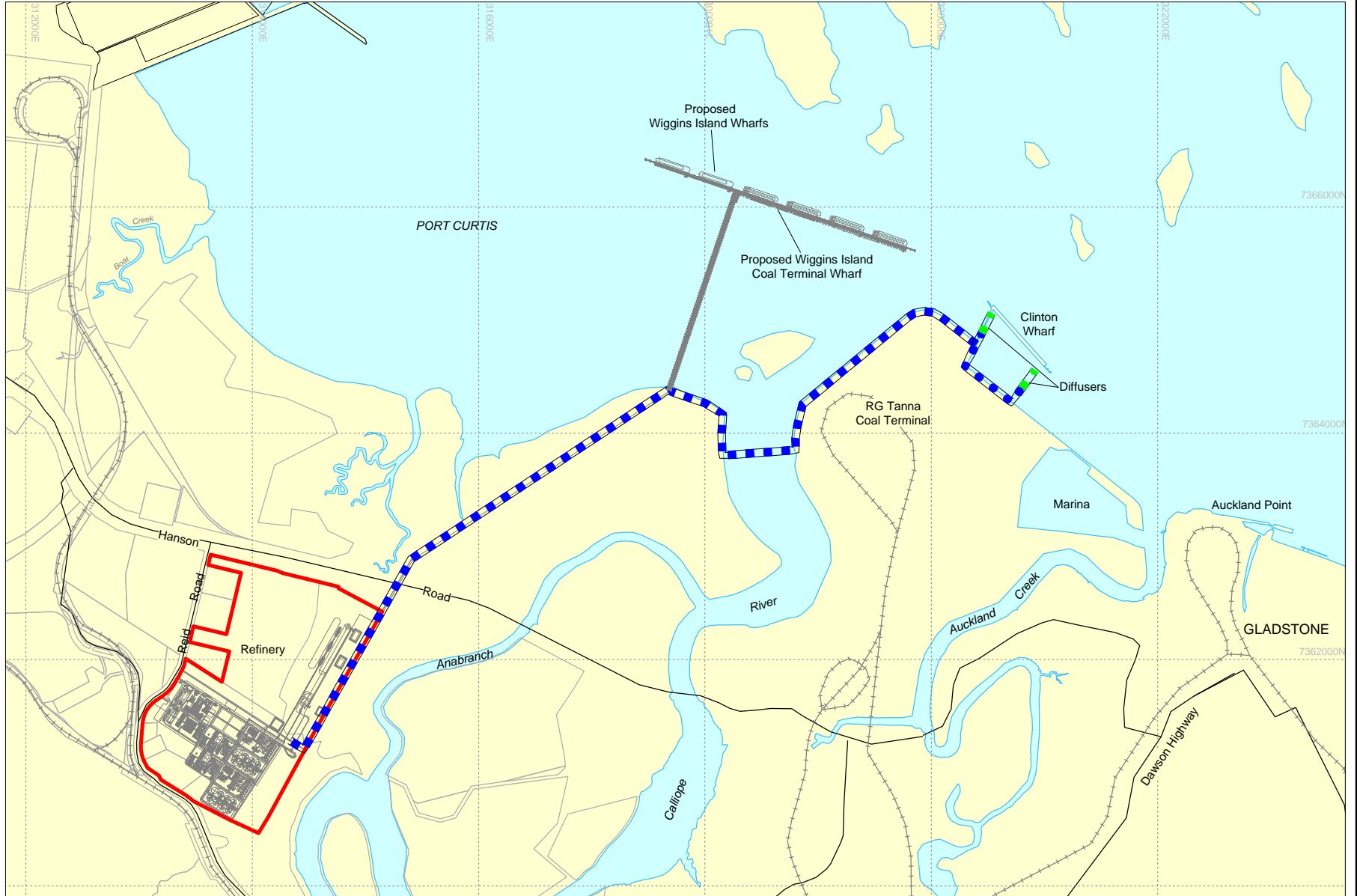


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Client Gladstone Pacific Nickel Ltd	Project GLADSTONE NICKEL PROJECT ENVIRONMENTAL ASSESSMENT OF TREATED WATER DISCHARGE AT PORT CURTIS	Title REGIONAL LOCALITY	
	Drawn: VH	Approved: CMP	Date: 22/07/2008
Job No: 4262 5791	File No: 42625791-g-277.wor		Figure: 1-1 Rev:A A4

		Client Gladstone Pacific Nickel Ltd	
Project GLADSTONE NICKEL PROJECT ENVIRONMENTAL ASSESSMENT OF TREATED WATER DISCHARGE AT PORT CURTIS		Title DISCHARGE PIPELINE ROUTE	
Drawn: VH Job No.: 4262 5791	Approved: CMP File No.: 42625791-g-279.wor	Date: 22/07/2008	Figure: 1-2
Rev: A A4			



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Note: Stage 1 - 1 diffuser
 Stage 2 - 2 diffusers
 Discharge Pipeline



Gladstone Pacific Nickel Ltd

Client

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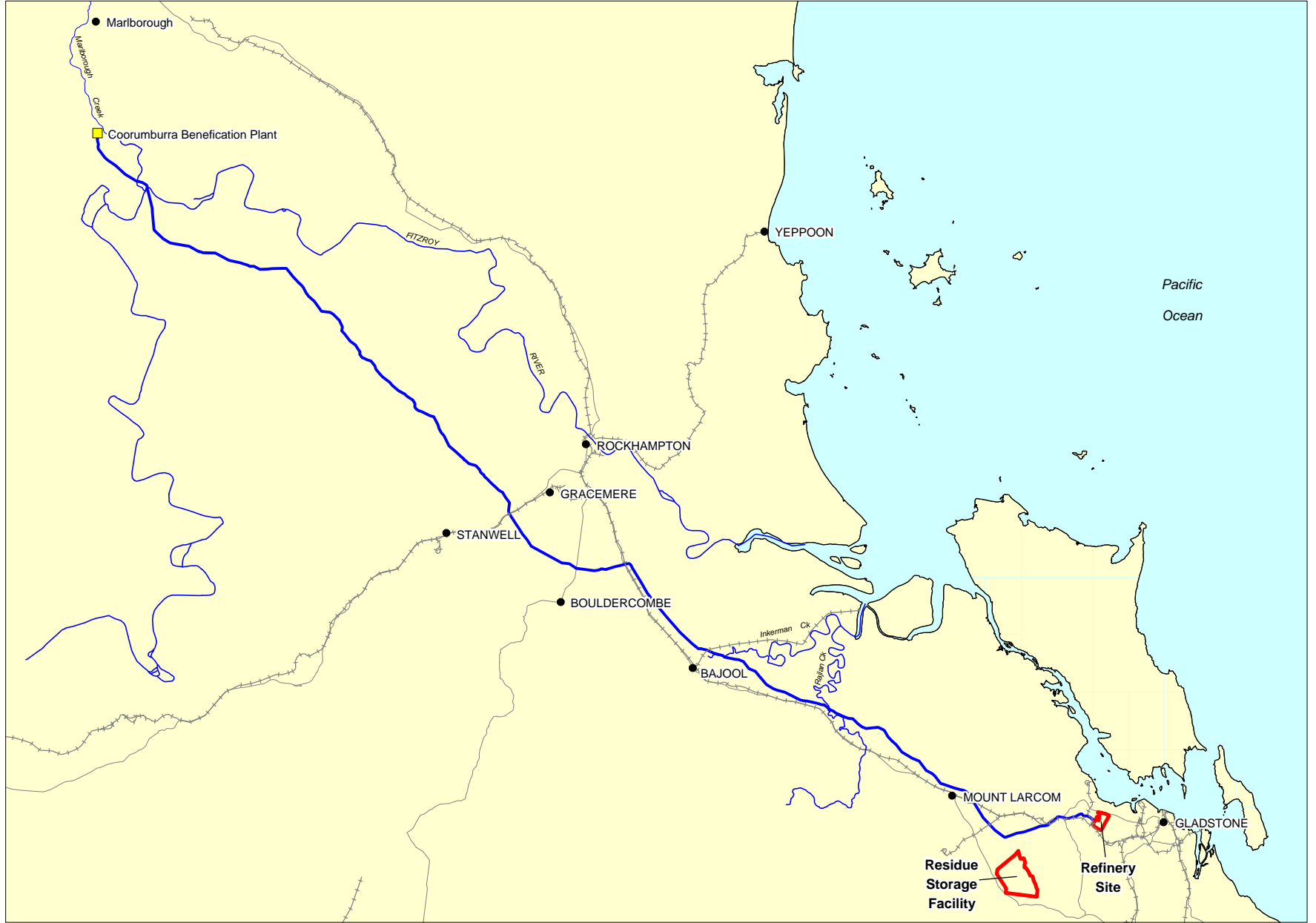
GLADSTONE NICKEL PROJECT
ENVIRONMENTAL ASSESSMENT
OF TREATED WATER DISCHARGE
AT PORT CURTIS

Title

Figure: 1-3



SLURRY PIPELINE ROUTE

Rev:A
A4



0 12.5 25km

Scale 1:750,000 (A4)
MGA Z56, GDA94

-  Proposed Development Footprint (Refinery and RSF)
-  Slurry Pipeline

2.1 Discharge Options

In the development of a suitable arrangement to discharge the treated water from the refinery to Port Curtis, numerous options were considered. Each option was investigated to determine:

- The far-field distribution of the constituents within the discharge;
- The likely dilutions to be achieved for the constituents of concern; and
- Likely behaviour of the near-field plume and assessment of the associated dilutions.

Through the iterative process of near-field and far-field modelling, the following options for disposal of the refinery discharge were considered. The discharge arrangements consisted of either eductors (single standalone outlets), diffusers (multiport pipes) or combinations of both.

The first option was eductors located at the proposed Wiggins Coal Terminal Wharf. An investigation was undertaken on the dynamics in the near-field (using the CORMIX model) and the far-field (using the RMA-11 model). The eductors were aligned perpendicular to the main direction of tidal flow, and a variety of different flow rates and pollutants concentrations were tested. The near-field modelling showed that there was bottom attachment of the plume and the far-field results showed that there was poor dilution of the pollutant discharge, especially within the mangrove regions to the north and south of Fisherman's Landing. The modelling also suggested there might be recirculation of the pollutant discharge back towards a precious seawater intake location, and longer term accumulation in the mangrove areas. For these reasons this option was not pursued.

The second option moved further south to the existing RG Tanna wharf. The configuration consisted of four discharge pipes with eductors located along the RG Tanna wharf, parallel to the main direction of tidal flow, but discharging perpendicular to ambient tidal flows. The results showed that there was a tendency for the pollutant discharge to accumulate in the marina and to disperse up the Calliope River during spring tides. Also, insufficient vertical mixing was attained by the use of these eductors, making the conceptual link between the near-field and (vertically averaged) far-field modelling difficult.

The third option consisted of the discharge pipe situated along the RG Tanna wharf, extending approximately 1 km. The diffuser was aligned parallel to the main currents and there were further options of two different flow rates with different concentrations of pollutants. The results from this far-field modelling suggested that the dilutions were constrained by the parallel alignment of the discharge pipe with the ambient tidal flow regime. In particular, insufficient dilution was attained. Near-field modelling suggested that there would be greater dilutions if the pipe was to be situated perpendicular to the flow, instead of parallel. This option was pursued.

The fourth option consisted of a diffuser line situated along the approach jetty to RG Tanna wharf, perpendicular to the main direction of tidal flow. Transformation rates for dissolved manganese were applied in the far-field modelling. These rates consisted of 4-day and 30-day transformation rates. Whilst the resultant near and far-field concentrations were considerably lower than previously observed, dilutions were still insufficient.

The fifth option consisted of two diffuser lines, one situated along the approach jetty to RG Tanna wharf, and another diffuser line 900m east, both perpendicular to the main direction of tidal flow. Transformation rates for manganese were applied in the far-field modelling, however the dilutions were still not sufficient.

The sixth option comprised two diffuser lines located as before, but approximately 1.7 km apart.

Section 2

Options Considered

The seventh option consisted of two diffuser lines as per above for Stage 1, with an additional two diffusers for Stage 2 included equi-spaced between those of Stage 1. A transformation rate of 28 day a half-life was simulated for manganese and no decay was assumed for all other discharge constituents.

The eight options considered a variety of non-linear diffuser arrangements at both the RG Tanner wharf and the proposed Wiggins Island wharf, however dilutions were insufficient and accumulation of pollutants in mangrove areas was predicted.

The ninth option consisted of two linear diffuser lines (one for Stage 1, increasing to two for Stage 2) perpendicular to the main direction of flow and located within the area between the proposed tug harbour and the RG Tanner wharf. These diffusers were to have eductors installed at all ports. Again, the dilutions were generally insufficient and other operational constraints precluded adoption of this approach.

As the analysis of the various discharge options was pursued, more laboratory testing work was being performed in parallel. In particular an enhancement of the treatment of the residue slurry material and/or the neutralised liquor indicated significant improvements to the ultimate quality of the treated liquor proposed for discharge.

After extensive investigations of different options and greatly improved treated water quality proposed for discharge, the final diffuser arrangement included a tenfold onshore dilution of effluent in response to regulatory advice. In contrast to the previous options investigated, this final option does not use an eductor arrangement on the outfall pipes, but rather, has adopted a simple perforated pipe installation (diffusers). A transformation rate of a 10 day half-life was simulated for manganese, based on expert advice from CSIRO (Appendix B1), and no decay was assumed for all other discharge constituents. In addition to this ten-fold dilution, GPNL has also committed to increasing this to a twenty-fold dilution when ambient tidal velocities fall below 0.1 ms^{-1} . The modelling results of this option are discussed in Section 7.

2.2 Discharge Dilution Options

A number of options for diluting the treated refinery water were considered with the objective of achieving the required dilution of 10:1 prior to discharge. As this could not be achieved by a single stage of eductors, two main approaches were used; either supplement the eductors' performance, or use a mixing tank.

Following the review, the latter approach was adopted because it has a number of advantages over the use of eductors. The system is based on similar systems currently used for deep sea tailings placement in Indonesia and PNG, where seawater is mixed with the effluent prior to discharge. For GNP seawater will be pumped into the mixing tank, mixed with the refinery water and pumped to the diffusers for discharge to Port Curtis. Three pumps each with a capacity of 55% of the required duty will be installed. This will enable one to be taken out of service for repair or refurbishment without interrupting the operation. The mixing tank will be in the form of a pit. The pit will be located at the wharf of the new tug berth on-shore from the RG Tanna coal loading wharf. The discharge pipe will be a simple large bore pipe with ports at 2.5 m intervals. This will reduce the risk of both marine growth blocking the ports of eductors and of passing sea vessels snagging on the eductors.

This system uses well proven equipment, whereas the eductors are less well used at this size. The system also provides some flexibility in operation, particularly if the pumps are driven with variable speed motors. GPNL believes that this will be a reliable method of achieving the required 10:1 dilution with high availability and long life. It will also be relatively easy to expand or duplicate if the need arises in later stages of the project.

Proposed Water Discharge Configuration

Section 3

Treated barren liquor (treated water) generated from the refinery is proposed to be discharged to Port Curtis at Clinton Wharf. This is proposed for the following reasons:

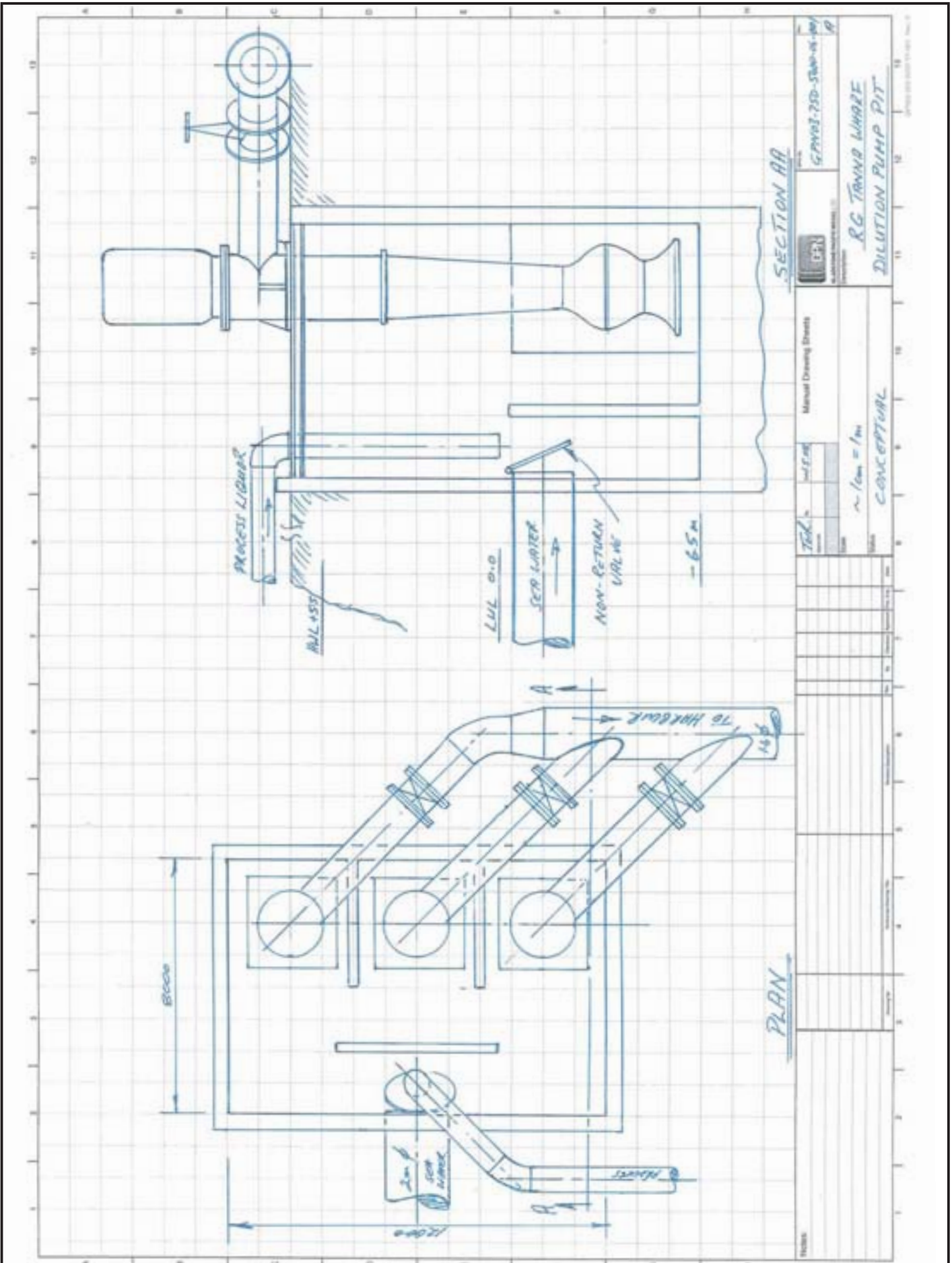
- The flushing characteristics are favourable, the main channel flows assist in the removal of the discharge from Port Curtis;
- Marine areas at Clinton Wharf are disturbed by dredging, wharf and marina operations and rock walls which extend from the eastern side of the Calliope River mouth to Auckland Inlet; and
- It is further from sensitive receivers including seagrass environments than other potential locations.

The treated water will be piped from the refinery to a dilution pump pit (Figure 3-1). Seawater will be mixed into the treated water and the dilution discharged to Port Curtis at a dilution ratio of 10:1 seawater to treated water, and at 20:1 in periods when ambient tidal velocity is less than or equal to 0.1 ms^{-1} (approximately 50 minutes during high and low tide change over, or "slack water").

The proposed configuration of the discharge will include two diffuser pipes with the following characteristics:

- Total diffuser length of 250 m, but discharge only over the last 175 m of pipe;
- Pipe diameter: 1.6 m;
- Diffuser type: unidirectional with discharge through vertically orientated ports (holes);
- Number of ports per diffuser: 70 (2.5 m spacing);
- Port diameter: 240 mm;
- Discharge density: 1030 kg/m^3 for the ten-fold dilution of the effluent discharge and 1027 kg/m^3 for the twenty-fold dilution of the effluent discharge;
- Background receiving water density: 1024.5 kg/m^3 ;
- Main pipeline elevation: on sea bed;
- Ambient velocity (dynamic): Ambient velocity ranging from $+0.25$ to -0.25 ms^{-1} over several hours, based on the far-field RMA-11 model predictions;
- Ambient velocity (steady state): Ambient velocities of 0.1, 0.2, 0.3, 0.5 and 1.0 ms^{-1} have been assumed as representative of tidal currents;
- Effluent discharge velocity of 3 ms^{-1} ;
- Total effluent discharge rate of $17,100 \text{ m}^3/\text{hr}/\text{diffuser}$ (i.e. $244 \text{ m}^3/\text{hr}/\text{port}$). This accounts for the 10:1 dilution of effluent with seawater; and
- Average water depth: 10 m for Diffuser 1, 9.5 m for Diffuser 2. The diffuser line will follow the natural slope of the bed.

The first diffuser will be commissioned with Stage 1 of the refinery, and the second with commissioning of Stage 2 of the refinery. The locations of these diffusers are shown in Figure 3-2, and the cross-sections at the proposed diffuser locations from the bank are shown in Figure 3-3.



Client Gladstone Pacific Nickel Ltd URS	Project GLADSTONE NICKEL PROJECT ENVIRONMENTAL ASSESSMENT OF TREATED WATER DISCHARGE AT PORT CURTIS	Title RG TANNA WHARF DILUTION PUMP PIT CONCEPT DESIGN	Rev. A
	Drawn: LL Job No.: 4262 5791	Approved: CMP File No. 42625791-g-276.cdr	Date: 25/07/2008 Figure: 3-1

Proposed Water Discharge Configuration

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Figure 3-2 Proposed Diffuser Locations

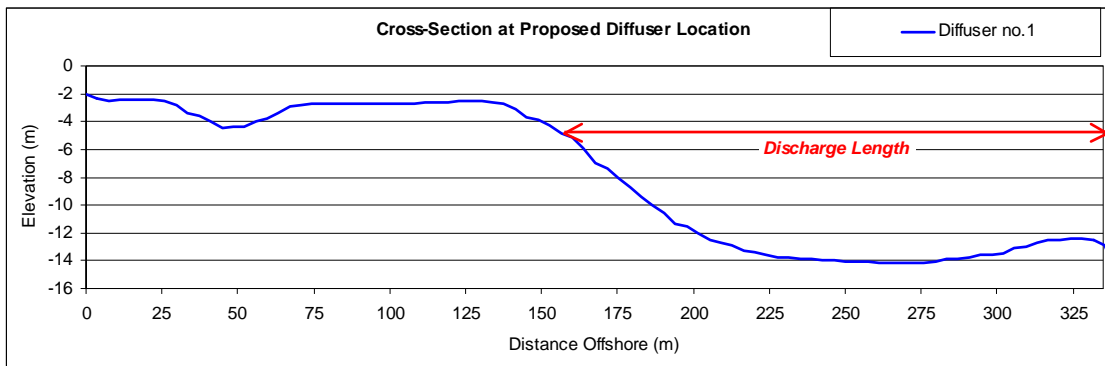


Figure 3-3 Cross-Sections at Proposed Diffuser Locations from Bank

The treated water will have the following water quality parameters:

Section 3

Proposed Water Discharge Configuration

Table 3-1 Water Quality Parameters of Treated Water

Constituent	Ambient* Concentrations (µg/L)	Treated Barren Liquor Concentrations (µg/L)	Release Concentrations at 10:1 Dilution (µg/L)	Release Concentrations at 20:1 Dilution (µg/L)
Nickel	0.5	560	57	29
Cobalt	0.1	100	10	5
Manganese	7.6	10,000	1010	510
Cadmium	0.02	20	2	1
Chromium 3+	0.15	2,500	250	175
Chromium 6+	0.15	440	44	22
Zinc	0.5	40	4.5	2.5
Iron	90	3,000	390	240
Aluminium	73	2,000	273	173
Magnesium	1,290,000	17,900,000	3,080,000	2,815,000
Calcium	411,000	670,000	478,000	444,500
Chloride	19,400,000	12,080,000	20,608,000	20,004,000
Sulfate	2,688,000	66,400,000	9,320,000	6,008,000
Stage 1 Flowrate (m ³ /hr)	NA	1,710	17,100	34,200
Stage 2 Flowrate (m ³ /hr)	NA	3,420	34,200	68,400

* Concentration of constituent naturally in the seawater prior to mixing with the liquor. See Section 4.9.3 for discussion on source of ambient concentrations.

The treated refinery water metal concentrations are dissolved metal ion concentrations. These ions will remain in dissolved form in the water column. The exception is potentially manganese which may oxidise after some time and form insoluble particles of MnO₂. GPNL retained CSIRO and Central Queensland University researchers to investigate the potential behaviour of manganese. The results of this work indicated:

- Manganese oxidises very slowly and is hindered by efficient tidal mixing.
- Manganese oxides from the refinery discharge are less toxic than dissolved manganese.
- If the oxides adsorb other metals in the seawater, it may have a beneficial effect on marine organisms in the water column due to reduced bioavailability of these metals.

Further information about the CSIRO studies is given in Section 5.2.

This section describes the existing marine biology and water quality of Port Curtis.

4.1 Review of Existing Information

A range of marine habitat mapping studies, baseline reports and monitoring programs have been undertaken over the past decade or so in the Port Curtis area. The following studies were collated and reviewed for the present study:

- LeProvost Dames & Moore (unpub. data, 1995), Dames & Moore (1998), QDEH & GPA (1994), Connell Wagner (1997), Enviroscience (1993), McKinnon et al. (1995), Patrick (1995), Saenger (1996), URS (2003).
- CRC contaminant risk assessment review (Apte et. al. 2005) and associated modelling study (Herzfeld et. al. 2004).
- CRC contaminant pathways study (Apte et. al. 2006).
- Department of Primary Industries and Fisheries (DPIF) intertidal habitat review (Danaher et. al. 2005) and seagrass monitoring program (Rasheed et al. 2003, 2005, Taylor et al., 2006).
- Recent water quality and bio-monitoring studies undertaken for the Port Curtis Integrated Monitoring Program (PCIMP) by Central Queensland University (CQU).
- *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) Protected matters search (conducted May 2006).
- WICT Initial Advice Statement (Connell Hatch, 2005) and WICT EIS (Connell Hatch, 2006).

4.2 Field Survey

4.2.1 Methodology

A three day 'gap-filling' survey to ground-truth the type and current status of marine habitats and associated communities close to Wiggins Island was undertaken in February 2006. The aim was to improve knowledge on the extent and characteristics of intertidal and subtidal assemblages in the vicinity of the planned seawater intake. Planned survey effort was focussed on the subtidal extent of seagrass, macroalgal and reefal communities as these would more likely come into contact with the components of a dispersing plume than intertidal assemblages along shoreline areas. A series of visual transects¹ and spot inspections by snorkelling, SCUBA diving and remotely-operated 'drop-down' video camera was undertaken.

Transect effort was focussed on marine habitats surrounding the small islands opposite Wiggins Island (i.e. Mud Island, Tide Island, Witt Island and Picnic Island) and the bays on the south side of Curtis Island between Hamilton Point and Grass Point (Figure 4-1). Subsequent transect effort occurred in areas north of Wiggins Island where seagrass beds had been previously mapped, to determine the extent of an apparent decline in seagrass cover and if there was any evidence of tarry residues from the Global Peace fuel oil spill. The 25 tonne spill occurred at the RG Tanna terminal on 24 January 2006, two weeks prior to the survey (Taylor et al. 2006).

¹ Transect has a meaning in ecological studies where it refers to a strip of ground along which ecological measurements, for example the number of organisms, are made at regular intervals.

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4.2.2 Conditions

The February 2006 survey was undertaken during a prolonged period of dry, hot and very sunny weather. Sea breezes were weak and water temperatures were generally close to or above 30°C and exceptionally warm (>32°C) over the shallow banks near the mouth of the Calliope River and north-west of Wiggins Island. Despite the neap² tide period, turbidity levels were very high and prevented the drop-down video camera from supplying an adequate field of view (visibility was virtually zero if the lens was raised more than 10-15 cm from the seafloor). Due to the lack of visibility, all transects were undertaken by snorkelling or SCUBA diving with two divers working abreast and making a zigzag course to provide a 10-20 m wide belt. Seafloor visibility was rarely above 0.6 m and often below 0.2 m.

4.2.3 Field Survey Results

Divers undertook transects close to Mud Island and the small islands on the north-east side of the shipping channel. The bare silty sand substrates varied greatly in this small area from gravely and shelly near Mud Island to being sorted and sandiest on the shallow north banks of Picnic and Tide Islands. The siltiest substrate in the bays was found on the south side of Curtis Island. No aggregated or isolated seagrass patches were found in this area.

As no seagrasses and no evidence of the recent fuel oil spill were detected in these areas, the banks of the lower Calliope River were inspected to ascertain the nature and extent of fuel oil residues that may have been pushed into the lower reaches and banks of the Calliope River by the incoming tide.

Transects were subsequently undertaken on the north side of Wiggins Island, i.e. across shallow beds where relatively extensive seagrass beds had been mapped by previous surveys (Dames & Moore 1998, Rasheed et al. 2003, 2005). Only very sparse, small and isolated patches of *Halophila ovalis* were found in this area, representing a marked reduction to what the same divers had observed in previous surveys in the 1990s.

² Neap tides refer to weak tides. Spring tides are strong tides and are not linked to the season of spring. Spring and neap tides are due to gravitational effects from the moon and sun. A spring tide occurs towards full moons, neap tides occur during quarter moon phases.

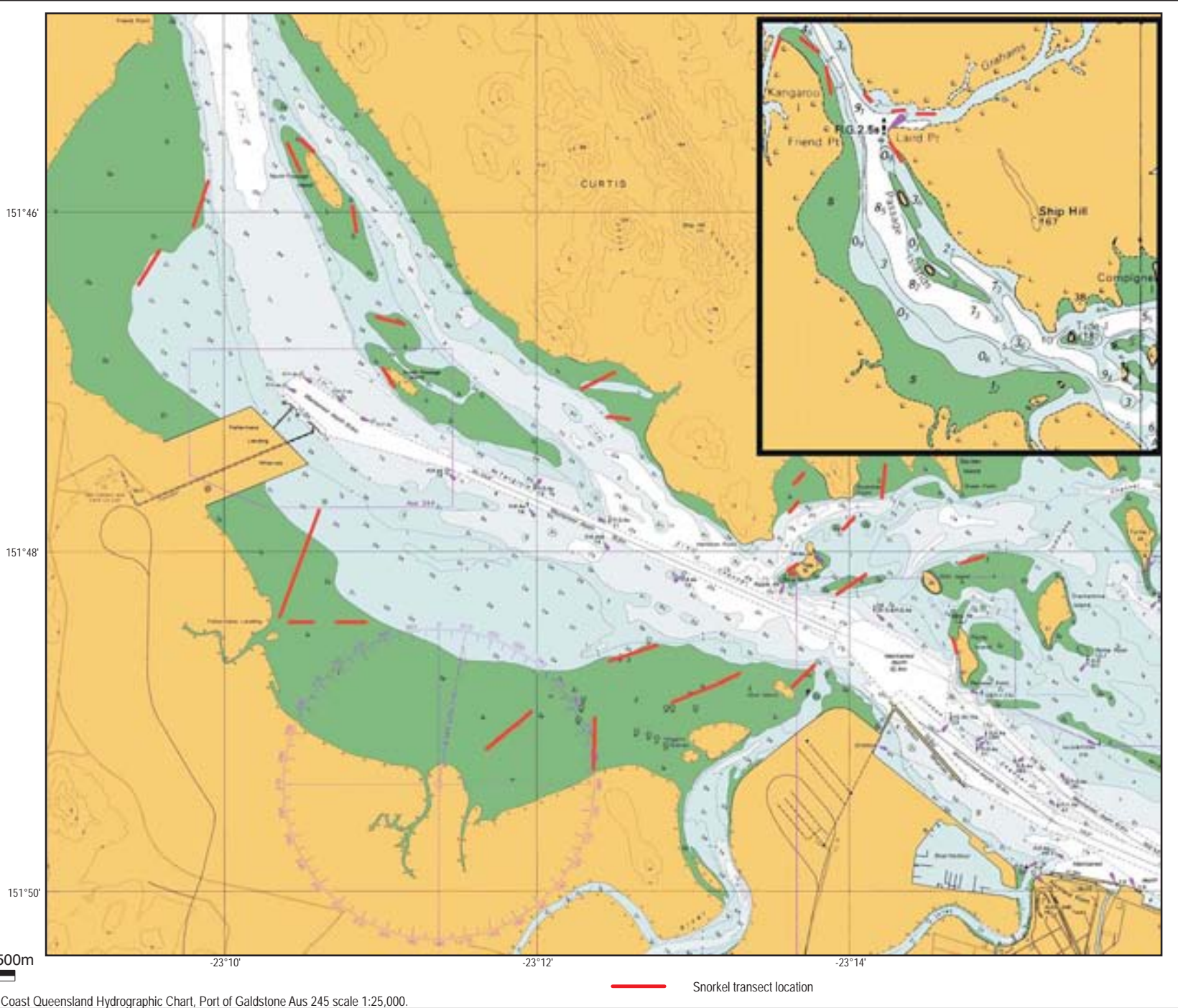
Client
Gladstone Pacific Nickel Ltd

Project
**GLADSTONE NICKEL PROJECT
 ENVIRONMENTAL ASSESSMENT
 OF TREATED WATER DISCHARGE AT
 PORT CURTIS**

Title
**LOCATION OF SNORKEL
 TRANSECTS UNDERTAKEN
 ON 7 - 8 FEBRUARY 2006**

Drawn: VH
 Job No.: 4262 5791
 Approved: CMP
 File No. 42625791-g-271.cdr
 Date: 22/07/2008

Figure: **4-1**
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Because of the ecological value of seagrass habitats and the potential exposure and sensitivity of the shallow subtidal/lowermost intertidal zone, transect effort for the remainder of the survey was focussed mostly on ascertaining the present extent and status of previously mapped seagrass beds between Wiggins Island and Fisherman's Landing and from Fisherman's Landing north to Graham Creek and Targinie Creek in The Narrows. SCUBA dives were also undertaken at the drop-offs on the south side of Picnic Island to determine the type and extent of soft and hard coral on this rocky slope. These observations are discussed in Section 4.5 below.

4.3 Port Curtis Setting

Port Curtis is a natural deepwater harbour located beside Gladstone just south of the Tropic of Capricorn. Port Curtis is a composite estuarine system including estuaries of the Calliope River, The Narrows and several creek systems and inlets. Seaward of the Calliope River is Auckland Creek and the mouth of the Boyne River which is dammed upstream by the Awoonga Dam. These estuarine systems merge with deeper waters to form the naturally deep Gladstone harbour that is protected by southern Curtis Island and Facing Island.

Substantial urbanisation, industrialisation and port development has occurred in recent decades. On the coastal strip beside Port Curtis is the urban centre of Gladstone (>40,000 regional population) which is a major industrial centre for coal exports, cement and chemicals manufacture, alumina refining and aluminium smelting.

4.4 Physical Characteristics of Port Curtis

The climate of Port Curtis is governed by a wet-dry regime, with high summer rainfall and dry winter conditions. Average annual rainfall is typically 900 - 1,000 mm, though this is highly variable. Mean air temperatures range from a minimum of 18.5°C in winter to a maximum mean of 27.6°C in summer. Annual average water temperatures range between 22-29°C. This is relatively high compared to waters in similar latitudes in eastern Australia and is due to the sheltered and almost enclosed nature of Port Curtis. Water temperatures over the shallow mudflats regularly exceed 30°C in summer. This also occurs in areas of deeper water (e.g. 30-32°C).

Port Curtis is connected to the Fitzroy River estuary via The Narrows. It is rare for a Fitzroy River flood event to produce a plume that extends throughout The Narrows to enter Port Curtis (as occurred following a 1-in-50-year flood event in 1991; Jones, in Apte et al. 2005). For most of the time, waters from the Fitzroy River converge with Port Curtis waters near the channel between Facing and Curtis Islands, which is in the outer limits of the Gladstone harbour.

The salinity of Port Curtis ranges between 3-3.5%. Typically freshwater inputs are low, except when summer season storm and cyclonic events produce pulses of freshwater-flush from the Calliope River and smaller creek systems. When heavy rainfall does occur, the net direction of runoff from creeks inside The Narrows is in a northward direction, while freshwater flows from the Calliope River move in a south-east direction (Apte et al. 2005).

The strong tidal regime in Port Curtis gives rise to naturally high turbidity levels. This is associated with the elevated levels of suspended sediment that enter the estuary from the Calliope River and creek systems and the flow regime in Port Curtis which results in particles remaining in suspension and being remobilised. Suspended sediments are also mobilised from the various mud flats, with turbidity levels highest during spring tides and usually lowest at or close to neap tides.

The flow regime in Port Curtis promotes wide dispersal and distribution of suspended particles and dissolved material throughout the estuary. Port Curtis has a large tidal range, which typically results in high current velocities in all major channels. These tidal velocities generally assist in maintaining the waterway as a natural deep-water

port. Due to the large tidal storage areas and the amplification effect on water levels, good tidal flushing and large tidal velocities result in well-mixed conditions throughout Port Curtis.

It has been estimated that the time required for total mass of material (suspended and dissolved) to decrease to a third of its original mass ('e-folding flushing time') is in the order of 12-16 days for the entire estuary (WBM, 2006). Flushing times within Port Curtis vary, with smaller sub-regions in the estuary having much shorter flushing times. These flushing times potentially reduce the net dispersion of suspended solids and dissolved contaminants that enter the system.

4.5 Marine Habitat Characteristics of Port Curtis

4.5.1 Habitats Types

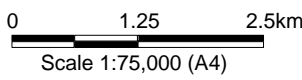
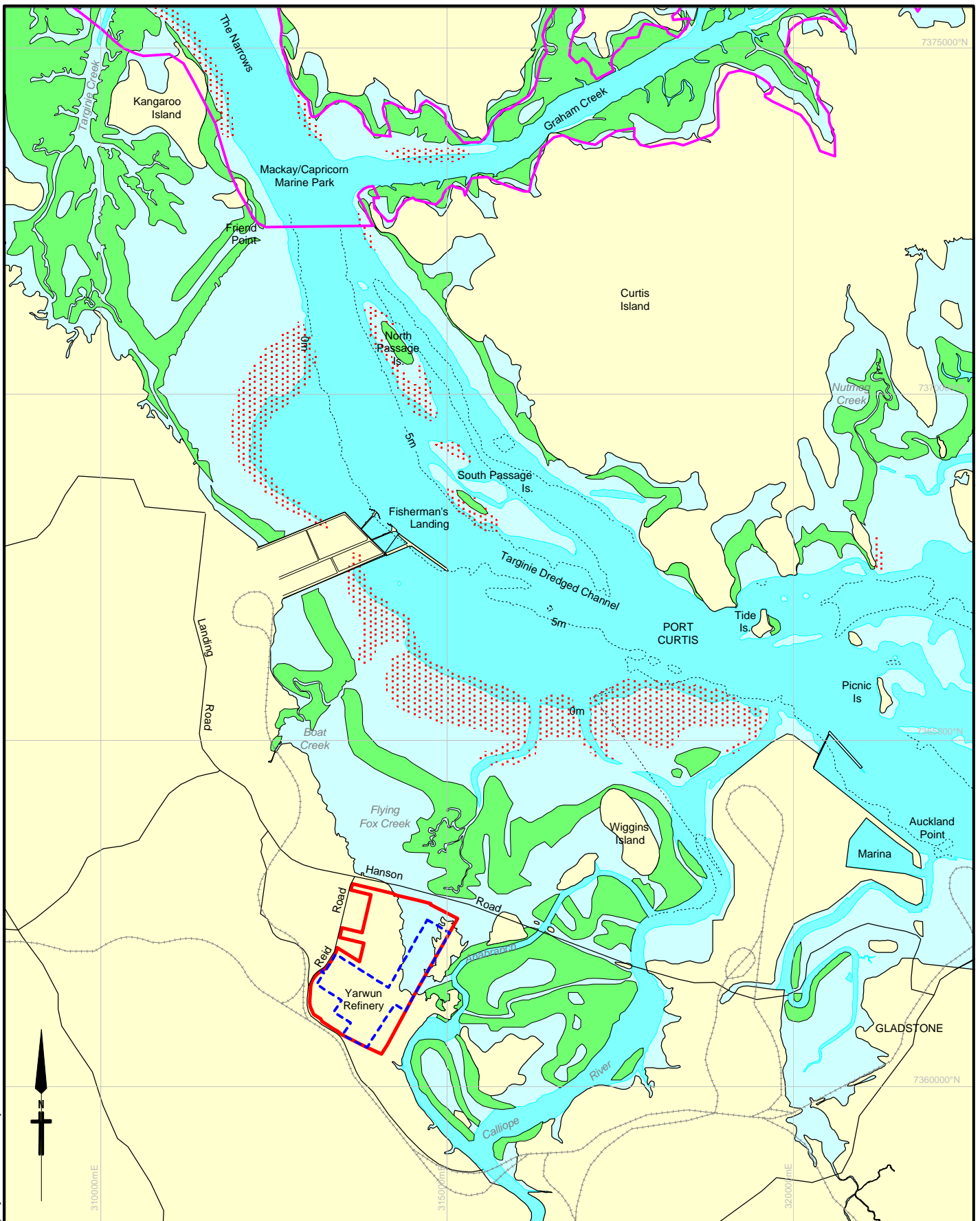
The principal marine habitats of Port Curtis are shown in Figure 4-2.

The intertidal (between high and low water) and supratidal (above high water) shoreline consists of the following habitats:

- Poorly vegetated high tidal salt marsh and/or bare saline mud flats in the supratidal /supralittoral zone;
- Upper to mid intertidal zones that are typically colonised by mangrove forest; and
- Lower intertidal sand, shelly-mud and soft mud flats, sometimes colonised by linear bands or patches of seagrass meadow (typically *Zostera capricornis*).

Seaward of the intertidal zone is the benthic zone. This is the area of the sea bottom. A variety of organisms that feed on detritus (decomposing organic matter) live in the benthic zone.

Marine plants, including plants (living, dead, standing or fallen) that grow on or adjacent to tidal land (i.e. intertidal and benthic zones) are protected under the *Fisheries Act 1994*. This includes the following species: mangroves, seagrass, saltcouch, algae and samphire (succulent) vegetation and adjacent plants such as *Melaleuca* (Paper barks) and *Allocasuarina* (coastal She-oaks) (DPIF, 2006). Marine plants provide a wide range of habitats for fish and benthic organisms. These plants also provide carbon to the estuarine environment.



- Refinery Site Boundary
- Proposed Development Footprint
- Lower Intertidal Mud Flats (LAT to Mean Sea Level)
- Upper Intertidal Salt Flats (Mean Sea Level to HAT)
- Mangroves
- Area Containing Seagrass
- State Marine Park Boundary
- Hinterland

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Project
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Drawn: VH | Approved: CMP | Date: 22/07/2008

Job No: **4262 5791** | File No: 42625791-g-272.wor

Title
DISTRIBUTION OF MANGROVES AND SEAGRASS HABITATS

Figure: **4-2**

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4.5.2 Supratidal and Intertidal Habitats

There are over 1,000 km² of shoreline habitats in the Port Curtis-Gladstone harbour region, an area including estuary and tidal creek systems plus some 310 km² of intertidal/supratidal wetlands.

The landward boundary of the high intertidal zone is delineated in most places by a slight but frequently abrupt change in elevation and soil type. Terrestrial vegetation fringing the edge of the supratidal zone is dominated by grassland, paper-bark and/or eucalypt woodlands, particularly where non-saline groundwater is persistent.

In the region between Boyne Island and Ramsey's Crossing (midway in The Narrows), there are over 160 km² of supratidal/intertidal salt marsh, mud flats and fringing mangrove forest (e.g. Saenger 1996, Danaher et al. 2005). Mangrove and salt marsh areas in the Port Curtis - Gladstone harbour region have decreased since 1925 by stepwise reclamation of foreshore areas that has taken place for urban and industrial development (Lewis, Arnold, in Apte et al. 2005).

Salt marsh vegetation in Port Curtis is considered to have relatively low development and species diversity compared to southern areas, with cyanobacterial and diatom algal mats plus *Suaeda australis*, *Sesuvium portulacastrum*, *Sarcocornia quinqueflora* and *Halosarcia* spp. being the most prevalent taxa (e.g. QDEH 1994, Saenger 1996, Dames & Moore 1998).

Mangroves are dominant in the mid-to-upper intertidal zones, fringing much of the mainland and Curtis Island coasts between mean sea level and mean high water springs. Of the 13 mangrove species recorded in Port Curtis (refer Table 4-1) the dominant species are *Rhizophora stylosa*, *Avicennia marina* and *Aegiceras corniculatum* (Saenger 1996, Rasheed et al. 2005, Danaher et al. 2005). Mangroves fringing the lower Calliope River occupy some 6.5 km², while 15 km² of mangroves surround the Boyne River (Digby, in Apte et al. 2005). Detailed descriptions were also provided in Dames & Moore (1998) while Danaher et al. (2005) provided mapping coverage estimates for a set of 16 mangrove units.

Table 4-1 Mangrove Species Recorded in the Curtis Coast Region*

Mangrove Species	Common Name
<i>Acanthus ilicifolius</i> L.	Holly leaf mangrove
<i>Acrostichum speciosum</i> Willd.	Mangrove fern
<i>Aegialitis annulata</i> R. Br.	Club mangrove
<i>Aegiceras corniculatum</i> (L.) Blanco	River mangrove
<i>Avicennia marina</i> (Forsk) Vierh.	Grey mangrove
<i>Bruguiera exaristata</i>	Orange mangrove
<i>Bruguiera gymnorrhiza</i> L. Lam.	Large-leafed orange mangrove
<i>Ceriops tagal</i> C. T. White	Yellow mangrove
<i>Excoecaria agallocha</i> L.	Milky mangrove
<i>Lumnitzera racemosa</i> Willd.	Black mangrove
<i>Osbornia octodonta</i> F. Muell.	Myrtle mangrove
<i>Rhizophora stylosa</i> Griff.	Red mangrove
<i>Xylocarpus granatum</i> Koen	Cannonball mangrove
<i>Xylocarpus moluccensis</i> Pierre	Cedar Mangrove

*from Saenger (1996), Danaher et al. (2005).

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4.5.3 Benthic Habitats

Approximately 250 km² of the Port Curtis-Gladstone harbour region comprises open water and subtidal benthic habitats (seagrass beds are included in this estimation; Apte et al. 2005). The predominant subtidal benthic habitats inside Port Curtis comprise:

- Winding channels of the tidal creek systems which drain the mud flats and hinterland in Port Curtis and The Narrows, plus the deeper channels of the lower Calliope River and its mangrove-lined anabranch (refer Figure 4-2);
- The relatively turbid and tidally dominated water column that overlies the soft silty sediments of Port Curtis (0-10 m lowest astronomical tide (LAT) depth range, extending to 15-18 m LAT near Hamilton Point; refer Figure 4-1);
- Restricted areas of rocky outcrop and drop-offs below headlands and beside channels;
- The dredged shipping channel leading to the swing area and berths at Fisherman's Landing (7-15 m LAT) with mixed, variable and often coarse substrate dominated by cobbles, silty sandy gravel and shelly, silty sand; and
- Shelly, gravelly sand and silt substrates of the nearshore shallow subtidal zone, bare or colonised by macroalgae and *Halophila* seagrasses in depths <1 m below LAT.

Substrate

Gastropods have been recorded as the dominant benthic faunal component along the lower reaches of the Calliope and Boyne Rivers and at sites in the outer harbour, while polychaete worms have been reported to be numerically predominant in other areas (Saenger, Walker & McNamara, in Apte et al. 2005). The mud banks of the tidal creeks are generally steep, and exploratory sieving in Boat Creek in November 1997 confirmed the presence of a rich burrowing macrofauna dominated by polychaete worms, crustaceans and small bivalve molluscs (Dames & Moore 1998). Of four creek systems investigated in 1995 and 1997, Targinie Creek (behind Kangaroo Island on the west side of The Narrows) contained a wider range of habitats and was more biodiverse than Boat Creek, Flying Fox Creek and Nutmeg Creek. Targinie was distinguished by clearer waters that flowed across rubbly and coarse sandy substrates in several sections of its middle and lower reaches.

These substrates were colonised by macroalgae (predominantly filamentous reds and *Caulerpa* spp.) and seagrasses (*Zostera*, *Halodule* and *Halophila* spp.) as well as hydroids, grey sponges, tube worms, Pinna molluscs, several crab taxa (including three *Uca* spp.), tunicates and even some small, isolated hard corals (cf. *Goniastrea*; LDM, in Dames & Moore 1998). By contrast, no seagrass, macroalgae or coral were found along the muddier middle and upper reaches of Boat Creek, Flying Fox Creek and Nutmeg Creek. However, patches of seagrass meadow (mostly *Zostera capricornis*) were present on the lower intertidal sand banks and cheniers that were present between these creek mouths and adjacent mangrove fringe (Dames & Moore 1998).

Limited areas of subtidal rocky outcrops are restricted to small headlands and drop-offs off Curtis and Facing Islands and some of the small islands south of Curtis Island, including Tide and Picnic Islands. Brown algae have been reported to be the predominant macroalgae on these substrates, with coral habitat restricted to sites between Facing and Curtis Islands (QDEH, 1994). However, lower intertidal zones exposed to strong tidal flow contain gravelly and rubbly substrates often colonised by both red and brown macroalgae, with Sargassum sometimes dominant (e.g. at the entrance to The Narrows at Friend Point, Dames & Moore, 1998).

The field survey on the south side of Picnic Island in February 2006 found that the predominant reefal benthos comprised sea fans (*gorgonians*), other soft corals, anemones, fan worms, sponges and tunicates. A few small

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hard corals were found (mostly *Favidae* plus a few small *Goniopora*) but these were small, isolated and did not combine or provide height to form significant topographic habitat for enhanced reef fish, crustaceans or other reefal biota. The very high turbidity and erosive effects of spring tidal currents along the face of the drop-offs near Picnic Island likely explain why hard coral development was minimal.

Seagrass

Seagrass meadows improve coastal water quality through the absorption of nutrients and trapping of the sediments. The species that occur in Port Curtis are considered low light-adapted as these can recruit, grow and mature under disturbance regimes involving pulses of increased turbidity and nutrients and reduced salinity nearshore and physical disturbances that are seasonal and episodic in extent and amplitude (e.g. Schaffelke et al., 2005).

The seagrass beds can cover up to 9 km² of the lower intertidal/shallow subtidal zone of the Port Curtis region following good years of growth and comprise the small turbid-tolerant species *Halodule uninervis*, *Halophila decipiens*, *Halophila ovalis*, *Halophila minor*, *Halophila spinulosa* and *Zostera capricorni*, with the latter being generally the most visually dominant during the 1990s (e.g. Lee Long et al. 1992, QDEH 1994, Dames & Moore 1998, Rasheed et al. 2003).

Danaher et al. (2005) have provided coverage estimates for the three main seagrass units in the Port Curtis area (i.e. *Zostera*-, *Halodule*- or *Halophila*- dominated beds) for densities in the 2002 winter/spring period mapped as 'isolated', 'aggregated' or 'continuous patches'. The overall hectare and percentage estimates are listed in Table 4-2 for the region that extends from Wild Cattle Island in the south to the centre of The Narrows in the north (refer Figure 4-3). The seagrass units amount to a total of 4,501 ha (21.2% of all 21,251 ha of intertidal wetland units) and include the area where the seagrass beds were mapped into the shallow subtidal, so as to provide estimates for complete units (Danaher et al 2005). Restriction of most seagrass units to a depth of 1 m below LAT in Port Curtis waters (compared to up to 8 m below LAT along the open coast) is consistent with the higher turbidity and reduced light penetration in Port Curtis.

Table 4-2 Intertidal Wetland Habitats and Seagrasses in Port Curtis *

Unit	Hectares	%
Saline grass	193	0.91%
Samphire-dominated saltpan	486	2.29%
Bare saltpan	3894	18.3%
Exposed rocky substrate	297	1.40%
Mangrove units (16 units)	6736	31.7%
Exposed mud and sand banks	5144	24.2%
Isolated <i>Zostera</i> patches	108	0.51%
Aggregated <i>Zostera</i> patches	1807	8.50%
Continuous <i>Zostera</i> cover	626	2.95%
Isolated <i>Halodule</i> patches	25	0.12%
Aggregated <i>Halodule</i> patches	1299	6.11%
Continuous <i>Halodule</i> cover	245	1.15%
Isolated <i>Halophila</i> patches	0	0
Aggregated <i>Halophila</i> patches	391	1.84%

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Unit	Hectares	%
Continuous <i>Halophila</i> cover	0	0
Total	21,251	100%

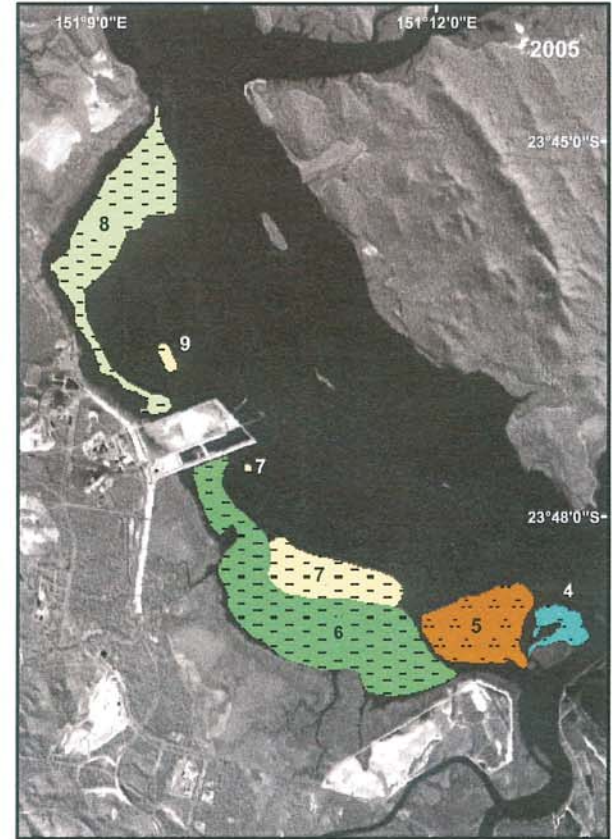
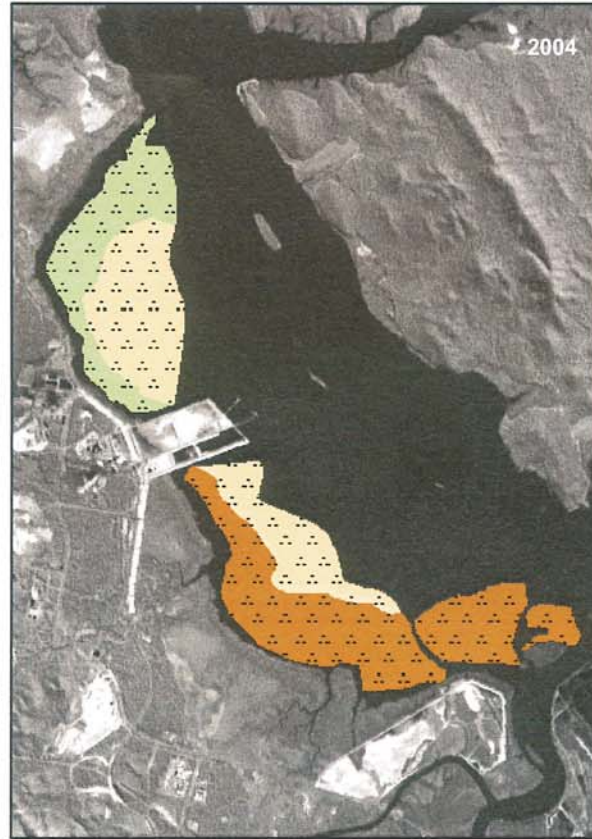
*from Danaher et al (2005).

During the February 2006 survey, no seagrasses were found between Mud Island and the small islands on the north-east side of the shipping channel. Only very sparse and small and isolated patches of *Halophila ovalis* were found on the north side of Wiggins Island, representing a marked reduction when compared to previous surveys.

Transects across previously mapped seagrass habitat west of the Calliope River (refer Figure 4-1) showed a widespread decline between Targinie Creek to the north-west and Wiggins Island to the south-east. No fuel oil residues or signs of recent seafloor substrate oiling were encountered on these transects.

These results were discussed with marine scientists from Central Queensland University and later with Department Primary Industry and Fisheries officers in April 2006. The results of DPIF aerial and ground-truthing surveys undertaken during low spring tides in November 2005 and late February 2006 matched the findings of the February 2006 transects. It was agreed that the regional decline in seagrass meadows noted in Rasheed et al. (2005) had continued but was not related to the Global Peace fuel oil spill (Section 4.2.1).

Client Gladstone Pacific Nickel Ltd		Project GLADSTONE NICKEL PROJECT ENVIRONMENTAL ASSESSMENT OF TREATED WATER DISCHARGE AT PORT CURTIS		Title COMPARISON OF SEAGRASS DISTRIBUTIONS MAPPED IN FISHERMANS LANDING REGION IN 2002, 2004 AND 2005	
URS		Drawn: VH Job No.: 4262 5791		Approved: CMP File No. 42625791-g-273.cdr	
		Date: 22/07/2008		Figure: 4-3	
		Rev: A		A4	



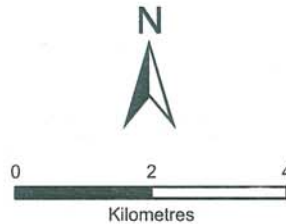
Legend

Community type

- Light *Halophila decipiens*
- Light *Halophila decipiens* with *Halophila ovalis*
- Moderate *Halophila decipiens*
- Light *Halophila ovalis*
- Light *Halophila ovalis* with *Zostera capricorni*
- Light *Zostera capricorni*
- Light *Zostera capricorni* / *Halophila ovalis*
- Light *Zostera capricorni* with *Halophila ovalis*

Meadow Cover

- Aggregated patches
- Continuous cover
- Isolated patches
- Meadow ID



* This is not a complete seagrass distribution, only selected seagrass monitoring meadows displayed

Source: Rasheed, M.A., Taylor, H.A. and Thomas, R. 2006. Long term seagrass monitoring in Port Curtis and Rodds Bay, Gladstone - November 2005. DPI&F Information Series QI05032 (DPI&F, Cairns).

© Central Queensland Ports Authority and the The State of Queensland through the Department of Primary Industries and Fisheries.

Funded by Ports Corporation Queensland, CRC Reef Research Centre and the Queensland Department of Primary Industries and Fisheries.

Produced by the Marine Ecology Group, Queensland Department of Primary Industries and Fisheries, Northern Fisheries Centre, Cairns, 2006.

Background: Landsat ETM + Panchromatic 24 July 1994



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It was also agreed that the very hot summer, with the unusually low cloud cover and no monsoonal activity, had caused elevated seawater temperatures and high insulation/UV levels that were likely to be the major, if not sole, cause for the apparent regional die-off of the intertidal seagrass beds. Because the fuel spill had not entered the Rodd's Bay area where the reduction in cover was considered equal to that observed from the Calliope River mouth to Graham's Creek, effects of this spill could not be attributed to the reduction. In fact, comparison of seagrass maps produced by WBM in the early 1990s with those from Dames & Moore (1998) and Rasheed et al. (2005) for the Calliope River – Fisherman's Landing region (refer Figure 4-3) provide evidence for a long term decline that may have started to accelerate at some point between 1997 and 2002.

Coral

Targinie Creek which is located on the west side of The Narrows and behind Kangaroo Island (Figure 4-2) is distinguished by frequently clear waters that flow across exposed rock, and coarse sandy substrates in several sections of its middle and lower reaches. Parts of these substrates are colonised by macroalgae, seagrasses, hydroids, grey sponges, tube worms, tunicates and small, isolated hard corals (*cf. Goniastrea*) (LDM, cited in Dames & Moore 1998). Other creeks in the area (Boat Creek, Flying Fox Creek and Nutmeg Creek) do not contain any significant areas of corals.

Other areas where subtidal rocky slopes and outcrops occur are restricted to small headlands, drop-offs and rocky outcrops off Curtis Island and Facing Island, and off some of the small islands south of Curtis Island (principally Tide and Picnic Islands) (Figure 4-2). Brown algae are the predominant macroalgae on these substrates, with hard coral assemblages restricted to relatively clear, open coastal water sites that are located between Facing Island and Curtis Island (DEH 1994, Dames & Moore, 1998).

While the February 2006 marine survey could not confirm the continuing presence of small, isolated favid coral colonies that had been previously been observed in parts of Targinie Creek, inspection transects by SCUBA diving of the most promising locations for supporting coral assemblages near Clinton Wharf re-affirmed previous conclusion that the nearest benthic assemblages where developed hard coral assemblages are common, are the rocky reef substrate sites between Facing and Curtis Islands (QDEH 1994, Dames & Moore 1998, URS 2003) and north of Targinie Creek in rocky parts of The Narrows channel (Connell-Hatch 2005).

The SCUBA dives undertaken in February 2006 at the drop-offs on the south side of Picnic Island to determine the potential extent and types of soft and hard corals showed that the predominant benthos comprised sea fans (gorgonians), other soft corals, anemones, fan worms, sponges and tunicates. Only a few small hard corals were found (mostly *Favidae* plus a few small *Goniopora*). These colonies were small, isolated and did not combine or grow large enough to provide height or significant topographic habitat that could enhance local biodiversity of coral reef fishes or other biota associated with coral reef communities.

The minimal development of hard corals near Picnic Island could be readily attributed to the naturally high water turbidities in Port Curtis plus the scouring, erosive effects of the strong spring tidal currents that flow along the face of the drop-offs near Picnic Island.

In summary, the survey data indicate that the closest significant coral communities to the planned discharge site are in the clearer water areas between Facing and Curtis Islands (in the vicinity of point 11 on Figure 4-4).



Gladstone
Pacific Nickel Ltd

Client

Drawn: VH
Job No.: 4262 5791
Approved: CMP
File No.: 42625791-g-274.wor
Date: 22/07/2008

Project

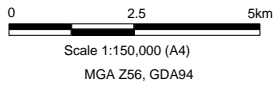
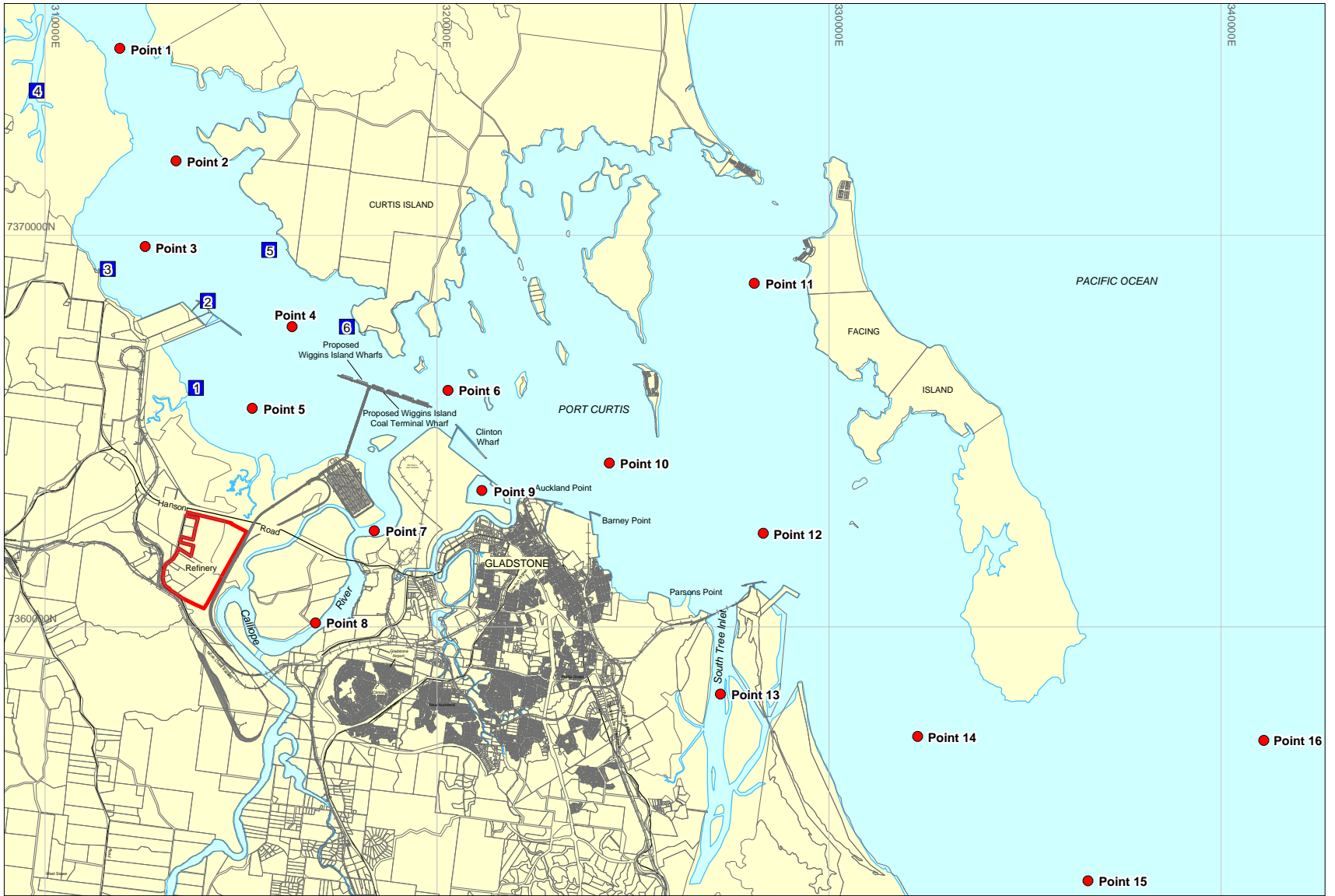
GLADSTONE NICKEL PROJECT
ENVIRONMENTAL ASSESSMENT
OF TREATED WATER DISCHARGE
AT PORT CURTIS

Title

MARINE WATER QUALITY
REPORTING LOCATIONS

Figure: 4-4

Rev/A
A4



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- Point 1 ● Marine Water Quality Reporting Location
- 1 ■ Water Quality Sampling Site

Section 4

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4.6 Marine Conservation Areas include World Heritage

4.6.1 Great Barrier Reef World Heritage Area and Marine Parks

Port Curtis is located within the Great Barrier Reef World Heritage Area (GBRWHA) the boundary of which is mean low water. The GBRWHA is administered by the Great Barrier Reef Marine Park Authority (GBRMPA) in association with the Environment Protection Agency. The extent of the GBRWHA in Port Curtis is shown on Figure 4-5.

Port Curtis lies outside the boundaries of the Great Barrier Reef Marine Park (GBRMP). The GBRMP boundary is the eastern side of Facing Island and Curtis Island (Figure 4-5) and extends offshore to the limit of Australian territorial waters.

The Great Barrier Reef Coast Marine Park (GBR Coast MP) is a State marine park that runs the full length of the GBRMP, providing protection for Queensland tidal lands and tidal waters (EPA 2006(c)). The Mackay/Capricorn Marine Park is part of the GBR Coast MP. The southern boundary of the Mackay/Capricorn Marine Park begins to the north of the Fisherman's Landing Wharf between Friend Point on the mainland and Laird Point on Curtis Island.

At the northern end of Port Curtis is The Narrows which is part of the Mackay/Capricorn Marine Park (a Queensland marine park). The Narrows is also listed in the National Estate Register.

The Great Barrier Reef was inscribed on the World Heritage List in 1981. Four different criteria were developed as the basis for its listing as a World Heritage property. These criteria are:

- 1) Outstanding example representing a major stage of the earth's evolutionary history;
- 2) An Outstanding example representing significant ongoing geological processes, biological evolution and man's interaction with his natural environment;
- 3) Contains unique, rare and superlative native phenomena, formations and features and areas of exceptional natural beauty; and
- 4) Provides habitats where populations of rare and endangered plants and animals still survive.

Client
URS
 Gladstone Pacific Nickel Ltd

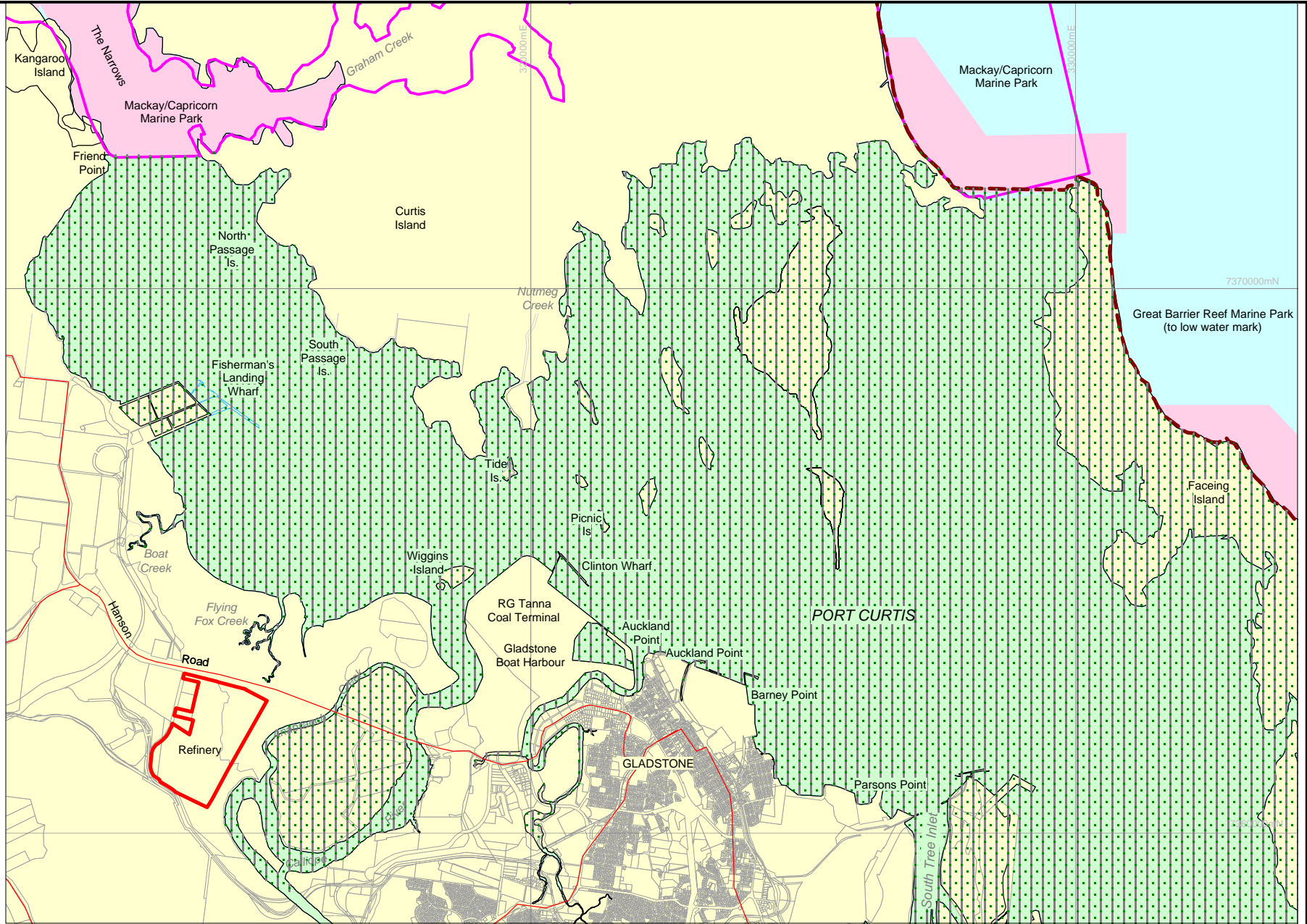
Project
GLADSTONE NICKEL PROJECT ENVIRONMENTAL ASSESSMENT OF TREATED WATER DISCHARGE AT PORT CURTIS

Drawn: VH Approved: CMP Date: 22/07/2008
 Job No.: 4262 5791 File No.: 42625791-g-275-wor

Title
MARINE CONSERVATION AREAS

Figure: 4-5

Rev/A
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0 1.25 2.5km
 Scale 1:100,000 (A4)
 MGA Z56, GDA94

- Great Barrier Reef Marine Park (Commonwealth)
- Marine Park/Conservation Area (State)
- World Heritage Area
- Port Curtis Wetland (Qld 019)
- Habitat Protected Zone
- Dugong Protected Area

Source: Queensland Government, Environmental Protection Authority, 2002
 Great Barrier Reef Marine Park Authority, 2002

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4.6.2 Port Curtis Wetland

Port Curtis is listed in the Directory of Important Wetlands in Australia (DEH, 2006(a)). The Port Curtis Wetland (Qld 019) is defined as nationally important and occupies an area of approximately 31,264 ha. The Port Curtis Wetland includes all the tidal areas in the vicinity of Gladstone, from Laird Point and Friend Point at the southern end of The Narrows, to Gatcome Head and Canoe Point at the southern end of Boyne Island, including Facing Island, and Curtis Island and the Calliope and Boyne Rivers and tributaries of these (DEH, 2006(a)). The extent of the Port Curtis Wetland in the project's vicinity is shown on Figure 4-5.

There are extensive mangrove forests and shrubland (3300 ha), seagrass beds (2,430 ha) and mudflats and saltflats (2800 ha) within the Port Curtis Wetland (DEH, 2006(a)). The seagrass beds provide vital habitat for commercially fished crustaceans (tiger, endeavour and king prawns) as well as being the preferred feeding grounds of several Japan Australia Migratory Bird Agreement (JAMBA) and China Australia Migratory Bird Agreement (CAMBA) migratory waders. Dugongs and marine turtles are known to utilise the Port Curtis Wetland for feeding, breeding and as a major nesting site (DEH, 2006(a)).

The area surrounding the Port Curtis Wetland is within the Curtis Coast catchment and is protected by the Curtis Coast Regional Management Plan (CCRMP) as required by the *Coastal Protection and Management Act 1995*.

The extent of intertidal wetland communities in the refinery site is shown on Figure 4-6.

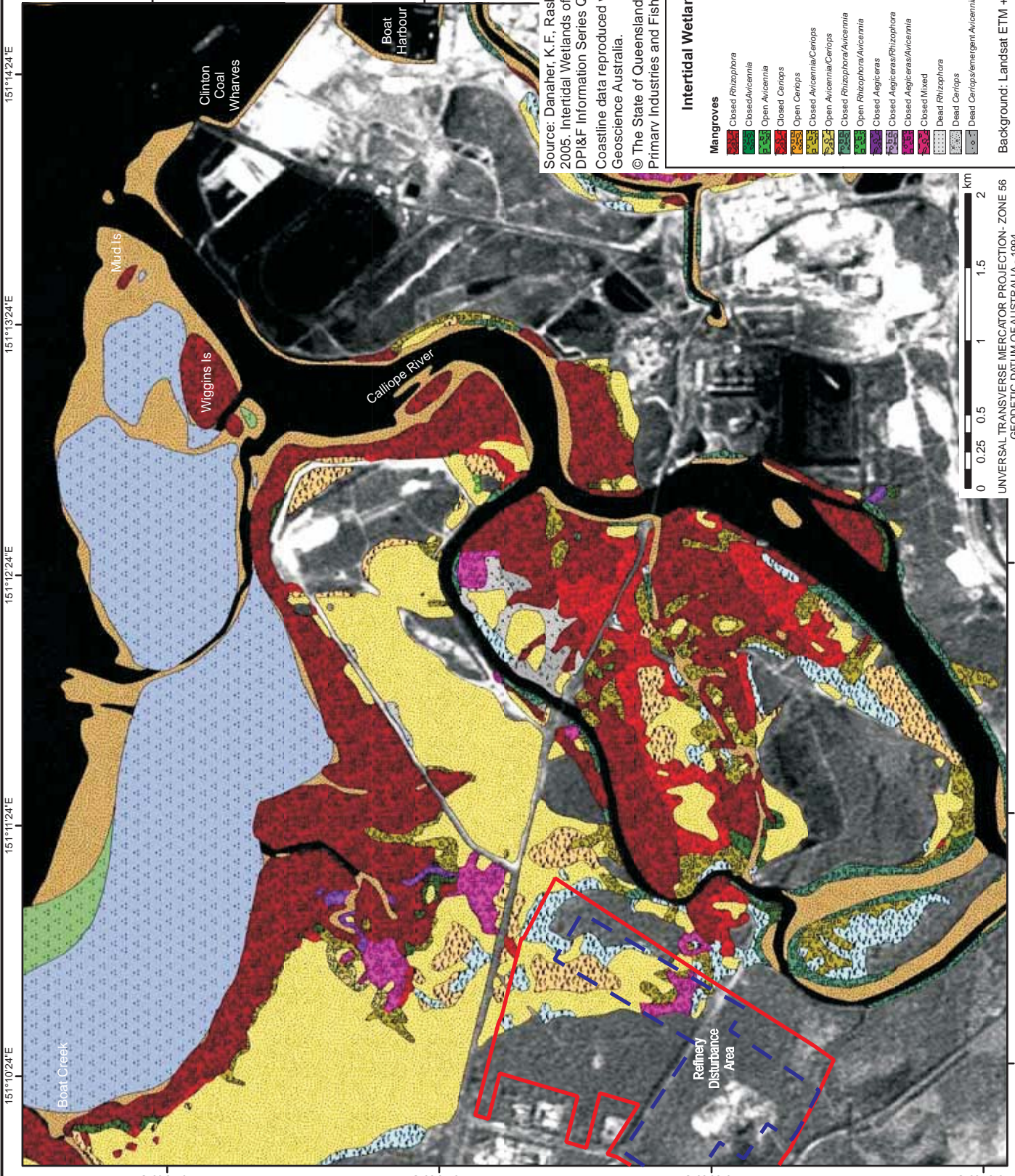
4.6.3 Habitat Protection Zones

There are no declared Fish Habitat Areas (FHAs) in the vicinity of the refinery and RSF sites. The nearest FHAs are located at Corio Bay at Yeppoon (north of Rockhampton) and Cawarral Creek near Emu Park (south-east of Rockhampton) (DPIF, 2006(a)).

There are a number of Habitat Protection Zones (HPZ) located in Port Curtis. These comprise the HPZ at Seal Rocks on the southern boundary of the Port Curtis shipping channel, the HPZ on the eastern side of Facing Island and the HPZ through The Narrows, an area between Curtis Island National Park and the mainland. This HPZ has been identified for its extensive range of marine wetlands: encompassing seagrass beds, mangrove forest and intertidal mudflats that provide habitat for a range of terrestrial and aquatic flora and fauna.

4.6.4 Dugong Protection Zone

The waters of Port Curtis also comprise the north western part of the Rodds Bay and Peninsula to the south-east of the region. The Rodds Bay Dugong Sanctuary is a zone B Dugong Protection Area (DPA) which stipulates and regulates legal netting practices to ensure the protection of Dugongs (GBRMPA, 2006(a)). The DPA extends from Rodds Peninsula in the south to beyond Graham Creek on Curtis Island National Park.

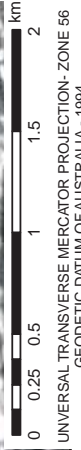


Refinery Site Boundary
Proposed Development Footprint

Source: Danaher, K.F., Rasheed, M.A. and Thomas, R. 2005. Intertidal Wetlands of Port Curtis. DPI&F Information Series Q105031. Coastline data reproduced with permission from Geoscience Australia.
© The State of Queensland, Department of Primary Industries and Fisheries 2005.

Intertidal Wetlands of Port Curtis

Mangroves	Saltmarsh & Substrate
Closed Rhizophora	Saltpan
Closed Avicennia	Samphire dominated Saltpan
Open Avicennia	Saline Grassland
Closed Ceriops	Exposed Banks (Mud and Sand)
Open Ceriops	Exposed Rocky Substrate
Closed Avicennia/Ceriops	Seagrass
Open Avicennia/Ceriops	Zostera Isolated Patches
Closed Rhizophora/Avicennia	Zostera Aggregated Patches
Open Rhizophora/Avicennia	Zostera Continuous Cover
Closed Agliceras	Halodule Isolated Patches
Closed Agliceras/Rhizophora	Halodule Aggregated Patches
Closed Agliceras/Avicennia	Halodule Continuous Cover
Dead Rhizophora	Halophila Isolated Patches
Dead Ceriops	Halophila Aggregated Patches
Dead Ceriops/emergent/Avicennia	Halophila Continuous Cover



UNIVERSAL TRANSVERSE MERCATOR PROJECTION - ZONE 56
GEODETTIC DATUM OF AUSTRALIA - 1994

Background: Landsat ETM + Panchromatic 24 July 2002

Client Gladstone Pacific Nickel Ltd URS	Project GLADSTONE NICKEL PROJECT ENVIRONMENTAL ASSESSMENT OF TREATED WATER DISCHARGE AT PORT CURTIS	Title INTERTIDAL WETLANDS OF THE PORT CURTIS AREA
	Drawn: VH Job No.: 4262 5791	Approved: CMP File No. 42625791-g-276.cdr
		Rev. A A4

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4.7 Threatened and Migratory Species including Matters of National Environmental Significance

Under the Environment Protection and Biodiversity Conservation (EPBC) Act, assessment and approval from the then Commonwealth Department of Environment and Heritage (DEH) ((now the Department of Environment, Water, Heritage and the Arts) is required for the project if it involves an action which will/is likely to have a significant environmental impact on matters of national environment significance (as identified in the EPBC Act) and/or on Commonwealth land. This is called a controlled action.

On 26 October 2005 a referral for the project was submitted to the DEH, which declared on 18 November 2005 that the project was a controlled action pursuant to Section 75 of the EPBC Act. The Part 3, Division 1 controlling actions of relevance to the project are:

- Sections 12, 15A (World Heritage);
- Sections 18 and 18A (Listed threatened species and communities); and
- Sections 20 and 20A (Listed migratory species).

Table 4-3 shows the results of a database search for threatened and migratory species.

Table 4-3 Threatened and Migratory Species

Common Name	Scientific Name	Conservation Status	
		Old NCA ¹	EPBC Act ²
Threatened Species			
Mammals			
Humpback Whale	<i>Megaptera novaeangliae</i>	V	V and M
Dugong	<i>Dugong dugong</i>	V	
Reptiles			
Loggerhead Turtle	<i>Caretta caretta</i>	E	E and M
Green Turtle	<i>Chelonia mydas</i>	V	V and M
Leatherback Turtle	<i>Dermochelys coriacea</i>	E	V and M
Hawksbill Turtle	<i>Eretmochelys imbricate</i>	V	V and M
Pacific/Olive Ridley Turtle	<i>Lepidochelys olivacea</i>	E	E and M
Flatback Turtle	<i>Natator depressus</i>	V	V and M
Sharks			
Whale Shark	<i>Rhincodon typus</i>		V and M
Migratory Species			
Marine Birds			
Southern Giant Petrel	<i>Macronectes giganteus</i>	E	M
Marine Mammals			
Bryde's Whale	<i>Balaenoptera edeni</i>		M
Irrawaddy Dolphin	<i>Orcaella brevirostros</i>	R	M
Killer Whale, Orca	<i>Orcinus orca</i>		M
Indo-Pacific Humpback Dolphin	<i>Sousa chinensis</i>	R	M

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Common Name	Scientific Name	Conservation Status	
Reptiles			
Estuarine Crocodile	<i>Crocodylus porosus</i>	V	M

¹Qld NCA – Queensland Nature Conservation (Wildlife) Regulation 1994; endangered (E), vulnerable (V), rare (R), common (C).

²EPBC Act– Environment Protection and Biodiversity Conservation Act 1999 (Cwlth); endangered (E), vulnerable (V), migratory (M).

Due to the lack of visibility and high turbidity in Port Curtis, no species listed under the EPBC Act or the Queensland Nature Conservation Wildlife Regulation was observed during the field survey in February 2006.

Of the species listed in Table 4-3, and as indicated by the literature review, it is likely that only the following species would be encountered within Port Curtis:

- Indo-pacific humpback dolphins (*Sousa chinensis*);
- Loggerhead turtles (*Caretta caretta*);
- Green turtles (*Chelonia mydas*);
- Dugong (*Dugong dugong*); and
- Flatback turtles (*Natator depressus*).

The Indo-pacific humpback dolphins (*Sousa chinensis*) and bottlenose dolphins (*Tursiops truncatus*) are known to utilise habitats in the outer harbour and occasionally move northward through Port Curtis into The Narrows.

The loggerhead turtles (*Caretta caretta*), green turtles (*Chelonia mydas*), and flatback turtles (*Natator depressus*) are known to utilise habitats in the outer harbour and occasionally move northward through Port Curtis into The Narrows. However, there are no recognised nesting beaches inside Port Curtis, with the closest sites being used by flatback turtles at North Cliff Beach (Facing Island) and the main beach at Southend (Curtis Island), where annual numbers have been estimated at 25-50 nesting turtles per beach (QDEH, 1994).

4.8 Commercial and Recreational Fishing

The flow of the Calliope River is paramount to the health of Port Curtis and the longevity of the commercial and recreational fisheries within Port Curtis (NRM&W, 2005). It is estimated that more than 750,000 people in Queensland fish for recreation per year. The combined recreational fish catch is estimated to be 8,500 tonnes of finfish, crabs and prawns per year from coastal and estuarine waters (DPIF, 2006(a)). The commercial fishing catch within the Gladstone coastal zone is valued at approximately \$1.6 million per year (NRM&W, 2005). There are approximately 500 commercial operators within the fishing industry in Queensland and approximately 150 in Gladstone (Connell Hatch, 2006)

Recreational fishing is important for the local economy. It includes direct economic benefits through the use of charter boats, bait and tackle shops, and accommodation services as well as indirectly through associated businesses and support industries. It is likely that the value of the recreational fishing industry to the local economy will increase slightly with the associated increase in population due to the GNP.

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Port Curtis is an important component of the region's commercial and recreational fishery. The Calliope River is frequently used for recreational fishing as well as for some commercial operations such as crabbing. Access to the Calliope River for fishers is generally via the boat ramp near the Gladstone Power Station. Recreational fishing is also undertaken within the tributaries of the Calliope River and the tidal creeks lining Port Curtis. These fishing locations are not on the proposed refinery site and will not be affected by the GNP.

4.9 Existing Water Quality

4.9.1 Tidal and Current Influences

Port Curtis is an estuary with a large tidal range, which typically results in high current velocities in all major channels. These tidal velocities generally assist in maintaining the waterway as a natural deep-water port. Due to the large tidal storage areas and the amplification effect on water levels, good tidal flushing and large tidal velocities result in well mixed, saline water conditions throughout Port Curtis. As a result dissolved and suspended material shows little variation from the surface to the bottom.

The interchange of tidal waters between Port Curtis and the ocean varies greatly between extreme neap and extreme spring tides. In the area between Curtis Island and Facing Island there are large tidal flats which become exposed at low water. At high water, there are extensive mangrove and intertidal saltflats in Port Curtis which become available for tidal storage. Changes in the available tidal storages with elevation cause the estuary to exhibit nonlinear flow behaviour for tides of large range. This means that water velocities can be quite strong close to high water, particularly on spring tides due to the available storages.

The mean neap tidal range at Gladstone is considerable at 1.54 m, whilst the mean spring tidal range of 3.24 m results in a large exchange of waters between the ocean and Port Curtis. The maximum tidal range is 4.69 m. The large exchange of waters approximately twice per day results in strong flood and ebb current velocities in all of the major channels of the area, particularly under spring tidal conditions. Spring tide velocities within the major channels are of the order of 1.5 - 2.0 m/s (approximately 3 - 4 knots). This is equivalent to a speed of 5.4 to 7.2 km/h enabling material carried in or out on the tide to move 20 to 30 km (assuming four hours at these velocities) which contributes substantially to dispersion in and flushing of the bay and naturally high turbidity levels.

Because of the large variations in the tidal range, considerable variations in water quality may exist in Port Curtis between high and low water and between spring and neap tidal conditions. The most obvious of these relate to water clarity, though other water quality indicators such as nutrient or trace element concentrations may also be affected. Near low water, the shallow water along the muddy foreshores is often highly turbid from the entrainment of fine bed sediments by wave action. Towards high water, turbidity associated with the suspension of fine bed sediments by wave action may be less pronounced due to the depth of water overlying the intertidal areas and the coarse or sandy nature of the strand line sediments.

The naturally high levels of water turbidity within Port Curtis were demonstrated by a recent monitoring program for CQPA of the natural variation in turbidity at the Clinton Coal Wharf between February 2004 and April 2005 (GHD, 2006). This sampling was conducted prior to a subsequent dredging project for the RG Tanna Coal Terminal. A summary of the results of the turbidity monitoring is given in Table 4-4 and can be compared against the ANZECC/ARMCANZ (2000) guideline of 20 NTU.

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Table 4-4 Turbidity at the Clinton Coal Wharf (February 2004 and April 2005)

Statistic	Value (NTU) ¹
Mean	10.3
Median	5.0
80 th percentile	17.0
95 th percentile	38.0
99 th percentile	52.0
Minimum	0.0
Maximum	125.0

¹ Turbidity is commonly measured in Nephelometric Turbidity Units (NTU)

Source: GHD (2006)

Furthermore, water quality and flow modelling undertaken in Port Curtis in 2003 (URS, 2003) showed that clarity and turbidity of the water was such that visibility (by secchi dish) rarely exceeded one metre due to the re-suspension of fine sediments. Further studies carried out for the WICT EIS (Connell Hatch, 2006) also demonstrated the naturally high sediment load of the Port Curtis system.

With respect to sediment mobility, the Connell Hatch (2006) indicates that:

- High transport potential occurs in the main channel with net sediment circulation occurring southward. The strongest transport potential to the south-east is on the northern channel whilst the southern channel (berth-side) has a weaker net transport to the north-west;
- There is net transport predicted out of the Calliope River entrance which discharges 30,000 t of sediment annually;
- Fine sediments are mobilised during spring tides;
- High sediment transport potential occurs at the mouth of the Calliope River based on modelling of a 5 year ARI event; and
- Natural scouring occurs between Wiggins Island and Mud Island declining as it reaches the main channel.

Ongoing maintenance dredging reflects relatively small removal rates reflecting minimal siltation.

A study by the CRC for Coastal Zone Estuary and Waterway Management (Apte et. al., 2005) showed that the proportion of fine particles (< 60 micron) in the main channel bed is low and the rate of sediment deposition in identified depositional zones of Port Curtis (northern Narrows, lower Calliope River and South Trees Inlet-Boyne River areas) has been at least 0.6cm/y on average since 1958.

4.9.2 Other Influences

Port Curtis has an established range of residential, commercial, industrial and port facilities within its immediate catchment. Urban, commercial and industrial infrastructure and port reclamation developments for existing and future industry may result in short or long term impacts to the receiving water quality of Port Curtis. Reclamation activities have recently been undertaken by CQPA at Fisherman's Landing wharf. Further large scale dredging activities are proposed for the Wiggins Island area to facilitate the construction and operation of the Wiggins Island

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Wharf (Connell Hatch, 2006). This is a staged development with dredging required to enable each stage to proceed.

The quality of the marine waters of Port Curtis will continue to be influenced by existing industrial infrastructure and port and shipping operations. For example, a waste liquid effluent discharge pipeline and diffuser structure is situated off the Fisherman's Landing wharf. Some local industries have discharge licenses with the EPA permitting the discharge of waste effluent to Port Curtis via this structure.

4.9.3 Water Quality Data

Extensive water quality testing has been carried out in Port Curtis in recent years. WBM Oceanics Australia has undertaken an extensive Marine Water Quality Program (MWQP) in Port Curtis between December 1998 and November 2001. This work was commissioned by Southern Pacific Petroleum (Development) Pty Ltd as part of a baseline water quality survey of Port Curtis. The monitoring locations are mapped in Figure 4-4, and the results of this program which were reported in URS (2003) are summarised in Table 4-5.

Table 4-5 20th, 50th and 80th Percentiles for Water Quality Data in Port Curtis

Parameter	Unit	1 Boat Creek			2 Fishermans Landing			3 Gully C			4 Targinie Creek			5 Curtis Island (1)			6 Curtis Island (2)		
In-situ measurements: (20th percentile, 50th percentile, 80th percentile)																			
Temperature	°C	23.9	25.3	25.8	20.4	24.5	27.1	20.6	25.2	27.5	20.0	24.7	27.7	20.2	25.3	27.4	20.2	25.2	27.5
Conductivity	mS/cm	52.8	54.3	54.6	52.0	54.1	56.3	49.9	54.3	55.6	48.7	54.1	55.4	51.3	54.0	56.2	51.6	54.1	56.4
Salinity	g/L	34.7	36.0	36.2	34.3	35.9	37.3	32.8	36.0	36.9	31.9	35.9	36.8	33.8	35.8	37.1	34.0	35.8	37.4
pH	Units	8.0	8.1	8.1	8.0	8.1	8.2	8.0	8.1	8.2	7.8	7.9	8.0	8.0	8.1	8.1	8.0	8.1	8.2
Redox	mV	163.0	171.0	286.2	159.0	249.5	340.0	166.0	255.0	339.8	174.2	294.0	396.0	158.2	259.0	338.8	157.0	241.0	347.6
DO	mg/L	5.4	5.5	6.4	5.6	6.2	6.7	5.8	6.3	6.9	5.2	5.9	6.7	5.7	6.3	6.9	5.7	6.3	6.8
DO %	% Sat	81.0	82.7	92.7	85.9	89.3	96.3	86.9	90.5	98.8	80.3	85.7	93.2	87.0	91.0	100.1	87.0	90.5	99.0
Turbidity	NTU	6.9	14.7	15.2	10.9	19.3	32.9	6.2	9.4	27.2	9.3	13.5	30.8	12.5	24.3	36.7	11.2	22.9	35.8
Secchi Depth	m	1.1	1.2	1.3	0.9	1.0	1.3	0.9	1.1	1.3	0.9	1.0	1.2	0.6	0.8	1.0	0.8	1.0	1.1
Trace Elements:																			
Aluminium	µg/L	29	47	71	34	87	210	30	70	120	37	66	120	48	80	140	48	63	100
Arsenic	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Barium	µg/L	9	12	14	8	9	12	9	11	15	9	12	14	7	10	12	7	8	11
Boron	µg/L	4,200	4,500	5,000	4,200	4,540	5,100	4,100	4,600	5,000	4,100	4,500	5,100	4,100	4,500	5,000	4,200	4,500	5,100
Cadmium	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chromium	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Copper	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1.2	<1	<1	1.4	<1	<1	<1
Iron	µg/L	22	46	100	24	76	320	27	51	180	35	87	170	43	110	270	20	67	140
Lead	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Manganese	µg/L	4	8	11	4	8	17	4	8	13	7	11	18	3	7	17	3	6	15
Mercury	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nickel	µg/L	<1	<1	1.3	<1	<1	2	<1	<1	1.4	<1	<1	2	<1	<1	3	<1	<1	2
Zinc	µg/L	<1	<1	3	<1	1.4	6	<1	<1	3	<1	<1	3	<1	<1	3	<1	<1	4
Fluoride	µg/L	890	960	1,000	900	990	1,100	900	1,000	1,100	900	990	1,100	930	980	1,100	940	1,000	1,200
Compounds:																			
Cyanide	µg/L	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Nutrients:																			
Total Nitrogen	µg/L	130.0	180.0	280.0	140.0	180.0	240.0	140.0	210.0	251.2	140.0	200.0	278.0	140.0	200.0	290.0	130.0	180.0	270.0
Total Kjeldahl Nitrogen	µg/L	120.0	180.0	270.0	110.0	180.0	240.0	140.0	210.0	240.2	120.0	200.0	250.0	120.0	196.0	250.0	120.0	180.0	250.0
Organic Nitrogen	µg/L	90.0	150.0	210.0	100.0	160.0	220.0	115.2	172.5	221.6	110.0	170.0	230.0	110.0	180.0	230.0	120.0	150.0	240.0
Ammonia	µg/L	6.0	10.0	40.0	7.0	12.0	24.0	5.2	11.5	25.8	6.0	13.0	26.0	7.0	10.0	23.0	5.0	10.0	30.0
Nitrite	µg/L	<5.0	<5.0	5.0	<5.0	<5.0	9.0	<5.0	<5.0	5.0	<5.0	<5.0	5.0	<5.0	<5.0	5.0	<5.0	<5.0	5.0
Nitrate	µg/L	<5.0	<5.0	20.0	<5.0	7.0	13.0	<5.0	<5.0	5.8	<5.0	<5.0	5.0	<5.0	<5.0	20.0	<5.0	<5.0	18.0
Total Phosphorus	µg/L	10.0	12.0	14.8	10.0	12.0	19.0	10.0	11.5	18.8	10.0	12.0	15.6	10.8	16.0	22.6	10.0	11.0	15.2
Orthophosphorus	µg/L	<5.0	<5.0	7.0	<5.0	<5.0	8.0	<5.0	<5.0	9.8	<5.0	<5.0	9.0	<5.0	<5.0	8.0	<5.0	<5.0	9.0
Suspended Solids:																			
Suspended Solids	mg/L	9.0	17.0	34.0	14.0	36.0	56.0	12.0	17.0	43.0	14.0	31.0	51.0	18.0	36.0	62.0	17.0	25.0	59.0

More recent water quality data for Port Curtis have been sourced from 10 years of EPA monitoring (1996-2006), Marine Water Quality Program (MWQP) (1998-2001), monitoring over two seasons in 2006 for the WICT EIS (Connell Hatch, 2006), and monitoring undertaken by Port Curtis Integrated Monitoring Program (PCIMP) (2006). These data (Table 4-6 and Table 4-7) have been used to supplement the data presented in the table above.

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Table 4-6 Port Curtis Water Quality- Supplementary Data

Parameter	Minimum	20 th %ile	Median	80 th %ile	Maximum	n
Turbidity (NTU)	1.0	5.0	12.0	27.0	225.0	946
Chlorophyll-a (µg/L)	0.33	1.07	1.87	4.85	11.36	127
Dissolved Oxygen (%sat)	71.5	91.5	94.5	99.7	128.1	1035
pH	4.73	7.88	7.99	8.13	8.60	1032
Suspended Solids (mg/L)	2.0	12.0	24.0	48.0	116.0	331
Conductivity (mS/cm)	23.6	52.4	54.9	56.6	60.5	1036
Temperature (°C)	17.0	22.4	25.9	29.2	35.5	331
Ammonia (µg/L)	2.5	7.0	11.0	30.4	200.0	189
Nitrates and Nitrites (µg/L)	5.0	5.0	5.0	25.0	422.5	195
Total Nitrogen (µg/L)	25.0	140.0	190.0	270.0	2300.0	194
Filterable Reactive Phosphorous (µg/L)	2.5	2.5	2.5	10.0	50.0	192
Total Phosphorous (µg/L)	5.0	10.0	25.0	25.0	32.0	194
Aluminium (µg/L)	2.5	35.0	73.0	140.0	3,700.0	
Iron (µg/L)	2.5	31.6	90.0	210.0	2,100.0	174
Nickel (µg/L)	0.5	0.5	0.5	1.5	20.0	174
Manganese (µg/L)	0.5	3.9	7.6	15.0	59.0	194
Zinc (µg/L)	0.5	0.5	0.5	3.3	14.0	174

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Table 4-7 Biomonitoring by Port Curtis Integrated Monitoring Program (PCIMP) (2006)

Zone	DGT-labile metal concentrations (µg/L)									
	Cu	Zn	Al	Cd	Co	Cr	Fe	Mn	Ni	Pb
LOD	0.04	10.97	0.167	0.001	0.001	0.077	0.676	0.005	0.027	0.001
Wiggins Island (WI)	0.20 ± 0.01	<10.97	3.1 ± 1.5	0.010 ± 0.003	0.03 ± 0.00	<0.077	14 ± 2	1.2 ± 0.1	0.32 ± 0.03	0.006 ± 0.001
Calliope Ananbranch (Ana)	0.22 ± 0.01	<10.97	7.7 ± 2.6	0.004 ± 0.000	0.07 ± 0.01	<0.077	12 ± 1	3.5 ± 0.6	0.30 ± 0.01	0.005 ± 0.001
Calliope River (CR)	0.20 ± 0.02	<10.97	0.8 ± 0.2	0.004 ± 0.000	0.04 ± 0.00	<0.077	9 ± 0	2.1 ± 0.6	0.27 ± 0.01	0.003 ± 0.000
Auckland Creek (AC)	0.22 ± 0.02	<10.97	0.6 ± 0.2	0.006 ± 0.001	0.02 ± 0.00	0.09 ± 0.01	9 ± 0	1.2 ± 0.1	0.20 ± 0.01	0.003 ± 0.000
Mid harbour (Mid)	0.12 ± 0.01	<10.97	5.9 ± 2.7	0.003 ± 0.000	0.03 ± 0.00	<0.077	19 ± 5	1.0 ± 0.2	0.21 ± 0.02	0.008 ± 0.002
Outer harbour (Out)	0.05 ± 0.01	<10.97	0.6 ± 0.3	0.004 ± 0.003	0.01 ± 0.00	<0.077	8 ± 1	0.4 ± 0.1	0.10 ± 0.01	0.006 ± 0.001
Reference – Estuarine (RE)	0.06 ± 0.01	<10.97	0.6 ± 0.2	0.002 ± 0.001	0.06 ± 0.00	0.11 ± 0.02	10 ± 0	2.6 ± 0.4	0.13 ± 0.00	0.004 ± 0.001
Reference-Oceanic (RO)	0.07 ± 0.01	<10.97	0.3 ± 0.1	0.012 ± 0.005	0.01 ± 0.00	0.10 ± 0.02	10 ± 2	0.4 ± 0.1	0.11 ± 0.01	0.007 ± 0.001
AWQG 95% trigger	1.3	15	-	5.5	1	(III) 27 (IV) 4.4	-	-	70	4.4

DGT-labile metal concentrations in GPN report zones. Values are means ± se (n = 6 to 19). LOD indicates laboratory limit of detection for each metal. AWQG 95% trigger values (ANZECC/ARMCANZ, 2000)

Table 4-8 provides the adopted ambient concentration for each of the constituents, and a description of the source of the concentration.

Table 4-8 Ambient Concentration of Constituents

Constituent	Ambient Concentration (µg/L)	Source
Nickel	0.5	Table 4-6, median
Cobalt	0.1	Table 4-7, maximum (0.07 + 0.01) = 0.08 rounded up to 0.1 µg/L
Manganese	7.6	Table 4-6, median
Cadmium	0.02	Table 4-7, maximum (0.012 + 0.005) = 0.017 rounded up to 0.02 µg/L
Chromium 3+	0.15	Table 4-7, maximum (0.10 + 0.02) = 0.12 rounded up to 0.15 µg/L
Chromium 6+	0.15	Table 4-7, maximum (0.10 + 0.02) = 0.12 rounded up to 0.15 µg/L
Zinc	0.5	Table 4-6, median
Iron	90	Table 4-6, median
Aluminium	73	Table 4-6, median
Magnesium	1290000	Typical seawater value (http://www.seafriends.org.nz/oceano/seawater.htm)

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Constituent	Ambient Concentration (µg/L)	Source
Calcium	411000	Typical seawater value (http://www.seafriends.org.nz/oceano/seawater.htm)
Chloride	19400000	Typical seawater value (http://www.seafriends.org.nz/oceano/seawater.htm)
Sulfate	2688000	http://www.enclabs.com/question.html

The baseline water quality data compiled for the three year period by the MWQP indicated good quality, though frequently turbid, marine waters occur within Port Curtis. The waters had low nutrient concentrations and generally low total concentrations of most elements, with the notable exceptions being aluminium, iron and manganese.

Understanding of the potential impacts to the marine environment of contaminants discharged to Port Curtis is currently being advanced through the Port Curtis Integrated Monitoring Program (PCIMP), a consortium of members from industry, government, research institutions and other stakeholders who are charged with developing a cooperative monitoring program for assessing the ecosystem health of Port Curtis. GPNL is a member of PCIMP and has participated in PCIMP's 2006 and 2007 water quality and intertidal monitoring programs covering Port Curtis. For each program, GPNL sponsors three sampling sites located in the Calliope River and anabranch.

PCIMP's water quality program provides a time-averaged measurement of bioavailable metals in waters (Andersen et.al. 2006(b)) and includes in-situ monitoring techniques using transplanted oysters and Diffuse Gradients in Thin films (DGT) (passive samplers). In accordance with the ANZECC/ARMCANZ (2000) guidelines, DGTs may be used to provide bioavailable metal concentrations, which are a better estimate of potential impacts than dissolved metal concentrations. Currently the program has investigated DGT take-up of seven metals and further development of the DGT program to expand the range of metals investigated, including manganese which is a component of the GNP discharge, will be undertaken under proposed extension research projects.

PCIMP's intertidal monitoring program includes assessment of intertidal sediments, examination of mangrove condition and preservation of intertidal macroinvertebrate samples (Andersen et. al. 2006(c)). Sediment sample analysis includes a suite of seventeen metals including manganese, nickel and cobalt. Combined with the water quality program, the intertidal monitoring program will assist in understanding the behaviour of metals in Port Curtis and the potential impacts on marine life.

Additionally, PCIMP proposes to work with other research organizations on a number of projects including:

- Development of relevant trigger values³ for metals discharged in Port Curtis;
- Increasing the understanding of deposition of fine particulates in Port Curtis; and
- Extension of current hydrodynamic modelling tools available for Port Curtis to include modelling of particulate movement.

This will improve the understanding of the behaviour of metals and particulates in the water column. GPNL will continue to support such projects undertaken by PCIMP, and will continue to participate in the PCIMP to assess the ecosystem health of Port Curtis.

³ A trigger value refers to a limit at which the water may not be safe for the relevant environmental values and management action should be triggered to either more accurately determine whether the water is safe or to rectify the situation.

