Gladstone Ports Corporation

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Chapter 8 – Water Resources

8. Water Resources

Overview

This chapter describes the existing environment for surface (non-marine) and groundwater resources that may be affected by the Project in the context of environmental values. It addresses Section 3.4 (Water Resources) of the ToR, where relevant to the Project (Appendix A). Impacts on the benthic environment are described in Chapter 9, and impacts to marine water quality are discussed in Chapter 7.

A detailed Groundwater Resources Assessment is provided in Appendix O. A review of hydrology and conceptual stormwater design for the Reclamation Area was undertaken as part of a Preliminary Engineering Study for the Western Basin Reclamation Area (GHD, 2009e).

Legislation

Various water types within the Project Area have been identified on the basis of the classification system in the Queensland Water Quality Guidelines 2006 (QWQG 2006), Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000), and by information in both the State Coastal Plan – Queensland's Coastal Policy (State Coastal Plan) and the Curtis Coast Regional Coastal Management Plan (Curtis Coastal Plan, EPA 2003) for coastal resource types. The *Environmental Protection (Water) Policy 1997* (EPP (Water)) is subordinate legislation to the *Environmental Protection Act 1994* and applies to all Queensland waters.

The relevant legislation is discussed more fully in Chapter 7.

8.1 Surface Water and Watercourses

This section addresses surface water and stormwater management issues associated with the Reclamation Area of the Project. This area, along with the adjacent Fisherman's Landing Northern Expansion (subject of a separate EIS), was considered as a single entity for the purposes of this study, as the stormwater systems will be combined.

This section focuses on impacts of the Western Basin Reclamation Area on surface water discharges within the Project Area and stormwater management on the proposed Reclamation Area. The following specific issues are addressed:

Surface Waters

- Potential impacts of possible afflux on the relevant waterways;
- Potential impacts of possible afflux on the stormwater outlets of the two existing industrial developments;
- Potential impacts of stormwater conveyance on the intertidal channel, including:
  - Water quality;
  - Afflux under Highest Astronomical Tide (HAT) conditions, when the intertidal channel will be 'full' as a result of tidal conditions; and
  - Velocity under Lowest Astronomical Tide (LAT) conditions, when the intertidal channel is devoid of tidal waters; and

- Potential impacts of stormwater conveyance (afflux and/or velocity) associated with the proposed temporary at-grade construction access road that is to traverse the intertidal channel in order to gain access to construct the western bund wall.

Proposed Reclamation Area

- Conceptual stormwater drainage following the filling of the reclamation, with consideration of possible future development; and
- Conceptual stormwater treatment measures during the construction and operational phases, with consideration of possible future development.

8.1.1 Description of Environmental Values

Overview

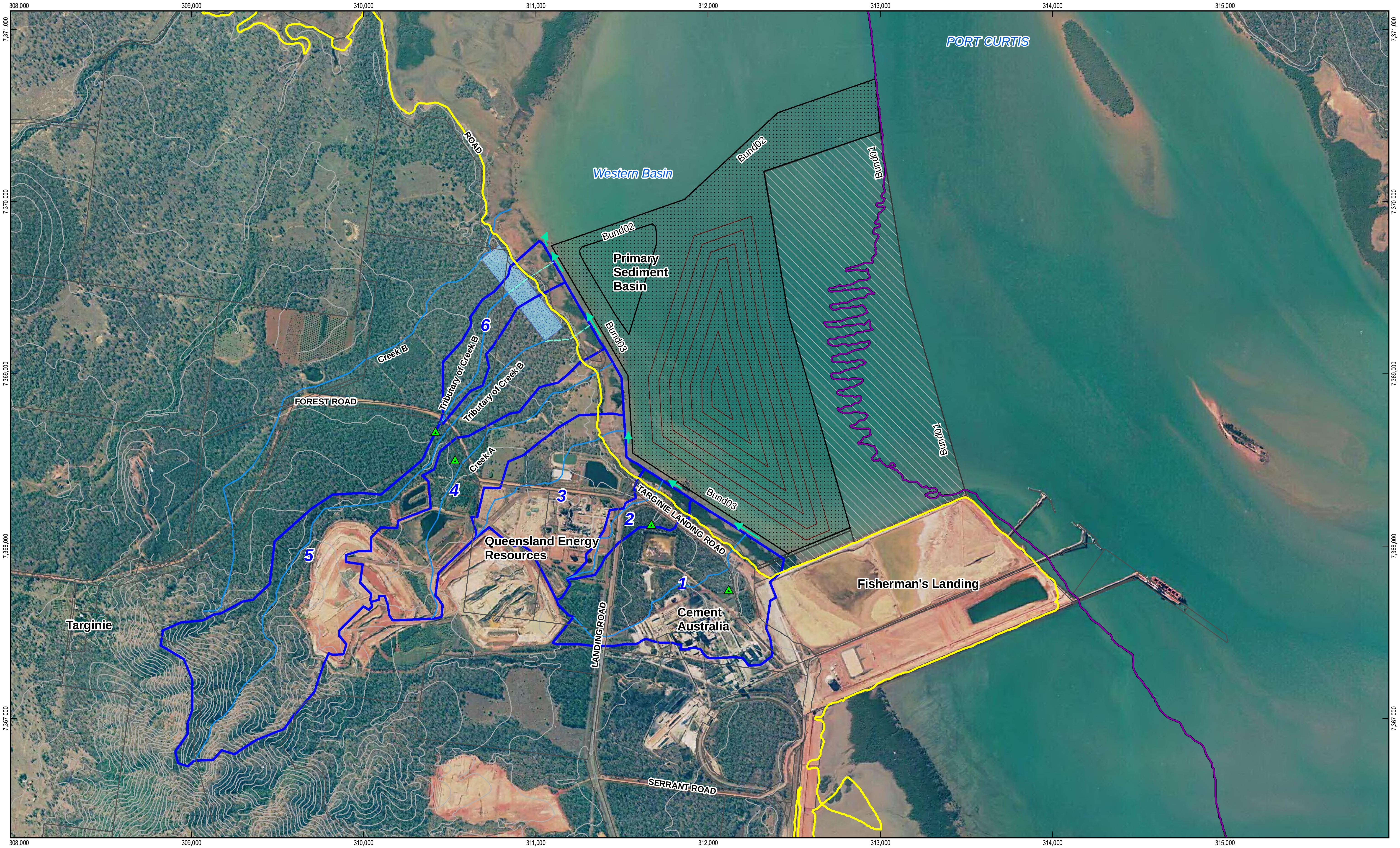
As described in Chapter 2, the proposed Reclamation Area will be wholly situated within the line defined by HAT - that is, the reclamation will entirely be sited on land that is inundated by the highest tides. The proposed Reclamation Area will be land-attached along the southern end to the existing Fisherman's Landing Reclamation. The proposed western bund wall (Bund 03) will be situated approximately 40 m east of the existing mangroves that line the foreshore (Figure 8-1). Given that the western bund wall is situated within the intertidal zone (the part of the shore that lies between the highest and lowest watermarks), an intertidal channel will be formed between the foreshore and the bund. The proposed northern (Bund 02) and eastern (Bund 01) bund walls will front directly onto the marine environment, with the northern bund wall also situated partly within the intertidal zone.

Surface Water

Waterways

Two unnamed creeks (hereinafter referred to as Creeks A and B) and several small overland flow paths presently discharge into the area to the north of the existing Fisherman's Landing Reclamation (hereafter referred to as the Western Basin area). Furthermore, two existing industrial developments, Cement Australia and Queensland Energy Resources Ltd, also discharge into the Western Basin area.

The closest river to the Project Area is the Calliope River, located approximately 6 km south-east of the proposed Western Basin Reclamation Area. The Queensland Department of Environment and Resource Management (DERM) gauging station on the Calliope River indicates that numerous flood events have occurred since the installation of the gauge in 1938 (Connell Hatch 2006). The BoM website indicates that these events are generally associated with cyclones or associated rain depressions (Connell Hatch 2006). The distance of the river from the Reclamation Area, however, means it is unlikely to have any impact on the intertidal channel or the Reclamation Area itself.



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Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 56

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LEGEND

- Western Basin Reclamation Area
- Mound Contours (10 m Interval)
- Fisherman's Landing Northern Expansion
- Cadastre
- Subcatchment Boundary
- Depression Storage Area (Assumed)
- Industrial Discharge Points
- Contours (5m Intervals)
- Flow Path
- Adopted Flowpath
- Intertidal Channel showing Flow Direction
- HAT
- LAT

Port of Gladstone
Western Basin Dredging and Disposal Project

Surface Waters Discharging into the Western Basin Area and Catchment Delineation

Job Number	42-15386
Revision	A
Date	22 Oct 2009

Figure 8-1

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Catchments

Six catchments were identified as possibly discharging into the intertidal channel (Figure 8-1). The hydrologic catchment characteristics are summarised in Table 8-1.

Table 8-1 Catchment Characteristics

Catch ID	Area (ha)	Flow Length (km)	Ave Catch Slope (%)	Land Cover within Catchment
1	79	1.35	1.85	Industrial / timbered
2	14	0.90	3.41	Industrial / timbered
3	56	1.18	2.57	Industrial / exposed soil
4	66	2.50	1.38	Industrial / Timbered / exposed soil
5	142	4.46	1.61	Industrial / Timbered / exposed soil
6	22	1.20	1.16	Timbered

Catchment 1 consists primarily of the existing Cement Australia industrial development, with Catchment 2 an overland flow path. Catchment 3 consists primarily of the existing Queensland Energy Resources Ltd industrial development. Creek A falls within Catchment 4 and discharges into the intertidal channel.

The automated routines used to delineate the hydrologic catchments suggested that Catchments 5 and 6 also discharge into the intertidal channel. However, it was evident from a visual inspection of the Western Basin foreshore that these waterways do not discharge as indicated, but are probably tributaries of Creek B, that discharges further north into the area to the north of the proposed Reclamation Area. Furthermore, these tributaries probably flow through a significant depression storage area, located in the forest behind the foreshore.

Climatic Data

Refer to Section 4.1.1 for details of rainfall patterns for the Project Area.

Summary of Environmental Values

The environmental values of an area are determined by the existing beneficial uses of that area including conservation values and significance, human uses and spiritual and cultural significance (refer to Section 7.1.1. for more detail on water quality environmental values). The relevant environmental values for Creeks A and B are:

- Modified aquatic ecosystem;
- Indigenous traditional owner cultural resources and values [1];
- Habitat for native and migratory animals; and

[1] Indigenous traditional owner cultural resource values - (significant animals, fishing practices, spiritual significance, cultural significance, economic significance, self determination, knowledge systems)

- Habitat for native plants.

Stormwater

There are two existing industrial facilities on the mainland adjacent to the proposed reclamation (QERL and Cement Australia) that discharge stormwater from licensed discharge points into the area to the north of the existing Fisherman's Landing Reclamation. These stormwater discharges are required to meet Development Approval conditions, therefore the quality of these discharges is managed before it leaves the site from which it is generated. There are no other significant catchment pollutant sources that discharge into the Project Area.

8.1.2 Potential Impacts and Mitigation Measures

Surface Waters

Methodology

The methodologies adopted in the hydrologic and hydraulic assessments are based on current practices and, where applicable (or in the absence of more accurate data), adopt conservative assumptions in order to demonstrate the likely worst case scenario(s) (GHD, 2009e).

Given the uncertainty associated with Catchments 5 and 6, the decision was made to include these in the hydrologic and hydraulic models but to exclude the effects of the probable depression storage.

Peak discharges from Creek A, Creek B, the several small overland flow paths and two existing industrial developments were estimated using the Rational Method, in accordance with Institution of Engineers Australia, Australia Rainfall and Runoff, 1997 (IEAust 1997).

In the absence of detailed information regarding current site water management practices for the Cement Australia and Queensland Energy Resources Ltd developments, the decision was made to discount the effects of on-site storage facilities. This has resulted in more conservative estimates of peak discharge.

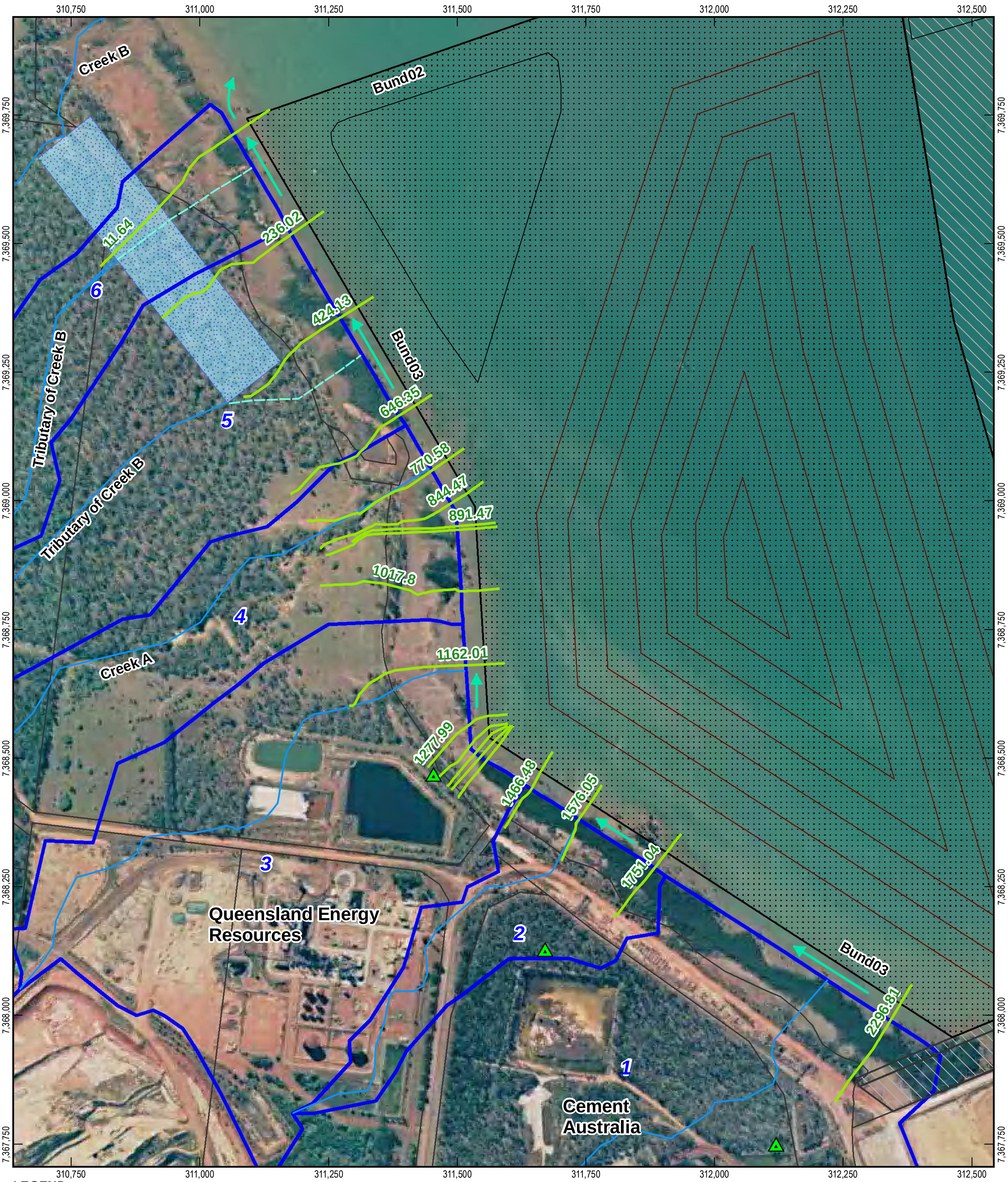
Three hydraulic regimes could exist within the intertidal channel:

- Tidal flows only;
- Stormwater only; or
- A combination of tidal flows and stormwater.

The hydrologic and hydraulic regimes are summarised in Table 8-2.

This Section addresses the use of a one-dimensional steady flow model to assess the flooding regimes in the intertidal channel under a range of tide levels. A two-dimensional hydrodynamic and transport model was used to assess the impacts of tidal flows and is reported separately (Appendix J).

The one-dimensional steady flow modelling was undertaken using Hydrologic Engineering Center River Analysis System (HEC-RAS) version 4.0ß software, developed by the US Army Corps of Engineers Hydraulic Engineering Center (Figure 8-2).



LEGEND

- Cadastre
- Depression Storage Area (Assumed)
- Subcatchment Boundaries
- Western Basin Reclamation Area
- Mound Contours (10 m Interval)
- Fisherman's Landing Northern Expansion
- Channel Cross-section
- Flow Path
- Adopted Flowpath
- Intertidal Channel showing Flow Direction
- Industrial Discharge Point

1:10,000 (at A4)

0 50 100 150 200 250

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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Port of Gladstone
Western Basin Dredging and Disposal Project

Flood Model Setup

Job Number	42-15386
Revision	A
Date	26 Aug 2009

Figure 8-2

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Table 8-2 Hydrologic and Hydraulic Regimes within Intertidal Channel

Climatic Conditions	Description
Tide: LAT	***LAT is lower than the intertidal channel invert. Intertidal channel will be devoid of tidal flow.***
No rainfall event	Intertidal channel will appear as mudflats, hence this scenario is not modelled.
Low intensity high frequency (i.e. common) rainfall event	Intertidal channel will have base flow resulting from stormwater runoff only. Discharge and water surface levels can be inferred from the 3 month average recurrence interval (ARI) data (GHD, 2009e).
High intensity low frequency (i.e. extreme) rainfall event	Intertidal channel will have significant flow resulting from stormwater runoff. Discharge and water surface levels can be read from the 1 – 1000 year ARI data (GHD, 2009e).
Tide: HAT	***HAT is higher than the intertidal channel invert. Intertidal channel will be 'full' as a result of tidal conditions.***
No rainfall event	Intertidal channel will be subject to the effects of tidal flushing only.
Low intensity high frequency (i.e. common) rainfall event	Intertidal channel will have combined tidal flow and stormwater runoff. However, the primary hydraulic regime will be tidal flushing, with the contribution of stormwater runoff being of lesser significance. Discharge and water surface levels can be inferred from the 3 month ARI data (GHD, 2009e).
High intensity low frequency (i.e. extreme) rainfall event	Intertidal channel will have combined tidal flow and stormwater runoff. Intertidal channel will have significant flow resulting from stormwater runoff. Discharge and water surface levels can be read from the 1 – 1000 year ARI data (GHD, 2009e).

Peak discharges were estimated for the 1, 2, 10, 50, 100 and 1000 year ARIs using the Rational Method, in accordance with the IEAust 1997 Guidelines. These peak discharges are summarised in Table 8-3. The 3 month ARI peak discharge was estimated as 50% of the 1 year ARI peak discharge.

Table 8-3 Estimated Peak Discharges from Catchments

Catch ID	Average Recurrence Interval (ARI) / Peak Discharge (m^3/s)						
	3 month	1 year	2 year	10 year	50 year	100 year	1000 year
1	3.3	6.6	8.5	13.3	22.7	27.5	43.8
2	0.7	1.5	1.9	3.0	5.1	6.1	9.5
3	2.7	5.3	6.8	10.6	18.1	21.9	33.7
4	1.3	2.6	3.4	5.1	8.7	10.5	22.7
5	1.9	3.9	5.1	8.1	14.1	17.1	39.4
6	0.7	1.4	1.8	2.9	4.9	5.9	11.6

Potential Impacts

As a result of the proposed Western Basin Reclamation Area, Creek A, the several small overland flow paths and the two existing industrial developments will all discharge into the intertidal channel. Creek B will discharge beyond the northern extremity of the proposed Reclamation Area.

Flood Hydrology

Estimated peak discharges within the intertidal channel are summarised in Table 8-4.

Table 8-4 Estimated Peak Discharges within Intertidal Channel

Average Recurrence Interval	Discharge at Start Section - Ch 2297 (m^3/s)	Discharge at End Section - Ch 12 (m^3/s)
3 month	3.3	10.7
1 year	6.6	21.3
2 year	8.5	27.5
10 year	13.3	42.8
50 year	22.7	73.6
100 year	27.5	89.0
1000 year	43.8	160.7

Afflux resulting from stormwater conveyance within the intertidal channel, under HAT conditions, is negligible (Table 8-5). Therefore, the effect on Creek A is considered negligible. Furthermore, the stormwater outlets of the two industrial developments should not be adversely affected.

Table 8-5 Predicted Flood Levels and Afflux within Intertidal Channel (GHD, 2009e)

Average Recurrence Interval	Water Level (m AHD)	Afflux Above HAT (m)
3 month	2.54	-
1 year	2.54	-
2 year	2.55	0.01
10 year	2.56	0.02
50 year	2.60	0.06
100 year	2.62	0.08
1000 year	2.75	0.21

Benthic sediments within the area of the future intertidal channel have not been specifically tested and classified. However, in accordance with Institution of Engineers Australia, Soil Erosion and Sediment Control, Engineering Guidelines for Queensland Construction Sites, 1996, it is likely that permissible velocities would be in the range of 0.7 – 1.1 m/s (GHD, 2009e). Predicted velocities resulting from stormwater conveyance within the intertidal channel were calculated for LAT and HAT (GHD, 2009e). Predicted velocities within portions of the intertidal channel, under LAT conditions, could be sufficiently high (approximately 0.7 m/s) to result in the resuspension of benthic sediments, thus increasing turbidity and potentially causing scour adjacent to the proposed bund wall. Furthermore, predicted peak velocities at the outlet of the intertidal channel during low tailwater conditions are considered high (>1.5 m/s).

It should be noted that the invert of the intertidal channel undulates (-0.24 m to 0.00 m AHD) (GHD, 2009e). Therefore, it is possible that the intertidal channel will seek to recreate a natural equilibrium through the scour of “ridges” and deposition in “valleys”.

The proposed temporary at-grade construction access road that is to traverse the intertidal channel in order to gain access for construction of the western bund wall, has not been modelled. However, impacts are considered negligible provided that the road elevation matches that of the channel invert.

Stormwater Quality

Following filling of the Reclamation Area, the final surface will be capped with suitable material and/or revegetated. However, there remains the potential for sediments to be entrained in the stormwater runoff and released to the harbour. This stormwater is unlikely to be contaminated with nutrients, organics, hydrocarbons or metals as there will be no activities occurring on the undeveloped Reclamation Area that would result in the introduction of contaminants into the stormwater runoff.

Typically, rainfall events up to the 3 month ARI will generate approximately 90% of the annual volumetric runoff. Therefore, these events tend to carry pollutant loads that could be associated with the long-term degradation of downstream receiving waters. However, the average number of days per annum with rainfall greater than 1 mm is only 66 (Gladstone Radar). Given that the intertidal channel is subject to daily flushing within the boundaries of the normal tidal range, tidal flushing will be the primary hydraulic transport regime with respect to water quality (Numerical Modelling Report, Appendix J).

Mitigation Strategies

The following management strategies are recommended with respect to the intertidal channel:

- The outlet of the intertidal channel rock armoured as required, and potentially flared to reduce the risk of scour;
- Permanent reference markers be installed at appropriate locations along the intertidal channel and that these be monitored on a regular basis (annual and after every rainfall event with a >1 year ARI) to determine if significant deposition or scour are occurring. In the event that scour is occurring, the effects on turbidity and stability of the bund wall should be reassessed and the bed should be stabilised where necessary;
- Construct temporary at-grade construction access road such that it does not impinge upon the vertical gradient of the intertidal; and
- The proposed temporary at-grade construction access road is removed in its entirety at the earliest opportunity practicable and the intertidal channel is rehabilitated should leaving the rock *in situ* not be considered suitable.

Reclamation Area

A conceptual design of a stormwater management system (including drainage system and stormwater treatment measures) for the proposed Reclamation Area was undertaken to demonstrate that a functional stormwater management system that can manage stormwater runoff and minimise the discharge of sediment-laden and turbid waters to Port Curtis is practicable (see Chapter 2.4.3 for a more detailed description of the system).

Stormwater Drainage System

The conceptual design of the stormwater drainage system for the reclaimed area (including the proposed mound) was based on industry norms and standards, with due consideration for possible future land use, staged construction, operation and maintenance.

Grass lined channels have been recommended as these represent the best compromise between hydraulic efficiency and cost efficacy. Unlined channels would require a substantially larger cross sectional area in order to reduce velocities, thereby minimising erosion.

The proposed Reclamation Area, and in particular the mound, could be subject to differential settlement. To mitigate the associated risks, the following monitoring program has been recommended:

- All drainage elements be visually inspected after all significant rainfall events (>2 year ARI) by a registered professional engineer;
- All drainage elements on the mound be surveyed on an annual basis to determine if significant differential settlement or siltation is occurring; and
- All drainage elements where excessive erosion, differential settlement, siltation or other forms of damage has occurred to be remediated.

Stormwater Treatment Measures

The primary water quality risk associated with the proposed Reclamation Area is the potential high suspended solids content of stormwater runoff. The conceptual design of the proposed stormwater treatment system has been based on structural source and treatment control, to address soil erosion and sediment control, respectively. The Revised Universal Soil Loss Equation (RUSLE) Method, as detailed in Brisbane City Council, Sediment Basin Design Construction and Maintenance, 2001 (BCC 2001), was used to determine probable maximum annual soil loss rate. A 2007 draft version of the International Erosion Control Association, Best Practice Erosion and Sediment Control Guidelines (IECA 2007 (draft)) was used to select and conceptually design stormwater quality improvement devices. It is noted that the conceptual stormwater design assumed the final reclamation surface was in place. The management of water quality during filling of the Reclamation Area is discussed in Chapter 7.1.2.

The following soil characteristics were inferred from the Douglas Partners (2005) report:

- 5 - 40% sand; and
- 60 - 95% clay and silt.

The high clay and silt content for the assumed soil type resulted in the need for *Type D wet sediment basins*. These sediment basins are designed to retain sediment-laden water for extended periods, allowing adequate time for the gravitational settlement of fine sediment particles, and thus require decant when the water level reaches the top of the sediment storage zone. Given that the proposed Reclamation Area will consist of marine sediments, stormwater runoff may be saline (subject to the degree of capping), which would aid in the flocculation of suspended particles. However, it is conceivably possible that chemical flocculation may be required to assist in meeting water quality objectives. It is also noted that the progressive capping of the Reclamation Area will also reduce the silt and clay content of runoff.

The recommended water quality objectives represent that which is achievable with current sediment basin design techniques. However, sediment basin design techniques are constantly being refined, and given that the sediment basins will only be constructed in the medium term, it has been recommended that reference be made to the latest best practice guidelines for soil erosion and sediment control at the time of design.

The primary sediment basin, located in the northwest of the reclamation, has a concept size of 31.3 ha, with a settling zone volume of approximately 188,000 m^3 and a required average cleanout frequency of approximately 5 years.

To limit soil erosion and loss at source, emphasis will be placed on the use of structural source control systems, such as sediment fences, and on vegetating the proposed Reclamation Area as soon as is practicable.

Future proponents will need to address the quantity and quality of stormwater discharge from any facilities constructed on the Reclamation Area, including the separation of clean stormwater from potentially contaminated stormwater. Conditions will be defined as part of the licensing process when proponents apply for development approvals.

8.2 Groundwater

A hydrogeological study was completed for the EIS, utilising published information and field investigation data to characterise existing groundwater conditions in the vicinity of the Project Area. This study assessed the potential impacts of the proposed development and identified mitigation strategies and ongoing groundwater monitoring requirements. The Groundwater Resources Assessment is provided in Appendix O.

8.2.1 Methodology

Overview

The following activities were carried out as part of the groundwater resources study:

- Desktop study, site visit and bore census;
- Installation of six additional groundwater monitoring bores;
- Groundwater monitoring at existing and new bores;
- Description of existing hydrogeological conditions;
- Construction and calibration of a groundwater flow model, in order to quantify the potential impacts of the proposed development on groundwater levels; and
- Identification of potential impacts and mitigation measures.

Refer to Section 2 in Appendix O for more detail on the methodology used.

Groundwater Monitoring Network

After a review of existing information (Appendix O) and a search of the groundwater bore census, a review of the location of existing groundwater bores in the area was carried out. This indicated an absence of boreholes in the coastal strip to the north and west of the proposed Reclamation Area. However, five existing groundwater monitoring bores with monitoring potential and/or with available historic data were identified to the south and south west of the proposed Reclamation Area. Permission was obtained from Cement Australia and Rio Tinto Alcan Yarwun (RTAY) to access these boreholes as part of the EIS investigations.

Locations

The monitoring network developed for the groundwater resources study is shown along with the published geology in Figure 8-4. Table 8-7 summarises the key to the geology. In addition to the 8 existing Cement Australia bores and the 1 RTAY bore to the south and south-west of the site, 6 new 'shallow' (c5-7 metres below ground level (mbgl)) and 'deep' (c20 mbgl) bores (prefixed by WB) were drilled at 4 locations to the west and north west of the proposed Reclamation Area. This network of 15 bores is considered to provide good spatial coverage around the Reclamation Area and monitoring of shallow and deeper groundwater flow horizons. No monitoring bores were located to the north of the proposed Reclamation Area as there is from 0.75 to 2 km of ocean between the reclamation footprint and the tidally inundated mudflats and mangroves of this area. All 15 bores in the network were monitored for groundwater levels and 9 for groundwater quality.

Monitoring Events

Three groundwater monitoring events were completed in July, August and September 2009.

Analytical Schedule

To obtain an understanding of the existing groundwater quality in the vicinity of the proposed Reclamation Area, groundwater samples were analysed for the range of parameters summarised in Table 8-6. Analysis for Phenols, PAHs (polycyclic aromatic hydrocarbons), BTEX (benzene, toluene, xylene, ethylbenzene) and TPH (total petroleum hydrocarbons) were only conducted in the first round of sampling due to first round analysis results confirmation that concentrations were at or below the laboratory level of reporting for these analytes.

Table 8-6 Summary of Analytes for Groundwater Monitoring

	Parameters Analysed/Measured
Field Parameters (measured prior to sampling)	Total dissolved solids (TDS), dissolved oxygen (DO), electrical conductivity (EC), pH, temperature, redox potential
Laboratory Analysis	TDS, pH
	Dissolved metals: Aluminium, arsenic, beryllium, barium, cadmium, chromium, cobalt, copper, lead, iron, manganese, mercury, molybdenum, nickel, selenium, vanadium, zinc
	Nutrients: Ammonia as N, total phosphorous as P, nitrite as N, nitrate as N, total oxidised nitrogen
	Major and minor ions: Calcium, magnesium, sodium, potassium, chloride, sulfate, alkalinity (carbonate and bi-carbonate), fluoride and silica
	Phenols, PAHs (polycyclic aromatic hydrocarbons), BTEX (benzene, toluene, xylene, ethylbenzene), TPH (total petroleum hydrocarbons)

Hydraulic Conductivity Testing

Falling head permeability tests (slug tests) were carried out in five wells and a rising head permeability test was carried out in one well to estimate the hydraulic conductivity (permeability) of the strata screened by the bores.

Groundwater Model Development

Model Design

A groundwater flow model of the Project Area was developed in order to quantify the impacts of the proposed development on groundwater levels. Given the relatively limited hydrogeological data currently available for the area, a relatively simple numerical model of the area was developed based on published geological and other mapping and using the few geological logs available for boreholes in the area. A four layer model was developed, including the main hydrogeological units present in the area, as follows:

- Layer 1 – Fill (existing Fisherman's Landing and proposed Western Basin Reclamation Areas);
- Layer 2 – Marine clay/alluvium
- Layer 3 – Colluvial deposits
- Layer 4 – Bedrock.

The model grid layout and boundary conditions are shown in Figure 8-3. The following sections provide a summary of the model methodology, with a detailed description provided in Appendix O.

Model development was carried out using the MODFLOW suite of modelling code and modules. Surface water and groundwater interactions in the offshore areas were simulated through the use of MODFLOW general head boundary cells set at sea level. On shore, MODFLOW drain cells have been defined to simulate discharge to the various creeks in the area where groundwater levels rise above ground surface.

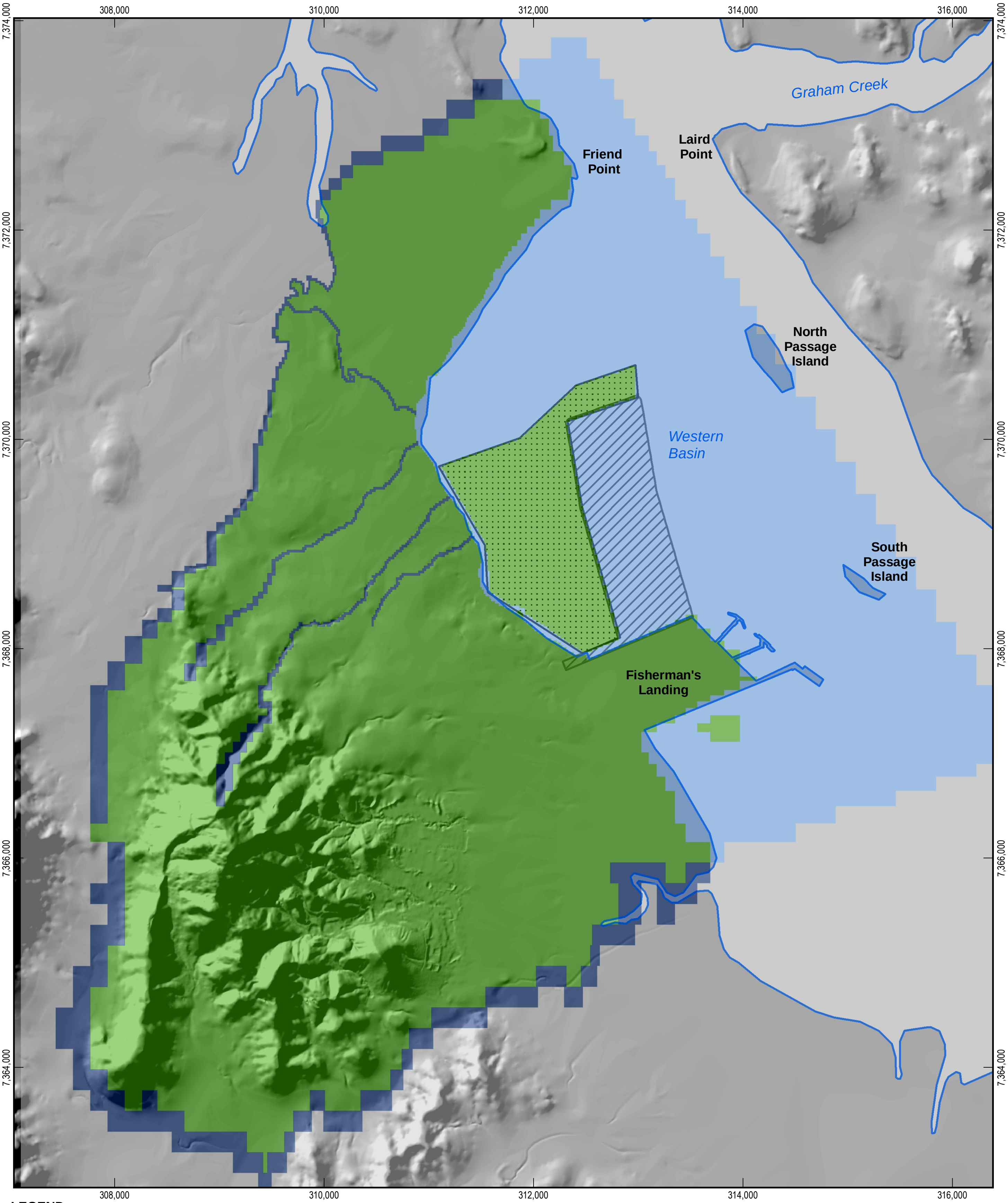
The boundaries of the modelled area are defined by major creek lines to the north and south, and the centre line of The Narrows to the north east. Little or no groundwater flow is anticipated across these boundaries and hence, all cells outside of these boundary lines have been modelled as no flow or inactive cells.

Recharge and Evaporation

Recharge to the upper surface of the groundwater flow model has been calculated using PERFECT (Littleboy *et al.*, 1989), a one-dimensional cropping and soil moisture balance model. For the purposes of the current study, deep drainage as calculated by PERFECT was apportioned between "interflow" and groundwater recharge using the algorithm of Rassam and Littleboy (2003), which utilises the vertical saturated hydraulic conductivity contrast within the soil profile, and the topographic slope.

Input data used included:

- Daily rainfall and potential evaporation from the Bureau of Meteorology SILO website; and
- Published soil, land use and ground elevation mapping.



LEGEND

Groundwater Model

- No Flow (Inactive Cells)
- General Head Boundary (Sea) Cells
- Drain Cells
- Active Cells
- Western Basin Reclamation Area
- Fisherman's Landing Northern Expansion

1:50,000 (at A4)

0 0.5 1 1.5 2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

N

Port of Gladstone
Western Basin Dredging and Disposal Project

Groundwater Model Grid Layout
and Boundary Conditions

Job Number	42-15386
Revision	A
Date	14 Oct 2009

Figure 8-3

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Modelling Approach

A groundwater model of the existing pre-development hydrogeological system was developed initially and calibrated to available groundwater level data for the period January 2000 to May 2009. This model was run in transient mode using monthly stress periods. Given that this model was intended to represent existing conditions, the Western Basin reclamation area was simulated using general head boundary cells to represent water levels in the offshore area. Levels in the Reclamation Area and the other offshore model cells were calculated based on monthly average tide level data.

This calibrated model was then used to provide initial groundwater levels for a second transient simulation of the area which was identical to the historic model except that model cells within the Western Basin Reclamation Area were converted to active cells, in order to simulate groundwater levels in the proposed development area.

Model calibration and predictive results are presented and discussed further in Section 8.2.2.

8.2.2 Description of Environmental Values

Topography and Drainage

The land immediately surrounding the Project Area is low lying (<20 mAHD) and slopes gently towards the north east (i.e. towards the coastline). It includes tidally inundated mudflats to the north, alluvial plains and forested land to the west and reclaimed land (Fisherman's Landing) to the south. Three surface water channels drain from south west to north east and discharge to the coast along the western boundary of the Western Basin Reclamation Area.

Hydrogeological Units

Digital mapped geology for the area surrounding the proposed Reclamation Area is summarised in Figure 8-4 and Table 8-7.

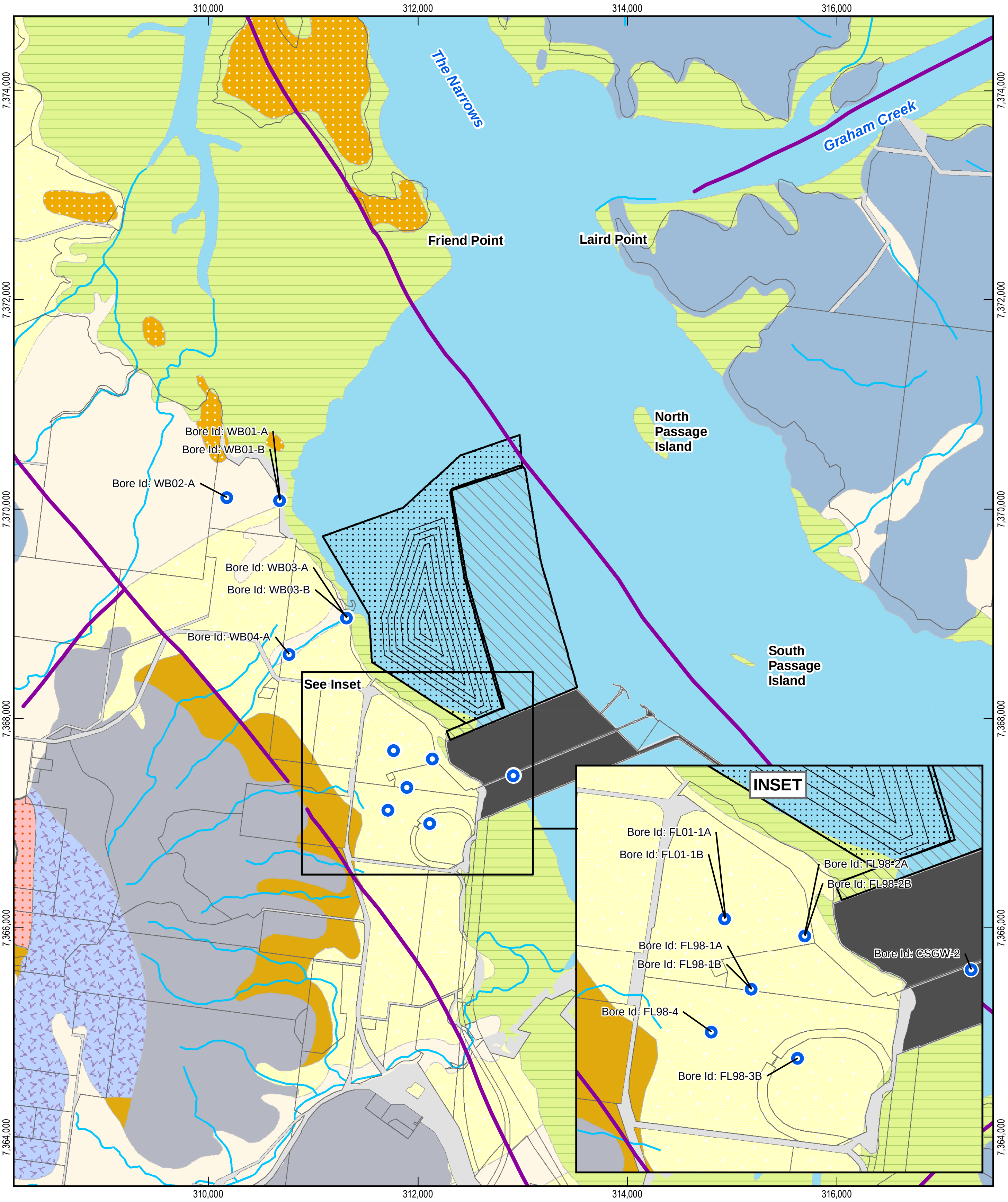
Table 8-7 Key to 1:100 000 Published Geology Presented in Figure 8-4

	Symbol	Description
Quaternary	Qhe/m	Estuarine channels and banks, supratidal flats and coastal grassland; mud, muddy sand, sandy mud, minor gravel
	Qa	Floodplain alluvium; clay, silt, sand, gravel
	Qr\s	Residual soil; sand, silt, mud, gravel
	Qr\s>Tr	Residual soil overlying Tertiary residual deposits
Tertiary-Quaternary	TQr	Colluvial and residual deposits; clay, silt, sand, gravel and soil
Tertiary	Ts	Conglomerate, sandstone
Later Permian - Early Triassic	PRgta	Targinie Quartz Monzonite; pink, medium-grained hornblende-biotite quartz monzonite

	Symbol	Description
Late Devonian – Early Carboniferous	DCcw	Wandilla Formation; mudstone, lithic sandstone, siltstone, jasper, chert, slate, schist
	DCcd	Doonside Formation; chert, jasper, mudstone, siltstone, lithic sandstone, tuff, limestone, altered basalt
	DCcd/b	Balnagowan Volcanic Member; basaltic to andesitic lava and volcaniclastic rocks, chert, mudstone, limestone

In summary, the geological/hydrogeological units identified in the vicinity of the Reclamation Area through the desktop review and field investigations are:

- Fill, including marine dredge and quarried material (not mapped);
- Coastal/estuarine sediments (Qhe/m, Holocene –age);
- Alluvium (Qa and TQa, Quaternary-age) and colluvium (TQr, Quaternary-age); and
- Bedrock of varying age, including:
  - The Narrows Group (Tertiary-age);
  - Targinie Quartz Monzonite (Late Permian to Early Triassic-age);
  - Wandilla Formation (Late Devonian to Carboniferous-age); and
  - Doonside Formation (Devonian to Carboniferous-age).



LEGEND

- Groundwater Bore
- Fault Lines
- Watercourse
- Western Basin Reclamation Footprint
- Fisherman's Landing Northern Expansion
- Cadastre
- Road
- Qhe/m
- Qa
- Qr\s
- Qr\s>Tr
- TQr
- Ts
- PRgta
- DCcw
- DCcd
- DCcd/b
- W

1:50,000 (at A4)

0 0.5 1 1.5 2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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Port of Gladstone
Western Basin Dredging and Disposal Project

Groundwater Monitoring Bores and Published Geology

Job Number	42-15386
Revision	A
Date	01 Sept 2009

Figure 8-4

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Fill

Fill material, including dredged marine deposits and quarry spoil, has been used to reclaim the existing Fisherman's Landing and is located just beyond the southern boundary of the proposed Reclamation Area. The lithology of the fill is not known, however it is likely to be variable and may range from low permeability material such as silt and clay to higher permeability materials such as sand and gravel.

Estuarine Sediments

Low lying, Holocene-age estuarine sediments including mud, sandy mud, and minor gravel are mapped at outcrop adjacent to the Project Area (to the north-west and west) and are likely to be of low permeability. These deposits include organic and shell material, as indicated by the geological log for WB01-A (Appendix O).

Alluvium and Colluvium

The published mapping indicates Quaternary-age alluvium and colluvium (both units described as clay, silt, sand and gravel) overlying the bedrock in lower lying areas (<20 mAHD) towards the west of the proposed Reclamation Area. The boreholes drilled as part of this study suggest that these deposits are dominated by clay and sandy clay deposits, with minor clayey gravel and gravelly clay layers, encountered up to 20 m bgl. The permeability of the alluvium/colluvium is likely to vary spatially within this area, depending on the presence or absence of significant sand and gravel horizons.

Bedrock

Published geological mapping and cross sections suggest that the bedrock strata underlying the Quaternary-age sediments include:

- The Narrows Group (Curlew Formation, Rundle Formation and Worthington Formation) which is a sequence of units including claystone, shales, limestone and sandstone;
- Targinie Quartz Monzonite (pink, medium-grained hornblende-biotite quartz monzonite);
- The Wandilla Formation (including mudstone, sandstone, siltstone, chert, slate and schist); and
- The Doonside Formation (including chert, mudstone, siltstone, sandstone, limestone and basalt).

The youngest of these bedrock formations, the Narrows Group, is not present at outcrop in the area but is indicated to be present at subcrop beneath the site in cross section (Department of Natural Resources and Mines, 2001) due to the influence of faults to south west and north east of the site (Figure 8-4). The downthrown area between these two faults forms the Narrows Graben. Given the regional deformation and faulting which is known to have occurred in the area, zones of relatively high bedrock permeabilities are likely. This is backed up to some extent by information for existing groundwater bores in the area which confirm that the bedrock is water bearing with typical yields of 0.07 to 3L/s, as indicated by records from the groundwater bore database (DERM 2009).

Groundwater Use

Forty eight groundwater bores were identified within a 5 km radius of the Project Area (Table 8-8) in a desktop review of the Queensland Groundwater Bore Database (DERM April 2009). This included 18 registered bores which are all recorded as being for water supply in the bore database, and 30 un-registered bores indicated to be for fire fighting (1 bore), domestic use (1 bore) and monitoring (22 bores). The primary purpose is not detailed for 6 of the un-registered bores.

Of the registered bores at the time of the site visit, two did not appear to be in use, one had been filled, six could not be located at the time of the visit and five have been confirmed as no longer present. One registered bore was confirmed as being in use and three other bores identified in the data review might be in use, however this has not been confirmed as it was not possible to visit these bores.

Of the eight un-registered bores not identified as monitoring bores, lack of infrastructure and poor condition of the bores indicated that six are unlikely to be in use. However, two of the bores are indicated to be in use.

Based on the desktop searches and field investigations, groundwater in the alluvium/colluvium within a 5 km radius of the Project Area does not appear to be used for water supply. A review of the available data suggests that groundwater in bedrock is used locally for water supply, however based on the results of the bore census, the nearest groundwater abstraction to the proposed Reclamation Area appears to be registered bore RN 91788, which is approximately 4.4 km west. Consultation with the land occupier indicated that water from this bore is used for plant watering and database records indicate that the bore penetrates the Targinie Granite. Two other bores were identified as being in use; the one bore that is used for fire fighting is located approximately 5.6 km west of the site; and the one bore that is used for domestic use is located approximately 4.6 km from the site. Three registered bores could not be inspected, but are reported to be for water supply in the groundwater database (DERM 2009). They may also be currently active and are located between 4.7 km and 4.9 km from the Project Area.

All of the bores identified are located up hydraulic gradient of the Project Area.

Groundwater Levels and Flows

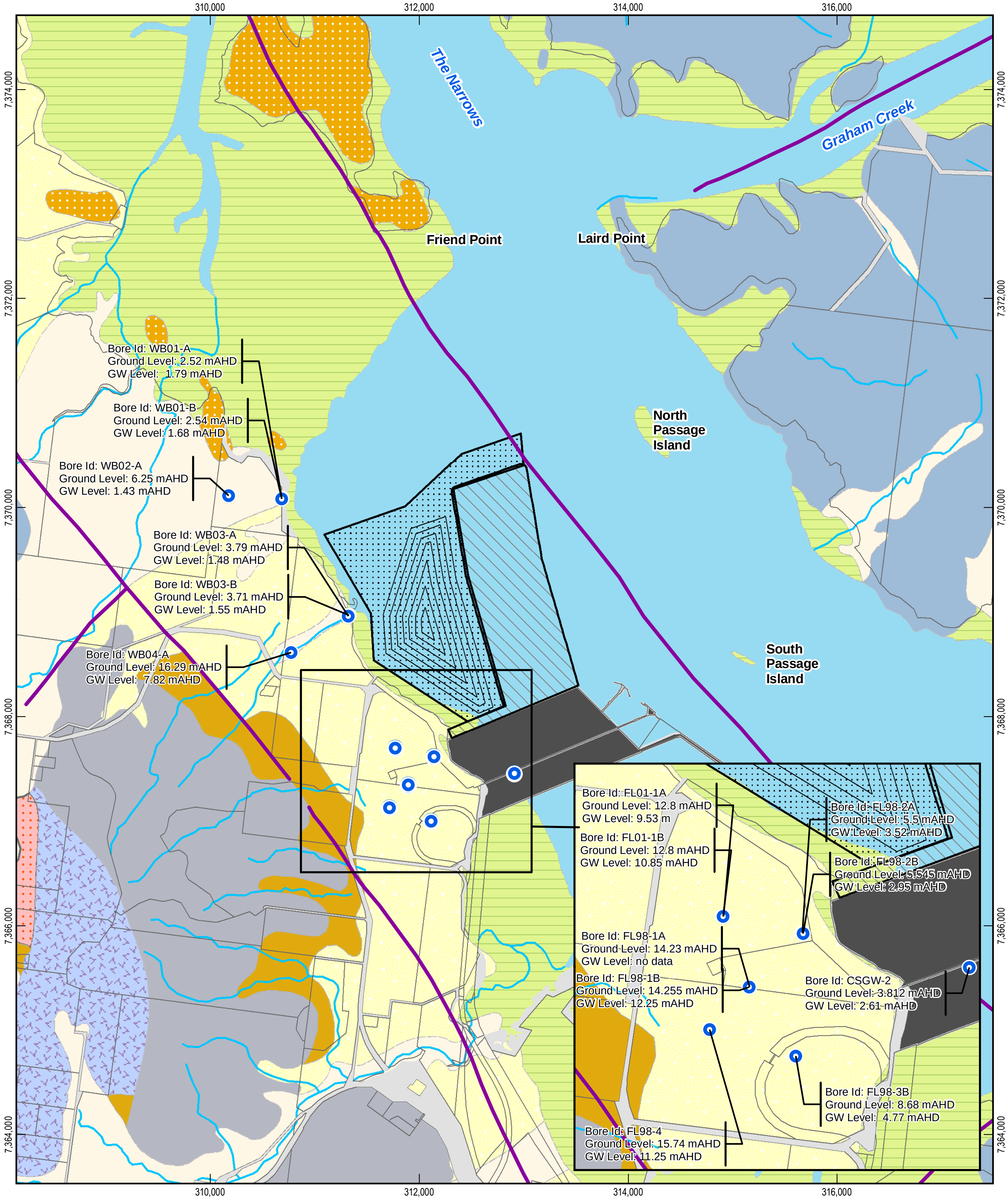
Historic groundwater level data provided by Cement Australia (for 2001 – 2009) suggest typical seasonal level fluctuations of 0.4 to 1 m in shallow groundwater (<15 m bgl) within natural strata. Data for 2005 to 2009 provided by RTAY for Fisherman's Landing, which is predominantly fill material, also indicate seasonal fluctuations of up to 1 m in near coastal areas. Groundwater levels close to the coastline are also likely to fluctuate on a sub-daily and monthly basis in response to tidal movements. Tide information for Gladstone (Australian Government Bureau of Meteorology website) indicates that the tidal range for the Gladstone area is typically in the order of 1.5 to 4.5 m. Groundwater levels for August 2009 are shown in Figure 8-4 and time series data for boreholes of the Project monitoring network are shown in Figure 8-6 and Figure 8-7.

Table 8-8 Summary of Selected Information for Registered Groundwater Bores Within 5 km of the Proposed Reclamation Area

RN	Facility Role	Facility Status	Groundwater Level (m AHD) (Year)	Groundwater Quality	Top of Aquifer (mbgl)	Bottom of Aquifer (mbgl)	Yield (l/s)	Water Bearing Horizon	Comments
84982	WS	Existing	-	-	21	22	0.07	Targinie Granite	-
88338	WS	Existing	-	EC 1,880 µS/cm	22	23.8	1	Doonside Formation	-
88456	WS	Existing	-15	EC 1,250 µS/cm	14	22.6	0.35	Targinie Granite	-
88459	WS	Existing	-	-	-	Base of borehole indicated to be 15 m depth	-	-	Lined well, assumed Targinie Granite based on depth
88464	WS	Existing	-	TDS 17,000 mg/L	62.5	65.6	0.65	Rundle Formation	-
91788	WS	Existing	-10	Potable	11	19	0.26	Targinie Granite	-
97440	WS	Existing	-6.1 (2002), -10 (1997)	EC 900 µS/cm, 1,170 µS/cm, 1,200 µS/cm 5 pH	17	23	3	Wandilla Formation	-
97444	WS	Existing	-	EC 4,430 µS/cm	-	-	-	-	Located on mapped outcrop of Quaternary-age alluvium
97960	WS	Existing	-	EC 1,800 µS/cm	13.7	Base of borehole indicated to be 18 m depth	1.26	Targinie Granite	-

RN	Facility Role	Facility Status	Groundwater Level (m AHD) (Year)	Groundwater Quality	Top of Aquifer (mbgl)	Bottom of Aquifer (mbgl)	Yield (l/s)	Water Bearing Horizon	Comments
97989	WS	Existing	-11 (1997)	EC 1,900 µS/cm	13	Base of borehole indicated to be 23 m depth	0.76	Targinie Granite	-
111120	WS	Existing	-15.24 (1993)	EC 1,485 µS/cm, 1,600 µS/cm	18.9	Base of borehole indicated to be 36.5 m depth	0.08	Targinie Granite	-
111423	WS	Existing	-15.24 (1999)	EC 1,100 µS/cm	19.51	22.56	0.45	Granite	Assumed to be Targinie Granite
111928	WS	Abandoned & Destroyed	-	-	-	-	-	-	Log indicates shale 12 to 72 m depth (Rundle Formation)
111929	WS	Abandoned & Destroyed	-	-	-	-	-	-	Log indicates shale 29 to 72 m depth (Rundle Formation)
111930	WS	Abandoned & Destroyed	-	-	-	-	-	-	Log indicates shale 6 to 24 m depth (Rundle Formation)
111931	WS	Abandoned & Destroyed	-	-	-	-	-	-	Log indicates shale 18 to 48 m depth (Rundle Formation)
111932	WS	Abandoned & Destroyed	-9	TDS 2,700 mg/L	24	36 m (base of borehole on log)	1.7	Rundle Formation	Log indicates shale (Rundle Formation)
122949	WS	Existing	-6.7	EC 1,250 µS/cm	18	24	2.5	Doonside Formation	-

Note: Information taken from the Queensland Bore Database (DERM 2009



LEGEND

- Groundwater Bore
- Fault Lines
- Watercourse
- Western Basin Reclamation Footprint
- Fisherman's Landing Northern Expansion
- Cadastre
- Road
- Qhe/m
- Qa
- Qr\s
- Qr\s>Tr
- TQr
- Ts
- PRgta
- DCcw
- DCcd
- DCcd/b
- W

1:50,000 (at A4)

0 0.5 1 1.5 2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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Port of Gladstone
Western Basin Dredging and Disposal Project

Measured Groundwater Elevations, August 2009

Job Number	42-15386
Revision	A
Date	01 Sept 2009

Figure 8-5

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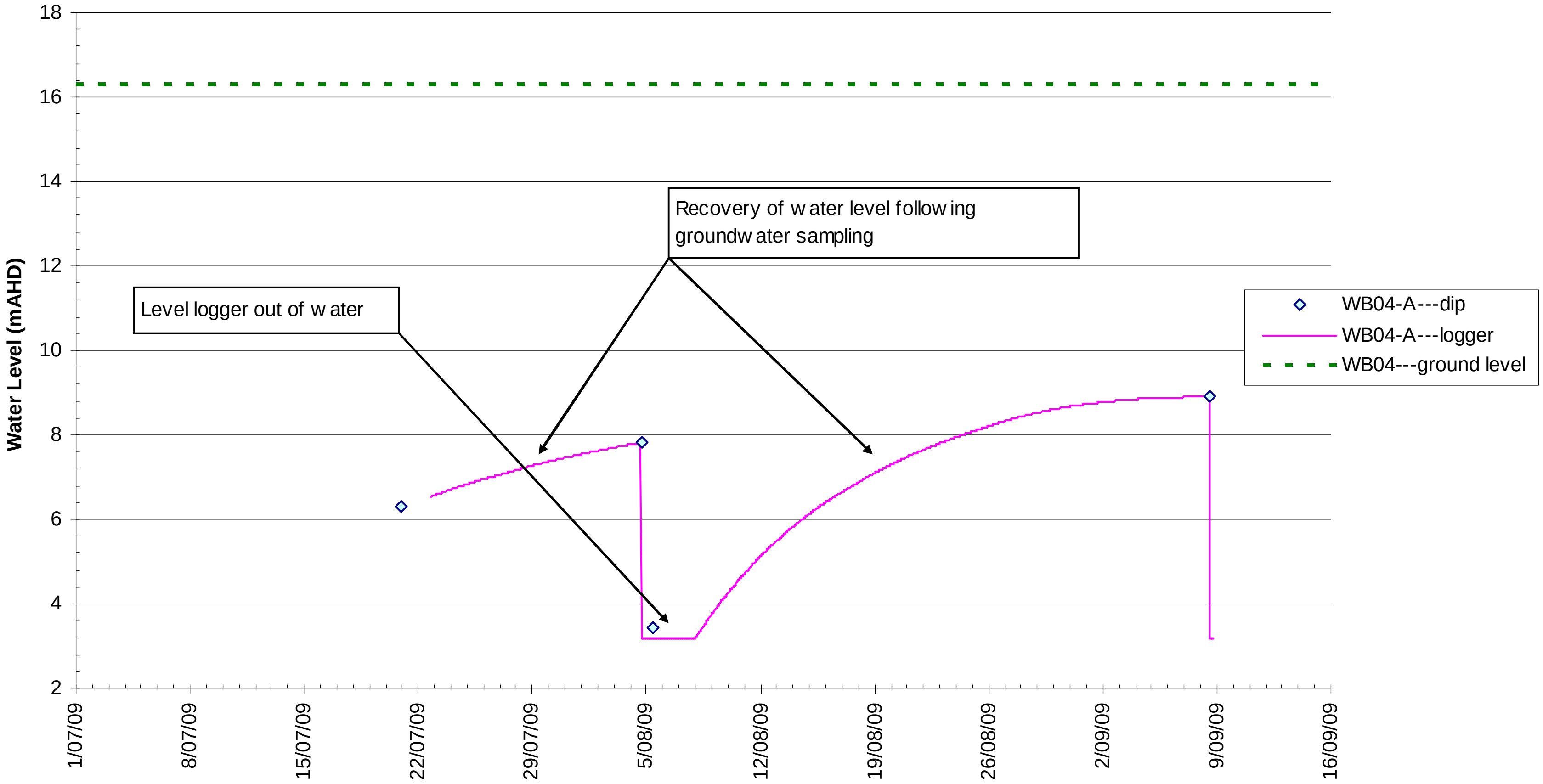


Figure 8-6 Groundwater Levels WB04-A, July to September 2009

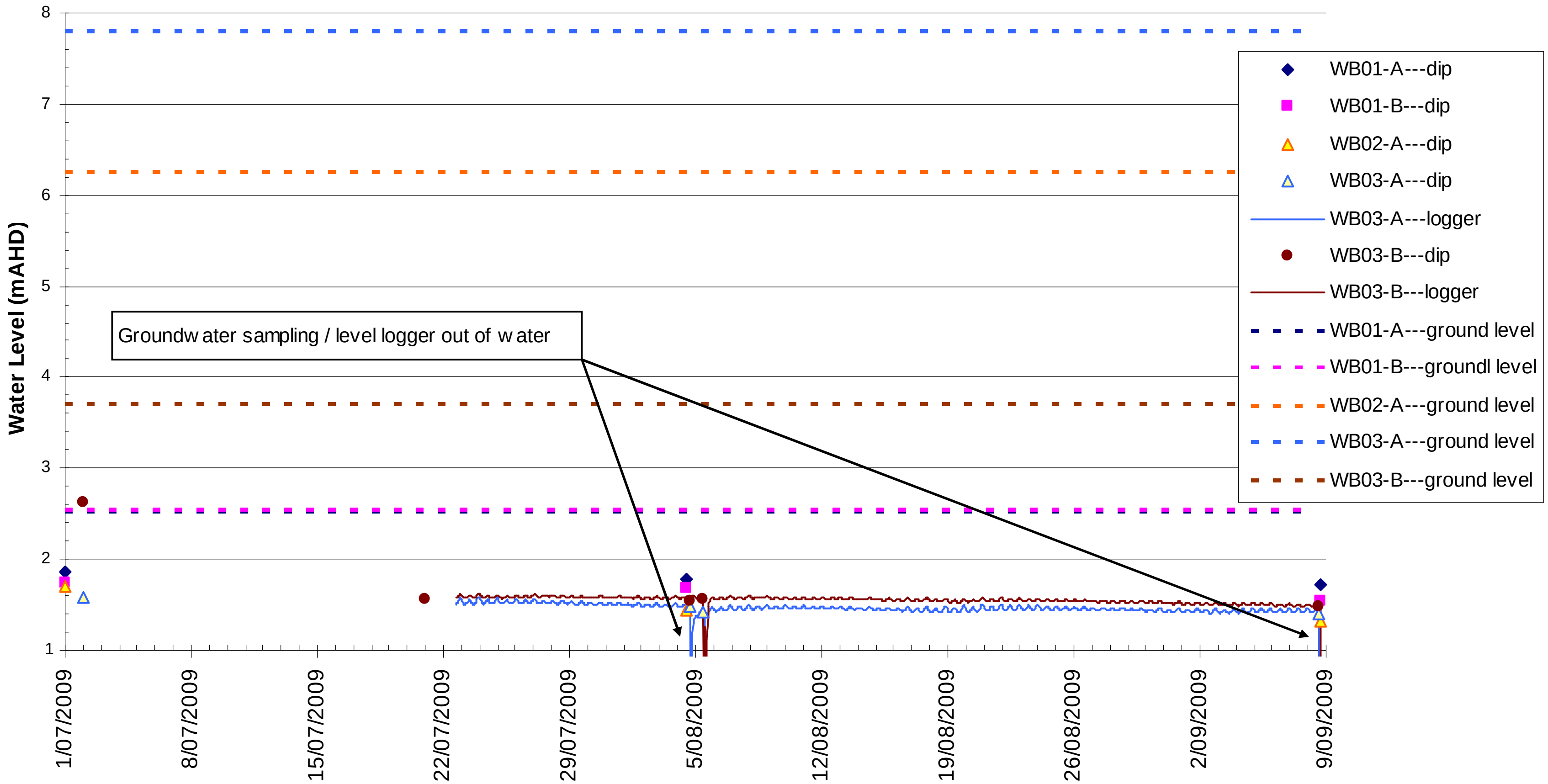


Figure 8-7 Groundwater Levels WB01-A&B, WB02-A, WB03-A&B, July to September 2009

Measured groundwater levels for the coastal strip (WB01-A, WB01-B, WB03-A, WB03-B) immediately west of the Project Area (July to September) ranged between 0.7 mBGL (below ground level) (WB01-A) and 2.8 mBGL (WB03-A). Groundwater levels for WB02-A and WB04-A, approximately 500 m further inland, ranged from 4.5 mBGL (WB02-A) to 7.4 mBGL (WB04A). Groundwater elevations were in the range of 1.3 (WB02-A) to 2.6 mAHD (WB03-B) except at WB04-A where water levels stabilised at around 8.8 mAHD. Automatically recorded groundwater level data for WB03-A and WB03-B, corrected for barometric pressure, confirm small sub-daily and monthly groundwater level fluctuations in response to tidal movements of between 0.02 and 0.075 m (Figure 8-7).

Groundwater elevations for the 15 monitored bores indicate groundwater flow in the alluvial/colluvial deposits is from south west to north east, towards the coast and the proposed Reclamation Area. Comparison of groundwater levels in the nested piezometers WB03-A and WB03-B suggest that the vertical component of groundwater flow is probably downward at and in the vicinity of these boreholes.

Groundwater within the alluvial/colluvial strata, which are predominantly characterised by low permeabilities, will tend to move through primary porosity pathways and preferentially through higher permeability material, i.e. material with a high sand or gravel component. A proportion of the groundwater flow within the alluvial strata will discharge direct to the sea with the remainder discharging to the low lying drainage channels close to the coast before ultimately discharging to the sea at low tide.

Groundwater in bedrock was not monitored in the study however, groundwater flow in the underlying bedrock is expected to be predominantly via fractures and joints and is likely to be driven by the fall in topography and recharge to bedrock outcrop, from south west to north east towards the coast. The distribution and connectivity of the secondary permeability is not well defined, although reported borehole yields for the area are typically 0.07 to 3 L/s (DERM 2009) suggesting relatively low permeabilities and hence, limited groundwater movement through the bedrock. Geotechnical investigations conducted by GHD suggest the presence of Quaternary and Holocene clays at outcrop offshore, which suggests that any flow within the bedrock strata is likely to discharge indirectly into the tidal zone via the overlying unconsolidated deposits (GHD, 2009c).

No information is available on the location or volume of submarine discharges of groundwater, although the possibility of direct freshwater discharges to the sea beneath the proposed development area cannot be discounted.

Groundwater Quality

Alluvial/Colluvial Deposits and Fill

Baseline groundwater monitoring quality sampling results for bores monitoring alluvial deposits (WB series of bores and FL98-2A and FL98-2B) and fill material placed at Fisherman's Landing (CSGW-2) are summarised in Appendix O and discussed below. Laboratory certificates are included in Appendix O also.

Analysis of the major ion groundwater chemistry data indicates that the groundwater is of sodium-chloride type, which is not unexpected given the proximity of the monitoring bores to the coast. The results of this analysis are shown on a piper plot in Figure 8-8.

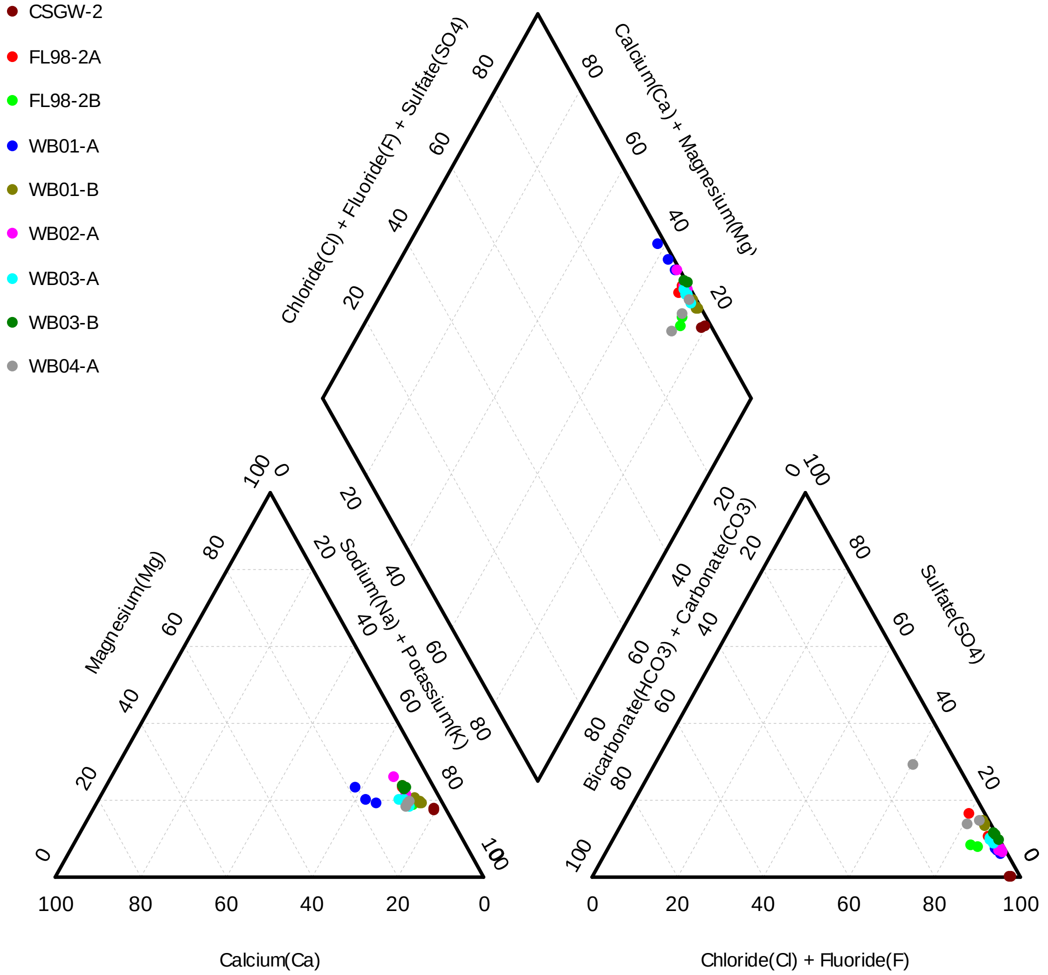


Figure 8-8 Piper Plot of the Major Ion Groundwater Chemistry Data

Field pH and laboratory TDS concentrations are shown in Figure 8-9 and Figure 8-10 respectively. Field monitoring results tend to confirm that groundwater immediately west (alluvial/colluvial deposits) and south (Fisherman's Landing) of the proposed development area is brackish to saline (measured field EC values ranged from 6,900 to 61,900 µS/cm) with a neutral to slightly acidic pH (7.6 to 5.7 pH, July 2009) except at WB03-B where groundwater is more acidic with a measured field pH range of 3.9 to 5.01 pH units. Laboratory TDS concentrations range from 4,200 mg/L to 60,100 mg/L confirming brackish and saline groundwater (Figure 8-10). These physico-chemical results are consistent with unpublished historic data in the vicinity of the site and with RN 97444 (4,700 µS/cm EC) located on a mapped Quaternary-age alluvial outcrop. The reported TDS concentrations and measured EC indicates that the groundwater in the alluvial/colluvial material in the coastal strip of land immediately adjacent to the proposed Reclamation Area and in the deposits of Fisherman's Landing is unsuitable for drinking, stock watering and irrigation.

Laboratory testing results also indicate that the groundwater contains concentrations of dissolved metals (chromium, copper, cobalt, lead, nickel and zinc) and nutrients (ammonia as N) above the ANZECC & ARMCANZ (2000) guideline values for marine aquatic ecosystems (at the 95% level of protection) at one or more monitoring locations. The ANZECC & ARMCANZ (2000) guideline values for marine aquatic ecosystems have been used for comparison given the marine receiving environment.

Concentrations of dissolved metals above the adopted guideline values, for concentrations above the laboratory detection limit, are summarised as follows:

- Dissolved chromium (III + VI). Concentrations exceeded the ANZECC & ARMCANZ (2000) guideline value (95%) of 0.0044 mg/L on one or more occasions in all of the WB series of monitoring bores, with exceedences from 0.005 to 0.023 mg/L;
- Dissolved cobalt. Concentrations in all monitored bores on all but one occasion exceeded the ANZECC & ARMCANZ (2000) guideline value (95%) of 0.001 mg/L and ranged from 0.004 to 0.53 mg/L;
- Dissolved copper. Exceedence of the ANZECC & ARMCANZ (2000) guideline value (95%) of 0.0013 mg/L was reported for all monitored locations with the exception of WB02-A;
- Dissolved lead. The ANZECC & ARMCANZ (2000) guideline value (95%) for lead (0.0044 mg/L) was exceeded on one occasion at WB03-B;
- Dissolved nickel. Concentrations exceeded the ANZECC & ARMCANZ (2000) guideline value (95%) of 0.07 mg/L at WB03-B (up to 0.194 mg/L);
- Dissolved zinc. Concentrations exceeded the ANZECC & ARMCANZ (2000) guideline value (95%) of 0.015 mg/L in all monitoring bores with the exception of CSGW-2 and WB04-A.

Concentrations of nutrients above the adopted guideline values, for concentrations above the laboratory detection limit, are summarised as follows:

- Ammonia. The ANZECC & ARMCANZ (2000) guideline value (95%) of 0.91 mg/L was exceeded at all monitored locations except for FL98-2A and FL98-2B. Exceedences ranged from 0.97 (WB01-B) to 14.1 mg/L (WB01-A).

Concentrations of phenols, PAHs (polycyclic aromatic hydrocarbons), BTEX (benzene, toluene, xylene, ethylbenzene) and TPH (total petroleum hydrocarbons) were reported equal to or less than the laboratory limit of reporting for these analytes in all of the bores except for FL98-2B where concentrations for 2 fractions of TPH (C15-C28 at 200 µg/L and C29-C36 at 100 µg/L) were reported to just above the laboratory reporting limits of 100 and 50 µg/L respectively.

Bedrock

Queensland Groundwater Database records (Figure 8-9, DERM 2009) indicate that groundwater in bedrock (Targinie Granite (or Targinie Monzonite), Wandilla Formation and Doonside Formation) within the 5 km search radius of the site is typically slightly brackish (reported up to 1,900 µS/cm EC (RN 97989) for bores indicated to penetrate bedrock) and slightly acidic pH (based on one data record of 5 pH).

Based on these limited data, the groundwater in bedrock is considered not to be good drinking water, but could potentially be used for irrigation and stock watering.

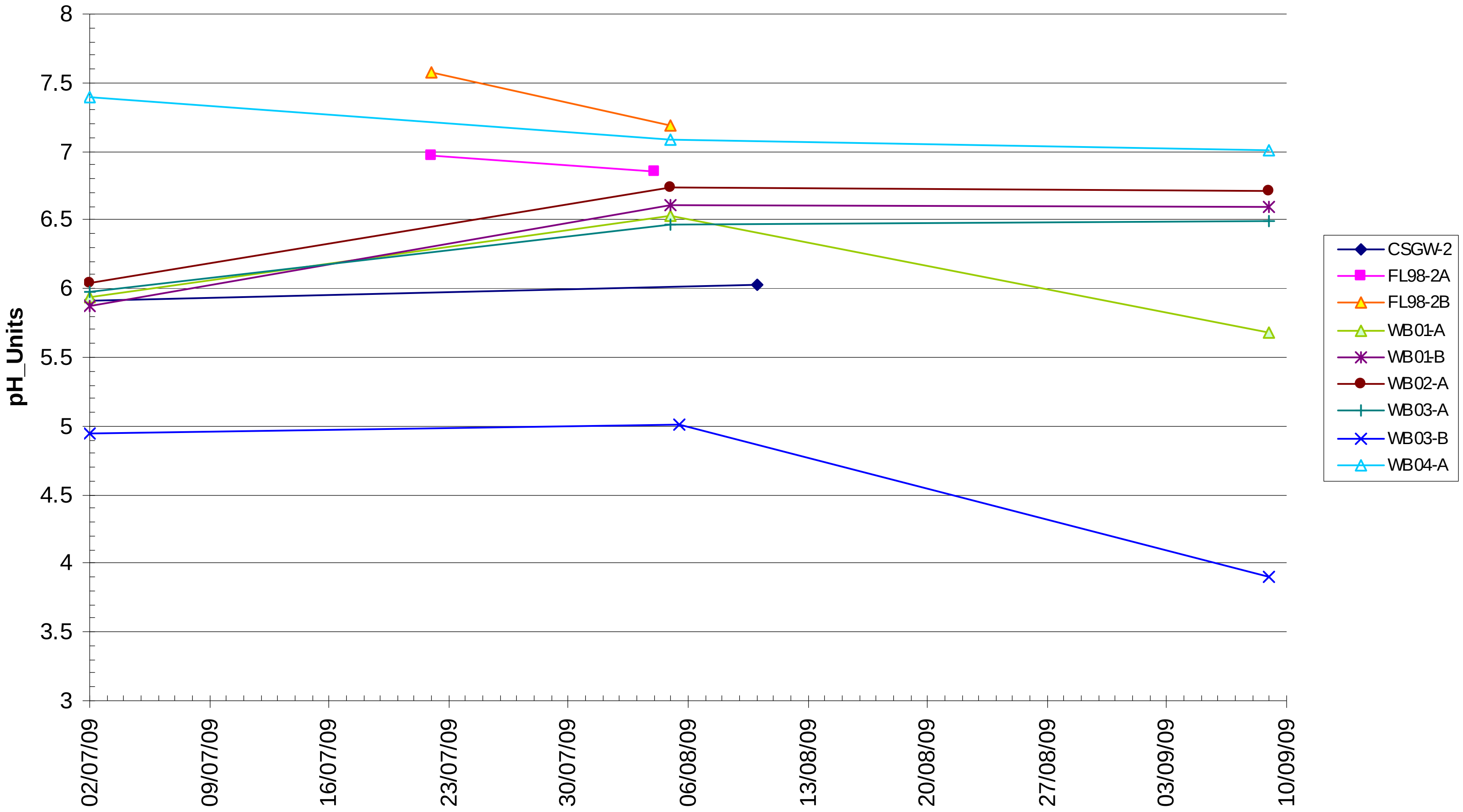


Figure 8-9 Field pH, July to September 2009

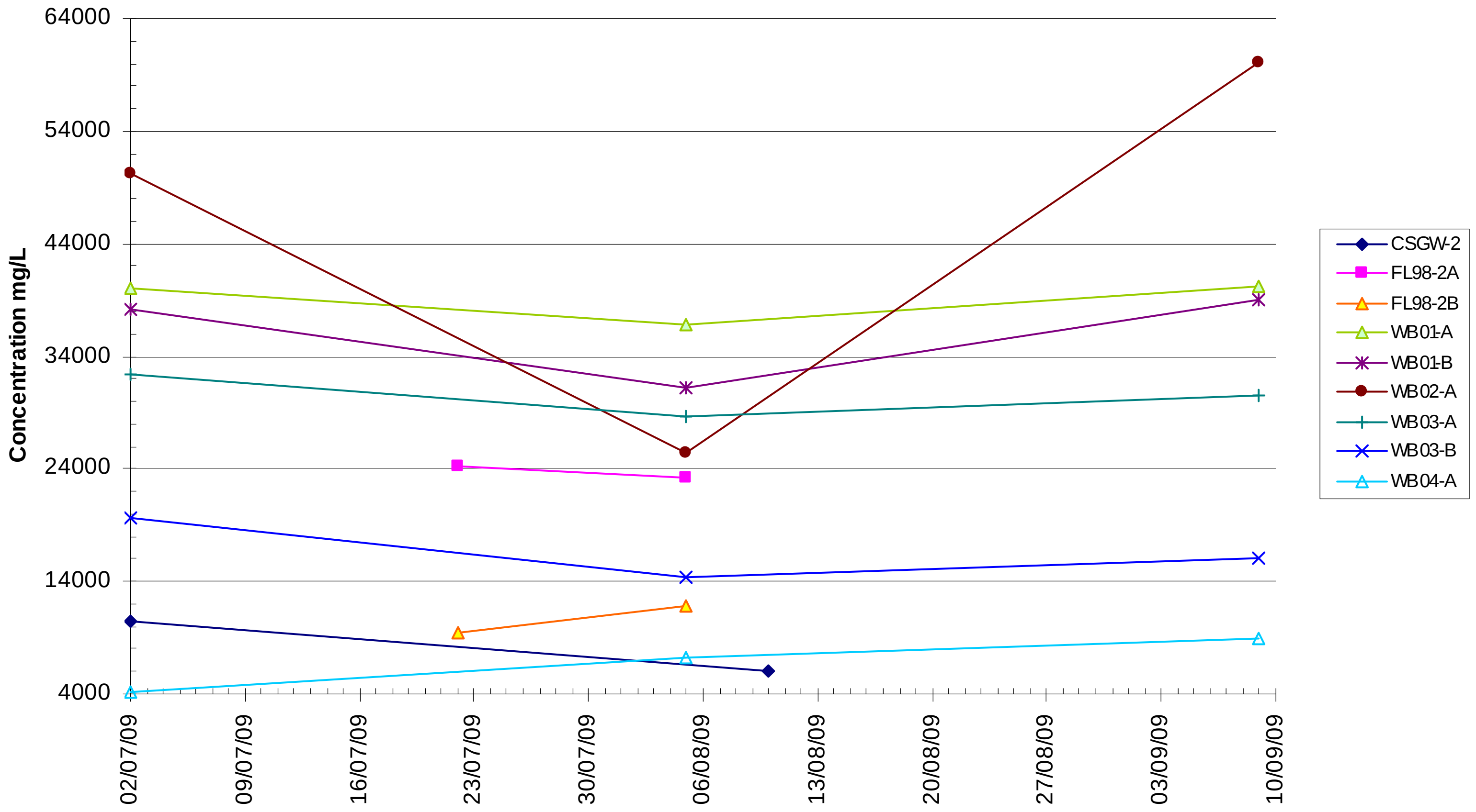


Figure 8-10 Laboratory TDS, July to September 2009

Hydraulic Parameters

Estimated hydraulic conductivity (K) values for the bores tested are summarised in Table 8-9. Graphs showing the results of the analysis are included in Appendix O.

The K value presented for each bore is an average of the two analytical solutions used (Hvorslev and Bouwer & Rice, 1951). The data suggest hydraulic conductivity of the alluvium/colluvium immediately to the west of the Project Area varies over at least three orders of magnitude, from 7.3×10^{-4} to 5.0×10^{-1} m/d. The results are consistent with the recorded lithology, and hence the higher conductivity values (5.0×10^{-1}, 3.4×10^{-2} and 4.0×10^{-2} m/d) correspond to tested lithologies of sandy clay and clay with lenses of sandy clay, respectively, whilst the lower conductivity values correspond to more clay dominated lithologies. In addition, the recovery of the groundwater level to the pre-groundwater sampling level at WB04-A (August sampling round) took approximately 19 days, which indicates very low permeability (Figure 8-6). These data support the assumption that the permeability of the alluvium/colluvium varies depending on the composition of the strata.

These values are comparable to a reported hydraulic conductivity value for colluvium of 8.64×10^{-3} m/d (URS 2007). The location of the test was not reported, however it is assumed that it was in the Gladstone/Fisherman's Landing area.

Analysis of data collected for CSGW-2 indicates an hydraulic conductivity of around 0.1 m/d, suggesting higher permeability materials such as silts and fine sands for this location on Fisherman's Landing.

The hydraulic conductivity of the bedrock is also likely to be highly variable and dependent on the degree of fracturing. URS (2007) reported a hydraulic conductivity for bedrock (mudstone/oil shale) of 8.64×10^{-2} m/d. Again, the location of the test was not reported.

Table 8-9 Permeability Test Results of Selected New Groundwater Bores

Bore ID	Estimated K Value (m/day)	Screened Interval	Lithology
WB01-A	3.0×10^{-3}	-13.7 to -16.7 m AHD (17-20 m bgl)	silty clay/ extremely weathered siltstone
WB01-B	5.0×10^{-1}	-0.7 to -3.7 m AHD (4-7 m bgl)	sandy clay
WB02-A	7.3×10^{-4}	-9.9 to -12.9 m AHD (17-20 m bgl)	clay with trace sand
WB03-A	4.0×10^{-2}	-11.5 to -14.5 m AHD (16-19 m bgl)	Clay
WB03-B	3.4×10^{-2}	1.9 to -1.1 m AHD (2.5-5.5 m bgl)	clay, lenses of sandy clay
CSGW-2	1.0×10^{-1}	2.3 to -0.7 mAHD (assumed) (1.5-4.5 mbgl)	Unconfirmed (potentially fill)

Groundwater Model Calibration

The groundwater model was calibrated for hydraulic conductivity, specific yield and specific storage for each model layer. These values were broadly consistent with the permeability results. Detailed calibration information is provided in Appendix O.

Groundwater Model Predictions

Following calibration of the historic model, a second transient predictive simulation was developed in order to assess the potential impacts of the proposed reclamation. Essentially, this predictive model is identical to the historic model, except that model cells within the Western Basin Reclamation Area were converted to active cells, with an upper elevation of 7 mAHD, in order to simulate groundwater levels in the proposed development area. The hydraulic properties of the Reclamation Area were assumed to be as per the calibrated values for fill material in the existing Fisherman's Landing area (see Table 6 in Appendix O).

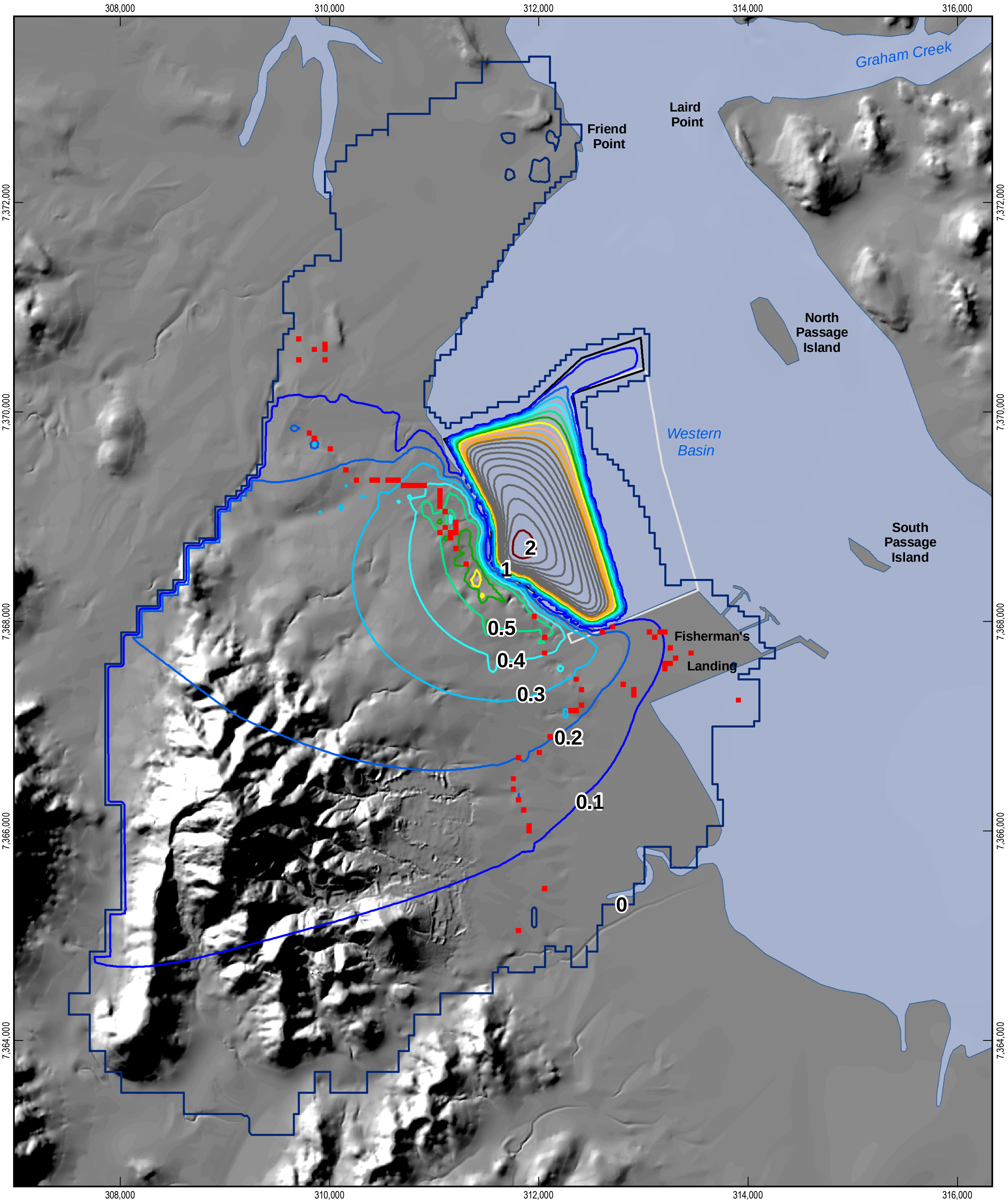
As would be expected, predictive model results suggest a tendency towards increased groundwater levels on the landward side of the Reclamation Area, as groundwater levels in the Reclamation Area itself rise in response to groundwater recharge to the reclaimed surface. Groundwater levels will increase gradually and hence, model results suggest onshore groundwater levels may increase by up to 0.5 m after 10 years, and by up to 0.8 m after running the model through to equilibrium or steady state conditions. Predicted steady state groundwater level impacts are shown in Figure 8-11 and indicate onshore groundwater level impacts of greater than 0.1 m over a relatively wide area. Further analysis of the groundwater model predictions, however, suggests that the water table will remain more than 1 m below ground surface over the majority of this area and hence, the predicted increase in groundwater levels will not in most cases lead to substantially increased risks of waterlogging. Through comparison of modelled depth to water table from the calibration and predictive models, it is possible to identify additional areas where the modelled post development water table is less than 1 m below the ground surface. These additional areas are shown in red shading in Figure 8-11, and cover a total area of around 0.175 km^2.

Summary of Environmental Values

The review of available data, field investigations and current understanding of existing groundwater conditions has identified the following environmental values of relevance to the groundwater regime in the vicinity of the Project Area are:

- Groundwater abstraction (up hydraulic gradient of the Reclamation Area); and
- Biological integrity (maintaining groundwater quality and levels for existing flora and fauna adjacent to the Reclamation Area).

It is recognised that groundwater abstraction has been identified at a distance of more than 2 km from the site, located up-hydraulic gradient (to the west) of the Reclamation Area. The registered groundwater bores within 2 km of the Reclamation Area are either no longer present (RN 88464, RN 111928, RN 111929, RN 111930, RN 111931, RN 111932) or do not appear to exist (RN 97440) and the un-registered bores identified within 2 km appear to be for groundwater monitoring purposes.



LEGEND

Predicted Groundwater Level Increase (m)

- 0
- 0.1
- 0.2
- 0.3
- 0.4
- 0.5
- 0.6
- 0.7
- 0.8
- 0.9
- 1
- 2

- Additional Shallow (<1m) Water Table Areas
- Western Basin Reclamation Area
- Fisherman's Landing Northern Expansion

1:50,000 (at A4)

0 0.5 1 1.5 2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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Port of Gladstone
Western Basin Dredging and Disposal Project

Predicted Groundwater Level Impacts

Job Number	42-15386
Revision	A
Date	14 Oct 2009

Figure 8-11

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8.2.3 Potential Impacts and Mitigation Measures

Based on the current design of the Project, which includes the maintenance of an intertidal channel between the existing coastline and the Reclamation Area, no significant impacts on groundwater resources and/or groundwater quality are anticipated. Nevertheless, potential sources of groundwater impacts during construction and/or post construction are outlined below.

Potential Impacts - Construction Phase

The following potential impacts on groundwater adjacent to the Project Area have been identified for the construction phase:

1. Groundwater modelling results indicate that groundwater levels in the coastal strip adjacent to the Reclamation Area may increase by up to 0.8 m due to revised groundwater flow patterns post development. However, model predictions also suggest that for the most part groundwater levels will remain more than 1 m below surface and hence risks of water logging and/or soil salinisation will only be increased in isolated areas totalling around 0.175 km^2;
2. Degradation of groundwater quality adjacent to the Project Area as a result of any leaks and spills originating from construction activities on the landward side of the proposed Reclamation Area; and
3. Acidification and degradation in quality of the surrounding sea water if any acid sulphate soil material used in the reclamation is not managed appropriately. This could lead to the mobilisation of metals in the fill material, such as aluminium and iron, and subsequent discharge to the sea.

Potential Impacts – Post Construction

Two of the identified potential impacts during the construction phase are also potentially relevant during the post construction phase, specifically points 1 and 3 above.

Cumulative Impacts and Mitigation Strategies

Cumulative Impacts

Potential cumulative impacts on groundwater, from current and proposed projects are summarised in Table 8-10.

Table 8-10 Summary of Potential Cumulative Impacts

Project	Location	Groundwater Impact Potential	Justification
Proposed LNG pipeline (Santos)	Traversing the landward side of the coastline to the west of the Western Basin Project Area	Possible	Possible additional groundwater contaminant source: Proposed pipeline route (URS 2009b) shown to be within a few tens of metres of the coastline and the proposed Western Basin Reclamation Area. Potential for the existing groundwater quality on the landward side of the coastline to be compromised during/as a result of the pipeline construction.

Project	Location	Groundwater Impact Potential	Justification
			Disturbance to shallow groundwater during construction of the pipeline.
Stuart Energy (existing facility)	Approximately 0.5 to 0.75 km south west of the Western Basin Project Area	Unlikely	Potential contaminant source, however the Reclamation Area of the Western Basin Dredging and Disposal Project will be separated from the mainland by a channel.
Cement Australia (existing facility)	Approximately 0.5 to 0.75 km south of the Western Basin Project Area	Unlikely	As above.
Existing facilities on Fisherman's Landing	Immediately south of the Western Basin Project Area	Unlikely	Potential contaminant source, however groundwater flow from Fisherman's Landing is likely to be towards open water, i.e. to the east and south.

Mitigation and Monitoring Strategies

Whilst no significant impacts on groundwater resources and/or groundwater quality are anticipated, this assessment is based on adoption of the mitigation strategies outlined below. Pre and post construction monitoring of groundwater levels and groundwater quality is also required to provide a more extensive baseline data set and to monitor the potential impacts of the Project.

During Construction

The following measures are proposed to monitor and mitigate the potential impacts identified above for the construction phase:

- Maintenance of regular groundwater monitoring (levels and quality), for a minimum 12 month period, prior to the start of construction to establish baseline groundwater conditions adjacent to the site and hence, confirm key groundwater quality and level action criteria against which to monitor conditions during construction. This program will be need to be agreed with the relevant authorities prior to commencement;
- A groundwater monitoring program will be developed and implemented to monitor groundwater levels and quality in the alluvial/colluvial deposits and fill material adjacent to the proposed Reclamation Area to confirm any groundwater impacts during the construction phase;
- Regular assessment of groundwater monitoring results against baseline groundwater conditions during construction;
- The installation of inlets and/or drainage channels at sea level within the proposed Reclamation Area, thereby minimising groundwater level mounding within the area itself and hence, reducing the potential for increased groundwater levels in onshore areas;

- If impacts on groundwater levels are identified, an assessment of potential mitigation measures will be conducted, which will include the use of the groundwater flow model to help assess the effectiveness of proposed mitigation measures;
- Storage areas for vehicles, machinery, equipment, chemicals etc., whether on land or within the Reclamation Area, during construction will require appropriate facilities to contain spills, leaks and surface water runoff to reduce the potential for contamination of groundwater through infiltration; and
- Groundwater monitoring will be conducted by a suitably qualified and experienced professional in accordance with the AS/NZS 5667.11:1998 *Australian/New Zealand Standard for water quality – sampling Part 11; guidance on sampling of groundwaters.*

Post Construction

The following measure is proposed to monitor and mitigate the potential identified impacts:

- A groundwater monitoring program will be developed and implemented to monitor groundwater levels and quality in the alluvial/colluvial deposits adjacent to the proposed Reclamation Area and fill material within and adjacent to the proposed Reclamation Area to confirm any groundwater impacts.