

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE)

Report on

The Abbot Point Growth Gateway Project Groundwater Studies

Prepared for WorleyParsons Services Pty Ltd

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Report on

The Abbot Point Growth Gateway Project Groundwater Studies

1 Introduction

The Port of Abbot Point (the Port) is located 25 km north-west of Bowen, on Queensland's north coast. The port comprises rail facilities, coal stockpiling/handling areas, and a 2.8 km jetty with offshore berths and two ship-loaders. The Queensland Government proposes to expand the current facilities as part of its proposed sustainable port development in accordance with the Reef 2050 Long-Term Sustainability Plan (Commonwealth of Australia, 2015).

The Abbot Point Growth Gateway Project (APGGP) plans to develop infrastructure to support development at the port. The referral relates to the development of infrastructure to support development of the Adani Abbot Point Coal Terminal (T0) (EPBC 2011/6194).

Projects relating to the proposed expansion of the Port have been the subject of extensive environmental studies, including assessment of cumulative impacts via the Abbot Point Cumulative Impact Assessment (CIA). These studies supported the T0 Environmental Impact Statement (EIS) and were published in June 2013. The Federal Government approved the development of the T0 coal terminal in December 2013 under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). At about the same time, the associated capital dredging and disposal associated with the terminal was approved as part of the greater T0, T2 and T3 Capital Dredging Project (2011/6213).

Alternative proposals for placement of the dredge material have also been considered and included development of a Beneficial Reuse Area through onshore placement of the dredge material within north eastern arm of the Caley Valley Wetlands adjacent to the western boundary of the proposed T3 site. This was proposed by the Queensland Minister for Economic Development in October 2014 as part of the Abbot Point Port and Wetland Strategy, but was withdrawn prior to an assessment decision. The two projects mentioned above are no longer being pursued by the State, in favour of the current proposal discussed below.

The APGGP proposal is identified as an alternative to the previous proposals, the option for utilising the previously nominated T2 site and adjoining land for the onshore placement of dredged material associated with the T0 development. This approach effectively:

- eliminates offshore placement of dredged material;
- minimises dredging volumes and offshore disturbance areas; and
- avoids disturbance of the wetland and associated habitats.

WorleyParsons Services Pty Ltd (WorleyParsons), on behalf of State of Queensland, requested Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) assess the groundwater regime within and adjacent to the proposed onshore placement area. This report presents the results of the investigations and discusses the potential impacts to the groundwater regime.

2 Project description

The Queensland Government referred the APGGP to the Commonwealth Minister for the Environment on 17 April 2015, with the following proposed actions:

- Construction of onshore dredged material containment pond(s) (DMCP) within the area previously allocated for the development of T2 and adjoining industrial land.
- Capital dredging of approximately 1.1 million m³ (Mm³) in situ volume of previously undisturbed seabed for new berth pockets and ship apron areas required to support the development of Terminal 0 (T0).
- Relocation of the dredged material to the DMCPs and offshore discharge of return water.
- Ongoing management of the dredged material including its removal, treatment, and beneficial reuse within the port area and the State Development Area, where appropriate.

This report focusses on the potential impacts on the groundwater regime of constructing the *DMCPs* and storing the dredge material in the T2 and adjoining industrial land until the material is suitable for beneficial re-use.

2.1 Terrain and hydrology

Abbot Point is characterised by coastal sand dunes and low lying mud flats at elevations below 5 m Australian Height Datum (AHD). The coastal land lies between abrupt rocky hills that extend to 300 mAHD at Mt Luce in the west, and 700 mAHD at Mt Roundback to the south. A smaller rock outcrop known as Bald Hill extends to around 50 mAHD and is present at the northern end of the Project area (Figure 2.1).

The dominant hydrological feature of the area is the Caley Valley Wetland system, which is listed under Department of the Environment (DotE) directory of important wetlands (Figure 2.1). This area is located immediately south and west of the Port area.

2.2 Climate

The nearest climate monitoring station run by the Bureau of Meteorology is located at Bowen Airport (station number 033257) which has rainfall and temperature records from 1987 to the present. The SILO climate dataset (DSITIA, 2015) was used to estimate average evaporation and rainfall in the region closer to the project area. The SILO data was available for an area located some 2 km west of the existing Port facilities. Table 2.1 presents the average monthly rainfall and evaporation datasets.

The Köppen-Geiger climatic system (Peel *et al.* 2007), classifies the region as 'Tropical Savannah' with rainfall being summer dominant with a marked wet summer and dry winter, and generally hot and humid. The bulk of the average rainfall of 900 mm falls during the summer months from December through to March, as shown on Table 2.1. The dry winter season is associated with milder temperatures and low (sometime nil) rainfall. Evaporation is high with the annual average pan evaporation generally exceeding the annual average rainfall by a factor of about two, and exceeding rainfall for all months except January and February. This high evaporation has important implications for the groundwater regime as it can concentrate salts in the groundwater systems.



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Month	Rainfall (mm)	Evaporation (mm)
Jan	240	194
Feb	234	161
Mar	153	165
Apr	59	139
Мау	41	118
Jun	35	99
Jul	23	109
Aug	19	131
Sep	15	164
Oct	20	199
Nov	40	206
Dec	112	211
Annual Total	991	1896

Table 2.1Average monthly rainfall and evaporation (SILO)

Note: Data range January 1889 to May 2015

The long term climatic trend is represented by Cumulative Rainfall Departure (CRD). The CRD shows trends in rainfall relative to the long term monthly average and provides a historical record of relatively wetter and drier periods. A rising trend in slope in the CRD plot indicates periods of above average rainfall, while a declining slope indicates periods when rainfall was below average. Figure 2.2 indicates that the region experienced a prolonged period of below average rainfall between 1991 and 2008. This was followed by a period of well above rainfall and floods experienced throughout the east coast of Queensland.



Figure 2.2 Comparison of average monthly rainfall and CRD – Abbot Point SILO data (DSITIA, 2015)

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2.3 Geology

GHD (2012) describe the geology of the Port and surrounds in their Cumulative Impact Assessment. Regionally, the basement bedrock geology comprises older Lower Permian to Carboniferous aged mafic igneous rocks. The bedrock is overlain in part by various phases of younger Cainozoic (Quaternary to Tertiary) aged sedimentary cover.

The Port area is located within the geological mapsheet of the Ayr, 1:250,000 scale (Paine *et al*, 1964). The surface geology is shown in Figure 2.3. The basement bedrock includes a mixture of granodiorites, adamellites, granites, diorites, and gabbro. These basement rocks have also been intruded by dykes of dolerite, andesite, and micro-diorite. Where these rocks are hard and resistant to erosion they form the elevated terrain surrounding the Port including:

- Mt. Luce adjacent to Dingo Beach;
- Bald Hill at Abbot Point; and
- Mt. Little and Mt. Roundback south of Abbot Point.

Cainozoic sediments encircle the outcropping hills and blanket the lower regions of the study area. Quaternary sediments dominate the lower terrain and coastal flats with three distinct sequences as follows:

- coastal mud flats, which comprise clays, silts and sands;
- coastal aeolian sand dunes, comprising sands mapped generally on the east side of Abbot Point, where the dunes are restricted to the coastline; and
- outwash and talus (colluvium), which includes localised fans along the east side of Mt. Luce.

Alluvial and deltaic sediments, and residual soils (early Quaternary) have been mapped south of the wetland and on terraces above the coastal mudflats. These sediments comprise variable mixtures of sands, gravels, clays, silts, and peats. Residual soils may include colluvium and rock debris.

The geology within the immediate Port area includes coastal sand dunes on the northern aspect. Coastal mud flats are present along the margins of the Caley Valley Wetland to the south and west of the existing terminal.



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3 Previous studies

There have been a number of previous studies undertaken for the Port of Abbot Point that provides useful information for the groundwater assessment include the following:

- Connell Hatch (2009) *Geotechnical Investigation Report. Abbot Point Bulk Coal Terminal X80/X110 Expansion*. Report H6000-80-GEO-GT06-002/01 prepared for the Ports Corporation of Queensland.
- North Queensland Bulk Ports Corporation (2009), *Environmental Management Plan*. Port of Abbot Point. E10/08613, August 2009.
- BMT WBM Pty Ltd, (2012) *Caley Valley Wetlands Baseline Report*, prepared for Office of the Coordinator-General, Department of State Development, Infrastructure and Planning, February 2012.
- GHD (2012), *Abbot Point Cumulative Impact Assessment. Technical Report Groundwater Assessment.* Commissioned for the Abbot Point Working Group, August 2012.
- CDM Smith, (2013), *Appendix E2 Groundwater Technical Report. Abbot Point Coal Terminal TO Project*, Final Environmental Impact Statement, June 2013.
- Aurecon, (2014), *Abbot Point Dredging. Onshore Deposition of Dredged Material Concept Study.* Report No. 242770, Revision B prepared for NQBP, 12 September 2014.

Of these, the Cumulative Impact Assessment (CIA) by GHD (2012) and the Groundwater Technical Report by CDM Smith (2013) provide the most comprehensive assessments for groundwater studies undertaken at Abbot Point. In addition, the Abbot Point Dredging Concept Study by Aurecon, 2014 provides detail in relation to the proposed methodology for onshore deposition of dredged material.

Information contained in the groundwater study undertaken by AGE in November 2014 as part of the Abbot Point Port and Wetland Strategy, has also been incorporated into this assessment. Specifically, data collected from the monitoring bores installed for that study form part of the groundwater monitoring data set utilised for this study.

4 Field investigation program

There have been two groundwater investigations undertaken by AGE at Abbot Point. The first was in November 2014, which focussed on the wetland area west of the T3 area and the second in March 2015 which investigated the T2 area. Details of the fieldwork components for each are summarised below.

4.1 **Objectives and scope of work**

Review of previous studies identified available groundwater data focussed principally on the T1 and T2 areas with minimal information available for the T0 and T3 areas and the adjacent Caley Valley Wetlands. Limited groundwater data including water level, quality, and formation permeability was identified as a key data gap. Hence, these recent investigations have focussed on those parts of the Project area with the aim being to better define and understand the groundwater regime across the Port area and its interaction with the adjacent wetlands.

The objective of the field investigation program was to assess the following within the proposed DMCP area and surrounds:

- groundwater levels and water quality;
- salinity of groundwater systems and how this varies with depth; and
- interconnectivity between groundwater systems and Caley Valley Wetlands.

To achieve this objective the scope of work included:

- installing ten monitoring bores within or adjacent the Caley Valley Wetlands (Sites 1 to 10);
- installing six monitoring bores within the proposed T2 DCMP area (bores MW01 to MW06);
- developing all monitoring bores to remove drilling fines and enhance hydraulic connection between the monitoring bore and surrounding formation;
- installing water level loggers and one salinity logger at selected bores across the T2 and T3 areas;
- measuring in-situ hydraulic conductivity (i.e. permeability) within each monitoring bore; and
- collecting samples of groundwater from selected monitoring bores for laboratory analysis of groundwater quality.

Sections below describe the field investigation program in more detail.

4.2 Construction of monitoring bores

Groundwater monitoring bores for this study were installed during two drilling campaigns. Initially, ten monitoring bores (Site 1 to Site 10) were installed around the wetland area, west of the T3 area, in November 2014. Six more monitoring bores (bores MW01 to MW06) were installed within the T2 area in May 2015.

A Class 1 Queensland licensed water bore driller supervised the drilling and construction of the bores, as required by the *Water Act 2000*. The design of the monitoring bores complied with the "*Minimum Construction Requirements for Water Bores in Australia*", (National Uniform Drillers Licensing Committee, 2012). A hydrogeologist from AGE designed the bores on site based on the lithology intersected.

Ayr Boring Company undertook the installation and construction of the initial bores between 5th and 7th November 2014. These boreholes were drilled using a 150 mm hollow stem auger to depths of between 6 m and 20 m below surface.

Geodrill installed the second group of monitoring bores within the T2 area between 19^{th} and 22^{nd} May 2015. These bores were drilled using a 125 mm blade bit and mud rotary drilling techniques to depths of between 10 m and 20 m below surface.

The boreholes were all cased with 50 mm diameter, Class 18, uPVC with factory slotted screens positioned over the basal section within the drill hole. A combination of collapsed in-situ sand and gravel pack was placed around and just above the screened section. A 2 m to 5.6 m thick cement seal was placed within the bore annulus above the gravel pack to the ground surface. Finally, a monument style, galvanised steel bore head was concreted around the protruding uPVC casing at ground surface. On completion, each monitoring bore was airlift developed to remove drilling fines and enhance hydraulic connection with the aquifer. Table 4.1 summarises the construction details for each of the new monitoring bores. Appendix A contains composite borehole logs. Figure 4.1 shows the location of each of the bores.

Bore	Easting ¹	Northing ¹	Ground elevation mAHD ³	Stickup (mAGL)	Surface seal (mBGL)	Gravel pack (mBGL)	Screened section (mBGL)	SWL² (mbTOC)	EOH (mBGL)
Caley Valley Wetland Bores									
Site 1	611104	7798594	2.76	0.45	0 - 4.0	4.0 - 7.2.	4.2 - 7.2	3.20	7.2
Site 2	610836	7799154	0.99	0.39	0 - 3.6	3.6 - 6.75	3.9 - 6.75	1.63	6.75
Site 3	612307	7799980	2.82	0.53	0 -2.7	2.7 - 6.0	3.0 - 6.0	3.03	6.0
Site 4	611487	7800268	1.83	0.41	0 - 2.0	2.0 - 20.3	2.3 - 20.3	1.89	20.3
Site 5	611893	7800032	3.55	0.5	0 - 3.5	3.5 - 9.3	6.0 - 9.0	3.78	9.3
Site 6	611946	7799423	4.43	0.5	0 - 4.5	4.5 - 8.5	5.5 - 8.5	5.14	8.5
Site 7	611490	7798908	1.96	0.45	0 - 3.8	3.8 - 7.95	4.95 -7.95	2.66	7.95
Site 8	611840	7798455	2.89	0.35	0 - 3.5	3.5 - 8.8	5.8 - 8.8	3.33	8.8
Site 9	610717	7799965	2.77	0.23	0 - 3.0	3.0 - 9.0	6.0 - 9.0	3.07	9.0
Site 10	611213	7799720	2.43	0.415	0 - 3.0	3.0 - 9.2	6.5 - 9.2	2.63	9.2
T2 DCMP Bores									
MW01	612469	7798238	5.28	0.82	0 - 3.5	3.5 - 10.0	4.0 - 10	6.21	10
MW02	612452	7798602	4.82	0.76	0 - 3.7	3.7 - 10.0	4.0 - 10	5.43	10
MW03	612289	7799178	4.25	0.80	0 - 4.1	4.1 - 20.5	4.5 - 20.5	4.81	20.5
MW04	612998	7798027	4.18	0.86	0 - 5.6	5.6 - 10	7.0 - 10.0	5.07	10
MW05	613131	7798199	4.31	0.75	0 - 3.9	3.9 - 20	4.0 - 20.0	4.83	20
MW06	613140	7798205	4.29	0.76	0 - 4.6	4.6 - 10	5.0 - 10.0	4.82	10

Table 4.1 Monitoring bore construction details

Note: 1 – Bore Coordinates: GDA 94, Zone 55

2 – SWL – Standing water level

- Ground elevation estimated from site LIDAR data

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4.3 Lithological units

The drilling intersected layers of sand, sandy clay, clayey sand, silty sand, and clay. Each of these sediment types had varying thickness. Commonly, the stratigraphic profile encompassed, surficial soil or sand that overlay clay to sand with underlying thick hard clay. Table 4.2 summarises the main lithological units intersected whilst drilling from surface to the base of hole. The maximum depth of the drill holes was about 20 m.

Lithological unit (from surface to base of hole)	Lithology description
Sand (SW)	fine to coarse grained, yellowish-reddish, light reddish brown to black, with minor clay and silt fractions, dry to wet.
Sandy Clay (CS)	medium to high plasticity, fine to coarse sand, sub-angular to sub-rounded, quartz, lithic and micaceous grains, grey, generally poorly sorted, yellowish, greenish, red and browns, and dry to wet.
Clayey Sand (SC)	very fine to coarse grained, poorly to well sorted, sub-angular to sub-rounded, quartz and lithic grains, light reddish browns to greys, interbedded low to high plasticity clay, wet.
Silty Sand (SM)	fine to medium and less commonly coarse grained , sub-angular, sub-rounded to rounded, quartz, micaceous, light brown, grey, greenish, dense, with medium plasticity clay, saturated or dry at swamp surface.
Clay (CH/CL)	medium to high plasticity, dark greenish brown to grey, moist, very hard, minor sub- rounded quartz sand, wet.
Silty SAND (SM)	fine to coarse sand, moderately sorted, silty matrix, light greenish to grey / brown.

Table 4.2Summary of main lithological units

4.4 In-situ permeability testing

Following construction, in-situ permeability tests were conducted in each monitoring bore to measure the hydraulic conductivity of the screened sediments. Either the rising head or falling head test methods were used depending on the bore. The tests were initiated by either inserting or removing a solid "slug" from the bore, and the time for the water level to equilibrate was measured.

Appendix B contains the water level measurements for each bore, and the graphical analysis of hydraulic conductivity. The data was analysed using the Bower & Rice or Butler Method for unconfined aquifers using Aquifer Test 2011.1 software (Schlumberger Water Services, 2011). Table 4.3 presents the hydraulic conductivity derived for each bore.

The results confirm the silty/sandy/clayey sediments have a moderate to high hydraulic conductivity. These values of hydraulic conductivity compare well with acknowledged literature values for similar sediment types.

Bore ID	Hydraulic conductivity		re ID Hydraulic conductivity Analysis method		Lithology		
	m/sec	m/day					
Caley Valley wet	land bores						
Site 1	4.2 x 10 ⁻⁶	0.36	Bouwer & Rice	Silty Clay			
Site 2	5.4 x 10 ⁻⁵	4.6	Bouwer & Rice	Sandy Clay/Clay			
Site 3	4.1 x 10 ⁻⁵	3.5	Bouwer & Rice	Sandy Clay and Sand			
Site 4	1.1 x 10 ⁻⁴	9.7	Butler High-K	Clayey Sand			
Site 5	2.5 x 10 ⁻⁶	0.3	Bouwer & Rice	Clayey Sand			
Site 6	4.6 x 10 ⁻⁵	4.0	Bouwer & Rice	Clayey Sand			
Site 7	7.6 x 10 ⁻⁶	0.7	Bouwer & Rice	Silty Sand			
Site 8	6.4 x 10 ⁻⁵	5.5	Bouwer & Rice	Clayey Sand/ Silty Sand			
Site 9	2.6 x 10 ⁻⁴	22.5	Bouwer & Rice	Sandy Clay, Sand			
Site 10	5.4 x 10 ⁻⁵	4.6	Bouwer & Rice	Sand, Clay			
T2 DCMP bores							
MW01	1.5 x 10 ⁻⁵	1.3	Bouwer & Rice	Silty Sand			
MW02	3.8 x 10 ⁻⁵	3.2	Bouwer & Rice	Clayey Sand			
MW03	1.2 x 10 ⁻⁵	1.1	Bouwer & Rice	Silty Sand/Clayey Sand			
MW04	2.7 x 10 ⁻⁵	2.3	Bouwer & Rice	Silty Sand			
MW05	2.5 x 10 ⁻⁵	2.2	Bouwer & Rice	Silty Sand/Clayey Sand			

Table 4.3Hydraulic conductivity measurements

4.5 Groundwater levels

Groundwater levels have been measured in the recently installed monitoring bores and also in the preexisting North Queensland Bulk Ports (NQBP) monitoring bores located within the T1 area. Details of these water levels are summarised in Table 4.4 and shown in Figure 4.2.

Bores ID	Installed by	Easting ¹	Northing ¹	SWL ² (mbTOC)	Groundwater elevation mAHD ³		
Site 1	AGE	611104	7798594	3.20	0.02		
Site 2	AGE	610836	7799154	1.63	-0.25		
Site 3	AGE	612307	7799980	3.03	0.32		
Site 4	AGE	611487	7800268	1.89	0.35		
Site 5	AGE	611893	7800032	3.78	0.28		
Site 6	AGE	611946	7799423	5.14	-0.21		

Table 4.4Summary of groundwater levels

Bores ID	Installed by	Easting ¹	Northing ¹	SWL ² (mbTOC)	Groundwater elevation mAHD ³
Site 7	AGE	611490	7798908	2.66	-0.25
Site 8	AGE	611840	7798455	3.33	-0.09
Site 9	AGE	610717	7799965	3.07	-0.07
Site 10	AGE	611213	7799720	2.63	0.22
GW01	NQBP	611560	7800352	3.36	0.15
GW02	NQBP	611909	7800111	2.25	0.25
GW03	NQBP	612305	7799993	2.74	0.61
GW04	NQBP	612318	7799481	4.08	0.17
GW05	NQBP	612317	7798996	4.16	0.22
GW06	NQBP	613129	7800342	3.31	0.50
MW01	AGE	612469	7798238	6.21	-0.11
MW02	AGE	612452	7798602	5.43	0.15
MW03	AGE	612289	7799178	4.81	0.24
MW04	AGE	612998	7798027	5.07	-0.03
MW05	AGE	613131	7798199	4.83	0.23
MW06	AGE	613140	7798205	4.82	0.23

Note: 1 – Bore Coordinates: GDA 94, Zone 55

2 – SWL – Standing water level; AGE bores 20 May 2015, NQBP bores 5 May 2015

3 – Ground elevation estimated from site LIDAR data





DATE FIGURE No: 24/06/2015 **4.2**

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Referral and Site Investigation Area
 Inferred groundwater flow directions

The measured depth to groundwater ranged between 2.2 m (0.6 mAHD) and 5.4 m (-0.1 mAHD) within the elevated topography associated with adjacent Terminals T0, T1 (NQBP), T2, and T3 areas. West of the T3 Terminal area within the wetlands, the depth to groundwater ranged from -1.2m (-0.3 mAHD) at Site 2 within the wetlands to 2.2 m (0.2 mAHD) at Site 10 along the north-western edge of the wetlands. These groundwater elevations indicate groundwater movement is generally away from the elevated topography (associated with the existing Port facility) towards the wetlands as shown in Figure 4.2.

Groundwater level data recorded from data loggers in seven of the Wetland monitoring bores installed in November 2014 is shown in Figure 4.3.

These also show response to rainfall events between December and February. Site 4 is located approximately 150 m south of Dingo Beach and shows a distinct response to oceanic tidal variations as well as a higher groundwater elevation compared to the other wetland monitoring bores. This would suggest a hydraulic interconnection between the ocean and the sand dunes adjacent to, and parallel, to the coastline. Whilst Figure 4.2 shows that groundwater movement and discharge will principally be towards the wetlands, it is likely there will be a component of groundwater flow that will discharge northwards towards the ocean along this northern coastal sand dune fringe.



Figure 4.3 Wetland monitoring bore groundwater level hydrographs

Limited longer term transient water level data is available for the NQBP monitoring bores and is presented in Figure 4.4. Similar to that observed in the Wetland monitoring bores, the hydrographs show a strong seasonal variation in groundwater levels in these bores, with a 1 m to 3 m fluctuation between wet and dry seasons.



Figure 4.4 NQBP monitoring bore groundwater level hydrographs

4.6 Groundwater quality

4.6.1 Field water quality

A minimum of three bore volumes was removed (purged) from each bore prior to sample collection, in accordance with the standard Australian guidelines for groundwater sampling (Australian/New Zealand Standard, [1998] and DERM, [2009]).

Electrical conductivity (EC) and pH were monitored during purging with a field meter to ensure collection of a representative water sample from the formation. The field pH/EC meter was calibrated prior to undertaking the work, using factory-supplied calibration standard solutions.

The salinity of the water samples can be categorised based on the following total dissolved solids (TDS) concentrations (FAO, 2013) for groundwater:

•	Fresh water	<500 mg/L ()
•	Brackish (slightly saline)	500 to 1,500 mg/L
•	Moderately saline	1,500 to 7,000 mg/L
•	Saline	7,000 to 15,000 mg/L
•	Highly saline	15,000 to 35,000 mg/L
•	Brine	>35,000 mg/L

However, the National Water Commission (December, 2011) defines brackish water as *"water that has a higher salt content than fresh water but a lower content than seawater"*. Based on this definition brackish water is considered that having a TDS concentration between 500 mg/L and 30,000 mg/L.

For the purposes of this groundwater assessment, the following salinity classification for groundwaters intersected has been adopted:

•	Fresh water	<500 mg/L (< ~750 μS/cm)
•	Brackish	500 to 7,000 mg/L (~750 to ~10,500µS/cm)
•	Saline	7,000 to 35,000 mg/L(~10,750 to ~53,000 $\mu S/cm)$
•	Hypersaline (brine)	>35,000 mg/L(> ~53,000 µS/cm)

Table 4.5 summarises the pH and EC measurements recorded at the time of sample collection.

Bore ID	Installed by	pН	Electrical conductivity	Salinity	
			(µS/cm)	classification	
Caley Valley Wetland	d Bores				
Site 1	AGE	7.1	106,900	Hypersaline	
Site 2	AGE	6.9	119,300	Hypersaline	
Site 3	AGE	7.8	34,400	Saline	
Site 4	AGE	6.8	93,000	Hypersaline	
Site 5	AGE	7.9	20,500	Saline	
Site 6	AGE	7.9	3,700	Brackish	
Site 7	AGE	6.8	84,300	Hypersaline	
Site 8	AGE	7.6	10,390	Saline	
Site 9	AGE	7.1	80,330	Hypersaline	
Site 10	AGE	6.3	67,060	Hypersaline	
T2 DCMP Bores					
MW01	AGE/Golders	7.9	3,285	Brackish	
MW02	AGE/Golders	7.5	7,570	Brackish	
MW03	AGE/Golders	7.1	102,700	Hypersaline	
MW04	AGE/Golders	8.1	10,380	Brackish	
MW05	AGE/Golders	6.9	126,200	Hypersaline	
MW06	AGE/Golders	8.1	13,030	Brackish	

Table 4.5Summary of field water quality for monitoring bores

The pH data show the groundwater quality is generally neutral to slightly alkaline. The EC measurements indicate groundwater ranges in salinity from brackish to hypersaline, with values from:

- 3,285 μ S/cm to 34,400 μ S/cm in the monitoring bores located within the elevated T2 and T3 areas (Sites 3, 5, 6, 8, and MW01, MW02, MW04, and MW06); and
- $67,060 \ \mu$ S/cm to 126,200 μ S/cm within the Caley Valley Wetland (Sites 1, 2, 4, 9, and 10) and deep within the T2 area (MW03 and MW05).

Salinity profiles within each of the bores were measured to determine their variability across the site. A salinity logger was slowly lowered down each monitoring bore to record change in EC with depth.



Figure 4.5 Salinity profiles, T2 and T3 area monitoring bores

The salinity profile within groundwater beneath the T2 and T3 areas are shown in Figure 4.5. The logger intersected three distinct salinity zones within the profiles, these being:

- brackish groundwater with an EC up to \sim 6,000 µS/cm between 0.4 mAHD and -4 mAHD;
- saline groundwater with an EC between 10,500 $\mu S/cm$ and 53,000 $\mu S/cm$ between 0.8 m and -7.2 mAHD; and
- hypersaline groundwater with an EC value between 53,000 $\mu S/cm$ and $\sim\!85,000$ $\mu S/cm$ in both deep bores from 0.2 mAHD to the end of hole at $\sim\!\!-15$ mAHD.

Whilst the data shows the salinity profiles are variable across the T2 and T3 areas, there is a general trend, which suggests a lens of brackish water, up to 3 m thick, is located above saline to hypersaline groundwater. However, the brackish groundwater lens was absent at GW03 and Site 3 for reasons that are not readily apparent.

The salinity profile within groundwater beneath the Caley Valley Wetland, west of the T3 area, is shown in Figure 4.6. The bores located around the edge of the wetland area also have a brackish water lens located above a saline to hypersaline water. However, monitoring bores at Site 1, Site 2, and Site 7, which are located within the wetland, intersects only hypersaline groundwater.



Figure 4.6 Salinity profiles, wetland area monitoring bores

4.6.2 Laboratory analyses

Groundwater samples were collected from each monitoring bore after the EC had stabilised during purging, and the bores were yielding generally clear water. The samples were stored in appropriate containers supplied by Australian Laboratory Services Pty Ltd (ALS), which is a NATA registered laboratory. The groundwater samples were submitted to ALS for laboratory analysis of:

- physical parameters pH, electrical conductivity, total dissolved solids, and alkalinity;
- major anions carbonate, bicarbonate, chloride, and sulphate;
- major cations calcium, magnesium, potassium, and sodium;
- dissolved and total metals aluminium, arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, and zinc; and
- nutrients ammonia, nitrate, nitrite, total Kjeldahl nitrogen, and total phosphorus.

Appendix C contains the laboratory analysis reports from ALS. The results are summarised in the sections below.

4.6.3 Water quality summary

Table 4.6 and Table 4.7 summarise the results of the field and laboratory analyses.

Table 4.6Summary of groundwater quality data - November 2014								
Parameter	Site 2	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	
Field pH (pH units)	6.09	7.04	7.02	6.55	7.3	6.81	6.62	
Laboratory pH (pH units)	6.46	7.4	7.66	6.71	7.69	7.11	6.98	
Field EC (µS/cm)	119,200	15,460	1,597	79,360	9,648	79,350	50,310	
Laboratory EC @ 25°C (µS/cm)	114,000	15,700	1,610	76,000	9,440	74,900	48,700	
Total Dissolved Solids (mg/L)	105,000	9,610	800	61,800	5,680	67,100	34,400	
Calcium (mg/L)	783	93	5	511	34	602	372	
Magnesium (mg/L)	4,170	234	10	2,220	134	2,550	1,340	
Sodium (mg/L)	26,000	2,730	318	18,000	1,730	15,300	10,300	
Potassium (mg/L)	951	126	11	599	73	502	360	
Bicarbonate (mg/L)	156	195	180	261	161	277	215	
Chloride (mg/L)	53,200	4,250	389	31,000	3,070	30,700	18,300	
Sulphate (mg/L)	8,400	1,370	58	6,820	420	6,440	2,440	

	10	rusie in Summary of Groundwater quanty and May 2015									
Parameter	MW01	MW02	MW03	MW04	MW05	MW06	SITE 3	SITE 5	SITE 6	SITE 7	SITE 8
Field pH (pH units)	7.5	6.7	6.5	7.5	6.8	7.4	6.0	7.0	8.5	6.5	7.1
Laboratory pH (pH units)	7.93	7.08	7.22	8.09	7.31	7.98	7.68	7.57	7.83	7.04	7.65
Field EC (µS/cm)	3,044	5,778	81,218	7,654	95,431	9,004	35,198	15,813	1,976	79,073	14,825
Laboratory EC @ 25°C (µS/cm)	2,940	5,340	80,200	7,130	83,400	8,710	35,000	16,100	2,010	78,700	14,000
Total Dissolved Solids (mg/L)	1,910	3,470	52,100	4,630	54,200	5,660	22,800	10,500	1,310	51,200	9,100
Calcium (mg/L)	7	58	786	27	996	42	229	96	7	538	57
Magnesium (mg/L)	17	119	2,070	65	2,430	76	542	240	12	1,920	208
Sodium (mg/L)	557	764	17,100	1,390	18,300	1,600	6,980	2,970	366	16,300	2,490
Potassium (mg/L)	19	31	488	34	382	18	239	112	14	537	92
Bicarbonate (mg/L)	183	112	279	397	359	342	656	203	193	270	177
Chloride (mg/L)	771	1,510	31,900	2,020	34,000	2,870	12,200	5,240	520	31,000	4,760
Sulphate (mg/L)	131	192	5,100	247	5,250	217	1,320	1,640	80	5,570	732

Table 4.7Summary of groundwater quality data - May 2015

The field and laboratory measured values of pH and EC are well correlated and indicate the samples did not undergo any significant chemical changes during transport to the laboratory.

The laboratory data indicates:

- pH of groundwater is slightly acidic to slightly alkaline and varies from 6.4 to 8.1;
- sodium and chloride are the dominant salts; and
- salinity (as total dissolved solids) varies from 800 mg/L to 105,000 mg/L and therefore varies from brackish to hypersaline.

Comparison of the wetland bore water quality data shows minimal variation between the November 2014 and May 2015 sampling events. The only exception is Site 8 where an increased total dissolved solids concentration from 9,440 mg/L to 14,000 mg/L is reported. Further sampling and analysis of these bores would further resolve the extent of this variation and whether it is a seasonal or temporal condition within the groundwater system.

4.6.4 Environmental value and beneficial use

Table D-1 of Appendix D compares the groundwater quality data to the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ, 2000), commonly referred to as the ANZECC (2000) guidelines. The guidelines are based on slightly to moderately disturbed systems based on the sites current activities and previous alteration of the flow dynamics within the wetlands. This adopts triggers levels calculated from a 95% protection level. GHD have noted that whilst there are more specific regional water quality guidelines such as the Queensland Water Quality Guidelines (2009) and the Great Barrier Reef Marine Park Water Quality Guidelines (2010), these guidelines do not provide much information specific to the heavy metal analytes.

Both freshwater and marine guidelines have been included, on the assumption that groundwater would ultimately discharge to either a fresh water or saline marine environment.

The results indicate that groundwater in the Project area comprises elevated salinity, sulphate, ammonia, total nitrogen (as TKN and nitrate) and some metals. Detectable levels of metals were recorded for aluminium, arsenic, copper, iron, manganese, nickel, and zinc. Elevated levels exceeding available threshold criteria in the ANZECC water quality guidelines for either marine or freshwater protection include:

- chloride in all bores and ammonia in bores at Sites 2, 7, 9, 10, and MW05;
- total aluminium in all bores except Sites 9, 10, and MW03;
- copper at Site 10;
- manganese in bores Sites 2, 7, 9, 10, MW03, and MW05 which occurs principally in a dissolved state;
- nickel in MW03; and
- zinc in bores Site 5, MW01, MW02, MW04, MW05, and MW06.

Nutrient levels indicate nitrogen occurs mainly in an organic form and as ammonia. Nitrogen levels exceeding the ANZECC water quality guidelines included ammonia at Sites 2, 7, 9, 10, and MW05, and nitrate at MW02 and MW05. Elevated levels of total phosphorus exceed the ANZECC water quality guidelines for wetland protection.

The elevated concentrations of major ions and trace metals are not considered to be a result of contamination from the facilities at the Port, but due to evaporative concentration of these elements in the hypersaline groundwater, and therefore occur naturally. Given the igneous geology that form the elevated topography and make up much of the catchment (i.e., Mt Roundback, Mt Little, Mt Luce, and Bald Hill), the elevated metals concentrations possibly reflect the baseline groundwater quality in this area.

4.6.5 Water types

A piper diagram of the groundwater quality data collected from the recently installed monitoring bores (Figure 4.7) shows that groundwater within the Project area can be classified as sodium-chloride type water and similar to seawater. Piper diagrams are based on the relative proportions of the major cations and anions.



Figure 4.7 Piper diagram Hydrogeological regime

5 Conceptual hydrogeological model

The hydrogeological investigation indicates all of the geological sequences located within the Port area are potentially water bearing and constitute an aquifer where saturated. These geological units can be characterised into the following four aquifer groups, which form the basis for the conceptual hydrogeological model for the Port area:

- bedrock aquifer;
- alluvial sediments;
- coastal dune system; and
- coastal mudflats.

The bedrock aquifer comprises mafic igneous geology and forms a fractured rock aquifer with groundwater flow within fractures, joints, and other discontinuities within the rock mass. Connell Hatch (2009) indicated a decomposed, weathered upper profile, overlain in places with up to 3 m to 12 m of colluvium, occurs within the foothills of Bald Hill and Mt Luce. The extent of any groundwater associated with these sediments is not defined. Where it does occur, it is likely to be laterally restricted.

The groundwater investigations undertaken for this study have intersected alluvial sediments over the majority of the T2 and T3 areas. The drilling to date indicates the occurrence of terrace sediments in the T2 and T3 areas to at least 20 m thick, with the upper 10 m comprising variable mixtures of sands, silts, clays, and a basal sand sequence. Hollingsworth & Associates (1979) indicate the presence of 'shoe string' sand aquifers, i.e. narrow, sinuous sands and gravels, south of the wetland.

Connell Hatch (2009) describe the coastal dune system comprising coarse grained permeable beach sands that are laterally restricted to the eastern parts of the Port area. The sands are described as being up to 4 m thick, and occur on top of 3 m to 6 m of residual soils (clayey and sandy silts) overlying decomposed rock.

The Coastal mudflats extend west and south of T1, T2, and T3 areas and comprise interbedded sequences of unconsolidated clay, slit, and sand sediments of variable permeability. The recent drilling results confirm the mudflats west of the T3 area generally comprise 2 m of clayey/silty sand overlying a similar thickness of lower permeability clay. These upper sediments overly interbedded sequences of sandy and clayey sediment that host hypersaline groundwater.

GHD (2012) provide a hydrogeological conceptualisation of the study area. They indicate recharge rainfall occurs in the higher terrain and recharges the bedrock and alluvial terrace deposits. Groundwater movement is principally under gravity towards the coast with discharge generally into the Coral Sea.

Groundwater levels fluctuate in response to the summer dominated rainfall. During the dry season, when recharge to groundwater systems reduces and evaporation and evapotranspiration effects are high, groundwater levels slowly fall. Conversely, in the wet season, when there is a greater supply of fresh rainfall recharge to the groundwater system, groundwater levels rise.

During the wet season, there is expected to be a zone beneath the wetland mudflat where fresher wetland water sits above and mixes with underlying saline to hypersaline water. This zone will only be present if there is a transmissive hydraulic connection between the wetlands and the underlying groundwater system whereby flooding of the wetlands influences the underlying groundwater quality in the wet season.

Regionally, groundwater discharge occurs towards the Caley Valley Wetlands, with localised discharge towards the ocean along the coastal fringes. The hypersaline groundwater intersected within the wetland and at depth below the elevated terraces within T1, T2 and T3 areas, suggest limited flow of groundwater occurs in this hypersaline zone. It would appear that this hypersaline groundwater is effectively trapped, stagnant groundwater that has probably formed from evapo-concentration processes from a combination of seawater ingress during extreme high tides and brackish groundwater seepage into the wetlands.

The direction of groundwater flow in the proposed DMCP area appears to be a subtle reflection of the surface terrain with flows in a southerly and westerly direction towards the main bodies of water making up the Caley Valley Wetlands.

Figure 5.1 shows graphically the conceptual behaviour of the groundwater system.



Conceptual Hydrogeological Model



Figure 5.1 Abbot Point (G1702A)

6 Numerical groundwater model

6.1 Objectives and approach

A numerical groundwater flow and (salinity) transport model was developed to simulate the impact of the proposed dredge material on the groundwater receiving environment.

The onshore placement of dredge material will potentially provide a short term 'pulse' of additional recharge to the underlying groundwater regime. The purpose of the groundwater modelling was to assess the likely impact of saline seepage from the proposed dredge material on the receiving groundwater environments beneath the T2 development area and adjoining industrial land, and also the adjacent wetlands and coastal dunes areas. The model also considered the influence of a low permeability barrier/liner on the internal batters of the DMCP to minimise this saline seepage.

6.2 Code selection

The MODHMS code simulated groundwater flow and transport within the project area. MODHMS is a commercial derivative of the standard MODFLOW code. It is capable of simulating unsaturated conditions, which are important in representing the wetting and drying dynamics of the wetland area, and changes in water quality (salinity) resulting from seepage out of the DMCP. The MODFLOW pre and post processor PMWIN (Chaing and Kinzelbach, 1996) generated some of the input files, while the remainder were created through in house FORTRAN code.

6.3 Model grid

The aim of the layer discretisation was to find a balance between having sufficient layers to represent detail in the geology, whilst still limiting the number of cells to ensure model run times were manageable. Figure 6.1 shows the position and extent of the model grid. The north-west corner of the grid was is located at 603,409 mE and 7,801,544 mN (MGA 94, Zone 55). The model grid is 12 km wide (E-W) and 11 km long (N-S) with a direct north-south alignment.

The model adopted a cell size of 50 m x 50 m, which was refined to 20 m x 20 m within the proposed DMCP area, resulting in a total of 131,043 cells in each layer of the model.

Model layers were constructed using the borehole logs from the Connell Hatch (2009) geotechnical report. These bores are concentrated within the current Port of Abbot Point area and cover a small area within the model domain. In order to provide coverage over the rest of the model area, geology data obtained from borehole logs from the DNRM Groundwater database registered bores were used. The surface topography of the model was sourced from high resolution LIDAR data across the model domain provided by WorleyParsons. Figure 6.2 shows a North-South cross section through the model. Table 6.1 summarises the model layers.

Model cells where groundwater flow was not included in the simulations were made inactive. These include those cells within Layers 5, 6 and 7.



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North

South



Model grid cross section - north - south

Figure 6.2 Abbot Point (G1702B)

Model layer	Hydrostratigraphy	Thickness range (m)
1	sand, gravelly sand, silty sand, clayey sand, basement geology outcrop, topsoil	1-276
2	sandy clay, clayey silt, clay	1-23
3	silty sand, sand, gravely and silty sand, sandy clay	1-11
4	clayey sand, clay silt, silty clay, clay	1-27
5	sand, silty sand, gravelly sand, sandy silt	1-28
6	clayey gravel, weathered basement) fractured rock	1-20
7	basement geology – granite, granodiorite, diorite (unweathered), siltstone, sandstone	20

Table 6.1Model layers

6.4 Time

A transient groundwater model was used to represent the seasonality created by distinct wet and dry weather seasons in the region and the dynamic nature of water levels within the groundwater system and its connection with the wetlands. A transient groundwater model was also required to represent the filling of the DMCP with dredged material. Weekly stress periods were used to represent recharge to the DMCP areas based on the proposed DMCP dimensions and dredging production and pumping rates.

6.5 Boundary conditions

Water enters and leaves the groundwater regime at site through natural processes. The model simulated the transfer of water into and out of the model domain with boundary conditions. The specific boundary conditions represented in the model are shown in Figure 6.3 and discussed below.

6.5.1 Fixed head boundaries

A fixed head boundary condition 'fixes' the hydraulic head in selected cells regardless of the system conditions in the surrounding grid cells. These cells can act as an infinite source of water entering or leaving the groundwater system. Fixed head boundaries at 0 mAHD were assigned along the northern and eastern boundary of the model in all layers to represent the ocean. The head value was determined from the mean sea level at Abbot Point.

6.5.2 Recharge

Recharge to the aquifer system was distributed across the model domain according to mapped surface geology, and comprised low recharge and high recharge zones. The recharge rate was estimated by calibration to field observations.

6.5.3 Rivers

Watercourses were incorporated into the model, using the river package. The river package was set up to only take water out of the model domain in locations of water courses. The river package was also used to simulate the wetland. It simulated the wetland's transient nature by being turned on during the wet season to provide a head of water to flow into the underlying aquifer. During the dry season the river package was turned off to allow water levels to subside with evaporation remaining active.

6.5.4 Evaporation / evapotranspiration

Losses in groundwater occur when it is close to the ground surface either by direct evaporation or evapotranspiration through uptake by plants. This process occurs across the project site, particularly within the wetland where areas of evaporative concentrated salts are evident on the ground surface.

The evapotranspiration package was used to simulate this process. An extinction depth of 1m was assigned using climate data to determine the maximum evaporation rate. The extinction depth defines the depth below the evaporation surface where evaporation ceases to occur. The increase in the evaporation rate between the extinction depth and the evaporation surface is linear. Above the evaporation surface the evaporation rate is constant at the specified maximum evaporation rate.

This boundary condition was applied across the model domain, but switched off in the wetland during the wet season when the river package was used to represent flooding of the wetland.

6.5.5 Horizontal Flow Barrier

The project proponent is considering the benefit of installing a low permeability liner around the inside wall and down through the upper sandy layer (Layer 1) and upper most clay layer (Layer 2), down to the top of the underlying sandy layer (Layer 3). The model used the horizontal flow barrier package (HFB) to simulate the effect of a vertical low permeability liner. This package restricts the flow between two neighbouring cells by overriding the conductance term with a user specified conductance that is significantly lower. This essentially directs connection to the underlying shallow sand aquifer and means that water in the DMCP mostly exits and migrates away from the DMCP site via Layer 3.


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6.6 Hydraulic properties

The hydraulic properties were assigned to each layer based on the results of in-situ permeability testing undertaken for this project, and on experience in similar environments. The adopted values fit within published ranges for similar sediments (e.g. Krusemann & de Ridder, 2000), and are shown in Table 6.2.

The groundwater model was setup to include simulation of groundwater flow and transport within Layers 1 to 4 where shallow groundwater movement would occur. As such, Layers 5 to 7 were made inactive and play no part in the simulations.

Model	Lithology	Hydraulic co (m/da	nductivity ay)	Specific Yield	Specific Storage
layer		horizontal	vertical	Sy	Ss (m ⁻¹)
1	Basement outcrop,	5 x 10 ⁻⁵	5 x 10 ⁻⁶	1 x 10 ⁻⁴	1 x 10 ⁻⁶
1	Sand, Silty Sand (Wetland area)	2.0	0.2	1 x 10 ⁻⁴	1 x 10 ⁻⁵
1	Sand, Gravelly Sand, Silty Sand, Clayey Sand	4.0	0.2	5 x 10 ⁻²	1 x 10 ⁻⁵
2	Sandy Clay, Clayey Silt, Clay	1 x 10 ⁻³	1 x 10 ⁻⁴	5 x 10 ⁻³	1 x 10 ⁻⁴
3	Silty Sand, Sand, Gravely and Silty Sand	2.0	0.2	5 x 10 ⁻²	1 x 10 ⁻⁵
4	Clayey Sand, Clay Silt, Silty Clay, Clay	1 x 10 ⁻³	1 x 10 ⁻⁴	5 x 10 ⁻³	1 x 10 ⁻⁴

Table 6.2Model layers and aquifer properties

6.7 Model calibration

6.7.1 Model confidence level classification

The degree of confidence in the model's predictions can be classified based on the following factors:

- available data;
- calibration procedures;
- consistency between calibration and predictive analysis; and
- level of stresses.

Barnett *et al* (2012) have developed a system to classify the confidence-level for groundwater models. Models are classified as either Class 1, Class 2 or Class 3 in order of increasing confidence. Some aspects of Class 2 models outlined by Barnett *et al* (2012) include:

- groundwater head observations and bore logs are available but may not provide adequate coverage throughout the model domain;
- calibration statistics are generally reasonable but may suggest significant errors in parts of the model domain;
- long-term trends not replicated in all parts of the model domain;
- transient calibration to historic data but not extending to the present day;
- mass balance closure error is less than 1% of total;
- streamflow data and baseflow estimates available at a few points; and
- metered groundwater-extraction data may be available but spatial and temporal coverage may not be extensive.

Abbot Point groundwater model satisfied criteria for a Class 2 model.

6.7.2 Calibration

The steady state and transient groundwater models were calibrated to available groundwater level measurements. The objective of the steady state calibration was to reproduce dry season groundwater levels measured at the individual monitoring bores, and to replicate the water table surface and the direction of groundwater flow. The objective of the transient model calibration was to match historical water level behaviour over a number of seasonal fluctuations.

The transient calibration used a combination of the five-year (2010-2015) groundwater level data set for the NQBP monitoring bores and the recent water level data for the wetland bores (Sites 4 to 10). Dry season water levels in the monitoring bores and water levels available from the Queensland government groundwater database to describe groundwater conditions south of the site were utilised in steady state calibration.

6.7.3 Calibration setup

Calibration of the model followed the methods set out by Barnett et al, (2012) to statistically measure and ascertain the level of calibration.

The steady state model was used to provide the transient model with starting water levels. The steady state and transient models were calibrated together in a combined process whereby shared parameters were varied in both models. Manual and automated calibration techniques were used to replicate groundwater levels for the period between 2010 and 2015.

The automated calibration software PEST was used. The software made iterative adjustments to the parameter set within pre-defined bounds to reduce the residual difference between the predicted results and the observed data. PEST adjusted the following properties in the model to achieve the steady state and transient calibrations:

- horizontal and vertical hydraulic conductivity;
- recharge rate to each recharge zone;
- storage parameters (specific yield and specific storage); and
- conductance of the river bed (representing the wetland).

6.7.4 Steady state calibration data points

The steady state calibration utilised 43 bores with measured groundwater levels representative of the dry season conditions. Table 6.3 shows the average measured water levels and the level simulated by the groundwater model for model steady state calibration.

Bore ID	Layer	Easting	Northing	Groundwate	Difference	
		(GDA94 z55)	(GDA94 z55)	Observed	Simulated	(m)
BH307	1	612,793	7,798,556	0.74	0.55	0.19
BH314	1	613,081	7,799,076	0.80	0.59	0.21
BH315	1	613,100	7,799,373	0.77	0.47	0.30
BH316	1	613,077	7,800,682	0.79	1.01	-0.22
BH327	1	611,909	7,798,493	0.21	0.48	-0.27
BH330	1	612,059	7,799,432	0.22	0.66	-0.44
BH332	1	612,207	7,799,913	0.41	0.89	-0.48

Table 6.3Steady state calibration results

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Bore ID	Layer	Easting	Northing	Groundwate	Difference	
		(GDA94 z55)	(GDA94 z55)	Observed	Simulated	(m)
BH335	1	612,540	7,798,999	0.86	0.54	0.32
BH337	1	612,060	7,799,046	0.37	0.73	-0.36
BH342	2	611,730	7,800,274	0.10	0.16	-0.06
BH343	1	611,796	7,799,290	0.30	0.61	-0.31
BH345	1	611,910	7,800,030	0.18	0.60	-0.42
CPT245	1	611,797	7,798,751	-0.14	0.34	-0.48
GW01	3	611560	7800352	0.95	0.77	0.18
GW02	3	611909	7800111	0.92	0.75	0.17
GW03	2	612305	7799993	0.81	0.65	0.16
GW04	2	612318	7799481	0.79	0.58	0.21
GW05	2	612317	7798996	-0.14	0.49	-0.63
GW06	2	613129	7800342	0.23	0.40	-0.17
Site 1	2	611,104	7,798,594	0.46	0.17	0.29
Site 2	2	610,836	7,799,154	-0.22	-0.05	-0.17
Site 3	2	612,307	7,799,980	0.40	0.75	-0.35
Site 4	3	611,487	7,800,268	0.57	0.15	0.42
Site 5	3	611,893	7,800,032	0.46	0.40	0.06
Site 6	3	611,946	7,799,423	-0.01	0.65	-0.66
Site 7	3	611,490	7,798,908	0.03	0.25	-0.22
Site 8	3	611,840	7,798,455	0.12	0.44	-0.32
Site 9	2	610,717	7,799,965	0.12	0.45	-0.33
Site 10	2	611,213	7,799,720	0.01	0.17	-0.16
Gol_1A	2	611,339	7,798,682	-0.07	0.38	-0.45
Gol_1B	3	611,339	7,798,682	-0.10	0.38	-0.48
Gol_5A	2	611,517	7,800,280	-0.11	0.01	-0.12
Gol_5B	3	611,517	7,800,280	0.48	0.01	0.47
Gol_8A	2	610,747	7,799,097	-0.06	-0.06	0.00
Gol_8B	3	610,747	7,799,097	-0.22	-0.06	-0.16
Gol_9A	3	610,905	7,798,685	0.02	-0.07	0.09
Gol_9B	3	610,905	7,798,685	-0.08	-0.07	-0.01
Gol_10A	3	610,989	7,799,589	-0.18	-0.03	-0.15
Gol_10B	3	610,989	7,799,589	-0.18	-0.03	-0.15
60138	1	604,490	7,792,603	4.70	5.93	-1.23
60140	1	605,020	7,793,646	2.55	3.11	-0.56
60150	1	604,574	7,791,988	6.20	7.64	-1.44
153652	1	609,645	7,791,335	21.6	27.65	-6.05

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6.7.5 Steady state calibration results

Table 6.3 compares the observed and simulated groundwater levels from the steady state calibration. Figure 6.4 presents the data graphically as a scattergram.

An objective method to evaluate the calibration of the model is to examine the statistical parameters. One such method measures the error between the modelled and observed water levels. The root mean square (RMS) below is the best measure of error, if errors are normally distributed.

$$RMS = \left[1/n \sum (h_o - h_m)_i^2 \right]^{0.5}$$

Where *n* is number of measurements, h_o is observed water level and h_m is simulated water level. The RMS error calculated for the calibrated model is 1.02. The maximum acceptable value for the calibration criterion depends on the magnitude of the change in heads over the model domain. If the ratio of the RMS error to the total head loss in the system is small, the errors are only a small part of the overall model response (Anderson and Woessner, 1992).

The steady state calibration produced a scaled RMS of 4.66 %. The Australian guidelines has suggested a target SRMS of 5% to 10% depending on the type of the problem or environment (Barnett et al, 2012). Therefore, the calculated SRMS indicates an acceptable level of calibration.



Figure 6.4 Steady state calibration – modelled vs observed groundwater levels

6.7.5.1 *Calibrated steady state water budget*

Table 6 4

The difference between calculated model inflows and outflows at the completion of the steady state simulation (expressed as a percentage of discrepancy) was 0.01%. This mass balance error indicates that the model was very stable with an accurate numerical solution. Table 6.4 summarises the steady state model water budget.

Table 6.4	Water budget – stea	dy state model	
Parameter	In (ML/day)	Out (ML/day)	In - Out (ML/day)
Constant head boundary	0.20	0.02	0.18
Recharge	0.26	0.00	0.26
Evapotranspiration	0.00	1.17	-1.17
River leakage	0.80	0.06	0.74
Totals	1.26	1.25	0.01

- The water budget indicates on average during the dry season there is:
 - 0.26 ML/day of water entering the groundwater system as diffuse rainfall recharge; ٠
 - 0.8 ML/day entering the groundwater system through major creeks while 0.06 ML/day ٠ discharging to surface drainages;
 - 0.02 ML/day discharging to the ocean while 0.2 ML/day entering from the ocean; and •
 - 1.17 ML/day of water leaving the groundwater system through evapotranspiration when the • water table is within 1 m of the ground surface.

6.7.6 Transient calibration data points and results

A total of 13 monitoring bores were used to calibrate the transient model. Figure 6.5 to Figure 6.8 show the transient calibrated hydrographs for Site 4, Site 8, GW01 and GW04. The hydrographs for all 13 transient calibration bores are shown in Appendix E. The hydrographs show that the model simulates the water level trends well in all of the bores. However, the calibration could not reproduce the climate-induced peaks in some of the bores such as GW04.







Figure 6.6 Calibration hydrograph- Site 8



Figure 6.7 Calibration hydrograph- GW01



Figure 6.8 Calibration hydrograph- GW04

The RMS error calculated from the unweighted data points for the transient calibrated model is 0.5 m. The scaled RMS for the modelled and observed water levels is 13 % for the transient calibration. This result is slightly higher than the model guidelines recommend, however when the simplifying assumptions are considered (where the real world heterogeneity at site is lumped together and described by uniform hydraulic parameters and recharge rates), then the result is acceptable.

Table 6.5 presents the average water budget from the transient model.

	Parameter	In (ML/day)	Out (ML/day)	In - Out (ML/day)		
	Constant head boundary	0.18	0.08	0.10		
	Recharge	1.64	0.00	1.64		
	Evapotranspiration	0.00	2.39	-2 39		
	River leakage	0.89	0.18	0.71		
	Totals	2.71	2.65	0.06		

Table 6.5Average groundwater budget - Transient model (ML/day)

For each time step, the mass balance error is less than 2% and the cumulative mass balance error across the transient model is 0.02%, which indicates an accurate numerical solution that is within limits recommended by Barnet et al (2012).

6.7.7 Hydraulic heads

Figure 6.9 shows the transient calibrated groundwater level contours for model Layer 1 representing the surficial silty sands and outcrop areas where they occur and model Layer 3 representing the deeper silty sands. The heads reflect the groundwater flow regime. Where present, the groundwater level within Layer 1 generally follows the surface topography. The major creeks act as groundwater discharge locations in the model. The predicted groundwater levels in Layer 3 also generally follow the surface topography but have a muted flow pattern and elevation to that of Layer 1.



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6.8 Model predictions

The aim of the modelling was to identify the impacts to the groundwater regime from onshore placement of dredge material. The assessment also examined the influence of a low permeability liner through the upper sand (Layer 1) and clay layers (Layer 2). This liner would mean the effective DMCP base is the top of the lower sandy layer (Layer 3).

6.8.1 Simulation of the DMCP

The groundwater model did not directly represent the DMCP structure and dredged material, rather the effect of the DMCP, being additional recharge through seepage was simulated. The seepage was represented in the model through additional recharge across the DMCP footprint using the river package.

It is understood that during operations the free draining water from the dredged material within the DMCP will be pumped back to the ocean. This will reduce the volume of seawater available for seepage to the underlying aquifers. The exact amount of water removed directly from the DMCP is unknown at this stage. The model represented placement of dredged material and discharge of "excess" water by setting a river package boundary condition across the DMCP footprint to represent the pond operating level and seepage conductance equivalent to the deposited dredged material. The maximum operating level for the DMCP was set at 7.4 mAHD and seepage conductance set at 0.86 m/day based on the expected permeability value of 1×10^{-5} m/s for the deposited dredged material (Golder Associates, email correspondence dated 29 May 2015).

Removal of excess water within the DMCP is expected to continue for a short period of time after dredging is complete. To simulate this removal of water, the evaporation boundary condition was reapplied to the DMCP footprint with an evaporation surface equivalent to the proposed final landforms (at 6.4 mAHD).

6.8.2 Transient model setup

A transient groundwater flow model was used to represent the filling of the DMCP for the different wet and dry climate conditions. The model used the water levels from the end of the calibrated transient model as starting heads. When a transient simulation was started from this condition, it was run until a new equilibrium was established for each climate condition prior to applying the DMCP seepage. The model run was then continued for a further eight years using the same climate condition to simulate migration of any available seepage away from the DMCP footprint post dredging.

6.8.3 Prediction scenarios

The climate plays an important part in the groundwater dynamics at the site with very distinct dry and wet seasons. The model was used to assess the impact of climate variability on the impacts with three specific climates. The datasets represented low, average and high rainfall periods respectively. Each scenario model was set up with one of these rainfall datasets, which was then repeated throughout the simulation period.

As discussed in Section 6.5.5, inclusion of a low permeability liner on the inside batter of the DMCP embankments was simulated with a horizontal flow barrier positioned around the perimeter of the DMCP in Layers 1 and 2 of the model. This approach assumed that the upper sand and clay layers were cut off from the DMCP by the liner, making the flow path out of the DMCP through the underlying sand layer (Layer 3). Table 6.6 summarises the simulations undertaken.

Table 6.6Simulation summary						
Simulation	Rainfall	Condition	Figure number			
Layers 1 and 3	Low	End of dredging	Figure 6.10, Figure 6.11			
Layers 1 and 3	High	End of dredging	Figure 6.12, Figure 6.13			
Layers 1 and 3	Low	Six months post dredging	Figure 6.10, Figure 6.11			
Layers 1 and 3	High	Six months post dredging	Figure 6.12, Figure 6.13			
Layers 1 and 3	Low	One year post dredging	Figure 6.10, Figure 6.11			
Layers 1 and 3	High	One year post dredging	Figure 6.12, Figure 6.13			
Layers 1 and 3	Low	Three years post dredging	Figure 6.10, Figure 6.11			
Layers 1 and 3	High	Three years post dredging	Figure 6.12, Figure 6.13			

To determine the change in the groundwater regime (mounding) due to the DMCP, another three model simulations were undertaken which did not simulate the DMCP ('no-pond' scenario), and thus provided a baseline for determining changes in seepage for each scenario.

6.8.4 *Changes to the groundwater regime due to the DMCP seepage*

A key impact on the groundwater regime is increased groundwater levels due to seepage from the DMCP. This results in a temporary mounding of groundwater levels, the extents of which are shown in Figure 6.10 to Figure 6.14 and summarised in Table 6.7. The groundwater mound contours represent the difference between the increased groundwater level and that predicted without inclusion of the DMCP (i.e. 'no-pond' scenario).

Circulation	Height of mounding (m)			Extent of mounding (m)		
Simulation	Kaiman	No HFB ¹	With HFB ¹	No HFB ¹	With HFB ¹	
Layer 1, end of dredging	Low	6.8	6.8	150-300	100-200	
Layer 3, end of dredging	Low	7	7	300-1,100	300-1,100	
Layer 1, end of dredging	High	5.5	5.5	100-400	150-400	
Layer 3, end of dredging	High	6	6	300-1,150	300-1,150	
Layer 1, 6 months post dredging	Low	4.5	5	200-400	200-400	
Layer 3, 6 months post dredging	Low	4.5	5	350-1,050	400-1,050	
Layer 1, 6 months post dredging	High	2.5	3.5	150-850	200-850	
Layer 3, 6 months post dredging	High	3	3.5	350-800	350-900	
Layer 1, 1 year post dredging	Low	3	4.5	100-600	200-650	
Layer 3, 1 year post dredging	Low	3	4.5	400-1,100	450-1,150	
Layer 1, 1 year post dredging	High	2	3	50-850	250-850	

Table 6.7Extent of temporary groundwater mounding

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Cimulation	Deinfall	Height of mo	unding (m)	Extent of mounding (m)	
Simulation	No HFB ¹		With HFB ¹	No HFB ¹	With HFB ¹
Layer 3, 1 year post dredging	High	2	3.5	300-700	350-900
Layer 1, 3 years post dredging	Low	2	2.5	50-400	150-650
Layer 3, 3 years post dredging	Low	2	2.5	200-1,000	400-1,100
Layer 1, 3 years post dredging	High	1	1.5	100-600	200-850
Layer 3, 3 years post dredging	High	1	1.5	50-150	450-650

Note: HFB – horizontal flow barrier (i.e. low permeability membrane)

The simulations that include the horizontal flow barrier representing the low permeability liner along the DMCP internal batters, show less mounding occurring immediately beyond the DMCP footprint in the surficial layer. That is, the lined batters restrict horizontal flow through the upper sandy layer (Layer 1). The seepage flow path from the DMCP is therefore horizontally through the underlying sand layer (Layer 3). Due to the upward head gradient between Layers 3 and 1, water moves upwards into Layer 1 at a rate limited by the intervening upper clayey layer (Layer 2) outside of the DMCP footprint.

The figures show the mounding occurs principally within Layer 3 and extends upwards into Layer 1. The extent of this mounding is therefore greater in Layer 3 extending some 300m to 1,150m from the DMCP depending on the rainfall condition.

Post dredging, the lateral extent of mounding predicted outside of the DMCP for Layer 1, increases as the mound gradually flattens and migrates away from the DMCP footprint. This is at its greatest extent six months post dredging when the groundwater mound extends some 750 m to the east and 850 m to the southeast, south of the railway loop.

Inclusion of the horizontal flow barrier representing the lined DMCP batters, results in an increased extent of groundwater mounding post dredging within Layer 3. This is due to a greater volume of seepage into Layer 3 as a result of the horizontal flow barrier restricting groundwater flow into Layer 1.

The height of the groundwater mound varies depending on the climate condition simulated. This is a function of different groundwater levels across the model domain for each climate condition. A wet climate condition will result in a higher background groundwater level compared to a dry climate condition. The maximum height of groundwater mounding occurs within the DMCP footprint but does not extend above the DMCP operating level.

Outside of the DMCP footprint, the groundwater mound in Layer 1 remains below the ground level, due mainly to evapo-transpiration processes, with no surface expression predicted. However, the model predicts groundwater mounding in Layer 3 that is higher than the ground surface, but not extending upwards through Layers 2 and Layer 1. This is due to the predicted groundwater level in Layer 3 being confined beneath the upper clayey layer represented as Layer 2 in the model. That is, the groundwater within Layer 3 is pressurised because of the overlying Layer 2 (upper clayey layer) limiting hydraulic connection through these upper sedimentary units. This pressure head within Layer 3 is referred to as a potentiometric surface. The extent of this groundwater potentiometric surface is at its greatest extents at the end of dredging, and is shown where this occurs above the ground surface in Figure 6.14. The maximum height of this potentiometric surface above the ground surface is greatest at the end of dredging (3.6 m) and declines to 0.5 m three years post dredging.

Hence, where the upper clay layer (Layer 2) is present and exists above the lower sandy layer (Layer 3), the groundwater mounding predicted in Layer 3 is not anticipated to result in any surface expression above the ground surface.

With liner - End of dredging



No liner - End of dredging





Six months post dredging







1 year post dredging





DMCP horizontal flow barrier representing liner

LEGEND

----- Mounding contour (m) Caley Valley wetland (GHD 2012)

3 years post dredging



3 years post dredging

Abbot Point (G1702B)

Predicted groundwater mounding -Layer 1, low rainfall, with and without liner .







No liner - End of dredging



GDA94, Zone 55 1:1 (When printed at A3)





Six months post dredging

0



1

2 Km



1 year post dredging





LEGEND DMCP footprint ----- Mounding contour (m) Caley Valley wetland (GHD 2012)

3 years post dredging

Abbot Point (G1702B)

Predicted groundwater mounding -Layer 3, low rainfall, with and without liner.







No liner - End of dredging









2 Km





1 year post dredging





LEGEND

----- Mounding contour (m)

Caley Valley wetland (GHD 2012)

3 years post dredging

3 years post dredging

Abbot Point (G1702B)

Predicted groundwater mounding -Layer 1, high rainfall, with and without liner.







No liner - End of dredging



GDA94, Zone 55 1:1 (When printed at A3) Six months post dredging

0



1

2 Km



1 year post dredging





LEGEND DMCP footprint Mounding contour (m) Caley Valley wetland (GHD 2012)

3 years post dredging



3 years post dredging

Abbot Point (G1702B)

Predicted groundwater mounding -Layer 3, high rainfall, with and without liner.





6.8.5 Groundwater seepage from the DMCP

Table 6.8 shows model predicted groundwater seepage out of the base of the DMCP into the underlying sandy layer (Layer 3). This is represented for the lined DMCP scenario for dry and wet climate conditions. The pulse of groundwater flow in the first week of operation represents the initial filling of the unsaturated zone under the DMCP footprint. Thereafter from the second week onwards, the predicted seepage rate declines to quasi steady state conditions once this zone becomes saturated.

Period (week)	Seepage rate(ML/week)					
Week	Low rainfall condition	High rainfall condition				
1	70.3	53.0				
2	5.7	4.8				
3	5.4	4.6				
4	5.2	4.4				
5	5.0	4.3				
6	4.8	4.2				
7	4.7	4.1				
8	4.6	4.0				
9	4.5	3.9				
10	4.4	3.8				
11	4.3	3.8				
12	4.2	3.7				
13	4.2	3.6				
Total	127.3	102.2				

Table 6.8Predicted seepage from DMCP (with liner)

The maximum predicted seepage out of the proposed DMCP is 10 ML/day (70.3 ML/week) for a dry climate condition. This declines to around 0.5 ML/day at the end of dredging (high rainfall condition).

6.8.6 Impact of lining the DMCP wall

The previous sections indicate that lining the internal batter of the DMCP reduces the extent of the mounding in upper sandy layer (Layer 1) surrounding the DMCP, but does not reduce the flow of seepage to the underlying groundwater system (Layer 3). This is due to the base of the DMCP being constructed to the base of the upper clay layer (Layer 2), which is effectively the top of Layer 3. This is expected to be conservative in that a portion of the DMCP floor may not extend fully through the upper clay layer (Layer 2), in which case that portion would exhibit a lower seepage than has been simulated.

Table 6.9 shows the total predicted seepage from the DMCP for the period of dredging (13 weeks) for each simulated climate condition. The model predicts the total seepage from the unlined DMCP scenario to be at least three times that for the lined scenario for each climate condition.

Table 6.9Comparison of predicted seepage for lined vs unlined DMCP

Option/Condition	Total seepage for 13 week dredging period (ML)		
Unlined Option			
Low rainfall condition	383.1		
Average rainfall condition	354.6		
High rainfall condition	333.3		
Lined Option			
Low rainfall condition	127.3		
Average rainfall condition	105.3		
High rainfall condition	102.2		

Seepage from the DMCP extends to the south and west towards the wetlands principally as flow within Layer 3. This is greatest at the end of dredging, for the dry climate condition when higher groundwater gradients occur. A worst case estimation of the cumulative volume of seepage that could potentially report to the wetlands south and west of the DMCP at the end of dredging is summarised in Table 6.10. This has been determined pro rata, based on the perimeter of the DMCP adjacent to wetland, and indicates up to 26 ML of seepage reports to the south, and 40 ML to the west into the wetlands.

Table 6.10 Cumulative seepage towards Caley Valley Wetlands to end of dredging

Seepag	e southwar	ds (ML)	Seepage westwards (ML)			
High rainfall	Average rainfall	Low rainfall	High rainfall	Average rainfall	Low rainfall	
20.7	21.3	25.8	32.2	33.2	40.1	

Note: Seepage volumes are cumulative of the 13 weeks dredging period

These seepage volumes do not take into consideration losses attributable to evapo-transpiration processes or seepage retained as pore water within the aquifer. As such, they are considered an upper end volume for seepage that could potentially report to these parts of the wetlands.

6.9 Salinity Transport

The potential change in water quality was predicted by modelling salinity transport from seepage out of the DMCP during and post dredging. Factors influencing change in solute concentration in groundwater include advection, dispersion, retardation, degradation and chemical reactions. The transport simulation was conducted assuming that only advection and dispersion would affect the movement of salinity. Since salinity is a stable solute, this assumption is appropriate and is widely used worldwide. Retardation, degradation and chemical reactions were not simulated as these are not considered to have significant impacts on the transport of salinity in groundwater.

Advection is the process by which solutes are transported at the same velocity as the groundwater. For many field-scale contaminant transport problems, the advection process dominates over other terms. Dispersion refers to the spreading of contaminants over a greater region than would be predicted solely from the average groundwater velocity.

Current (pre-dredging) salinity concentrations vary across the model domain as summarised in Section 4.6.1 and Section 4.6.3. The source for the variation observed in the shallower groundwater is not clearly understood, and as such it is difficult to reproduce the complex distribution of salinity concentrations through calibration of the transport model. Without continuous solute sources to maintain the concentration distribution, any interpolated initial concentration over the model domain would increase uncertainty in the simulation results and could alter the shape of contaminate plume. As such, the transport model for this assessment was not calibrated, rather a uniform, initial concentration value of 5,000 mg/L was assigned across the model domain at the start of dredging assumed to be in the dry season.

6.9.1 Predictive salinity transport simulations

The salinity transport modelling simulated inclusion of the DMCP over a 13 week period of operation coinciding with a dry (season) period. During this time, a constant head was maintained within the DMCP footprint, being the source of seawater quality seepage (at 34,500 mg/L – TDS value) into the underlying groundwater receiving environment, represented as Layer 3. On completion of dredging, the DMCP remains in place with the residual seawater seepage continuing to report to Layer 3 post dredging. That is, no rehabilitation or removal of the DMCP or associated dredged material is considered post-dredging.

The salinity transport simulation shows saline water enters the groundwater beneath the DMCP footprint, and migrates radially outwards away from the DMCP. The extents of the resultant saline water plume is shown in Figure 6.15 and Figure 6.16 and summarised in Table 6.11.

As discussed in Section 6.8.4, evapotranspiration maintains the groundwater levels below the ground surface in Layer 1. Eight years post dredging the saline plume extends up to 700 m within Layer 1, principally towards the west and south, and to a lesser extent to the north and east. Evaporative concentration predicts salinity concentrations up to 70,000 mg/L within the DMCP footprint, six months post dredging.

Within Layer 3, the radial migration of saline water is more pronounced, extending between 300 m and 700 m beyond the DMCP footprint eight years post dredging. Lower salinity concentrations are predicted, ranging from 40,000 mg/L at the end of dredging to 20,000 mg/L after eight year post dredging.

Time	Lavon	Maximum sa	linity (mg/L)	Extent of plume (m)		
Time	Layer	Low rainfall	High rainfall	Low rainfall	High rainfall	
Start of dredging	1	35,000	35,000	0	0-50	
Start of dredging	3	30,000	25,000	25-75	0-50	
End of dredging	1	40,000	40,000	0-200	0-150	
End of dredging	3	40,000	30,000	150-200	100-150	
6 months post dredging	1	70,000	70,000	0-250	150-200	
6 months post dredging	3	35,000	30,000	200-300	200-250	
1 year post dredging	1	40,000	35,000	0-350	250-350	
1 year post dredging	3	35,000	30,000	250-350	250-350	
3 year post dredging	1	25,000	25,000	0-500	0-500	
3 year post dredging	3	25,000	20,000	300-500	300-500	
8 year post dredging	1	25,000	20,000	0-700	0-700	
8 year post dredging	3	25,000	20,000	300-650	300-700	

Table 6.11Transient simulation of salinity plume within groundwater receiving
environment

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Changes in salinity concentration with time for the low and high rainfall conditions are presented graphically in Figure 6.18 to Figure 6.20 for four key locations around the DMCP. These effectively show the predicted range of salinity concentration at locations east, south and west of the DMCP within the T1, T2 and T3 areas. Following commencement of dredging, salinity levels within Layer 3 adjacent to the DMCP increase relatively rapidly in response to seepage of seawater from the dredged material. This continues until concentrations generally stabilise between 15,000 mg/L and 20,000 mg/L. The timing for the stabilising of concentration is dependent on the distance from the DMCP. For example, Site 6 and MW04 are predicted to stabilise approximately five years post dredging, but will take longer further from the DMCP as observed for Site 8.

As discussed in Section 6.8.4, the extent and height of the groundwater mound dissipates beyond three years post dredging. After this time, the transport regime will change from that dominated by advective transport to a regime driven by dispersion. That is beyond three years post dredging, the resultant groundwater gradient will be insufficient to enable continued discharge of the higher salinity groundwater away from the elevated topography (beneath the DMCP footprint) towards the wetlands as discussed in Section 4.5. However, dispersion will continue to alter salinity based on the concentration gradient, but this process will be slow and salinity concentrations are predicted to persist.



Figure 6.17 Predicted salinity concentrations in Layer 3 – Site 6



Figure 6.18 Predicted salinity concentrations in Layer 3 – Site 8



Figure 6.19 Predicted salinity concentrations in Layer 3 – East of DMCP



Figure 6.20 Predicted salinity concentrations in Layer 3 – MW04

6.10 Model sensitivity analysis

Sensitivity analysis evaluates the effects of model parameters on model results, and provides information on the degree to which the adopted values for the various parameters in the model influence the calibration and predictions. It can provide an indication of the uncertainty in the results and guide future data collection to reduce this uncertainty.

Parameter sensitivity on the calibration and prediction period was explored through additional model simulations by varying specified model parameters for the lined DMCP option and an average rainfall condition. The parameters selected were those considered to be particularly sensitive to impacts from changes in groundwater discharge and resultant mounding around the DMCP. The sensitivity analysis assessed changes to the following parameter ranges:

- ± half order of magnitude change in horizontal and vertical hydraulic conductivity;
- ± half order of magnitude change in vertical hydraulic conductivity;
- ± half order of magnitude change in horizontal hydraulic conductivity;
- ± one order of magnitude change in specific storage of all model layers;
- ± 50 % change in specific yield of all model layers; and
- ± 50 % change in recharge.

The ranges adopted above are considered to be within the variation for these parameters that could occur across the model domain. Where available, this is supported by the range in field measurements provided from the monitoring bores (e.g. permeability testing for hydraulic conductivity).

6.10.1 Calibration statistics

Table 6.12 summarises the sensitivity of the steady state calibration statistics to changes in the model parameters. A reduction in horizontal and vertical conductivity showed the greatest change (54%) in SRMS.

Case	RMS (m)	SRMS (%)	SRMS Change
base case	1.02	4.66	-
recharge + 50%	1.18	5.40	16%
recharge - 50%	1.18	5.40	16%
horizontal and vertical hydraulic conductivity + 0.5 OM	1.18	5.39	16%
horizontal and vertical hydraulic conductivity – 0.5 OM	1.57	7.20	54%
horizontal hydraulic conductivity + 0.5 OM	1.16	5.30	14%
horizontal hydraulic conductivity – 0.5 OM	1.30	5.94	28%
vertical hydraulic conductivity + 0.5 OM	1.18	5.41	16%
vertical hydraulic conductivity – 0.5 OM	1.35	6.20	33%
specific yield + 50%	1.02	4.66	0%
specific yield - 50%	1.02	4.66	0%
specific storage + 1 OM	1.02	4.66	0%
specific storage - 1 OM	1.02	4.66	0%

Table 6.12 Steady state calibration sensitivity statistics

Note: % – percentage compared to baseline

Table 6.13 summarises the change in transient calibration statistics resulting from the change in parameters.

Table 6.13 Transient calibration sensitivity statistics

Case	RMS (m)	SRMS (%)	SRMS Change
base case	0.47	13.50	-
recharge + 50%	0.62	17.82	32%
recharge - 50%	0.56	16.07	19%
horizontal and vertical hydraulic conductivity + 0.5 OM	0.67	19.31	43%
horizontal and vertical hydraulic conductivity – 0.5 OM	0.56	16.20	20%
horizontal hydraulic conductivity + 0.5 OM	0.58	16.61	23%
horizontal hydraulic conductivity – 0.5 OM	0.55	15.93	18%
vertical hydraulic conductivity + 0.5 OM	0.54	15.39	14%
vertical hydraulic conductivity – 0.5 OM	0.49	14.18	5%

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Case	RMS (m)	SRMS (%)	SRMS Change
specific yield + 50%	0.48	13.65	1%
specific yield - 50%	0.48	13.81	2%
specific storage + 1 OM	0.51	14.76	9%
specific storage - 1 OM	0.48	13.65	1%

Note: % – percentage compared to baseline

For transient calibration, a half order of magnitude reduction in horizontal hydraulic conductivity, \pm 50 % change in specific yield, and one order of magnitude reduction in specific storage had little influence on the RMS and SRMS change (being 5% or less). However, changes to the other parameters resulted in RMS and SRMS change between 9% and 43%, with change in vertical and horizontal hydraulic conductivity (together) having the greatest impact on the calibration statistics. This magnitude of change resulted in a reduction in the level of calibration, and is therefore considered less plausible.

Table 6.13 indicates the model is most sensitive to those parameters having a SRMS change greater than 20%. During the calibration process these most sensitive parameters were largely constrained by either field measurements or published data and are considered within a realistic range in the model.

The model was relatively insensitive to changes in specific yield and specific storage and remaining calibrated when these parameters were changed. Whilst this is a good outcome it is also important to note that non-unique solutions can occur for these parameters.

Table 6.14 shows the results of the sensitivity analysis on the predicted groundwater seepage from the base of the DMCP for each sensitivity simulation for the lined DMCP scenario and average climate condition. The greatest change resulted from a half order of magnitude increase in the vertical and horizontal hydraulic conductivity values which resulted in a 100% increase in seepage.

Both an increase and decrease in recharge and specific storage resulted in small changes (<20%) in the seepage rate, while an increase in the vertical and horizontal hydraulic conductivity separately or together provided more significant changes to predicted seepage (14%-100%). It should again be noted that some of these changes in hydraulic properties uncalibrate the model and the seepage values shown in the table are improbable extremes.

Case	Seepage rate(ML/week)	Change in seepage rate
Base case	105.3	-
recharge + 50%	104.9	0%
recharge - 50%	118.3	12%
horizontal and vertical hydraulic conductivity + 0.5 OM	210.1	100%
horizontal and vertical hydraulic conductivity – 0.5 OM	71.4	32%
horizontal hydraulic conductivity + 0.5 OM	172.5	64%
horizontal hydraulic conductivity – 0.5 OM	77.2	27%
vertical hydraulic conductivity + 0.5 OM	132.5	26%

Table 6.14 Total predicted seepage from DMCP (with liner) - sensitivity

Case	Seepage rate(ML/week)	Change in seepage rate
vertical hydraulic conductivity – 0.5 OM	90.1	14%
specific yield + 50%	153.5	46%
specific yield - 50%	76.3	28%
specific storage + 1 OM	123.8	18%
specific storage - 1 OM	99.8	5%

6.10.2 Groundwater mounding

The changes in aquifer parameters also resulted in variation in the predicted extent of groundwater mounding. Figure 6.21 shows the predicted extent of the 1 m contour groundwater mounding for the average rainfall condition, at the end of dredging and one year post dredging. As discussed in Section 6.8.4, the 1 m groundwater mound contour represents the difference between the increased groundwater level and that predicted without inclusion of the DMCP. This shows the extent of mounding is close to the basecase for most of the scenarios, with only changes to either vertical or horizontal hydraulic conductivity resulting in significant changes to the 1 m or more mounding zone. These changes to horizontal and vertical hydraulic conductivity do result in an uncalibrated model, and as such present an improbable extreme extent of mounding.

6.10.3 Sensitivity classification

The Murray Darling Basin Modelling Guidelines (MDBC, 2000) recommends classifying sensitivity by the resultant changes to the model calibration and predictions. The four sensitivity types are as follows:

- Type I: Insignificant changes to calibration and prediction;
- Type II: Significant changes to calibration insignificant changes to predictions;
- Type III: Significant changes to calibration –significant changes to predictions; and
- Type IV: Insignificant changes to calibration –significant changes to predictions.

Types I and II are of no concern as these sensitivities either have an insignificant impact on model predictions. Type III is only of concern for un-calibrated models. Types I to III are of no concern for the current assessment, as the model developed for the assessment is a calibrated, high complexity model.

Type IV is classed as 'a cause for concern' as non-uniqueness in a model input might allow a range of valid calibrations but the choice of value impacts significantly on a prediction (MDBC, 2000).

There are no Type IV parameters in the model, which provides confidence in the range of predictions. All parameters tested in this analysis were either Type I, II or III and thus of no concern.

Layer 3 - End of dredging



Specific yield + 50%

Specific yield - 50%

---- Specific storage + 1 OM

- Specific storage - 1 OM

Layer 3 - 1 year post dredging



Abbot Point (G1702B)

Extent of 1 m groundwater mounding, average rainfall, with liner- Sensitivity analysis

DATE 8/07/2015 FIGURE No:

6.21

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- Recharge - 50%

--- Horizontal and vertical conductivity + 0.5 OM

- Horizontal and vertical conductivity - 0.5 OM

- Horizontal conductivity + 0.5 OM

6.11 Model assumptions and limitations

The generation of a numerical flow model requires the real world conditions be simplified through discretisation. Where possible, when simplifying assumptions were required conservative parameters were adopted. The necessary simplifying assumptions used in this numerical model included:

- representing the coastal boundary condition as a constant water level (fixed head boundary) at mean sea level;
- defining stress periods in the model at a monthly level this means that tidal influences could not be represented;
- fixing water levels in the wetland ranged from 1.0 mAHD (dry climate condition) to 1.4 mAHD (wet climate condition);
- turning off evaporation on the wetland during the wet season;
- assigning pre-dredging salinity concentrations in the transport model as a uniform, initial concentration value of 5,000 mg/L across the model domain; and
- the relative densities of the waters moving into, around, and out of the groundwater regime have not been considered the reported salinity measurements indicate that density dependent flow occurs within the aquifers.

The proportion of water decanted from the DMCP was not known and it was assumed the water level within the DMCP remained at the maximum operating level for the duration of dredging.

There has been no adjustment for seepage rates resulting from the consolidation of the dredged material and silting of the bed sediments within the DMCP footprint. As such, the predicted seepage from the DMCP provides a conservative estimate in terms of impacts on the underlying groundwater regime.

While the recharge rate has been calibrated, it still contains an element of uncertainty.

7 Groundwater issues and potential impacts on Caley Valley Wetland

A review of the existing reports in relation to the dredged material sediment quality was undertaken to determine indicative dredged (tail) water quality data that could be expected to be associated with the dredged material. This review was undertaken by Terrenus Earth Sciences (Terrenus) on behalf of AGE. The aim of this review was to understand the potential geochemical impacts that dredged material may have on the DMCP and the nearby, surrounding receiving environment.

The reports reviewed included the following documents provided by WorleyParsons:

- Dredged material sampling, analysis and implementation
 - GHD (2012b). Abbot Point, Terminals 0, 2 and 3 Capital Dredging. Sediment Sampling and Analysis Plan. Consultant report 41/23701/11/430551 prepared for North Queensland Bulk Ports Corporation, April 2012. [Appendix A of GHD 2012c and Appendix G of GHD 2012e]
 - GHD (2012c). Abbot Point, Terminals 0, 2 and 3 Capital Dredging. Sediment Sampling and Analysis Plan Implementation Report. Consultant report 41/23742/19/427956 prepared for North Queensland Bulk Ports Corporation, July 2012. [Appendix G of GHD 2012e]

- Dredged material placement options
 - GHD (2012d). Report for Abbot Point, Terminals 0, 2 and 3 Capital Dredging Project -Dredged Material Relocation and Reuse Options Assessment. Consultant report 41/24541/04/435219 prepared for North Queensland Bulk Ports Corporation, July 2012. [Appendix E of GHD 2012e]
- Dredged material (sediment) and seawater quality
 - GHD (2012e). Abbot Point, Terminal 0, Terminal 2 and Terminal 3 Capital Dredging. Public Environment Report (EPBC 2011/6213/GBRMPA G34897.1). Consultant report 41/24541/07 prepared for North Queensland Bulk Ports Corporation, December 2012.
 - Chapter 3. Environmental Values, Potential Impacts and Mitigation
 - Section 3.4 Sediment and Water Quality and Marine Ecology
 - Section 3.4.1. Description of Sediment Quality Values
 - Section 3.4.2. Description of Water Quality Values
- Potential receiving environment (Caley Valley Wetlands)
 - BMT WBM (2012). Kaili (Caley) Valley Wetlands Baseline Report. Consultant report prepared for Office of the Coordinator General: Department of State Development, Infrastructure and Planning. February 2012.

7.1 Dredged material sample collection, description and number of samples

7.1.1 Sample collection

Sea bed sediment samples were collected from the dredging area (using a vibracorer) in 0.5 m intervals from seafloor (0 m) to the required depth or until refusal. GHD (2012e) make an assumption that potentially contaminated material was probably limited up to 1 m below the seabed surface (mbss). As such, most analyses were within the upper 0 to 1 mbss. Samples for particle size distribution (PSD), nutrients and metals/metalloids were analysed in deeper sediments to 0.5 m below the proposed dredging depth (where refusal was not encountered). Samples for acid sulphate soil (ASS) assessment were collected to 1 m below the proposed dredging depth (where refusal was not encountered).

The 'proposed dredging depth' is about 20 m to 21 m below the lowest astronomical tide (LAT; *i.e.* - 20 m to -21 m LAT). The current seafloor elevation at the proposed dredging area ranges from about - 17 m to -20 m LAT. Therefore, approximately 0.5 m to 4 m thickness of sediment is expected to be dredged (dredging thickness is not uniform throughout the dredging area).

7.1.2 Sample description

The following description is paraphrased from GHD (2012e):

- Samples generally comprised a mixture of terrigenous sandy clay, clayey sand or silty clay. The predominant sediment type was fine to medium sand.
- Clay content typically increased with depth, largely typifying lithology beyond 1.5 mbss. Sediments were typically wet and loose near the surface of the seabed, grading to moist with depth. Consistency of clays varied from very soft to very stiff, with increasing stiffness with depth, which caused the majority of core refusals.
- Shell grit was encountered throughout the majority of the sediment cores, particularly near the surface, with occasional lenses of whole and broken shells, coral pieces and terrestrial gravels.

- Overall, these visual observations indicate that natural residual geologic materials (as opposed to recently transported geologic materials) are present below 0.5 to 1 m.
- Cores showed low variability among sampling locations and the increase of clays from the underlying geology of sediment below 1 m was relatively homogenous throughout the dredge area.
- Dredge material has the following average PSD (GHD, 2012e: Table 3-5). PSD was measured using both freshwater (standard test) and seawater. The results suggest that seawater acts as a flocking agent, causing the clay fraction to fall out of suspension over a short period of time.

Results of PSD analysis undertaken by GHD are presented in Table 7.1.

Particle size	Average PSD (%) (using freshwater)	Average PSD (%) (using seawater)
Cobbles (>6 cm)	0	0
Gravel (2 mm – 6 cm)	7.7	5.2
Sand (60 µm – 2.0 mm)	54	52
Silt (2 μm – 60 μm)	19	43
Clay (<2 μm)	20	<1

Table 7.1Particle size distribution analysis

7.1.3 Number of samples

GHD (2012e) provide summary statistics for the geochemical data collected from the dredging area. The total number of sampling sites (within the dredging area) and total number of samples collected by all consultants based on the summary data indicates over 170 sites have been sampled with approximately 1 to 5 samples collected from each site – therefore it appears that well over 200 samples have been collected in total. Not all samples underwent analysis for the same parameters - the number of analytical results for the various parameters ranged from 10 to 216 results per parameter. The sampling density and the number of samples collected and analysed would be considered sufficient to understand the geochemical characteristics of the dredged material sediments.

7.2 Analytical tests

The sampling and analytical program is presented at length by GHD (2012b; 2012c) and is of an appropriate high standard. Detailed information is provided regarding sampling methods (including rationale for selecting sampling locations), sampling QA/QC (including duplicate and triplicate samples and field blanks), analytical methods appropriate for the sample types and the analytical detection limits required (NATA accredited methods were used where applicable) and appropriate laboratory and analytical QA/QC.

7.3 Geochemical characteristics of dredged material

7.3.1 Potential acid generation

The potential for the dredged sediment to generate acid was assessed from 260 samples as outlined by the Queensland Acid Sulfate Soil Investigation Team (QASSIT, 1998). All 260 samples underwent 'standard' acid sulphate soil (ASS) tests of which 34 underwent additional suspended peroxide oxidation combined acidity and sulphur (SPOCAS) testing.

Most (92% of) samples had chromium reducible sulphide (Scr) concentrations above the 0.03% threshold 'action criteria' value established by QASSIT, however all samples had greater acid neutralising capacity (ANC) compared to actual acidity (TAA). The actual acidity was less than the practical quantification levels (PQLs) for all samples (<0.02% pyrite S) and the ANC ranged from 0.3%S to 18.5%S, with average and median values of 9.0 and 9.4% S, respectively. That is, on average the ANC was about nine times greater than the actual acidity. The neutralising capacity was considered likely due to the presence of shell and other calcareous materials throughout the sediment.

Based on these results, and due to the excess neutralising capacity in all samples, generation of low pH (acidic) conditions in the dredged material are unlikely. As such, there is no requirement for liming of the dredged material following exposure to oxidising conditions (as per the requirements outlined in QASSIT). The significantly greater proportion of neutralising capacity compared to actual acidity means that even if not all of the neutralising capacity was readily available, there should still be sufficient neutralising capacity available to buffer any acidity generated.

The results suggest that the dredged material has a low risk of developing acid drainage when exposed (deposited), and hence under the QASSIT guidelines there is no requirement to undertake liming of dredged material. However, monitoring of seepage/run-off water quality should be undertaken to confirm and validate these predictions.

7.3.2 Salt

The dredged material will be naturally saline, due to it being marine sediment. Whilst the salinity of the dredged material slurry is currently unknown, it is reasonable to assume that this slurry will have a salinity approximately equal with seawater (\sim 35,000 mg/L [\sim 53,000 µS/cm]). Most of this salinity is expected to be present in the liquid fraction (including pore water). However, once flushed with rainwater (over time), the dredged material will likely have an inherent salinity below seawater salinity.

7.3.3 Total metals and metalloids

Metals and metalloids were analysed for 122 samples, and the results compared against the National Assessment Guidelines for Dredging (NAGD, 2009) and the National Environment Protection (Assessment of Site Contamination) Measure (NEPM, 1999) environmental investigation levels (EIL). With the exception of manganese and arsenic concentrations in a few samples, all individual samples analysed in the dredging area for heavy metals and metalloids had concentrations less than NAGD screening levels and, where applicable, less than the NEPM EIL (GHD, 2012c).

With respect to manganese, four samples returned concentration values exceeding the NAGD screening levels, yet with concentrations less than the natural background level reported in NEPM. Similarly, the overall 95 % upper confidence limit was less than the NAGD screening level. Therefore, the overall manganese concentrations in the sediments were considered within naturally occurring background levels.

With respect to arsenic, a single sample (depth 0.5 to 1.0 mbss) reported a concentration of 29.6 mg/kg. This value exceeds the NAGD screening level (20 mg/kg) and NEPM (1999) EIL (20 mg/kg), but not the NAGD sediment quality high value (70 mg/kg) or the NEPM (1999) health-based investigation level A for standard residential use (HIL A) (100 mg/kg). Retesting of this sample in triplicate returned similar results, thereby validating the original result. The reasons for this elevated arsenic concentration are unknown, however, it could be related to a localised difference in geology at that location and hence reflect naturally occurring variation in background arsenic concentrations.

Heavy metal and metalloid concentrations from sampling depths deeper than 1.0 mbss demonstrated no discernible trend in concentrations, indicating homogeneity throughout the sediment profile for these analytes.

The results indicate that there is negligible heavy metal and metalloid concentrations within the dredging area (within likely/potential dredged material), as surface sediments and sediments at depth contained similar low metal and metalloid concentrations.

7.3.4 Organic compounds

Sixty-nine samples were analysed for benzene, toluene, ethyl benzene and xylenes (BTEX), organochlorine pesticides (OCP), organophosphorous pesticides (OPP), polychlorinated biphenyls (PCB), total cyanide and total petroleum hydrocarbons (TPH). Excluding TPH, the results for all 69 samples had concentrations either less than the NAGD screening levels or the PQL, suggesting there are no anthropogenic sources of these constituents at the dredging area. Concentrations of TPH were less than the NAGD screening levels, though low concentrations were detected in some surface samples. Further laboratory analysis suggested that the TPH concentrations were due to natural vegetative oils present in surface sediments.

Polycyclic aromatic hydrocarbons (PAH) were measured on 136 samples and, similar to the TPH results, all had concentrations less than the NAGD screening levels, though low concentrations were detected in some surface samples. The detected PAH concentrations may be due to some anthropogenic sources.

7.3.5 Soluble parameters (metals & metalloids, organic compounds, nutrients)

No solubility testing (e.g. bottle leaching or column leaching) has been undertaken for sediments within the dredging area, which is not surprising given the original proposal for offshore placement. Soluble data is only available for seawater (water samples). Despite this, the information provided above suggests that these sediments would not be expected leach significant concentrations of metals/metalloids or organic compounds. Any leachate would primarily be characterised by its salinity, which would be saline.

7.4 Seawater quality

Seawater samples from a number of locations near-shore and off-shore in the Abbot Point area were initially collected on several occasions by consultants between 2008 and 2014. These are reported in various documents (referenced in GHD, 2012e) and more recently in the baseline studies undertaken by WorleyParsons (2014). The key finding is that there is a high level of temporal variability in water quality conditions at Abbot Point, including seasonal and inter-annual variability, consistent with regional assessments of the water quality conditions of the Great Barrier Reef lagoon. A high degree of seasonality in rainfall in the Abbot Point region influences fluctuations in turbidity, total suspended solids (TSS) and salinity, whereby increased runoff and freshwater inputs result in increased suspended solids in the water column and reduced salinity and pH.

The marine water quality environment at Abbot Point is influenced by coastal (currents and waves) and fluvial processes (discharges from coastal rivers and creeks), as well as weather conditions. These processes contribute to significant temporal, and particularly seasonal, variation in water quality. Near-shore coastal environments are known to exhibit a high degree of temporal variability and to a lesser degree, spatial variability in water quality parameters, given the marked influence of waves, currents and local discharges from rivers and creeks within shallow coastal environments.

7.4.1 Spatial and temporal variability

The degree of spatial variation in levels of water quality conditions at Abbot Point was considerably less than the temporal variation. This suggests that the coastal waters of Abbot Point are well mixed under non-flood conditions, consistent with other coastal waters of the Great Barrier Reef. Lower spatial variation in some water quality parameters during the wet season are predominantly due to large inputs of freshwater masking site level variation in water quality.

7.4.2 Salinity

The salinity data exhibited small spatial variability with no strong seasonal variability observed. Average salinity levels for seawater ranged from 34,720 mg/L (52,290 μ S/cm) in the dry season to 34,720 mg/L (53,280 μ S/cm), during the dry season. The lowest salinity level of 32,850 mg/L (50,250 μ S/cm) was recorded in the wet season, whilst the highest level of 36,530 mg/L (55,320 μ S/cm) was also recorded during the wet season. An average seawater salinity value of 34,750 mg/L (~52,680 μ S/cm) was determined from the most recent baseline water quality data collected by WorleyParsons (2014).

There are no guidelines for salinity for comparison with recorded data. However, the salinity of seawater off Abbot Point is comparable to other areas of the Great Barrier Reef. A low degree of spatial variation in salinity indicates the waters of Abbot Point are well mixed under non-flood conditions.

7.5 Factors potentially influencing tail water quality from disposed material

Dredged material is expected to mostly comprise fine-grained sediments, generally in the range of clay to sand. A relatively small proportion of dredged material will likely comprise gravels and coarse sand-size particles, shell fragments, clay balls and harder (consolidated) sediment fragments. Seawater appears to act as a flocking agent, causing clay to fall out of suspension relatively quickly. Therefore, it is reasonable to assume that dredged tail water in the DMCP should contain relatively low clay content, with most clay remaining as a solid on the dredged pile.

Coarse materials can be expected to drain relatively easily, thus releasing saline water within days to weeks and also being flushed (over many years) by rainwater infiltration. Indicatively, materials comprising medium to coarse sand-size fractions will reduce the concentration of their starting salinity by about 70-90% within about five full pore volumes being flushed.

Column experiments on fine- to medium-grained saline estuarine sediments have shown that about three pore volumes of rainwater will reduce the salinity (in column leachate) to about 10-15% of its starting concentration. However, several more pore volumes of rainwater (indicatively in the order of six to ten pore volumes in total), are required to reduce the salinity to very low (e.g. potable) concentrations. (e.g. Appelo, 1994; Myers et al., 1996)
This same analogy, however, does not apply to very fine-grained sediments (i.e. less than 0.06 mm diameter), such as silts and clays where the permeability is low and, as the material compacts, becomes lower. As compaction increases (over time), it is assumed that most incident rainfall falling onto dredged fines will not infiltrate, but run-off instead (assuming the dredged material surface does not erode and allow infiltration). Therefore, seepage rates from very fine grained dredged material can be expected to be low, with high run-off rates. Furthermore, tail water quality from very fine grained sediments is greatly influenced by processes such as ion exchange (Appelo, 1994; Appelo & Postma, 1994).

High seepage rates can often correlate with high initial leachate concentrations as solutes are readily flushed (such as for the column test example above). However, leachate solute concentrations associated with high seepage rates usually diminish relatively quickly (months to years, subject to rainfall infiltration). Conversely, materials with very low seepage rates usually correlate with higher concentrations of solutes in pore water (due to lower dilution rates).

Table 6.8 presents predicted flows from the dredged material placement within the DMCP. If this first pulse of seepage during and immediately after dredging is assumed to have a similar salinity to seawater, then the volume of saline seepage into the adjacent wetland is predicted to be up to approximately 70.4ML over this 13 week period. Note this does not account for any dilution that could occur within the placement area from rainfall.

7.6 Potential dredged tail water quality from onshore placement

The run-off or seepage from the onshore contained dredged material is assumed will be highly saline, comparable to seawater concentration, and most likely more turbid.

The chemical analysis of the sediments and seawater, also assumes the metals concentrations will be within the applied NAGD and NEPC water quality guidelines referred to in Section 7.3.3. It can also be assumed that leachate will not be acidic (i.e. pH value neutral to slightly alkaline).

Depending upon the residence time of the dredged water and the time of year (i.e. wet season or dry season), this water within the DMCP may be subject to evapo-concentration. Evapo-concentration would likely only occur during the dry season, when the DMCP is not subject to rainfall input, and if the water is not returned to the sea (as proposed). Whilst the amount of evaporation (loss of water) required for minerals to precipitate varies slightly with different types of seawater, the general process is described below.

Calcium carbonate (CaCO₃) is the first mineral to precipitate, which commences once about 50% of the water has been removed (evaporated). As calcium carbonate precipitates, alkalinity is removed and calcium builds up in the residual solution. Once about 80% of the water has evaporated (and essentially all of the carbonate precipitated), then does gypsum (CaSO₄.2H₂O) begin to precipitate. The subsequent precipitation of gypsum removes all remaining calcium from the water, resulting in an increased concentration of sulphate. After about 90% of the water has been removed, halite (NaCl) starts to precipitate.

Providing the dredged material tail water is captured and returned to the sea relatively quickly (to minimise storage requirements and reduce seepage into the underlying groundwater regime), and given the site location in a tropical (humid) zone, significant evaporation of seawater is probably unlikely. At best, it is likely that there may be some precipitation of calcium carbonate, with further precipitation of gypsum (and halite) considered unlikely.

7.7 Comments regarding the wetlands receiving environment

Groundwater within the wetlands receiving environment immediate south and west vicinity of the DMCP is identified as being saline to hypersaline, with groundwater salinity concentration typically averaging about 1.5 times seawater concentration (and as high as 2.5 times seawater concentration in places).

Groundwater from bores installed by Golder Associates and AGE adjacent to the wetlands have identified groundwater salinity values range from approximately 10,500 mg/L to over 80,000 mg/L. The 20th percentile and median values are approximately 38,000 mg/L and 53,150 mg/L, respectively, indicating 80% of groundwater samples at the proposed placement area have salinity values greater than seawater concentration (i.e. greater than 34,750 mg/L). These salinity values are indicative of the wetlands being periodically inundated by supra-tidal influences (king tides) and also storm surges, particularly from cyclonic activity. Therefore, the groundwater receiving environment in the wetland area is naturally highly saline, with significant influence from natural and frequent seawater inundation.

Less-saline groundwater occurs within the DMCP area, and potentially within the existing coastal vegetation areas to the northwest and east of the proposed DMCP. These areas are slightly more elevated, with the brackish groundwater suggesting infiltration of fresher water (rainwater) occurs into these areas. Section 6.8.6 provides estimated volumes of potentially saline (seawater quality) seepage at the end of dredging that could potentially report to the wetlands to the south and west of the DMCP. This seepage is predicted to continue post dredging, however the volume and salinity of this seepage will decline post dredging and disposal of dredged material into the DMCP.

Groundwater mounding resulting from the DMCP operation is not anticipated to extend above the ground surface with groundwater levels in Layer 1 remaining below ground level. Similarly, any groundwater mounding within in Layer 3 is confined beneath the upper clayey layer (Layer 2) restricting potential for surface expression above the ground surface.

7.8 Summary

Information about geochemical characteristics of dredged material and the water quality of seawater at the dredging location indicates that dredged material (as a bulk material) is expected to be non-acid forming, contain low concentrations of metals and metalloids and low concentrations of organic compounds. It is assumed that the slurry pumped into the DMCP will be saline, with a salinity approximating seawater concentration (~35,000 mg/L, ~53,000 μ S/cm). The wetland receiving environment is already saline to hypersaline, shallow groundwater system, which is recharged periodically by seawater inundation (from king tides and storm surges).

Therefore, from an environmental geochemical perspective, the dredged material and resultant seepage would be expected to have a low to negligible impact on the currently saline to hypersaline wetland areas south and west of the DMCP area.

There is the potential for saline groundwater seepage to mound up as a result of the DMCP. However, by installing a low permeability liner around the inside wall of the DMCP down to the top of the underlying sandy layer (Layer 3), groundwater levels in Layer 1 are predicted to remain below ground level, and confined in Layer 3 beneath the upper clayey layer (Layer 2), restricting potential for surface expression above the ground surface.

8 Recommendations

It is recommended that a groundwater monitoring and management plan (GMMP) be developed and implemented to provide an on-going assessment of the predicted impact from the proposed DMCP, as well providing a proactive indicator of any potential impacts on the groundwater regime. The aim of the GMMP will be to:

- Establish an appropriate monitoring program.
- Develop a high quality background data set against which potential impacts can be assessed.
- Identify potential impacts from the DMCP operation within sufficient time to manage these potential impacts before mitigation may be required.
- Enable detection of long-term trends and potential cumulative effects from current and future operations.
- Gain an appreciation of natural groundwater variability in the APGGP area.
- Verify and refine understanding of the project scale hydrogeology.
- Generate data against which predictions made in the groundwater modelling can be verified and/or calibrated.
- Obtain high quality data to develop trigger thresholds and values for key parameters.
- Provide an investigation and response process should there be a breach in triggers, thresholds or values.

Using the process outlined above, the groundwater monitoring will provide a basis for identifying that the dredged material and resultant seepage will have a low to negligible impact on the adjacent wetland areas.

In the event that groundwater monitoring indicates divergence from the results predicted by this assessment, an impact investigation and response process should be initiated. Investigations and responses will be entirely dependent on the particulars of the circumstance, but as a minimum, they should aim to:

- Identify the divergence to verify the results by re-sampling/re-measuring.
- Define the divergence with respect to its location, date and comparison against adopted thresholds level.
- Identify the likely cause to identify whether site or non-operational related.
- Assess the environmental impact to confirm whether environmental harm has occurred,
- Identify actions required to mitigate or prevent further environmental harm occurring. :

This GMMP should commence at the earliest opportunity and continue for the life of the APGGP.

Figure 4.1 shows the locations of the groundwater monitoring bores installed for this groundwater assessment. During the operational phase APGGP, it is possible that groundwater monitoring bores will be either destroyed or become unserviceable and need to be replaced. NQBP will proactively maintain the groundwater monitoring network, replacing bores as necessary, and use the regular review of monitoring data to inform the location of additional monitoring bores, if required.

At this stage, monitoring bores MW01, MW02, MW03 and Site 3 will most likely be destroyed during construction of the DMCP. These bores should be decommissioned in accordance with the "Minimum Construction Requirements for Water Bores in Australia" (National Uniform Drillers Licensing Committee, 2012) prior to construction commencing to remove the potential for a preferential flow path into the underlying aquifer.

The locations, depths, drilling and construction requirements of any replacement and/or new monitoring bores will be confirmed in consultation with NQBP.

The groundwater monitoring program should include recording of groundwater levels from existing monitoring bores (as shown on Figure 4.1), and should continue from pre to post dredging operations for the following reasons:

- to enable natural water level fluctuations (such as responses to rainfall and wetland flows) to be distinguished from potential water level impacts due to the proposed onshore placement of dredged material into the dredged material management areas;
- to assist with determination of groundwater trigger levels; and
- be used to validate and update model predictions if this is identified as a requirement.

In addition, groundwater quality sampling of existing monitoring bores should continue for the following reasons:

- to establish a baseline groundwater quality dataset;
- to assist with the determination of trigger levels; and
- to assess the potential groundwater quality impacts during and post dredging.

The GMMP will define the parameters, frequency and time frame for this groundwater monitoring program.

The results of this monitoring should be reported at appropriate intervals in accordance with operating requirements. Following completion of the initial 12 month sampling, a review of the data should be undertaken to establish which water quality parameters should continue to be monitored and the frequency of this monitoring. Further reporting requirements will be defined in the GMMP.

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10 Glossary

Alluvial Sediments/Alluvium - sediment (gravel, sand, silt, clay) transported by water (i.e. deposits in a stream channel or floodplain).

Aquifer - Rock or sediment in a formation, group of formations, or part of a formation which is saturated and sufficiently permeable to transmit economic quantities of water to wells and springs.

Aquifer, Confined - An aquifer that is overlain by a confining bed. The confining bed has a significantly lower hydraulic conductivity than the aquifer.

Aquifer, Unconfined - An aquifer in which there are no confining beds between the zone of saturation and the surface. There will be a water table in an unconfined aquifer. Water-table aquifer is a synonym.

Barrier Boundary - An aquifer-system boundary represented by a rock mass that is not a source of water.

Baseflow - That part of stream flow that originates from ground water seeping into the stream.

Bore Development - The process whereby a well (bore) is pumped or surged to remove any fine material that may be blocking the well screen or the aquifer outside the well screen.

Bore Screen - A tubular device with either slots, holes, gauze, or continuous-wire wrap; used at the end of a well casing to complete a well. The water enters the well through the well screen.

Colluvium - Sediment (gravel, sand, silt, clay) transported by gravity (i.e. deposits at the base of a slope).

Concentration Gradient - The change in total parameter concentration with a change in distance in a given direction. The direction is that which yields a maximum rate of decrease in parameter concentration.

Discharge - The volume of water flowing in a stream or through an aquifer past a specific point in a given period of time.

Discharge Area - An area in which there are upward components of hydraulic head in the aquifer. Ground water is flowing toward the surface in a discharge area and may escape as a spring, seep, or baseflow or by evaporation and transpiration.

Falling/Rising Head (Slug) Test - A test made by the instantaneous addition, or removal, of a known volume of water to or from a well. The subsequent well recovery is measured and analysed to provide a permeability value.

Groundwater - The water contained in interconnected pores located below the water table in an unconfined aquifer or located in a confined aquifer.

Groundwater Flow - The movement of water through openings in sediment and rock; occurs in the zone of saturation.

Ground water, unconfined - The water in an aquifer where there is a water table.

Heterogeneous, Heterogeneity - Pertaining to a substance having different characteristics in different locations. A synonym is non-uniform.

Hydraulic Conductivity - A measure of the rate at which water moves through a soil/rock mass. It is the volume of water that moves within a unit of time under a unit hydraulic gradient through a unit cross-sectional area that is perpendicular to the direction of flow.

Groundwater (Hydraulic) Gradient - The change in total head with a change in distance in a given direction. The direction is that which yields a maximum rate of decrease in head.

Hydrogeology - The study of the interrelationships of geologic materials and processes with water, especially ground water.

Igneous Rock - A rock formed when molten rock called lava cools on the earth's surface.

Infiltration - The flow of water downward from the land surface into and through the upper soil layers.

Model Calibration - The process by which the independent variables of a digital computer model are varied in order to calibrate a dependent variable such as a head against a known value such as a water-table map.

Monitoring Bore (Piezometer) - A non-pumping well (bore), generally of small diameter, that is used to measure the elevation of the water table or potentiometric surface. A piezometer generally has a short well screen through which water can enter.

Porosity - The ratio of the volume of void spaces in a rock or sediment to the total volume of the rock or sediment.

Potentiometric Surface - A surface that represents the level to which water will rise in tightly cased wells. If the head varies significantly with depth in the aquifer, then there may be more than one potentiometric surface. The water table is a particular potentiometric surface for an unconfined aquifer.

Recharge (Area) - An area in which there are downward components of hydraulic head in the aquifer. Infiltration moves downward into the deeper parts of an aquifer in a recharge area.

Recharge Zone/Boundary - An aquifer system boundary that adds water to the aquifer. Streams and lakes are typically recharge boundaries.

Sedimentary Rock – a rock formed by the deposition of material at the Earth's surface and within bodies of water.

Specific Yield - The ratio of the volume of water a rock or soil will yield by gravity drainage to the volume of the rock or soil. Gravity drainage may take many months to occur. This represents the storage component in an unconfined aquifer.

Specific Storage - The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head while remaining fully saturated. In an unconfined aquifer, the specific storage will be less than or equivalent to the specific yield. The product of specific storage and aquifer thickness is referred to as storativity or storage coefficient.

Transmissivity - The rate at which water of a prevailing density and viscosity is transmitted through a unit width of an aquifer or confining bed under a unit hydraulic gradient. It is a function of properties of the liquid, the porous media, and the thickness of the porous media.

Unsaturated Zone - The zone between the land surface and the water table. It includes the root zone, intermediate zone, and capillary fringe. The pore spaces contain water at less than atmospheric pressure, as well as air and other gases. Saturated bodies, such as perched ground water, may exist in the unsaturated zone. Also called zone of aeration and vadose zone.

Water Budget - An evaluation of all the sources of supply and the corresponding discharges with respect to an aquifer or a drainage basin.

Appendix A

Monitoring bore logs





AGF.	Australasian Groundwater & Environmental Consultants Ptv Ltd							BOREHOLE LOG page:1 of 2			
SHOUNDWATER & ENVIRONMENTAL	Level 2, 15 Mallon Street,	Bowen H	Hills, Que	ensl	and 4	4006		MW03			
PROJECT No: G17(PROJECT NAME: A DATE DRILLED: 20, LOGGED BY: TW (A LICENCED DRILLE COMMENTS: Deep sali	PROJECT No: G1702BDRILLPROJECT NAME: Abbot Point GGPDRILLDATE DRILLED: 20/05/2015DRILLLOGGED BY: TW (AGE)DRILLLICENCED DRILLER: Steven ParteltonCOMMENTS: Deep salinity profiling bore.				∕∶Ge yers Rota	odrill ary mud				EASTING: 61 NORTHING: DATUM: MG/ RL: 4.25 mAI TD: 20.5 mB(2289mE 7799178mN A94 (z55) HD GL
Soil or R	Pock Field Material Description		Graphic		Depth (mBGL)	Bo	re Const	ruction		Bore Descri	ation
			Log	R.L. (mAHD)							
Silty SAND: fine to medium a moderately sorted, light grey 0.8mBGL low percentage of	sand with silt, sub-angular, quartz clasts, /ish brown and orange, damp at approxim clay content evident.	nately	· × × · · ×	4-	- 0	-		GL +4.25	Prote PVC	Citive lockable steel Stick up: +0.8 m mm (134.7) PN18 ι ace casing: 0 m to 1	collar: +1.25 m IPVC (12.8 mm) m
			× × × × × ×					-0.8m	125 Cem	mm : 1 m to 20.5 m	(Rotary mud)) m to 4.1 m
Sandy CLAY: high plasticity poorly sorted, clay matrix an	Sandy CLAY: high plasticity clay, fine to coarse sand, rounded, quartz clasts, poorly sorted, clay matrix and light grey with orange pockets.				-				50 m to 4.4	nm PN18 uPVC blar 5 m	ık casing: +0.8 m
Silty SAND: fine sand to silt, and light grey.	rounded, quartz clasts, well sorted, silty	matrix	· × × · · × · × · × · ×	0-	4			- 3.8m	SWL	. 4.01 mBGL 24/05/2	2015
SAND: fine to coarse sand, moderately sorted and light l	rounded to sub-rounded, quartz clasts, brown.		×		-		·	-5.9m	3 mr	n gravel: 4.1 m to 20).5 m
Silty SAND: silt to find sand, dark greenish brown and mi	quartz clasts, moderately sorted, silty ma nor sand lenses.	atrix,	· × × · · × × .	-				-6.9m	50 m casir lengt 20.5	nm PN18 uPVC mac ng, slot apperture: 0 th: 45 mm, 131 slots m	chine slotted .4 mm, (slot 5 / m), 4.5 m to
Clayey SAND: clay to fine sa light grey.	and, sub-rounded, quartz clasts, well sort	ed and	· · · · · · · · · · · · · · · · · · ·	4 -			·	-8.1m	Bore 102,	e development: 1:40 700 μS/cm; pH: 7.1	hours; EC:
Sandy CLAY: high plasticity stiff. Higher clay content that	clay, clay to fine sand, well sorted, light g n 8.1 - 8.9mBGL.	grey and	× × × × × × × × × ×		-			-8.9m	Bore	e development airlift	flow rate: 0.25 L/s

AGF	Australasian Grou	ndwater	r & Env	viror	nme	ntal		BOR	EHO	LE LOG	page:2 of 2
SHOUNDWATER & ENVIRONMENTER	Level 2, 15 Mallon Stree	t, Bowen F	Hills, Que	ensl	and 4	4006		MW03	6		
PROJECT No: G1702B DRILLING COMPANY: 0 PROJECT NAME: Abbot Point GGP DRILLER: Tyson Meyer DATE DRILLED: 20/05/2015 DRILLING METHOD: Ro LOGGED BY: TW (AGE) DRILL RIG: GD04 LICENCED DRILLER: Steven Partelton COMMENTS: Deep salinity profiling bore.						odrill ary mud				EASTING: 6 NORTHING: DATUM: MG RL: 4.25 mA TD: 20.5 mB	12289mE : 7799178mN GA94 (z55) GHD GGL
Soil or Rock Field Material Description			Graphic		Depth (mBGL)	Bo	ore Const	ruction		Bore Descr	rintion
Clayey SAND: fine to medium brown.	ı sand, rounded, well sorted and light	greenish		(mAHD) (mAHD) 8	- 12				n 8m		
Sandy CLAY: high plasticity cl grey / brown and stiff. Comme	iay, clay to very fine sand, poorly sort ant - clay very hard and very stiff.	ed, light	· · · · · · · · · · · · · · · · · · ·	12	_ 10			16. 16.	6m		
Silty SAND: very fine to coarse brown.	e sand, poorly sorted and light yellow	<i>i</i> ish greyish	× × × × × × ×		_				n		
Silty SAND: silt to fine sand, ro and light brown.	ounded, quartz clasts, well sorted, silf	ty matrix	· × × · · ×	-							
Silty SAND: very fine to coars clasts, poorly sorted, silty matr 20.5mBGL two fining up seque	e sand, sub-angular to sub-rounded, rix, light greenish grey / white. Commences.	quartz ıent - 16.6 -	· ×	16 — -	- 20			-19. -20r	End o	cap of hole: 20.5 mBG	L



AGE Au	ustralasian Groundwa Consultant	BO	BOREHOLE LOG page:1 of 2						
SROUNDWATER & ENVIRONMENTY LE	evel 2, 15 Mallon Street, Bow	ven Hills, Qu	eens	land 4	4006	MW	05		
PROJECT No: G1702B PROJECT NAME: Abbot DATE DRILLED: 21/05/20 LOGGED BY: TW (AGE) LICENCED DRILLER: Ste COMMENTS: Deep salinity pr	LLING COM LLER: Tyso i LLING METH LL RIG: GD(Pan` n Me <u>y</u> Hod:)4	Ƴ∶ Ge yers Rota	odrill ary mud			EASTING: 61 NORTHING: DATUM: MG/ RL: 4.31 mAI TD: 20 mBGI	3131mE 7798199mN A94 (z55) ID -	
Soil or Rock Fi	Soil or Rock Field Material Description		R.L. (mAHD)	Depth (mBGL)	Во	re Construction		Bore Descri	otion
				-	-		Prote GL +4.31m	ective lockable steel	collar: +1.25 m
Silty SAND: fine to medium sand, po brown.	porly sorted, silty matrix and light greyis	h × · · ×	4-	0			 PVC 150 surfa -1m 125 	Stick up: +0.75 m mm (134.7) PN18 υ ace casing: 0 m to 1 mm : 1 m to 20 m (F	PVC (12.8 mm) m Rotary mud)
Sandy CLAY: medium plasticity clay brown / red.	r, fine to coarse sand, poorly sorted, da	 					Cem	ient grout (100 %): C	m to 3.9 m
		· · ×					50 m m to -3.5m	nm PN18 uPVC blar 4 m	k casing: +0.75
		× · · · · · · · · · · · · · · · · · · ·	0 -	- 4			SWL	. 4.08 mBGL 24/05/	2015
		× · · × · · ×	•				3 mr	n gravel: 3.9 m to 20) m
Silty SAND: silt to coarse sand, qua matrix and light greenish grey. Silty	rtz and lithic clasts, poorly sorted, silty sand with indurated silt lithics, silt conte	nt ×	•				50 m casir lengt	nm PN18 uPVC mac ng, slot apperture: 0 th: 45 mm, 131 slots	hine slotted 4 mm, (slot / m), 4 m to 20 m
increasing from 3.5 to 8.8mBGL.		× · · · · · · · · · · · · · · · · · · ·		_			Bore 126,	e development: 1:30 200 μS/cm; pH: 6.9	hours; EC:
		× × ×	4 -	- 8			Bore	e development airlift	flow rate: 0.4 L/s
		× · · · · · ×	•	_			-10m		
		x x x x	-	_					

AGF	& Environmental			BOREHOLE LOG page:2 of				page:2 of 2			
SROUNDWATER & ENVIRONMENTA	Level 2, 15 Mallon Street,	Bowen H	lills, Que	eensl	and 4	4006		MW05			
PROJECT No: G170: PROJECT NAME: AI DATE DRILLED: 21/0 LOGGED BY: TW (A LICENCED DRILLER COMMENTS: Deep salin	2B [bbot Point GGP [05/2015 [GE) [C Steven Partelton [bity profiling bore.	DRILLING COMPANY: Geodrill DRILLER: Tyson Meyers DRILLING METHOD: Rotary mud DRILL RIG: GD04							EASTING: 61: NORTHING: 7 DATUM: MGA RL: 4.31 mAH TD: 20 mBGL	3131mE 7798199mN A94 (z55) ID	
Soil or Ro	ock Field Material Description		Graphic Log	R.L. (mAHD)	Depth (mBGL)	Во	re Constr	ruction		Bore Descrip	tion
Sandy CLAY: medium plastic lithic clasts, poorly sorted and fraction 8.8 to 10 mBGL. Incre	ity clay, clay to medium grained sand, qu l light greenish white. Medium grained gr easing clay content from 8.8 to 14mBGL.	uartz and ravel	× ×	8-	- - - - - -						
Silty CLAY: low plasticity clay light greenish / brown / yellow drill cuttings, distinctly brown tube taken at 14mBGL.	r, clay to coarse sand, moderately sorted ι. High clay content poor bolous formatio from 14m with mottled grey and yellows.	and n from Push			- 16			-14m			
Silty SAND: clay to coarse sa grey / brown.	ınd, moderately sorted, silty matrix, light ç	greenish			- - - - - - - - - - - - - - - - - - -			-16.8	End	cap of hole: 20 mBGL	
				-							



Australasian Grour Consul	ndwater tants P	· & Enviro ty Ltd	nmental	BOR	EHOLE LOG page:1 of 1
Revel 2, 15 Mallon Street	, Bowen H	Hills, Queens	and 4006		Site 1
PROJECT No: G1702A PROJECT NAME: Abbot Point DATE DRILLED: 7/11/2014 LOGGED BY: TW (AGE) LICENCED DRILLER: D. Giddy (License No. 3 COMMENTS: Wetland monitoring bore.	DRILLIN DRILLEF DRILLIN DRILL R 346)	IG COMPAN R: D. Giddy IG METHOD IG: Hollow s	Y: Ayr Boring : Auger stem rig	I Company	EASTING: 611108mE NORTHING: 7798582mN DATUM: MGA94 (255) RL: 2.76 mAHD TD: 7.2 mBGL
Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Cor	nstruction	Bore Description
Claybound SAND: fine sand to coarse sand, sub-rounded to sub-angular, quartz clasts, light brown, dry, driller - hard around 1m mark. Silty SAND: medium plasticity, fine sand to coarse sand, sub-rounded to sub-angular, quartz and lithic clasts, light greenish brown / grey, damp, driller - wet by 5.4m. Silty SAND: medium plasticity, fine sand to medium sand, rounded, quartz and lithic clasts, light greenish brown / grey, soft, wet, comment - brown-grey to grey-green, micaceous and sulfides with increasing depth. Silty SAND: fine sand to fine sand, dark grey, firm, dense, comment - dense, stalled the drill rig. Sulfides present.	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$			+0.45 m -2.76 m -1 m -1 m -5.4 m -7 m -7.2 m	Protective lockable steel collar: +1.2 m Stick up: +0.45 m 150 mm Auger: 0 m to 7.2 m (Hollow Stem) 50 mm PN18 uPVC blank casing: 0.45 m to 3.9 m Cement grout (100 %): 0 m to 3.4 m Bentonite seal: 3.4 m to 4 m 3.0-5.0 mm washed, well rounded, 3-5mm gravel pack (Burdekin River sourced): 4 m to 5.95 m 50 mm PN18 uPVC machine slotted casing, slot apperture: 1 mm, slot length: 45 mm, 131 slots / m, 3.9 m to 6.75 m Hole collapse: 5.95 m to 7.2 m End cap End of hole: 7.2 m BGL Bore development: 1:45 hrs; EC: 106900 µS/cm; pH: 7.07 Airlift flow rate: 0.026 L/s SWL 2.75mTOC 9/11/14

Australasian Group Consu	ndwater Itants P	r & E ty Li	BOR	EHOLE LOG page:1 of 1	
Show of the R & ENVIRONMENT Level 2, 15 Mallon Stree	et, Bowen I	Hills,	Queensland 4006		Site 2
PROJECT No: G1702A PROJECT NAME: Abbot Point DATE DRILLED: 7/11/2014 LOGGED BY: TW (AGE) LICENCED DRILLER: D. Giddy (License No. 3 COMMENTS: Wetland monitoring bore.	DRILLIN DRILLEF DRILLIN DRILL R 3346)	ig CC R: d. Ig Me Rig: h	DMPANY: Ayr Boring Giddy ETHOD: Auger Iollow stem rig	J Company	EASTING: 610838mE NORTHING: 7799155mN DATUM: MGA94 (255) RL: 0.99 mAHD TD: 6.75 mBGL
Soil or Rock Field Material Description	Graphic Log	R.L. (mAHD)	Depth (mBGL) Bore Col	nstruction	Bore Description
			-0	+0.39 m -0.99 m	Protective lockable steel collar: +1.2 m Stick up: +0.39 m
Silty SAND: fine sand, sub-rounded, quartz and lithic clasts, greenish black, comment - dried crust to 0.5mBGL.	× · · · × · · · · · · · · · · · · · · ·	•	-		150 mm Auger: 0 m to 6.75 m (Hollow Stem)
	× · · · × · · × × · · ·		-	-2.8 m	50 mm PN18 uPVC blank casing: 0.45 m to 3 m Cement grout (100 %): 0 m to 3.25 m
Sandy CLAY: medium plasticity, fine sand to coarse sand, sub-rounded, quartz and lithic clasts, light bluish grey, damp, driller - firmer by 2.8mBGL. M-L plasticity.					Bentonite seal: 3.25 m to 3.6 m Hole collapse: 3.6 m to 6.75 m
Sandy CLAY: medium plasticity, fine sand to coarse sand, sub-angular, quartz and lithic clasts, dark greenish brown, wet, comment - bluey to brown and increasing predmomant grainsize 2.8 to 6.3mBGL.	× × × × × × × ×-	4		4.8 m	50 mm PN18 uPVC machine slotted casing, slot apperture: 1 mm, slot length: 45 mm, 131 slots / m, 3 m to 6 m
CLAY: high plasticity, dark greenish brown / black, hard, driller - >6.3mBGL firmer and hard at 6.9mBGL.		6	-8	-6.3 m	End cap End of hole: 6.75 m BGL Bore development: 26 minutes; EC: 119300 µS/cm; pH: 6.87 Airlift flow rate: 0.33 L/s SWL 1.93mTOC 11/11/14
		 8 			

Australasian Grour Consul	ndwater tants P	• & Envii ty Ltd	BOREHOLE LOG page:1 c			
Round Harris & Environment Level 2, 15 Mallon Street	t, Bowen H	Hills, Quee	ensland 4006		Site 3	
PROJECT No: G1702A PROJECT NAME: Abbot Point DATE DRILLED: 7/11/2014 LOGGED BY: TW (AGE) LICENCED DRILLER: D. Giddy (License No. 3 COMMENTS: Wetland monitoring bore.	DRILLIN DRILLEF DRILLIN DRILL R 346)	IG COMPA R: D. Gidd IG METHC IG: Hollo v	ANY: Ayr Boring ly DD: Auger w stem rig	EASTING: 612309mE Northing: 7799980mN Datum: Mga94 (255) RL: 2.82 mahd TD: 6 mbgl		
	Orachia	Depth (mPCL)				
Soil or Rock Field Material Description	Log	(mBGL) R.L. (mAHD)	Bore Con	struction	Bore Description	
SAND: fine sand, light brown, comment - sand with minor soil. / SOIL: light brown.		4		+0.53 m -2.82 m	Protective lockable steel collar: +1.2 m Stick up: +0.53 m	
Sandy CLAY: medium plasticity, fine sand to coarse sand, sub-angular, quartz and lithic clasts, light brown / red / grey, stiff, comment - red to brown to grey with increasing depth. Driller - wet ~4mBGL.	× × × × × × × ×-	2		-0.8 m	 150 mm Auger: 0 m to 6 m (Hollow Stem) Cement grout (100 %): 0 m to 2.6 m 50 mm PN18 uPVC blank casing: 0.53 m to 2.3 m Bentonite seal: 2.6 m to 2.7 m 3.0-5.0 mm washed, well rounded, 3-5mm gravel pack (Burdekin River sourced): 2.7 m to 3.6 m Hole collapse: 3.6 m to 6 m 	
SAND: fine sand to medium sand, moderately sorted, dark greenish brown, wet, comment - cuttings wet, sloppy and micaceous.		6		∍m 	50 mm PN18 uPVC machine slotted casing, slot apperture: 1 mm, slot length: 45 mm, 131 slots / m, 2.3 m to 20.3 m	
		4		-6 m	End cap End of hole: 6 m BGL Bore development: 52 minutes; EC: 34390 µS/cm; pH: 7.8 Airlift flow rate: 0.21 L/s SWL 2.94mTOC 10/11/14	

AGE ^A	ustralasian Grou Consu	ndwater Itants Pi	& E tv L	Envi td	BOREHOLE LOG page:			
SROUNDWATER & ENVIRONMENTIN	evel 2, 15 Mallon Stree	t, Bowen H	-j – Hills,	Quee	ensland 4006		Site 4	
PROJECT No: G1702A PROJECT NAME: Abbo DATE DRILLED: 4/11/20 LOGGED BY: TW (AGE) LICENCED DRILLER: D COMMENTS: Salinity profile bo	t Point)14) . Giddy (License No. 3 ^{ore.}	DRILLIN DRILLEF DRILLIN DRILL R 3346)	g C(r: d. g Mi ig: h	OMP/ Gida ETHC Iollo	ANY: Ayr Boring dy DD: Auger w stem rig) Company	EASTING: 611 NORTHING: 7 DATUM: MGA RL: 1.83 mAH TD: 20.3 mBG	476mE 800262mN 94 (z55) D L
Soil or Rock Field M	laterial Description	Graphic Log	RL.	Depth (mBGL)	Bore Cor	nstruction	Bore Descri	iption
SOIL: loose, comment - soil horizo	n.		-	0		+0.41 m -1.83 m	Protective lockable steel colla Stick up: +0.41 m	ar: +1.2 m
SAND: quartz clasts, light yellowisi horizon.	h yellow, comment - sand		-			-0.3 m	150 mm Auger: 0 m to 20.3 n	n (Hollow Stem)
CLAY: medium plasticity, sub-roun yellowish brown / red, stiff, wet, co table 2.5m.	ided, quartz clasts, light mment - sandy clay with water		0-	- 2		-2.5 m	Cement grout (100 %): 0 m to Bentonite seal: 1.5 m to 2 m	o 1.5 m
SAND: sub-rounded, quartz clasts dense, comment - medium to coar	, light greyish brown, medium se sandy clay.			- 4			3.0-5.0 mm washed, well rou gravel pack (Burdekin River s m 50 mm PN18 uPVC blank cas	nded, 3-5mm sourced): 2 m to 10 sing: 0.45 m to 6 m
			4			-5.5 m	50 mm PN18 uPVC machine apperture: 1 mm, slot length: m, 6 m to 9 m	slotted casing, slot 45 mm, 131 slots /

AGE, Australasian Gr Con	BOREHOLE LOG page:2 of				
CROUNDWATER & ENVIRONMENT ^A Level 2, 15 Mallon S	treet, Bowen I	Hills, Que	ensland 4006		Site 4
PROJECT No: G1702A PROJECT NAME: Abbot Point DATE DRILLED: 4/11/2014 LOGGED BY: TW (AGE) LICENCED DRILLER: D. Giddy (License N COMMENTS: Salinity profile bore.	DRILLIN DRILLEI DRILLIN DRILL R 0. 3346)	g Company	EASTING: 611476mE NORTHING: 7800262mN DATUM: MGA94 (z55) RL: 1.83 mAHD TD: 20.3 mBGL		
Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Cor	nstruction	Bore Description
NO SAMPLE RETURN: comment - kept drilling with no samplereturn.	e			-20 m -20 m -20.3 m	Hole collapse: 10 m to 20.3 m Bore development: 14 minutes; EC: 93000 µS/cm; pH: 6.79 Airlift flow rate: 1.17 L/s SWL 1.67mTOC 11/11/14
		20 - 22			

AUSTRALASIAN GROUN	ndwater tants P	[.] & Env ty Ltd	BOREHOLE LOG page:1			
Chowner and the service of the servi	, Bowen I	- Hills, Que	ensland 4006		Site 5	
PROJECT No: G1702A PROJECT NAME: Abbot Point DATE DRILLED: 5/11/2014 LOGGED BY: TW (AGE) LICENCED DRILLER: D. Giddy (License No. 33 COMMENTS: Wetland monitoring bore.	DRILLIN DRILLEF DRILLIN DRILL R 346)	ig comp R: d. gid Ig meth Ig: Hollc	ANY: Ayr Boring dy OD: Auger ww stem rig	EASTING: 611890mE NORTHING: 7800033mN DATUM: MGA94 (z55) RL: 3.55 mAHD TD: 9.3 mBGL		
Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Cor	nstruction	Bore Description	
Sandy CLAY: high plasticity, fine sand to coarse sand, sub-angular, quartz and lithic clasts, moderately sorted, light yellow / brown, and dry. Claybound SAND: low plasticity, fine sand to medium sand, sub-rounded, light greyish brown, loose, driller - damp 2.2 to 3.2mBGL.	× ×			+0.5 m -3.55 m -2.2 m -3.2 m	Protective lockable steel collar: +1.2 m Stick up: +0.5 m 150 mm Auger: 0 m to 9.3 m (Hollow Stem) Cement grout (100 %): 0 m to 2.8 m Bentonite seal: 2.8 m to 3.5 m 3.0-5.0 mm washed, well rounded, 3-5mm gravel pack (Burdekin River sourced): 3.5 m to 7 m	
NO SAMPLE RETURN.		1- 1- - - - - -				
Claybound SAND: fine sand to medium sand, sub-angular, clay matrix, dark grey, wet, comment - samples not returning up the auger, small sample available from drill stem blades.		6 6 6 		-6 m -6.1 m	50 mm PN18 uPVC machine slotted casing, slot apperture: 1 mm, slot length: 45 mm, 131 slots / m, 5.5 m to 8.5 m	
NO SAMPLE RETURN. Claybound SAND: medium plasticity, fine sand, quartz clasts, well sorted, dark yellowish grey, soft, comment - interbedded yellowish clays metting against dark gravite sand grains. Noticed fluid flow	··		0.0.0.	0 	Hole collapse: 7 m to 9 m Bore development: 1:39 hrs; EC: 20450 µS/cm; pH: 7.89 Airlift flow rate: 0.03 L/s SWL 3.72mTOC 11/11/14	
from bore -9mBGL.	·· <u> </u>		- -	• • • •	End cap End of hole: 9.3 m BGL	

Australasian Group Consu	ndwater Itants P	r & E ty L	BORE	HOLE LOG page:1 of 1	
Revel 2, 15 Mallon Stree	t, Bowen I		Site 6		
PROJECT No: G1702A PROJECT NAME: Abbot Point DATE DRILLED: 6/11/2014 LOGGED BY: TW (AGE) LICENCED DRILLER: D. Giddy (License No. 3 COMMENTS: Wetland monitoring bore.	DRILLIN DRILLEI DRILLIN DRILL R 3 346)	ig Co R: d. Ig Mi Rig: f	OMPANY: Ayr Borin Giddy ETHOD: Auger Hollow stem rig	g Company	EASTING: 611947mE NORTHING: 7799429mN DATUM: MGA94 (z55) RL: 4.43 mAHD TD: 8.5 mBGL
Soil or Rock Field Material Description	Graphic Log	R.L. (mAHD)	Depth (mBGL) Bore Ce	onstruction	Bore Description
	·	5-	-0	+0.5 m -4.43 m	Protective lockable steel collar: +1.2 m Stick up: +0.5 m
Claybound SAND: sub-rounded, quartz clasts, moderately sorted, dark reddish brown, dry, comment - distinctive red colour. Observation - increasing clay content from 1 to 2.5mBGL.					150 mm Auger: 0 m to 8.5 m (Hollow Stem) Cement grout (100 %): 0 m to 4.2 m
Sandy CLAY: high plasticity, rounded, dark reddish brown, soft, dry, observation - decreasing clay content from 2.5 to 3.8mBGL.	× x x ×	•		-2.5 m -3.5 m	50 mm PN18 uPVC blank casing: 0.5 m to 4.95 m
				Q	Bentonite seal: 4.2 m to 4.5 m Hole collapse: 4.5 m to 8.5 m
Claybound SAND: low plasticity, fine sand to coarse sand, sub-rounded to sub-angular, quartz and lithic clasts, poorly sorted, dark brown, soft, loose, wet, driller comments increasing damp at 4.3mBGL. Observation - increasing sand grain and clast size from 4.3mBGL. Sorting poorer at depth.				· a	50 mm PN18 uPVC machine slotted casing, slot apperture: 1 mm, slot length: 45 mm, 131 slots / m, 4.95 m to 7.95 m
	· · · · · · · · · · · · · · · · · · ·			····: 0. j. ···: 0	Bore development: 1:03 hrs; EC: 3776 µS/cm; pH: 7.92 Airlift flow rate: 0.158 L/s SWL 4.92mTOC 11/11/14 End cap
		- - - 5 –		-8.5 m	Ena of noie: 8.5 m BGL



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Revel 2, 15 Mallon Street	, Bowen H	Hills, (Quee		Site 8	
PROJECT No: G1702A PROJECT NAME: Abbot Point DATE DRILLED: 6/11/2014 LOGGED BY: TW (AGE) LICENCED DRILLER: D. Giddy (License No. 33 COMMENTS: Wetland monitoring bore.	DRILLIN DRILLEF DRILLIN DRILL R 346)	g CC R: d. (g Me Ig: h	ompa Gidd THC ollov	ANY: Ayr Boring ly DD: Auger w stem rig	Company	EASTING: 611842mE NORTHING: 7798464mN DATUM: MGA94 (255) RL: 2.89 mAHD TD: 8.8 mBGL
Soil or Rock Field Material Description	Graphic Log	RL.	Depth (mBGL)	Bore Con	struction	Bore Description
SAND: fine sand to coarse sand, poorly sorted, light greenish brown, comment - sand horizon. Sandy CLAY: medium plasticity, fine sand to coarse sand, sub-angular, quartz clasts, poorly sorted, light brown, firm, driller - easier to drill and damp at 2.5mBGL. Grey-brown to yellow-brown with depth.	× × × × × × ×	4	- 0		+0.35 m -2.89 m -0.9 m	Protective lockable steel collar: +1.2 m Stick up: +0.35 m 150 mm Auger: 0 m to 8.8 m (Hollow Stem) Cement grout (100 %): 0 m to 2.8 m
Claybound SAND: fine sand to coarse sand, sub-rounded, quartz and lithic clasts, poorly sorted, light grey, loose, wet, driller - increasing saturation from 3.5mBGL.					-2.5 m	50 mm PN18 uPVC blank casing: 0.38 m to 6 m Bentonite seal: 2.8 m to 3.5 m Hole collapse: 3.5 m to 8.8 m 50 mm PN18 uPVC machine slotted casing, slot apperture: 1 mm, slot length: 45 mm, 131 slots / m, 6 m to 9 m
Silty SAND: fine sand to coarse sand, light grey, comment - pieces of fine grained gravel (<4mm). CLAY: high plasticity, dark greenish grey, hard, moist, comment -	× × × × × × × × × × × × × × × × × × ×				0 -6.5 m	Bore development: 53 minutes; EC: 10390 µS/cm; pH: 7.59 Airlift flow rate: 1 L/s SWL 3.04mTOC 11/11/14
very hard stiff clay.		6 -		• <u>1</u>	-8.8 m	End cap End of hole: 8.8 m BGL



Australasian Grour Consul	ndwater & Environmental Itants Ptv Ltd			BOREHOLE LOG page:1 of 1	
Stound ATER & ENVIRONMENT Level 2, 15 Mallon Street	, Bowen Hills, Queensland 4006			Site 10	
PROJECT No: G1702A PROJECT NAME: Abbot Point DATE DRILLED: 5/11/2014 LOGGED BY: TW (AGE) LICENCED DRILLER: D. Giddy (License No. 3 COMMENTS: Wetland monitoring bore.	31702A DRILLING COMPANY: Ayr Boring Company IE: Abbot Point DRILLER: D. Giddy D: 5/11/2014 DRILLING METHOD: Auger W (AGE) DRILL RIG: Hollow stem rig LLER: D. Giddy (License No. 3346) nd monitoring bore.				EASTING: 611214mE NORTHING: 7799720mN DATUM: MGA94 (255) RL: 2.43 mAHD TD: 9.2 mBGL
Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Co	nstruction	Bore Description
	×	30		+0.415 m -2.43 m	Protective lockable steel collar: +1.2 m Stick up: +0.415 m
Sandy CLAY: medium plasticity, fine sand to coarse sand, light brown, soft, driller - 1.6mBGL drilling conditions inferred as change. Observation - decreasing clay content.	× × × × × × × × ×			-1.6 m	150 mm Auger: 0 m to 9.2 m (Hollow Stem)
Claybound SAND: low plasticity, fine sand to coarse sand, brown / grey, wet, driller - damp to wet with increasing depth. Observation - increasing sand content.			o. 0		Cement grout (100 %): 0 m to 2.5 m 50 mm PN18 uPVC blank casing: 0.67 m to 3.2 m Bentonite seal: 2.5 m to 3 m 3.0-5.0 mm washed, well rounded, 3-5mm gravel pack (Burdekin River sourced): 3 m to 4.8 m Hole collapse: 4.8 m to 9.2 m
Claybound SAND: medium sand to coarse sand, sub-angular, Lithic clasts, grey / brown, wet, driller - firmer at 8.2 to 8.3mBGL. CLAY: high plasticity, fine sand, dark very stiff, dry, comment - minimal content of fine sand <5% within the clay.		36	J	-6.3 m	50 mm PN18 uPVC machine slotted casing, slot apperture: 1 mm, slot length: 45 mm, 131 slots / m, 3.2 m to 9.2 m Bore development: 45 minutes; EC: 67060 μS/cm; pH: 6.29 Airilif flow rate: 1 L/s SWL 2.725mTOC 11/11/14
Claybound SAND: high plasticity, fine sand to coarse sand, sub-rounded, light brown / grey, and moist.	·	7-		ب -9 m -9.2 m	End cap End of hole: 9.2 m BGL

Appendix B

In-situ permeability test analysis
































Appendix C

Laboratory analysis certificates



CERTIFICATE OF ANALYSIS

Work Order	EB1519496	Page	: 1 of 11
Client	: AUST GROUNDWATER & ENVIRO CONSULTANTS	Laboratory	Environmental Division Brisbane
Contact	: MR DUNCAN IRVINE	Contact	: Customer Services EB
Address	: LEVEL 2, 15 MALLON STREET	Address	: 2 Byth Street Stafford QLD Australia 4053
	BOWEN HILLS QLD, AUSTRALIA 4006		
E-mail	: duncan.irvine@ageconsultants.com.au	E-mail	: ALSEnviro.Brisbane@alsglobal.com
Telephone	: +61 07 32572055	Telephone	: +61-7-3243 7222
Facsimile	: +61 07 32572088	Facsimile	: +61-7-3243 7218
Project	: ABBOT POINT G1702B	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	:	Date Samples Received	: 25-May-2015 10:57
C-O-C number	:	Date Analysis Commenced	: 25-May-2015
Sampler	: STEPHEN JONES	Issue Date	01-Jun-2015 09:41
Site	:		
		No. of samples received	: 11
Quote number	·	No. of samples analysed	· 11

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Signatories NATA Accredited Laboratory 825 This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11. Accredited for compliance with NATA ISO/IEC 17025. Signatories Position Accreditation Category Senior Inorganic Chemist Andrew Epps **Brisbane Inorganics** Greg Vogel Laboratory Manager Brisbane Inorganics WORLD RECOGNISED Kim McCabe Senior Inorganic Chemist **Brisbane Inorganics** ACCREDITATION



General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society. LOR = Limit of reporting

^ = This result is computed from individual analyte detections at or above the level of reporting

- ø = ALS is not NATA accredited for these tests.
- It is recognised that EG020-T (Total Metals by ICP-MS) is less than EG020-F (Dissolved Metals by ICP-MS) for some samples. However, the difference is within experimental variation of the methods.
- EG020-F (Dissolved Metals by ICP-MS): Limit of reporting raised for some samples due to saline sample matrix.
- EG020-T (Total Metals by ICP-MS): Limit of reporting raised for some samples due to saline sample matrix.
- E057G (Nitrite as N): Sample EB1519496-011 was diluted due to matrix interference. LOR adjusted accordingly.
- EK059G (Nitrite and Nitrate as N): Sample EB1519496-011 was diluted due to matrix interference. LOR adjusted accordingly.
- EK071G (Reactive phosphorus as P): Sample EB1519496-011 was diluted due to matrix interference. LOR adjusted accordingly.
- EK061G (Total Kjeldahl Nitrogen as N): Samples were diluted due to matrix interference. LOR adjusted accordingly.
- It has been noted that in particular samples Reactive Phosphorus as P is greater than Total Phosphorus as P, however this difference is within the limits of experimental variation.
- EA016: Calculated TDS is determined from Electrical conductivity using a conversion factor of 0.65.

Page : 3 of 11 Work Order : EB1519496 Client : AUST GROUNDWATER & ENVIRO CONSULTANTS Project : ABBOT POINT G1702B



Sub-Matrix: WATER (Matrix: WATER)		Clie	ent sample ID	MW01	MW02	MW03	MW04	MW05
	CI	ient samplii	ng date / time	[22-May-2015]	[22-May-2015]	[22-May-2015]	[23-May-2015]	[23-May-2015]
Compound	CAS Number	LOR	Unit	EB1519496-001	EB1519496-002	EB1519496-003	EB1519496-004	EB1519496-005
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value		0.01	pH Unit	7.93	7.08	7.22	8.09	7.31
EA006: Sodium Adsorption Ratio (SAR)								
^ Sodium Adsorption Ratio		0.01	-	25.9	13.2	72.6	33.0	71.2
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C		1	μS/cm	2940	5340	80200	7130	83400
EA016: Calculated TDS (from Electrical C	Conductivity)							
^ Total Dissolved Solids (Calc.)		1	mg/L	1910	3470	52100	4630	54200
FA065: Total Hardness as CaCO3								
 A Total Hardness as CaCO3 		1	mg/L	87	635	10500	335	12500
ED037P: Alkalinity by PC Titrator			<u> </u>					
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	ma/l	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	ma/L	183	112	279	397	359
Total Alkalinity as CaCO3		1	ma/L	183	112	279	397	359
ED041G: Sulfate (Turbidimetric) as SO4 2	2- by DA		<u> </u>					
Sulfate as SO4 - Turbidimetric	14808-79-8	1	ma/L	131	192	5100	247	5250
ED045C: Chlorido by Discrete Analyser	14000 70 0		g					
Chloride	16887.00.6	1	ma/l	771	1510	31900	2020	34000
	10887-00-0	·	iiig/2			01000	1010	04000
Calcium	7440 70 2	1	ma/l	7	59	796	27	996
Magnesium	7440-70-2	1	mg/L	17	119	2070	65	2430
Sodium	7439-93-4	1	mg/L	557	764	17100	1390	18300
Potassium	7440-23-3	1	mg/L	19	31	488	34	382
ECO20E: Dissolved Matels by ICD MS	7440-03-7	·						
Aluminium	7420.00.5	0.01	ma/l	<0.01	<0.01	<0.50	<0.01	<0.50
Arsenic	7429-90-3	0.001	mg/L	0.008	0.002	<0.00	0.012	<0.00
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.001	<0.0050	<0.0001	<0.0050
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.010	< 0.001	<0.010
Copper	7440-50-8	0.001	mg/L	<0.001	<0.001	<0.050	<0.001	<0.050
Nickel	7440-02-0	0.001	mg/L	<0.001	0.001	<0.050	<0.001	<0.050
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.010	<0.001	<0.010
Zinc	7440-66-6	0.005	mg/L	<0.005	0.008	0.060	<0.005	<0.050
Manganese	7439-96-5	0.001	mg/L	0.017	0.255	11.3	0.264	14.8
Iron	7439-89-6	0.05	mg/L	<0.05	<0.05	<0.50	<0.05	<0.50

Page : 4 of 11 Work Order : EB1519496 Client : AUST GROUNDWATER & ENVIRO CONSULTANTS Project : ABBOT POINT G1702B



Sub-Matrix: WATER (Matrix: WATER)		Clie	ent sample ID	MW01	MW02	MW03	MW04	MW05
	Cl	lient sampli	ng date / time	[22-May-2015]	[22-May-2015]	[22-May-2015]	[23-May-2015]	[23-May-2015]
Compound	CAS Number	LOR	Unit	EB1519496-001	EB1519496-002	EB1519496-003	EB1519496-004	EB1519496-005
				Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	0.19	0.31	<0.50	0.19	0.72
Arsenic	7440-38-2	0.001	mg/L	0.009	0.002	<0.050	0.013	<0.050
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0050	<0.0001	<0.0050
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.010	<0.001	<0.010
Copper	7440-50-8	0.001	mg/L	0.001	0.001	<0.050	<0.001	<0.050
Nickel	7440-02-0	0.001	mg/L	<0.001	0.001	<0.050	<0.001	<0.050
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.010	<0.001	<0.010
Zinc	7440-66-6	0.005	mg/L	<0.005	0.010	0.055	<0.005	<0.050
Manganese	7439-96-5	0.001	mg/L	0.018	0.262	10.4	0.303	13.6
Iron	7439-89-6	0.05	mg/L	0.15	0.14	<0.50	0.27	0.87
EG035F: Dissolved Mercury by FIM	IS							
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EG035T: Total Recoverable Mercu	ry by FIMS							
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	1.0	0.3	0.1	1.4	0.2
EK055G: Ammonia as N by Discret	e Analvser							
Ammonia as N	7664-41-7	0.01	mg/L	0.02	<0.01	0.89	0.08	2.83
EK057G: Nitrite as N by Discrete A	nalyser							
Nitrite as N		0.01	mg/L	<0.01	<0.01	<0.01	<0.01	0.04
EK058G: Nitrate as N by Discrete	Analyser							
^ Nitrate as N	14797-55-8	0.01	mg/L	<0.01	0.20	<0.01	<0.01	0.37
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Ana	lyser						
Nitrite + Nitrate as N		0.01	mg/L	<0.01	0.20	<0.01	<0.01	0.41
EK061G: Total Kjeldahl Nitrogen B	y Discrete Analyser							
Total Kjeldahl Nitrogen as N		0.1	mg/L	<0.2	<0.2	<1.0	<0.2	3.2
EK062G: Total Nitrogen as N (TKN	+ NOx) by Discrete Ar	nalyser						
^ Total Nitrogen as N		0.1	mg/L	<0.2	0.2	<1.0	<0.2	3.6
EK067G: Total Phosphorus as P by	/ Discrete Analyser							
Total Phosphorus as P		0.01	mg/L	1.28	0.37	0.63	1.73	0.97
EK071G: Reactive Phosphorus as	P by discrete analyser							
Reactive Phosphorus as P	14265-44-2	0.01	mg/L	1.35	0.35	0.42	1.94	0.87
EN055: Ionic Balance								
^ Total Anions		0.01	meq/L	28.1	48.8	1010	70.0	1080
L					1	1		

Page : 5 of 11 Work Order : EB1519496 Client : AUST GROUNDWATER & ENVIRO CONSULTANTS Project : ABBOT POINT G1702B



Sub-Matrix: WATER	Client sample ID			MW01	MW02	MW03	MW04	MW05
(Matrix: WATER)								
	Cl	ient sampli	ng date / time	[22-May-2015]	[22-May-2015]	[22-May-2015]	[23-May-2015]	[23-May-2015]
Compound	CAS Number	LOR	Unit	EB1519496-001	EB1519496-002	EB1519496-003	EB1519496-004	EB1519496-005
				Result	Result	Result	Result	Result
EN055: Ionic Balance - Continued								
^ Total Cations		0.01	meq/L	26.5	46.7	966	68.0	1060
^ Ionic Balance		0.01	%	3.08	2.23	2.33	1.49	0.96

Page : 6 of 11 Work Order : EB1519496 Client : AUST GROUNDWATER & ENVIRO CONSULTANTS Project : ABBOT POINT G1702B



Sub-Matrix: WATER (Matrix: WATER)		Clie	ent sample ID	MW06	SITE 5	SITE 6	SITE 8	SITE 3
	CI	ient sampliı	ng date / time	[23-May-2015]	[22-May-2015]	[22-May-2015]	[22-May-2015]	[22-May-2015]
Compound	CAS Number	LOR	Unit	EB1519496-006	EB1519496-007	EB1519496-008	EB1519496-009	EB1519496-010
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value		0.01	pH Unit	7.98	7.57	7.83	7.65	7.68
EA006: Sodium Adsorption Ratio (SAR)								
^ Sodium Adsorption Ratio		0.01	-	34.0	36.9	19.5	34.3	57.4
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C		1	µS/cm	8710	16100	2010	14000	35000
EA016: Calculated TDS (from Electrical 0	Conductivity)							
^ Total Dissolved Solids (Calc.)		1	mg/L	5660	10500	1310	9100	22800
EA065: Total Hardness as CaCO3								
^ Total Hardness as CaCO3		1	mg/L	418	1230	67	999	2800
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	ma/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	342	203	193	177	656
Total Alkalinity as CaCO3		1	mg/L	342	203	193	177	656
ED041G: Sulfate (Turbidimetric) as SO4	2- by DA		_					
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	217	1640	80	732	1320
ED045G: Chloride by Discrete Analyser			U U					
Chloride	16887-00-6	1	mg/L	2870	5240	520	4760	12200
ED093E: Dissolved Major Cations			U.S.					
Calcium	7440-70-2	1	mg/L	42	96	7	57	229
Magnesium	7439-95-4	1	mg/L	76	240	12	208	542
Sodium	7440-23-5	1	mg/L	1600	2970	366	2490	6980
Potassium	7440-09-7	1	mg/L	18	112	14	92	239
EG020E: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.50
Arsenic	7440-38-2	0.001	mg/L	0.013	0.021	0.016	0.009	<0.050
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0050
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.010
Copper	7440-50-8	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.050
Nickel	7440-02-0	0.001	mg/L	<0.001	0.001	0.001	<0.001	<0.050
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.010
Zinc	7440-66-6	0.005	mg/L	<0.005	<0.005	0.005	<0.005	<0.050
Manganese	7439-96-5	0.001	mg/L	0.582	0.852	0.034	0.321	1.52
Iron	7439-89-6	0.05	mg/L	<0.05	2.21	<0.05	0.90	0.90

Page : 7 of 11 Work Order : EB1519496 Client : AUST GROUNDWATER & ENVIRO CONSULTANTS Project : ABBOT POINT G1702B



Sub-Matrix: WATER (Matrix: WATER)	Client sample ID			MW06	SITE 5	SITE 6	SITE 8	SITE 3
	Cl	lient sampli	ng date / time	[23-May-2015]	[22-May-2015]	[22-May-2015]	[22-May-2015]	[22-May-2015]
Compound	CAS Number	LOR	Unit	EB1519496-006	EB1519496-007	EB1519496-008	EB1519496-009	EB1519496-010
				Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	0.20	0.02	0.35	0.08	<0.50
Arsenic	7440-38-2	0.001	mg/L	0.013	0.018	0.016	0.006	<0.050
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0050
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.010
Copper	7440-50-8	0.001	mg/L	<0.001	0.001	<0.001	<0.001	<0.050
Nickel	7440-02-0	0.001	mg/L	<0.001	0.003	0.002	<0.001	<0.050
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.010
Zinc	7440-66-6	0.005	mg/L	<0.005	0.010	<0.005	<0.005	<0.050
Manganese	7439-96-5	0.001	mg/L	0.720	1.20	0.036	0.439	1.46
Iron	7439-89-6	0.05	mg/L	0.14	2.77	0.28	1.20	0.99
EG035F: Dissolved Mercury by FIM	S							
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EG035T: Total Recoverable Mercur	ry by FIMS							
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	1.2	0.7	1.0	2.3	0.7
EK055G: Ammonia as N by Discrete	e Analvser							
Ammonia as N	7664-41-7	0.01	mg/L	0.04	0.32	0.04	0.44	0.28
EK057G: Nitrite as N by Discrete A	nalvser							
Nitrite as N		0.01	mg/L	0.09	<0.01	<0.01	<0.01	<0.01
EK058G: Nitrate as N by Discrete A	Analyser							
^ Nitrate as N	14797-55-8	0.01	mg/L	0.05	<0.01	<0.01	<0.01	<0.01
EK059G: Nitrite plus Nitrate as N (N	NOx) by Discrete Ana	lvser	_					
Nitrite + Nitrate as N		0.01	mg/L	0.14	<0.01	<0.01	<0.01	<0.01
EK061G: Total Kieldahl Nitrogen By	v Discrete Analyser							
Total Kieldahl Nitrogen as N		0.1	mg/L	<0.2	<0.5	<0.2	<0.5	<1.0
EK062G: Total Nitrogon as N (TKN	+ NOv) by Discroto Ar	alveor						
 Total Nitrogen as N 		0.1	ma/L	<0.2	<0.5	<0.2	<0.5	<1.0
EK067G: Total Phoenhorus as P by	Discrete Analyser							
Total Phosphorus as P	Discrete Analysei	0.01	ma/l	2.95	0.25	1.83	8.00	0.13
EK071C: Paactive Phoenberus of	2 by discroto analyzer							
Reactive Phosphorus as P		0.01	ma/l	2.98	0.05	1.80	0.64	0.02
	14200-44-2	0.01	mg/L		0.00	1.00	0.07	0.02
A Total Anions		0.01	mea/l	02.3	186	20.2	153	385
		0.01	meq/L	32.3	100	20.2	100	505

Page : 8 of 11 Work Order : EB1519496 Client : AUST GROUNDWATER & ENVIRO CONSULTANTS Project : ABBOT POINT G1702B



Sub-Matrix: WATER		Clie	ent sample ID	MW06	SITE 5	SITE 6	SITE 8	SITE 3
(Mault. WATER)								
	Cl	ient sampli	ng date / time	[23-May-2015]	[22-May-2015]	[22-May-2015]	[22-May-2015]	[22-May-2015]
Compound	CAS Number	LOR	Unit	EB1519496-006	EB1519496-007	EB1519496-008	EB1519496-009	EB1519496-010
				Result	Result	Result	Result	Result
EN055: Ionic Balance - Continued								
^ Total Cations		0.01	meq/L	78.4	156	17.6	131	366
^ Ionic Balance		0.01	%	8.16	8.61	6.84	7.92	2.54

Page : 9 of 11 Work Order : EB1519496 Client : AUST GROUNDWATER & ENVIRO CONSULTANTS Project : ABBOT POINT G1702B



Sub-Matrix: WATER (Matrix: WATER)		Clie	ent sample ID	SITE 7				
	CI	ient samplii	ng date / time	[22-May-2015]				
Compound	CAS Number	LOR	Unit	EB1519496-011				
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value		0.01	pH Unit	7.04				
EA006: Sodium Adsorption Ratio (SAR)								
^ Sodium Adsorption Ratio		0.01	-	73.7				
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C		1	μS/cm	78700				
EA016: Calculated TDS (from Electrical 0	Conductivity)							
^ Total Dissolved Solids (Calc.)		1	mg/L	51200				
FA065: Total Hardness as CaCO3								
^ Total Hardness as CaCO3		1	mg/L	9250				
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	ma/L	<1				
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1				
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	270				
Total Alkalinity as CaCO3		1	mg/L	270				
ED041G: Sulfate (Turbidimetric) as SO4 (2- by DA		_					
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	5570				
ED045G: Chloride by Discrete Analyser			U.S.					
Chloride	16887-00-6	1	mg/L	31000				
ED092E: Dissolved Major Cations			<u> </u>					
Calcium	7440-70-2	1	ma/L	538				
Magnesium	7439-95-4	1	mg/L	1920				
Sodium	7440-23-5	1	mg/L	16300				
Potassium	7440-09-7	1	mg/L	537				
EG020E: Dissolved Metals by ICP-MS			_					
Aluminium	7429-90-5	0.01	mg/L	<0.50				
Arsenic	7440-38-2	0.001	mg/L	<0.050				
Cadmium	7440-43-9	0.0001	mg/L	<0.0050				
Chromium	7440-47-3	0.001	mg/L	<0.010				
Copper	7440-50-8	0.001	mg/L	<0.050				
Nickel	7440-02-0	0.001	mg/L	<0.050				
Lead	7439-92-1	0.001	mg/L	<0.010				
Zinc	7440-66-6	0.005	mg/L	<0.050				
Manganese	7439-96-5	0.001	mg/L	3.14				
Iron	7439-89-6	0.05	mg/L	28.6				

Page : 10 of 11 Work Order : EB1519496 Client : AUST GROUNDWATER & ENVIRO CONSULTANTS Project : ABBOT POINT G1702B



Sub-Matrix: WATER (Matrix: WATER)		Client sample ID						
	Cl	ient sampliı	ng date / time	[22-May-2015]				
Compound	CAS Number	LOR	Unit	EB1519496-011				
				Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.50				
Arsenic	7440-38-2	0.001	mg/L	<0.050				
Cadmium	7440-43-9	0.0001	mg/L	<0.0050				
Chromium	7440-47-3	0.001	mg/L	<0.010				
Copper	7440-50-8	0.001	mg/L	<0.050				
Nickel	7440-02-0	0.001	mg/L	<0.050				
Lead	7439-92-1	0.001	mg/L	<0.010				
Zinc	7440-66-6	0.005	mg/L	<0.050				
Manganese	7439-96-5	0.001	mg/L	3.13				
Iron	7439-89-6	0.05	mg/L	30.0				
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001				
EG035T: Total Recoverable Mercury	by FIMS							
Mercury	7439-97-6	0.0001	mg/L	<0.0001				
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	0.8				
EK055G: Ammonia as N by Discrete	Analyser							
Ammonia as N	7664-41-7	0.01	mg/L	3.21				
EK057G: Nitrite as N by Discrete Ana	alyser							
Nitrite as N		0.01	mg/L	<0.05				
EK058G: Nitrate as N by Discrete An	alvser							
^ Nitrate as N	14797-55-8	0.01	mg/L	<0.05				
EK059G: Nitrite plus Nitrate as N (NC	Dx) by Discrete Ana	lvser						
Nitrite + Nitrate as N		0.01	mg/L	<0.05				
EK061G: Total Kieldahl Nitrogen By F	Discrete Analyser		_					
Total Kieldahl Nitrogen as N		0.1	mg/L	3.2				
EK062G: Total Nitrogon as N (TKN + I	NOx) by Discrote Ar	alveor	<u> </u>					
 A Total Nitrogen as N 		0.1	ma/L	3.2				
EK067C: Total Phoenhorus as P by D	liserata Analyser		<u> </u>					
Total Phosphorus as P		0.01	ma/l	0.17				
EK071C: Posetive Phoenborus on Ph	av discroto analyzer							
Reactive Phosphorus as P		0.01	mg/l	<0.02				
	14200-44-2	0.01	iiig/L	-0.02				
EN055: Ionic Balance		0.01	mec/l					
I OTAL ANIONS		0.01	meq/L	аар				

Page : 11 of 11 Work Order : EB1519496 Client : AUST GROUNDWATER & ENVIRO CONSULTANTS Project : ABBOT POINT G1702B



Sub-Matrix: WATER (Matrix: WATER)		Clie	ent sample ID	SITE 7				
	Cli	ent sampliı	ng date / time	[22-May-2015]				
Compound	CAS Number	LOR	Unit	EB1519496-011				
				Result	Result	Result	Result	Result
EN055: Ionic Balance - Continued								
^ Total Cations		0.01	meq/L	908				
^ Ionic Balance		0.01	%	4.65				



CERTIFICATE OF ANALYSIS

Work Order	EB1446120	Page	: 1 of 6
Client	: AUST GROUNDWATER & ENVIRO CONSULTANTS	Laboratory	Environmental Division Brisbane
Contact	: MR DUNCAN IRVINE	Contact	: Customer Services EB
Address	ELVEL 2, 15 MALLON STREET	Address	: 2 Byth Street Stafford QLD Australia 4053
	BOWEN HILLS QLD, AUSTRALIA 4006		
E-mail	: duncan.irvine@ageconsultants.com.au	E-mail	: ALSEnviro.Brisbane@alsglobal.com
Telephone	: +61 07 32572055	Telephone	: +61-7-3243 7222
Facsimile	: +61 07 32572088	Facsimile	: +61-7-3243 7218
Project	: ABBOT POINT G1702A	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	:	Date Samples Received	: 13-Nov-2014 09:00
C-O-C number	:	Date Analysis Commenced	: 13-Nov-2014
Sampler	:	Issue Date	: 18-Nov-2014 18:39
Site	:		
		No. of samples received	: 7
Quote number		No. of samples analysed	: 7

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Signatories NATA Accredited Laboratory 825 This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11. Accredited for compliance with NATA ISO/IEC 17025. Signatories Position Accreditation Category Andrew Epps Senior Inorganic Chemist **Brisbane Inorganics** Andrew Matheson Senior Chemist Brisbane Inorganics WORLD RECOGNISED Kim McCabe Senior Inorganic Chemist **Brisbane Inorganics** ACCREDITATION



General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Key: CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society. LOR = Limit of reporting

^ = This result is computed from individual analyte detections at or above the level of reporting

- ø = ALS is not NATA accredited for these tests.
- EG020-F (Dissolved Metals): LOR raised due to saline sample matrix.
- EG020-T (Total Metals): LOR raised due to saline sample matrix
- EG035T (Total Mercury) and EG035F (Dissolved Mercury): LOR raised for samples EB1446120-001 (Site 2), -004 (Site 7), -006 (Site 9) and -007 (Site 10) due to saline sample matrix.
- It is recognised that EG020T (Total Metals) is less than EG020F (Dissolved Metals) for some samples. However, the difference is within experimental variation of the methods.
- TDS by method EA-015 may bias high due to the presence of fine particulate matter, which may pass through the prescribed GF/C paper.
- The presence of high SO4 may bias the EC low.

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Sub-Matrix: SALINE WATER (Matrix: WATER)	Client sample ID			Site 2	Site 7	Site 9	Site 10	
	Cl	ient samplii	ng date / time	[11-Nov-2014]	[11-Nov-2014]	[11-Nov-2014]	[11-Nov-2014]	
Compound	CAS Number	LOR	Unit	EB1446120-001	EB1446120-004	EB1446120-006	EB1446120-007	
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value		0.01	pH Unit	6.46	6.71	7.11	6.98	
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C		1	µS/cm	114000	76000	74900	48700	
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C		10	mg/L	105000	61800	67100	34400	
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	156	261	277	215	
Total Alkalinity as CaCO3		1	mg/L	156	261	277	215	
ED041G: Sulfate (Turbidimetric) as SO4 2	2- by DA							
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	8400	6820	6440	2440	
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	53200	31000	30700	18300	
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	783	511	602	372	
Magnesium	7439-95-4	1	mg/L	4170	2220	2550	1340	
Sodium	7440-23-5	1	mg/L	26000	18000	15300	10300	
Potassium	7440-09-7	1	mg/L	951	599	502	360	
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.50	<0.50	<0.50	<0.50	
Arsenic	7440-38-2	0.001	mg/L	<0.050	<0.050	<0.050	<0.050	
Cadmium	7440-43-9	0.0001	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	
Chromium	7440-47-3	0.001	mg/L	<0.010	<0.010	<0.010	<0.010	
Copper	7440-50-8	0.001	mg/L	<0.050	<0.050	<0.050	0.065	
Nickel	7440-02-0	0.001	mg/L	<0.050	<0.050	<0.050	<0.050	
Lead	7439-92-1	0.001	mg/L	<0.010	<0.010	<0.010	<0.010	
Zinc	7440-66-6	0.005	mg/L	<0.050	<0.050	<0.050	<0.050	
Manganese	7439-96-5	0.001	mg/L	4.76	3.32	2.88	2.12	
Iron	7439-89-6	0.05	mg/L	33.0	31.6	8.07	12.8	
EG020T: Total Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	1.65	4.38	<0.50	<0.50	
Arsenic	7440-38-2	0.001	mg/L	<0.050	<0.050	<0.050	<0.050	
Cadmium	7440-43-9	0.0001	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	

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Sub-Matrix: SALINE WATER (Matrix: WATER)		Clie	ent sample ID	Site 2	Site 7	Site 9	Site 10				
	Cl	ient sampli	ng date / time	[11-Nov-2014]	[11-Nov-2014]	[11-Nov-2014]	[11-Nov-2014]				
Compound	CAS Number	LOR	Unit	EB1446120-001	EB1446120-004	EB1446120-006	EB1446120-007				
				Result	Result	Result	Result	Result			
EG020T: Total Metals by ICP-MS - Cor	ntinued										
Chromium	7440-47-3	0.001	mg/L	<0.010	<0.010	<0.010	<0.010				
Copper	7440-50-8	0.001	mg/L	<0.050	<0.050	<0.050	<0.050				
Nickel	7440-02-0	0.001	mg/L	<0.050	<0.050	<0.050	<0.050				
Lead	7439-92-1	0.001	mg/L	<0.010	<0.010	<0.010	<0.010				
Zinc	7440-66-6	0.005	mg/L	<0.050	<0.050	<0.050	<0.050				
Manganese	7439-96-5	0.001	mg/L	4.40	2.90	2.71	1.90				
Iron	7439-89-6	0.05	mg/L	30.3	30.5	7.86	11.2				
EG035F: Dissolved Mercury by FIMS											
Mercury	7439-97-6	0.0001	mg/L	<0.0010	<0.0010	<0.0010	<0.0010				
EG035T: Total Recoverable Mercury by FIMS											
Mercury	7439-97-6	0.0001	mg/L	<0.0010	<0.0010	<0.0010	<0.0010				
EK055G: Ammonia as N by Discrete	Analvser										
Ammonia as N	7664-41-7	0.01	mg/L	6.23	4.87	2.04	1.96				
EK057G: Nitrite as N by Discrete Ana	alvser										
Nitrite as N		0.01	mg/L	<0.01	<0.01	<0.01	<0.01				
EK058G: Nitrate as N by Discrete An	alvser										
^ Nitrate as N	14797-55-8	0.01	mg/L	<0.01	<0.01	<0.01	<0.01				
EK059G: Nitrite plus Nitrate as N (NC	Dx) by Discrete Ana	lvser									
Nitrite + Nitrate as N		0.01	mg/L	<0.01	<0.01	<0.01	<0.01				
EK061G: Total Kieldahl Nitrogen By I	Discrete Analyser										
Total Kjeldahl Nitrogen as N		0.1	mg/L	6.3	4.9	2.4	2.3				
FK062G: Total Nitrogen as N (TKN +	NOx) by Discrete Ar	nalvser									
 Total Nitrogen as N 		0.1	mg/L	6.3	4.9	2.4	2.3				
EK067G [•] Total Phosphorus as P by D)iscrete Analyser		_								
Total Phosphorus as P		0.01	mg/L	0.66	0.14	0.11	0.17				
EN055: Ionic Balance			, j								
Total Anions		0.01	mea/L	1680	1020	1000	571				
^ Total Cations		0.01	meg/L	1540	1010	918	586				
^ Ionic Balance		0.01	%	4.40	0.77	4.56	1.26				
				-							

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Sub-Matrix: WATER (Matrix: WATER)	Client sample ID		Site 5	Site 6	Site 8							
	Cl	ient samplii	ng date / time	[11-Nov-2014]	[11-Nov-2014]	[11-Nov-2014]						
Compound	CAS Number	LOR	Unit	EB1446120-002	EB1446120-003	EB1446120-005						
				Result	Result	Result	Result	Result				
EA005P: pH by PC Titrator												
pH Value		0.01	pH Unit	7.40	7.66	7.69						
EA010P: Conductivity by PC Titrator												
Electrical Conductivity @ 25°C		1	µS/cm	15700	1610	9440						
EA015: Total Dissolved Solids												
^ Total Dissolved Solids @180°C		10	mg/L	9610	800	5680						
ED037P: Alkalinity by PC Titrator												
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1						
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1						
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	195	180	161						
Total Alkalinity as CaCO3		1	mg/L	195	180	161						
ED041G: Sulfate (Turbidimetric) as SO4 2	2- by DA											
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	1370	58	420						
ED045G: Chloride by Discrete Analyser												
Chloride	16887-00-6	1	mg/L	4250	389	3070						
ED093F: Dissolved Major Cations												
Calcium	7440-70-2	1	mg/L	93	5	34						
Magnesium	7439-95-4	1	mg/L	234	10	134						
Sodium	7440-23-5	1	mg/L	2730	318	1730						
Potassium	7440-09-7	1	mg/L	126	11	73						
EG020F: Dissolved Metals by ICP-MS												
Aluminium	7429-90-5	0.01	mg/L	<0.01	<0.01	<0.01						
Arsenic	7440-38-2	0.001	mg/L	0.013	0.018	0.009						
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001						
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001						
Copper	7440-50-8	0.001	mg/L	<0.001	<0.001	<0.001						
Nickel	7440-02-0	0.001	mg/L	0.002	0.002	0.001						
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001						
Zinc	7440-66-6	0.005	mg/L	<0.005	<0.005	0.005						
Manganese	7439-96-5	0.001	mg/L	0.890	0.024	0.195						
Iron	7439-89-6	0.05	mg/L	1.24	<0.05	0.45						
EG020T: Total Metals by ICP-MS												
Aluminium	7429-90-5	0.01	mg/L	0.60	0.58	1.39						
Arsenic	7440-38-2	0.001	mg/L	0.013	0.018	0.009						
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001						

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Sub-Matrix: WATER (Matrix: WATER)		Clie	ent sample ID	Site 5	Site 6	Site 8				
	Cli	ient sampli	ng date / time	[11-Nov-2014]	[11-Nov-2014]	[11-Nov-2014]				
Compound	CAS Number	LOR	Unit	EB1446120-002	EB1446120-003	EB1446120-005				
				Result	Result	Result	Result	Result		
EG020T: Total Metals by ICP-MS - Cor	tinued									
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	0.001				
Copper	7440-50-8	0.001	mg/L	<0.001	<0.001	<0.001				
Nickel	7440-02-0	0.001	mg/L	0.002	<0.001	0.002				
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001				
Zinc	7440-66-6	0.005	mg/L	<0.005	<0.005	<0.005				
Manganese	7439-96-5	0.001	mg/L	0.877	0.026	0.189				
Iron	7439-89-6	0.05	mg/L	1.62	0.35	0.93				
EG035F: Dissolved Mercury by FIMS										
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001				
EG035T: Total Recoverable Mercury by FIMS										
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001				
EK055G: Ammonia as N by Discrete	Analyser									
Ammonia as N	7664-41-7	0.01	mg/L	0.35	<0.01	0.30				
EK057G: Nitrite as N by Discrete Ana	llyser									
Nitrite as N		0.01	mg/L	<0.01	<0.01	<0.01				
EK058G: Nitrate as N by Discrete An	alyser									
^ Nitrate as N	14797-55-8	0.01	mg/L	<0.01	<0.01	<0.01				
EK059G: Nitrite plus Nitrate as N (NC	() () () () () () () () () () () () () (lyser								
Nitrite + Nitrate as N		0.01	mg/L	<0.01	<0.01	<0.01				
EK061G: Total Kieldahl Nitrogen By [Discrete Analyser									
Total Kjeldahl Nitrogen as N		0.1	mg/L	1.4	<0.1	0.4				
EK062G: Total Nitrogen as N (TKN + I	NOx) by Discrete An	alvser								
^ Total Nitrogen as N		0.1	mg/L	1.4	<0.1	0.4				
EK067G: Total Phosphorus as P by D	iscrete Analyser									
Total Phosphorus as P		0.01	mg/L	0.08	1.79	1.06				
EN055: Ionic Balance										
^ Total Anions		0.01	meq/L	152	15.8	98.6				
^ Total Cations		0.01	meq/L	146	15.2	89.8				
^ Ionic Balance		0.01	%	2.18	1.94	4.65				

Appendix D

Laboratory analysis results



Table D-1: LABORATORY WATER QUALITY RESULTS, NOVEMBER 2014												
Analytes	Units	LOR ^a	Site 2	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	ANZECC 2000	ANZECC 2000	ANZECC 2000
Aquifer	-	-								Marine Water (95% Level of	<u>Fresh water</u> (95% Level of	Wetland (95% Level of
Date Sampled	-	-	11/11/2014	11/11/2014	11/11/2014	11/11/2014	11/11/2014	11/11/2014	11/11/2014	Protection)	Protection)	Protection)
Field - Physical Parameters										-		
pH Value	pH Unit		6.09	7.04	7.02	6.55	7.3	6.81	6.62	-	-	6 - 8.0
Electrical Conductivity	μS/cm	-	119,200	15,460	1,597	79,360	9,648	79,350	50,310	-	-	-
Laboratory - Physical Parameter	s		•	•				•		-	•	
pH Value	pH Unit	0.01	6.46	7.4	7.66	6.71	7.69	7.11	6.98	-	-	6 - 8.0
Electrical Conductivity @ 25°C	µS/cm	1	114,000	15,700	1,610	76,000	9,440	74,900	48,700	-	-	-
Total Dissolved Solids	mg/L	10	105,000	9,610	800	61,800	5,680	67,100	34,400	-	-	-
Alkalinity	0,		• •				· · ·		<u> </u>	-		
Hydroxide Alkalinity as CaCO ₃	mg/L	1	<1	<1	<1	<1	<1	<1	<1	-	-	-
Carbonate Alkalinity as CaCO ₃	mg/L	1	<1	<1	<1	<1	<1	<1	<1	-	-	-
Bicarbonate Alkalinity as CaCO ₃	mg/L	1	156	195	180	261	161	277	215	-	-	-
Total Alkalinity as CaCO ₃	mg/L	1	156	195	180	261	161	277	215	-	-	-
Major/Minor Ions			•	•				•		-		
Calcium	mg/L	1	783	93	5	511	34	602	372	-	-	-
Magnesium	mg/L	1	4,170	234	10	2,220	134	2,550	1,340	-	-	-
Sodium	mg/L	1	26,000	2,730	318	18,000	1,730	15,300	10,300	-	-	-
Potassium	mg/L	1	951	126	11	599	73	502	360	-	-	-
Chloride	mg/L	1	53,200	4,250	<u>389</u>	<u>31,000</u>	<u>3,070</u>	<u>30,700</u>	<u>18,300</u>	-	0.003	-
Sulphate	mg/L	1	8,400	1,370	58	6,820	420	6,440	2,440	-	-	-
Nutrients												
Ammonia as N	mg/L	0.01	<u>6.23</u>	0.35	< 0.01	<u>4.87</u>	0.3	<u>2.04</u>	<u>1.96</u>	0.91	0.9	0.01
Nitrite as N	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	< 0.01	-	-	0.01
Nitrate as N	mg/L	0.01	< 0.01	<0.01	<0.01	<0.01	<0.01	< 0.01	<0.01	-	0.07	0.01
Nitrite + Nitrate as N	mg/L	0.01	< 0.01	< 0.01	< 0.01	<0.01	<0.01	<0.01	< 0.01	-	-	0.35 - 12
Total Kjeldahl Nitrogen as N	mg/L	0.1	6.3	1.4	< 0.1	4.9	0.4	2.4	2.3	-	-	0.35 - 12
Total Nitrogen as N	mg/L	0.01	6.3	1.4	<0.1	4.9	0.4	2.4	2.3	-	-	0.35 - 12
Total Phosphorus as P	mg/L	0.01	0.66	0.08	1.79	0.14	1.06	0.11	0.17	-	-	0.01 - 0.05
Dissolved Metals												
Aluminium	mg/L	0.01	<0.50	<0.01	<0.01	<0.50	<0.01	<0.50	<0.50	-	0.055	-
Arsenic	mg/L	0.001	<0.050	0.013	0.018	<0.050	0.009	< 0.050	< 0.050	-	0.024	-
Cadmium	mg/L	0.0001	<0.0050	<0.0001	<0.0001	<0.0050	<0.0001	<0.0050	<0.0050	0.0055	0.0002	-
Chromium	mg/L	0.001	<0.010	<0.001	<0.001	<0.010	<0.001	<0.010	<0.010	0.0274	-	-
Copper	mg/L	0.001	< 0.050	<0.001	<0.001	< 0.050	< 0.001	< 0.050	<u>0.065</u>	0.0013	0.0014	-
Iron	mg/L	0.05	33	1.24	< 0.05	31.6	0.45	8.07	12.8	-	-	-
Lead	mg/L	0.001	<0.010	<0.001	<0.001	<0.010	<0.001	<0.010	<0.010	0.0044	0.0034	-
Manganese	mg/L	0.001	<u>4.76</u>	0.89	0.024	<u>3.32</u>	0.195	<u>2.88</u>	<u>2.12</u>	-	1.9	-
Mercury	mg/L	0.0001	<0.0010	<0.0001	<0.0001	<0.0010	<0.0001	<0.0010	<0.0010	0.00004	0.00006	-
Nickel	mg/L	0.001	< 0.050	0.002	0.002	<0.050	0.001	< 0.050	< 0.050	0.07	0.011	-
Zinc	mg/L	0.005	< 0.050	<0.005	<0.005	<0.050	0.005	<0.050	<0.050	0.015	0.008	-
Total Metals												
Aluminium	mg/L	0.01	<u>1.65</u>	<u>0.6</u>	<u>0.58</u>	<u>4.38</u>	<u>1.39</u>	<0.50	<0.50	-	0.055	-
Arsenic	mg/L	0.001	<0.050	0.013	0.018	<0.050	0.009	<0.050	<0.050	-	0.024	-
Cadmium	mg/L	0.0001	<0.0050	<0.0001	<0.0001	<0.0050	<0.0001	<0.0050	<0.0050	0.0055	0.0002	-
Chromium	mg/L	0.001	<0.010	<0.001	<0.001	<0.010	0.001	<0.010	<0.010	0.0274	-	-
Copper	mg/L	0.001	< 0.050	<0.001	<0.001	<0.050	<0.001	< 0.050	<0.050	0.0013	0.0014	-
Iron	mg/L	0.05	30.3	1.62	0.35	30.5	0.93	7.86	11.2	-	-	-
Lead	mg/L	0.001	<0.010	<0.001	<0.001	<0.010	<0.001	<0.010	<0.010	0.0044	0.0034	-
Manganese	mg/L	0.001	<u>4.4</u>	0.877	0.026	<u>2.9</u>	0.189	<u>2.71</u>	<u>1.9</u>	-	1.9	-
Mercury	mg/L	0.0001	<0.0010	<0.0001	<0.0001	<0.0010	<0.0001	<0.0010	<0.0010	0.00004	0.00006	-
Nickel	mg/L	0.001	<0.050	0.002	<0.001	<0.050	0.002	<0.050	<0.050	0.07	0.011	-
Zinc	mg/L	0.005	<0.050	<0.005	<0.005	<0.050	<0.005	<0.050	<0.050	0.015	0.008	-
Ion Balance	-			1				1	-			
Total Anions	meq/L	0.01	1,680	152	16	1,020	99	1,000	571	-	-	-
Total Cations	meq/L	0.01	1,540	146	15	1,010	90	918	586	-	-	-
Ionic Balance	0/0	0.01	4	2	2	1	5	5	1		I -	

Notes: a.

0.7 0.024 0.1

ALS Limit of reporting (LOR) Minimum Limit of reporting value (LOR) Detected concentration above ANZECC (2000) Marine Water (95% Level of Protection) Detected concentration above ANZECC (2000) Freshwater (95% Level of Protection) Detected concentration above ANZECC (2000) Wetland (95% Level of Protection) No value



Table D-2: LABORATORY WATER QUALITY RESULTS, MAY 2015												
Analytes	Units	LOR ^a	MW01	MW02	MW03	MW04	MW05	MW06	ANZECC 2000 Marine	ANZECC 2000	ANZECC 2000	
Aquifer	-	-							Water (95% Level of	Fresh water (95% Level of	Wetland (95% Level of	
Date Sampled	-	-	22/05/2015	22/05/2015	22/05/2015	23/05/2015	23/05/2015	23/05/2015	Protection)	Protection)	Protection)	
Field - Physical Parameters												
pH Value	pH Unit		7.51	6.67	6.5	7.45	6.8	7.42	-	-	6 - 8.0	
Electrical Conductivity	μS/cm	-	3,044	5,777	81,218	7,653	95,431	9,003	-	-	-	
Laboratory - Physical Parameters	s	r	•	T	T	-	-	T	•	r		
pH Value	pH Unit	0.01	7.93	7.08	7.22	8.09	7.31	7.98	-	-	6 - 8.0	
Electrical Conductivity @ 25°C	μS/cm	1	2,940	5,340	80,200	7,130	83,400	8,710	-	-	-	
Total Dissolved Solids	mg/L	10	1,910	3,470	52,100	4,630	54,200	5,660	<u> </u>	-	-	
Alkalinity		1	1		4				r		1	
Hydroxide Alkalinity as CaCO ₃	mg/L	1	<1	<1	<1	<1	<1	<1	-	-	-	
Picarbonate Alkalinity as CaCO ₃	mg/L	1	<1 102	<1 112	270	<1 207	250	<1 242	-	-	-	
Total Alkalinity as CaCO	mg/L	1	103	112	279	397	359	342	-	-	-	
Major /Minor Jons	IIIg/L	1	105	112	2/9	397	337	342	-	-	-	
Calcium	mg/I	1	7	58	786	27	996	47		-	-	
Magnesium	mg/L	1	17	119	2070	65	2430	76		-		
Sodium	mg/L	1	557	764	17 100	1 390	18 300	1 600		-		
Potassium	mg/L	1	19	31	488	34	382	1,000		-		
Chloride	mg/L	1	771	1.510	31,900	2.020	34.000	2.870	-	0.003	-	
Sulphate	mg/L	1	131	192	5.100	247	5.250	217	-	-	-	
Nutrients		-	101	172	0,100	217	0,200	217		1		
Ammonia as N	mg/L	0.01	0.02	< 0.01	0.89	0.08	2.83	0.04	0.91	0.9	0.01	
Nitrite as N	mg/L	0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.04	0.09	-	-	0.01	
Nitrate as N	mg/L	0.01	<0.01	0.20	<0.01	<0.01	0.37	0.05	-	0.07	0.01	
Nitrite + Nitrate as N	mg/L	0.01	<0.01	0.20	<0.01	<0.01	0.41	0.14	-	-	0.35 - 12	
Total Kjeldahl Nitrogen as N	mg/L	0.1	<0.2	<0.2	<1.0	<0.2	3.2	<0.2	-	-	0.35 - 12	
Total Nitrogen as N	mg/L	0.01	<0.2	0.2	<1.0	<0.2	3.6	<0.2	-	-	0.35 - 12	
Total Phosphorus as P	mg/L	0.01	1.28	0.37	0.63	1.73	0.97	2.95	-	-	0.01 - 0.05	
Dissolved Metals				•	•			•	•			
Aluminium	mg/L	0.01	<0.01	<0.01	<0.50	< 0.01	<0.50	<0.01	-	0.055	-	
Arsenic	mg/L	0.001	0.008	0.002	<0.050	0.012	<0.050	0.013	-	0.024	-	
Cadmium	mg/L	0.0001	<0.0001	<0.0001	<0.0050	<0.0001	<0.0050	<0.0001	0.0055	0.0002	-	
Chromium	mg/L	0.001	<0.001	<0.001	<0.010	<0.001	<0.010	<0.001	0.0274	-	-	
Copper	mg/L	0.001	<0.001	<0.001	<0.050	<0.001	<0.050	<0.001	0.0013	0.0014	-	
Iron	mg/L	0.05	<0.05	<0.05	<0.50	<0.05	<0.50	<0.05	-	-	-	
Lead	mg/L	0.001	<0.001	<0.001	<0.010	<0.001	<0.010	<0.001	0.0044	0.0034	-	
Manganese	mg/L	0.001	0.017	0.255	<u>11.3</u>	0.264	<u>14.8</u>	0.582	-	1.9	-	
Mercury	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.00004	0.00006	-	
Nickel	mg/L	0.001	<0.001	0.001	<0.050	<0.001	<0.050	<0.001	0.07	0.011	-	
Zinc	mg/L	0.005	<0.005	0.008	0.060	<0.005	<0.050	<0.005	0.015	0.008	-	
Total Metals			•	-	-	1	-	-	-			
Aluminium	mg/L	0.01	<u>0.19</u>	<u>0.31</u>	<0.50	<u>0.19</u>	<u>0.72</u>	<u>0.20</u>	-	0.055	-	
Arsenic	mg/L	0.001	0.009	0.002	<0.050	0.013	<0.050	0.013	-	0.024	-	
Cadmium	mg/L	0.0001	<0.0001	<0.0001	<0.0050	<0.0001	<0.0050	<0.0001	0.0055	0.0002	-	
Chromium	mg/L	0.001	<0.001	<0.001	<0.010	<0.001	<0.010	<0.001	0.0274	-	-	
Copper	mg/L	0.001	0.001	0.001	<0.050	<0.001	<0.050	<0.001	0.0013	0.0014	-	
Iron	mg/L	0.05	0.15	0.14	< 0.50	0.27	0.87	0.14	-	-	-	
Lead	mg/L	0.001	<0.001	<0.001	<0.010	<0.001	<0.010	<0.001	0.0044	0.0034		
Manganese	mg/L	0.001	0.018	0.262	<u>10.4</u>	0.303	<u>13.6</u>	0.720	-	1.9		
Mercury	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.00004	0.00006	-	
NICKEI	mg/L	0.001	<0.005	0.010	0.055	<0.005	<0.050	<0.005	0.07	0.011	-	
Zinc	mg/L	0.005	<u>0.15</u>	<u>0.14</u>	<0.50	0.27	<u>0.87</u>	<u>0.14</u>	0.015	0.008	-	
Ion Balance	1.	0.01	20.1	40.0	1010	70.0	1000	02.2	1			
Total Anions	meq/L	0.01	28.1	48.8	1010	/0.0	1080	92.3	-	-	-	
Lonic Palanco	nieq/L	0.01	20.3	40./	222	1.40	1000	/0.4	-	-	-	
Notes	70	0.01	3.00	2.23	2.33	1.49	0.90	0.10	-	-		

a.
<0.010
0.7
<u>0.024</u>
0.1

ALS Limit of reporting (LOR)

ALS Limit of reporting (LUK) Minimum Limit of reporting value (LOR) Detected concentration above ANZECC (2000) Marine Water (95% Level of Protection) Detected concentration above ANZECC (2000) Freshwater (95% Level of Protection) Detected concentration above ANZECC (2000) Wetland (95% Level of Protection)

No value

Appendix D



Table D-3: LABORATORY WATER QUALITY RESULTS, MAY 2015											
Analytes	Units	LOR ^a	SITE 3	SITE 5	SITE 6	SITE 7	SITE 8	ANZECC 2000	ANZECC 2000	ANZECC 2000	
Aquifer	-	-						Marine Water (95%	Fresh water (95% Level	Wetland (95% Level of	
Date Sampled	-	-	22/05/2015	22/05/2015	22/05/2015	22/05/2015	22/05/2015	Protection)	01 Protection)	Protection)	
Field - Physical Parameters				,,	,,	,,					
pH Value	pH Unit	-	6	9.3	8.5	8	8.8	-	-	6 - 8.0	
Electrical Conductivity	μS/cm	-	35,198	15,813	1,976	79,073	14,825	-	-	-	
Laboratory - Physical Parameters											
pH Value	pH Unit	0.01	7.68	7.57	7.83	7.04	7.65	-	-	6 - 8.0	
Electrical Conductivity @ 25°C	µS/cm	1	35,000	16,100	2,010	78,700	14,000	-	-	-	
Total Dissolved Solids	mg/L	10	22,800	10,500	1,310	51,200	9,100	-	-	-	
Alkalinity			-								
Hydroxide Alkalinity as CaCO ₃	mg/L	1	<1	<1	<1	<1	<1	-	-	-	
Carbonate Alkalinity as CaCO ₃	mg/L	1	<1	<1	<1	<1	<1	-	-	-	
Bicarbonate Alkalinity as CaCO ₃	mg/L	1	656	203	193	270	177	-	-	-	
Total Alkalinity as CaCO ₃	mg/L	1	656	203	193	270	177	-	-	-	
Major/Minor Ions											
Calcium	mg/L	1	229	96	7	538	57	-	-	-	
Magnesium	mg/L	1	542	240	12	1920	208	-	-	-	
Sodium	mg/L	1	6,980	2,970	366	16,300	2,490	-	-	-	
Potassium	mg/L	1	239	112	14	537	92	-	-	-	
Chloride	mg/L	1	12,200	5,240	<u>520</u>	<u>31,000</u>	<u>4,760</u>	-	0.003	-	
Sulphate	mg/L	1	1320	1640	80	5570	732	-	-	-	
Nutrients	1	-		-	-	-					
Ammonia as N	mg/L	0.01	0.28	0.32	0.04	<u>3.21</u>	0.44	0.91	0.9	0.01	
Nitrite as N	mg/L	0.01	<0.01	<0.01	<0.01	<0.05	<0.01	-	-	0.01	
Nitrate as N	mg/L	0.01	<0.01	<0.01	<0.01	<0.05	<0.01	-	0.07	0.01	
Nitrite + Nitrate as N	mg/L	0.01	<0.01	< 0.01	<0.01	<0.05	<0.01	-	-	0.35 - 12	
Total Kjeldahl Nitrogen as N	mg/L	0.1	<1.0	<0.5	<0.2	3.2	<0.5	-	-	0.35 - 12	
Total Nitrogen as N	mg/L	0.01	<1.0	<0.5	<0.2	3.2	<0.5	-	-	0.35 - 12	
Total Phosphorus as P	mg/L	0.01	0.13	0.25	1.83	0.17	8.00	-	-	0.01 - 0.05	
Dissolved Metals	1		i	r	r	P	- i		-		
Aluminium	mg/L	0.01	<0.50	<0.01	<0.01	<0.50	<0.01	-	0.055	-	
Arsenic	mg/L	0.001	<0.050	0.021	0.016	<0.050	0.009	-	0.024	-	
Cadmium	mg/L	0.0001	<0.0050	<0.0001	<0.0001	<0.0050	<0.0001	0.0055	0.0002	-	
Chromium	mg/L	0.001	<0.010	<0.001	<0.001	<0.010	<0.001	0.0274	-	-	
Copper	mg/L	0.001	< 0.050	<0.001	<0.001	<0.050	<0.001	0.0013	0.0014	-	
Iron	mg/L	0.05	0.90	2.21	<0.05	28.6	0.90	-	-	-	
Lead	mg/L	0.001	<0.010	<0.001	<0.001	<0.010	<0.001	0.0044	0.0034	-	
Manganese	mg/L	0.001	<u>1.52</u>	0.852	0.034	<u>3.14</u>	0.321	-	1.9	-	
Mercury	mg/L	0.0001	<0.0010	<0.0010	<0.0001	<0.0001	<0.0001	0.00004	0.00006	-	
Nickel	mg/L	0.001	<0.050	0.001	0.001	<0.050	<0.001	0.07	0.011	-	
Zinc Total Matala	mg/L	0.005	<0.050	<0.005	0.005	<0.050	<0.005	0.015	0.008	-	
		0.01	-0.50	0.02	0.25	-0.50	0.00		0.055	1	
Auminium	mg/L	0.01	<0.50	0.02	0.01(<0.50	0.08	-	0.055	-	
Cadmium	mg/L	0.001	<0.050	-0.0001	-0.0001	<0.030	-0.0001	0.0055	0.024	-	
Caulinum	mg/L	0.0001	<0.0030	<0.0001	<0.0001	<0.0030	<0.0001	0.0274	0.0002	-	
Copper	mg/L	0.001	<0.010	0.001	<0.001	<0.010	<0.001	0.0274	0.0014	-	
Iron	mg/L	0.001	0.00	2.77	0.29	20.0	1 20	0.0013	0.0014		
Lead	mg/L	0.001	<0.010	<0.001	<0.001	<0.010	<0.001	0.0044	0.0034		
Manganese	mg/L	0.001	146	1 20	0.036	3 12	0.430	0.0044	19		
Mercury	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.001	0.00004	0.00006		
Nickel	mg/L	0.0001	<0.0001	0.003	0.002	<0.0001	<0.0001	0.07	0.011		
Zinc	mg/L	0.001	<0.050	0.003	<0.002	<0.050	<0.001	0.015	0.008		
Ion Balance		0.000	-0.000	0.010		-0.000	-0.000	0.015	0.000		
Total Anions	mea/I	0.01	385	186	20.2	996	153		-		
Total Cations	mea/L	0.01	366	156	17.6	908	131	-	-		
Ionic Balance	%	0.01	2.54	8.61	6.84	4.65	7.92	-	-	-	

Notes: a.

0.7 <u>0.024</u> 0.1

ALS Limit of reporting (LOR) Minimum Limit of reporting value (LOR) Detected concentration above ANZECC (2000) Marine Water (95% Level of Protection) Detected concentration above ANZECC (2000) Freshwater (95% Level of Protection) Detected concentration above ANZECC (2000) Wetland (95% Level of Protection) No value

Appendix E

Transient calibration hydrographs









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