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Report on
Additional Groundwater Investigation

Central Dune Sand Deposit
Great Keppel Island

Prepared for
GKI Resort Pty Ltd

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The undersigned, on behalf of Douglas Partners Pty Ltd, confirm that this document and all attached drawings, logs and test results have been checked and reviewed for errors, omissions and inaccuracies.

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Central Dune Sand Deposit, Great Keppel Island

1. Introduction

Douglas Partners Pty Ltd (DP) was commissioned by GKI Resort Pty Ltd (GKI Resort) to conduct an additional groundwater resource investigation in the central dune sand deposit on Great Keppel Island. Recent geotechnical investigations (DP 2010a) identified a more extensive sand deposit than that previously mapped by DNRMW (2006) that may have potential to provide a sustainable groundwater resource (potential Central Aquifer). This investigation focuses only on assessment of the potential Central Aquifer within the central region of Great Keppel Island.

This investigation was carried out for the proposed Great Keppel Island (GKI) Resort Revitalisation Plan (the "Project"). It is understood that redevelopment will include demolition of the existing resort, as well as construction of new resort facilities, a golf course and a marina. This assessment has been requested as part of an Environmental Impact Statement (EIS) for the Project.

1.1 Objectives

The objectives of this investigation were to:

- Investigate the extent and depth of the dune sand deposit;
- Identify if a viable groundwater resource is present within the dune sand; and
- Assess the long-term sustainable yield of the aquifer system.

To achieve these objectives, the following scope of work was carried out:

- Desktop review of existing groundwater information, including a search of the Department of Environment and Resource Management (DERM) groundwater database;
- Drilling of test bores and construction of five monitoring bores;
- Groundwater sampling and analysis to establish baseline groundwater quality;
- Development of the conceptual hydrogeological model (CHM) for the central dune sand deposit; and
- Groundwater modelling to assess sustainable yields.

2. Previous Investigations

Two investigations of groundwater aquifers on Great Keppel Island were carried out by DP in 2007 and one in 2010. Results of the investigations are detailed in DP (2007a), DP (2007b) and DP (2010b). These investigations and results are summarised in the following sub-sections.

2.1 Douglas Partners Pty Ltd (2007a)

DP conducted a groundwater supply investigation on Great Keppel Island in 2006 and 2007 for major redevelopments of the island that were proposed at the time. Groundwater was previously extracted from the dune sand deposit in the south-western end of the island as a water supply for the former resort. Hydrogeological investigations were carried out to determine whether potential groundwater resources existed elsewhere on the island and to assess their sustainable yields.

The investigation included a review of existing information, assessment of existing groundwater bores, mapping of dune sand deposits, an electromagnetic geophysical survey, installation of groundwater monitoring bores, groundwater quality sampling and analysis, development of conceptual hydrogeological models, and groundwater modelling to assess sustainable yields.

Based on the existing information and geology of the island, it was considered likely that potential aquifers containing potable groundwater would be located within the north-eastern and south-western parts of the island underlain by dune sand deposits. To investigate the groundwater potential of these sand deposits, 11 bores were drilled and groundwater monitoring bores were constructed in ten, six of in the south-western aquifer (MB1, MB2, MB7-MB11) and four in the north-eastern aquifer (MB3-MB6).

The south-western dune sand aquifer was considered to consist of two distinct aquifer areas divided by shallow bedrock beneath the southern end of the air strip. These two distinct aquifer areas were referred to as the “Resort Aquifer” draining to Putney Beach and Fisherman’s Beach, and the “Long Beach aquifer” draining to Long Beach. It was considered that the Resort Aquifer should not be considered as a potential water supply due to its poor water quality from salt water intrusion.

The hydrogeological investigations identified two viable groundwater resources which could be used as a water supply for the proposed development; the Long Beach aquifer in the south-western area of the island and the north-eastern dune sand aquifer. Field and laboratory water quality testing indicated the groundwater was fresh and suitable for a potable water supply, with the exception of a low pH. Salt water intrusion into the Long Beach aquifer due to historic over-pumping from bores which deceased the quality of the groundwater was also reported.

Groundwater modelling was conducted using Visual MODFLOW for the north-eastern aquifer and the Long Beach aquifer based on the results of the conceptual hydrogeological model to assess the sustainable aquifer yields and bore field design. A sustainable yield of approximately 100 kL/day (50 kL/day in each bore) was determined for two production bores in the Long Beach Aquifer, and a sustainable yield of approximately 270 kL/day was determined for three production bores in the Northeast Aquifer.

The groundwater modelling results and the estimated sustainable yield of the aquifers is dependent on the location and flow rates of productions comprising the borefield. To assist with the management of these two aquifers recommendations were provided for the construction requirements of the production bores (water bores) and for ongoing monitoring of groundwater levels, quality, as well as rainfall.

2.2 Douglas Partners Pty Ltd (2007b)

Based on the results and recommendations of DP (2007a), two production bores were installed within the Long Beach aquifer on Great Keppel Island in 2007. The bores were installed to supplement the existing resort water supply. Most of this aquifer had been affected by salt water intrusion, so the location of each bore and the long-term pumping rates would be critical to the sustainability of the supply.

Test pumping and analysis was carried out to assess the hydraulic parameters of the Long Beach aquifer and to confirm the maximum long term yields of each production bore. Analysis of the test pumping data confirmed that the aquifer is unconfined, has a transmissivity of approximately 220 m^2/day and a hydraulic conductivity of 20 m/day. As these parameters are similar to those used in predictive modelling, it was considered that the modelling results are accurate.

A groundwater management plan and recommendations for long term protection and monitoring of the bore field and Long Beach aquifer were also provided. These included the decommissioning of nine old water bores in the Long Beach aquifer, maintaining two monitoring bores for future monitoring purposes, installation of an additional monitoring bore, installation of protective covers and fencing around each production bore, regulation and monitoring of flow rates, exclusion of any potential contaminating activities over the surface of the aquifers, as well as a groundwater monitoring plan.

3. Site Information

Great Keppel Island is the largest island in the Keppel group of islands, and is located approximately 19 km east of Yeppoon off the Central Queensland coastline. It is located within the Mackay/ Capricorn region of the Great Barrier Reef Marine Park (GMRMP).

The former Great Keppel Island Resort is located on a dune sand deposit on the western side of the island between Fisherman's Beach and Long Beach. The main resort facilities are situated near Fisherman's Beach with some elevated villas on a hill immediately east of the former resort. A sealed landing strip is located to the east of the former resort aligned approximately north-west to south-east. Residential houses, some retail properties and accommodation facilities including the Keppel Haven Resort, and Keppel Island Village are also located on this dune sand deposit between Fisherman's Beach and Putney Beach.

3.1 Site Description

According to the proposed development plans provided by GKI Resort (dated October 2010), three regions of the island will experience disturbance as follows:

Precinct 1: Proposed marina precinct, northern section of Putney Beach and off-shore area;

Precinct 2: Proposed Fisherman's Beach precinct, footprint of existing resort, air strip, and vegetated areas east of the airstrip; and

Precinct 3: Proposed Clam Bay precinct, north of Clam Bay from the eastern base of Mount Wyndham and Wyndham Cove north to the historical Homestead, and east to the base of the mountain.

The "site" considered in this additional investigation is limited to the central area of the island which includes the area identified as Precinct 3. The proposed development precincts are shown on Drawing 1.

3.2 Geology

According to the published geological map for the Rockhampton region (DNRMW 2006), the central area of the island is primarily underlain by the Carboniferous aged Shoalwater Formation comprising metamorphic quartzose and lithic sandstones, with minor mudstone and schist. This Carboniferous sequence is mapped as being overlain by Quaternary alluvial deposits of clay, silt, sand, gravel, and flood-plain alluvium in the northern section of the site (Drawing 2).

DP (2011a) identified the presence of an extensive sand deposit within Precinct 3 to the termination depth of all boreholes (1.2 m below ground surface). Sand was described as very loose, initially dark brown and grey near the surface grading light brown, orange-brown and light grey with depth. Fine to medium grained sand was encountered from the surface at all borehole locations. The sand generally contained rootlets near the surface, and was moist with a trace to some silt.

3.3 Hydrogeology

Previous investigations (DP 2007a, 2011b) have confirmed the presence of aquifers with potable groundwater within the Quaternary dune sand deposits located within the north-eastern (Northeast Aquifer) and south-western (Resort Aquifer and Long Beach Aquifer) parts of the island. These three aquifers are described in detail in DP (2011b: Section 4).

Although the Northeast Aquifer would be sufficient to provide a sustainable groundwater resource, it is outside the current development footprint and is not currently being considered as a groundwater supply. Bore field design parameters and a groundwater management strategy for this aquifer are detailed in DP (2007b).

The Resort Aquifer has previously been identified as being unsuitable for providing a sustainable groundwater resource (DP 2007a). This aquifer has not been considered further for groundwater supply purposes.

Only the Long Beach Aquifer is within the proposed development footprint and would be sufficient to provide a sustainable groundwater resource. Two production bores were installed within the Long Beach Aquifer in 2007. The relevant bore field design parameters and a groundwater management strategy are detailed in DP (2007b).

The published geological map shows the central region of the island to be underlain by the Carboniferous Shoalwater Formation which was not considered to be a potentially viable aquifer. However, DP's recent preliminary geotechnical assessment of Precinct 3 (DP 2010a) identified a more extensive sand deposit than that previously mapped by DNRMW (2006) that may have potential to provide a sustainable groundwater resource (potential Central Aquifer, Drawing 2).

3.4 Climate and Rainfall

Great Keppel Island is located in a subtropical climate. According to data from the Bureau of Meteorology for Heron Island[1] (the closest island weather station), mean annual temperatures vary between 20.8ºC and 26.2ºC. January is the hottest month of the year with a mean maximum temperature of 29.8ºC. Mean annual rainfall for Heron Island was reported to be 1027 mm. February to May are the wettest months of the year.

Based on interpolated rainfall data sourced from the Bureau of Meteorology (BOM) SILO Database, the average annual rainfall (based on data from 1960-2011) for the island is 1,070 mm. The total annual rainfall has ranged from as low as 480 mm in 2001 up to 1854 mm in 2010. The data indicate that the island receives the highest rainfall between December and March. The total yearly rainfall is provided as a histogram in Appendix A (Figure A.1).

Average monthly rainfall and pan evaporation data listed in Table 1 are shown as a histogram in Appendix A (Figure A.2). The pan evaporation data have been corrected by a factor of 0.7 to obtain the actual evaporation for the region as recommended by BOM. Average monthly rainfall exceeded the average actual monthly evaporation between the months of January and March. Data in Table 1 shows that the average evaporation deficit, i.e. total evaporation minus total rainfall, is approximately 219 mm/year.

Table 1 – Great Keppel Island Average Monthly Rainfall & Evaporation

Month	Rainfall (mm)	Pan Evaporation (mm)	Actual Evaporation (mm)
January	153	169	140
February	176	140	116
March	136	128	120
April	95	94	97
May	96	64	78
June	57	53	65
July	44	61	70
August	40	81	84
September	31	108	105
October	45	143	131
November	70	153	137
December	128	172	145
Annual Average	1070	1842	1289

[1] Source: http://www.bom.gov.au/climate/averages/tables/cw_039122.shtml accessed on 17 December 2010.

The Cumulative Rainfall Residual Mass Balance (CRRMB) is calculated as a means of observing long-term trends in rainfall and relating these to observed groundwater levels. An increasing gradient in the CCRMB curve reflects an above average rainfall period where above average recharge is entering the aquifer system causing shallow groundwater levels to increase. Alternatively, downward trends in the CCRMB curve reflects low rainfall and recharge periods. The CRRMB shows the monthly deviation from the long-term average monthly rainfall and is calculated as follows:

$$CRRMB_n = (R_n - R_{av}) + CRRMB_{n-1}$$

Where:
$CRRMB_n$ = CRRMB for a given month
R_n = observed rainfall for a given month
R_{av} = long-term average rainfall
$CRRMB_{n-1}$ = CRRMB for a preceding month

Figure A-1 shows the annual rainfall and CRRMB curve between 1960 and 2010. The curve shows a sharp upward trend during 2010, since it was the wettest year on record, indicating that the groundwater levels over the past six months would have risen the most quickly and to the highest level over the past 50 years. The groundwater levels recorded during this investigation would be expected to be towards the highest on record.

3.5 Topography and Drainage

The topography of Great Keppel Island is relatively steep and is dominated by two southeast to northwest trending ridges with a maximum elevation of approximately 175 m AHD. Leeke's, Putney, and Blackall creeks drain these ridges to the west of the island towards Leeke's Beach. Some tidal wetlands exist behind Putney Beach and Leeke's Beach. Other minor, perennial creeks are relatively short and flow directly into the Pacific Ocean. A flat to undulating topography is present in the dune sand areas in the northeast and southwest regions of the island. The topography becomes slightly undulating on the eastern side towards Wreck Bay.

Topography in the central region of the island is relatively steep. It slopes from approximately 60 m AHD in the south-eastern end to sea level (0 m AHD) at the north-western end (Drawing 3). Based on the local topography, it is assumed that any groundwater in the Central Aquifer would drain to the northwest towards the tidal wetlands behind Leeke's Beach.

3.6 Existing Groundwater Information

Existing information relating to the known aquifers on the island is summarised in (DP 2011b: Section 4). Potential for an additional aquifer in the central region of the island was identified, but no groundwater assessment had previously been carried out in this area.

Review of the DERM groundwater database (DP 2011b) indicated that registered groundwater bores only exist in the Resort and Long Beach Aquifers.

4. Field Investigations

Field investigations were carried out under the supervision of Ms Karen Hager, DP Environmental Engineer, from 8-17 February 2011 and comprised:

- Drilling of six shallow boreholes (HA 21-HA 26) with a 4WD mounted EziProbe drilling rig to obtain information required for the effluent irrigation study;
- Drilling of eight boreholes (MB12, MB12a, MB12b-MB17) with a 4WD mounted EziProbe drilling rig;
- Collection of sand samples from the monitoring bores for particle size distribution (PSD) testing;
- Construction of five monitoring bores (MB12-MB16);
- Development of each new monitoring bore after construction;
- Measurement of depth to groundwater in all new monitoring bores;
- Recording each bore location with a GPS;
- Groundwater sampling; and
- Field analysis for pH, electrical conductivity (EC), and temperature.

General views of the drilling, installation and development of the monitoring bores are shown in Photographs 1-4.

4.1 Drilling and Construction of Monitoring Bores

Eight boreholes were drilled by Gladstone and Burnett Drilling using hollow flight auger drilling techniques, and six monitoring bores (MB12-MB16) were installed under DP supervision. Bore locations were selected to provide information on the depth of sand, the depth to groundwater, and groundwater quality. Bore locations are shown on Drawing 3.

All boreholes were lithologically logged based on an inspection of the auger returns. The subsurface conditions encountered in each borehole are given in detail on the borehole report sheets and should be read in conjunction with the *"Notes About This Report"* provided in Appendix B.

Monitoring bores were constructed using 50 mm diameter, Class 18 u PVC casing and 1.5 m lengths of pre-packed screen. Pre-packed screens consisted of factory slotted screens surrounded by 2-3 mm graded washed filter sand that was held in place with a fine stainless steel wire mesh. The annuli between the bore walls and casing/ screens were either filled with surrounding wet sand or, where necessary, backfilled with drilling spoil.

Bentonite seals were placed in the annuli above the screens to prevent surface water from entering the bore and impacting upon the groundwater. Steel monument covers were concreted over the top of bores for protection.

Construction details for individual wells are summarised in Table 2 and are illustrated on the borehole reports attached in Appendix B. Elevations of all monitoring bores were surveyed to allow the depth to groundwater to be referenced to a common datum (m AHD).

Table 2: Construction details for monitoring wells

Bore ID	Location[1]		Elevation (m AHD)[2]	Total Bore Depth (m BGL)	Screen Interval (m BGL)	Bentonite Seal (m BGL)	Filter Pack (m BGL)	SWL[3]	
	Easting (m)	Northing (m)						m BGL	m AHD
MB12	290979	7435629	7.49	8.96	2.79-8.96	1.55-2.20	2.79-8.91	1.03	6.47
MB13	291215	7435372	13.30	6.12	3.01-6.12	1.90-2.50	3.01-6.07	2.57	10.72
MB14	291484	7435428	15.15	6.58	3.47-6.58	1.70-2.40	3.47-6.53	3.11	12.04
MB15	291704	7435199	28.28	10.93	7.82-10.93	0.60-1.15	7.82-10.88	dry	dry
MB16	291545	7435361	19.41	13.28	7.11-13.28	2.60-3.20	7.11-13.23	6.73	12.68
MB17	292261	7435076	36.72	No Bore Installed					

Notes

m AHD	metres above Australian Height Datum
m BGL	metres below ground level
SWL	Standing water level
1	Coordinates in GDA 94 system; Surveyed by Schlencker Surveying Pty Ltd
2	Surveyed by Schlencker Surveying Pty Ltd
3	As measured after installation

4.2 Monitoring Bore Development, Purging and Sampling Procedure

Monitoring bore installation and development was conducted in accordance with The Land and Water Biodiversity Committee (2003). All bores were drilled using hollow flight augers. Development of the bores was carried out to remove fine sand/ clay particles from the screens of the bores to allow collection of representative groundwater samples. Development comprised purging the wells with disposable bailers until they produced groundwater with a constant pH and electrical conductivity (EC).

After bore development was completed, groundwater samples were collected from Bores MB12-MB16. Sampling complied with the standard operating procedures described in DP's Field Procedures Manual, as well as the Murray-Darling Basin Commission (1997). The general sampling procedure comprised:

- Purging a minimum of three bore volumes of groundwater using disposable bailers;
- Allowing the groundwater level to recover to within 15% of its natural level prior to sample collection;
- Collection of representative groundwater samples using disposable bailers;
- Measurement of field parameters;
- Transfer of the samples directly into the appropriate laboratory prepared containers;
- Field-filtering of the groundwater sample through a 0.45 µm filter for dissolved metals analysis;
- Labelling of sample containers with individual and unique identification, including project number and sample location; and
- Samples remained refrigerated and/or chilled with ice until arrival at the laboratory.

4.3 Particle Size Distribution Tests and Permeability Estimates

Particle size distribution tests (PSDs) were performed on the sand samples from boreholes MB12, MB13, MB14, and MB16 to assist in soils classification and to provide indicative permeability values. The disturbed sand samples were tested for PSD at DP's NATA registered soils laboratory. The results of these tests are provided in Appendix C. The Hazen method, as described by Fetter (1994), was employed to estimate the hydraulic conductivity (or permeability) of the sand samples to obtain an indication of the hydraulic conductivity of the aquifer within the dune sand deposit. Results are provided in Table 3.

Table 3: Permeability estimated from PSD tests

Sample (Bore & Depth)	Lithology	Permeability	
		m/day	m/sec
12 – 4.0 m	Sand with some silt	7.8	9.00E-05
13 – 3.5 m	Silty sand	0.6	6.75E-06
14 – 2.5 m	Sand with some silt	3.8	4.41E-05
16 – 9.2 m	Sand with some silt	6.3	7.29E-05
16 – 14.0 m	Sand with some silt	5.6	6.50E-05

Hazen's method estimates that at the drilling locations the aquifer has a low to medium permeability with a hydraulic conductivity which ranges between 0.6 m/day and 8 m/day. The average hydraulic conductivity is approximately 4.8 m/day. This is consistent with published estimates for a fine to medium grained sand.

5. Water Quality Testing

5.1 Regulatory Criteria

Groundwater quality was assessed against the Australian Drinking Water Guidelines (ADWG) (NHMRC 2004). The ADWG provides a framework for good management of drinking water supplies to assure safety at the point of use. The ADWG are designed to provide an authoritative reference on what defines safe, good quality water with regard to health and aesthetic quality. In the context of this project, the ADWG have been applied to assess the suitability of water for consumption purposes.

Where reference values are not available in the ADWG, ANZECC (2000) guidelines were applied to assess analytical data. Trigger values for 95% protection of slightly-moderately disturbed freshwater ecosystems (ANZECC 2000, Table 3.4.1) were used.

5.2 Field Water Parameters

Groundwater samples were assessed in the field using calibrated hand-held equipment for pH, EC and temperature during sampling. All of the new bores were sampled. Sampling locations are shown on Drawing 3 and the results are summarised in Table 4.

Table 4: Groundwater Field Monitoring Results

Sample ID	Date Sampled	SWL[1]		Temp. (°C)	pH	EC (μS/cm)	Turbidity	Observations
		m BGL	m AHD					
MB12	13/02/2011	1.03	6.47	24.5	5.2	920	Turbid	Pale brown colour, no odour, fast recharge rate
MB13	14/02/2011	2.85	10.44	24.7	5.6	2,330	Turbid	Orange-brown colour, no odour, moderate recharge rate
MB14	14/02/2011	3.11	12.04	24.9	5.7	740	Turbid	Pale brown colour, no odour, fast recharge rate
MB15	15/02/2011	Dry						
MB16	16/02/2011	6.73	12.68	25.1	5.5	980	Turbid	Pale brown colour, no odour, fast recharge rate
Site Assessment Criteria								
ADWG[2]					**6.5-8.5**	**2,200**		

Notes

1 Measured at time of sampling
2 Australian Drinking Water Guidelines 6 (NHMRC 2004: Table 10.10)
SWL Standing water level
m BGL metres below ground level
Yellow cells contain levels of an analyte outside than the ADWG (2004) guideline values
This table has been produced in colour to indicate exceedences of relevant criteria. Reproduction should be carried out in colour.

5.3 Laboratory Analyses

All groundwater samples were sent to Australian Laboratory Services Pty Ltd (ALS), at 32 Shand Street, Stafford, Brisbane for analysis. ALS are accredited by the National Association of Testing Authorities (NATA). Analytes included: total dissolved salts (TDS), total hardness, sodium adsorption ratio (SAR), major cations (Ca, Na, Mg, K), major anions (Cl, CO_3, HCO_3, and SO_4), and dissolved metals (arsenic, cadmium, chromium, copper, iron, lead, nickel, zinc, mercury).

5.4 Laboratory Results

Laboratory results are summarised in Table 5. Chain of custody documentation and laboratory reports are attached in Appendix D.

Table 5: Groundwater Laboratory Results

	Sample ID and Sampling Date			Assessment Criteria	
	MB12	MB13	MB16	ADWG[1]	ANZECC[2]
	13/02/2011	14/02/2011	16/02/2011		
General Groundwater Quality					
Turbidity (NTU)	2,200	1,700	2,700	**5***	**1-20**
Sodium Absorption Ratio	6.23	7.21	5.86	~	~
Total Dissolved Solids	528	1,170	452	**500***	~
Suspended Solids	-	1,750	-	~	~
Total Hardness	116	345	99	**200***	~
Bicarbonate	10	29	5	~	~
Chloride	264	709	253	**250***	~
Dissolved Major Anions & Cations					
Sulfate	70	27	31	**500**	~
Calcium	10	31	10	~	~
Magnesium	22	65	18	~	~
Sodium	154	308	134	**180***	~
Potassium	2	7	3	~	~
Dissolved Metals					
Arsenic	<0.001	<0.001	<0.001	**0.007**	**0.024**
Cadmium	<0.0001	0.0009	<0.0001	**0.002**	**0.0002**
Chromium	<0.001	<0.001	<0.001	**0.05^**	**0.001**
Copper	0.006	0.046	0.001	**2**	**0.0014**
Iron	0.08	0.14	<0.05	**0.3***	**0.3#**
Lead	<0.001	0.001	<0.001	**0.01**	**0.0034**
Nickel	0.004	0.038	0.004	**0.02**	**0.011**
Zinc	0.03	0.119	0.202	**3***	**0.008**
Mercury	<0.0001	<0.0001	<0.0001	**0.001**	**0.0006**
Nutrients					
Total Nitrogen	1.8	1.2	6.9	~	**0.35**
Total Phosphorus	0.6	0.86	1.29	~	**0.01**

Notes

	Results are reported in mg/L unless otherwise indicated
1	Australian Drinking Water Guidelines 6 (NHMRC 2004: Table 10.10)
2	ANZECC (2000) Trigger values for 95% protection of freshwater (Table 3.4.1); and default trigger values for physical and chemical stressors in southeast Australia (Tables 3.3.2 and 3.3.3: freshwater lakes and reservoirs)
*	Aesthetic value
^	Chromium as Cr(VI)
-	Not tested
~	No guideline available at time of investigation
Yellow	cells contain levels of an analyte greater than the ADWG (NHMRC 2004) guideline values
Blue	cells contain levels of an analyte exceeding the ANZECC (2000) trigger values
	This table has been produced in colour to indicate exceedences of relevant criteria. Reproduction should be carried out in colour.

5.5 Summary of Water Quality

Field and laboratory testing confirms the groundwater quality is generally fresh (MB12, MB14, and MB16) however within the more silty sand lithology the salt content increases to become slightly brackish at MB13. Laboratory testing confirmed the field water quality and reported total dissolved salt content of between 452 mg/L at MB16 up to 1170 mg/L at MB13. The ADWG guidelines provide an upper limit of 500 mg/L, however state that 500-1000 mg/L is acceptable depending on taste.

The pH of the groundwater is acidic and below the drinking water guidelines, however it is typical of groundwater quality within coastal sand aquifers.

Concentrations of major cations and anions for MB12, MB13 and MB16 were converted into milliequivalents and percentage reacting values of anions and cations were calculated. The percentage of each cation and anion was then plotted on the piper (trilinear) diagram (Drawing 4) to classify the hydrochemical facies of the groundwater. The piper diagram shows that water within the central dune sand aquifer appears to be a sodium-chloride type of water.

Levels of chloride exceeded the ADWG in the three samples tested and Hardness exceeded the aesthetic ADWG guideline in MB13. None of the other water quality parameters or heavy metals tested reported levels which exceeded the drinking water guidelines, with the exception of nickel in MB13. Iron levels are considered to be low and should not cause iron staining.

The preliminary water quality testing indicates the groundwater quality for irrigation and/or as a potable water supply maybe unsuitable depending on where the production bores are located. Generally MB16 reported a more suitable water quality. The water quality suitability as a potable water supply should be confirmed with additional water quality testing once the production bores have been installed.

6. Conceptual Hydrogeological Model

The Conceptual Hydrogeological Model (CHM) for central dune sand aquifer is based on a review of the geological and topographic maps, review of the existing information sourced from DERM, and the drilling and installation of the six monitoring bores. The CHM is outlined in the following sections and the major components are illustrated on the hydrogeological cross section provided on Drawing 5.

6.1 Geological Setting

The central dune sand aquifer is composed of Quaternary dune beach sand. The sand deposit is a relatively poorly-sorted fine to medium grained sand and grades into a silty sand in some areas. The sand deposit also contains some colluvium derived sediments from the surrounding hills. The sand deposit varies from between 2.5 m (MB17) to greater than 17 m (MB12a). The full extent of the dune sand deposit was inferred from recent field investigations, onsite geological mapping, and the Rockhampton 1:100,000 Geological Sheet, and is shown on Drawing 3.

The general profile of the sand deposit comprises light grey, fine to medium grained sand underlain by light orange/brown or brown fine to medium grained sand with some silt, which is inturn underlain by light orange/brown silty sand. No shell layers or indurated sand layers (or coffee rock) were evident in the drilling of the monitoring bores. The basement of the aquifer is comprised of residual silty clay/ clayey sand which overlies the metamorphic quartzose and lithic sandstones of the Carboniferous Shoal-water Formation. The dune sand deposit is bounded to the north, east and south by outcrop of the Shoalwater Formation.

6.2 Hydrogeology

The Great Keppel Island central dune sand aquifer extends from Leeke's beach to approximately half way along the valley to Clam Bay, as shown on Drawing 3. The location of the aquifer's eastern boundary may vary according to rainfall and the volume of recharge entering the aquifer, and represents the extent of saturated sand. The western boundary coincides with Leeke's Beach and the estuary/ tidal wetlands where the groundwater will discharge. The aquifer is bounded by outcrop of the Shoalwater Formation to the north and south. The basement of the aquifer is composed of the same formation.

It is an unconfined (or water table) aquifer that receives the majority of its recharge through direct infiltration of rainfall over its entire natural ground surface. It would also receive additional recharge through the infiltration of rainfall into the unsaturated sand deposit between the eastern boundary and Clam Bay. This infiltration of rainfall will seep through the sands, along the top of the bedrock, and into the eastern boundary of the aquifer. The groundwater discharges to the wetland and the Pacific Ocean via Leeke's Beach.

Permeability estimates based on PSD tests were derived for MB12, MB13, MB14 and MB16, indicating an average hydraulic conductivity of 5 m/day for the boreholes, a value which is characteristic of fine grained sands. The saturated thickness of the aquifer is relatively thin in parts and varies between 3.0 m at MB13 up to 10 m at MB16. The aquifer thickness is also inferred to increase towards the tidal wetland and Leeke's Beach as shown in cross section on Drawing 5.

Water inputs to the aquifer are:

- Rainfall infiltration over the entire surface area of the aquifer;
- Rainfall infiltration and seepage through the unsaturated sands to the south; and
- Minor component of stormwater runoff from the slopes to the north and south of the aquifer.

Water outputs or losses from the aquifer are:

- Evapotranspiration from the vegetation across the surface of the aquifer; and
- Discharge to the wetland and/or Leeke's Beach.

6.3 Groundwater Levels and Flow Direction

In shallow coastal aquifers the groundwater will be a subdued reflection of the surface topography. The monitoring data collected for this aquifer indicates that the groundwater flow patterns do follow the topography. Standing water levels measured in February 2011 range between 1.03 m and 6.7 m below ground surface, and 6.4 mAHD and 12.7 mAHD in elevation indicating the groundwater generally flows from MB16 towards MB12 in a north-westerly direction towards Leeke's Beach.

The average hydraulic gradient between MB12 and MB16 is calculated to be 0.01 which is a relatively high gradient for a coastal sand aquifer. The high hydraulic gradient is probably a reflection of the low permeability, high basement gradient and high rainfall recharge entering the aquifer at the time of the monitoring. The higher hydraulic gradient indicated on the cross section in Drawing 5 indicates a change in the lithology and permeability of the aquifer along the coastline.

6.4 Aquifer Recharge

Recharge to the aquifer comprises the direct infiltration of rainfall over the entire surface area of the aquifer, as shown on Drawing 3. There will be an additional contribution from surface runoff from the slopes bounding the aquifer to the north and south, as well as to the east through the sub-surface drainage of rainfall infiltration. For this preliminary assessment of aquifer recharge, any runoff component of recharge has been ignored.

Recharge to the aquifer was estimated by multiplying the surface area of the aquifer by a percentage of average annual rainfall for the region. Rainfall recharge represents the amount (i.e. percentage) of rainfall percolating downward into the ground and not taken up by the vegetation (through transpiration) or lost through direct evaporation (collectively known as evapotranspiration) or surface runoff. Taking into consideration several factors including studies conducted in the Tomago Sands region of NSW and North Stradbroke Island, and the presence of sandy soils over the aquifer area, a conservative estimate for rainfall recharge would be 20-40% of the rainfall.

The average annual rainfall (based on data from 1960-2006) for Great Keppel Island is 1070 mm. The records of annual rainfall range from 480 mm in 2001, up to 1854 mm in 2010.

The surface area of the aquifer as shown in Drawing 3was estimated to be 0.5 km^2. The total recharge for the entire central dune sand aquifer can be estimated as follows:

Annual Recharge Potential = Aquifer Surface Area x Annual Rainfall x 30%

Thus recharge for:	a wet year	=	264 ML
	an average year	=	152 ML
	a dry (drought) year	=	68 ML

6.5 Aquifer Sustainable Yield

A commonly adopted value for the sustainable yield of an aquifer is 70 % of the long-term average recharge. Because of the potential for salt water intrusion from the ocean and impacts to the tidal wetlands, a more practical estimate of the preliminary sustainable yield for coastal aquifers is considered to be approximately 50 % of the total recharge.

The total average annual recharge was calculated to be 152 ML/year. When multiplied by 50 %, this results in a sustainable yield for the aquifer of 76 ML/year (0.21 ML/day or 210 kL/day). Using the same methodology for the driest year on record, the sustainable yield of the aquifer would have been 34 ML/year (0.09 ML/day or 90 kL/day).

The method of assessing sustainable yield as an estimate based on a proportion of long-term average recharge is approximate only (Bredehoeft 2002). This is particularly so for dynamic systems such as coastal sand deposits. The sustainable yield of a groundwater extraction system will depend on its design and the volume of discharge from the aquifer that it can capture. This volume will depend on the dynamic response of the aquifer to the extraction of groundwater, and can be better assessed using groundwater flow modelling as described in Section 7.

7. Groundwater Modelling

Development of a groundwater flow model requires at least a reasonable approximation of the aquifer geometry, its hydraulic parameters, and the stresses (such as recharge, extraction etc) acting upon it. Once the geometry of the aquifer is defined and location of various existing and future stress points are determined, the aquifer is discretised into cells or elements and hydraulic properties are assigned to each cell. Prior to any predictive simulations, the model predictions are usually required to be confirmed as reasonable, by calibrating the model to observed groundwater levels and flow patterns. This calibration usually requires a number of model runs during which modifications are made of the unknown or uncertain aquifer parameters until a match between observed and simulated groundwater levels is achieved.

Model simulations were conducted using *MODFLOW* (McDonald & Harbaugh 1988), a numerical groundwater flow model developed by the United States Geological Survey. This is a three-dimensional groundwater head and flow model and it is accepted as the industry standard and is legally defensible. The model was based on site-specific data where possible, as well as estimates of unknown parameters based on experience with similar environments. The model was developed using the pre-processor or graphical interface program *Visual MODFLOW* and was based on the CHM described in Section 6.

The purpose of developing the model was to aid in the assessment of the sustainable yield of the aquifer, and to assist in designing an optimum bore field layout.

7.1 Model Geometry

The entire aquifer is represented as a one layer model. The aquifer boundaries of the model coincide with the known natural boundaries such as Leeke's Beach and associated wetlands/estuary, and the geological boundaries between the dune sand and the Shoalwater Formation.

The model grid extends 2000 m in an east-west direction and 1500 m in a north-south direction. The finite difference grid was initially discretised into 113 rows and 166 columns with variable cell dimensions. The dimensions were reduced to approximately 5 m by 7 m in the area of expected high hydraulic gradients, i.e. in the vicinity of the bore field. The top of the model was set to correspond to the natural surface contours. The base of the model was set to correspond to the inferred base of the dune sand as shown on Drawing 6.

7.2 Model Hydraulic Boundaries

Boundary conditions are applied to numerical models to represent the physical environment and to constrain the model calculation domain. The types of boundaries selected were consistent with the conceptual model (Section 8.1) and include no-flow and constant head boundaries as described below:

- Constant head boundaries were applied to the model where the aquifer is connected to Leeke's Beach and within the wetland were initially set at 0.3 m AHD. It should be noted that, even though the constant head cells are located at sea level, technically these cells are not at a head of 0mAHD, for that would take no account of the fact that freshwater escapes from the aquifer into the sea against the differential pressure induced by a column of salt water, the height of which is equal to the depth of water overlying freshwater discharge zones (i.e. a head of 0.3m allows fresh water to escape from the system against a column of salt water of up to 12m in height). Furthermore, tidal over-height effects (i.e. Nielsen, 1990) are also acknowledged in the setting of an equivalent freshwater head at greater than mean sea level along the ocean-aquifer interface."
- No-flow boundary along the northern, eastern and southern sides of the aquifer to represent the impermeable geological boundary between the aquifer sands and bedrock.

7.3 Initial Aquifer Parameters

Aquifer parameters required for the one-layer model included horizontal hydraulic conductivity, effective porosity and specific yield. Initial estimates were obtained from the PSD tests carried out on sand samples collected from the monitoring bores. Using Hazen's method, the average permeability for the sand was approximately 5 m/day. Estimates for the specific yield and porosity were obtained from published ranges for a medium grained sand. Initial estimates for these parameters used in the development of the aquifer model were:

- Horizontal hydraulic conductivity = 5 m/day
- Porosity = 0.20
- Specific yield = 0.15

7.4 Recharge

Aquifer recharge is the infiltration of rainfall over the entire surface area of the aquifer and through runoff from the hills which border the aquifer's northern and southern boundaries. As the runoff component is difficult to estimate and assumed to be minor compared to rainfall infiltration, it was not included in the model.

For a given value of hydraulic conductivity, various values of recharge will result in different elevations of the groundwater table. Rainfall recharge was simulated in the steady state simulations by obtaining the historical rainfall set for Great Keppel Island and applying a recharge coefficient of between 25%-50% to the average rainfall. This recharge was applied uniformly to the top layer of cells in the model.

7.5 Evapotranspiration

The *MODFLOW* evapotranspiration module was used for the steady state and transient simulations. The digital surface elevations were incorporated into the model as the evapotranspiration surface. The maximum evapotranspiration rate was the average actual evaporation rate of 1289 mm/year. The extinction depth used was 2 metres.

7.6 Steady State Model Calibration

Calibration of a flow model refers to the trial and error process by which model parameters (hydraulic conductivity, recharge and boundary conditions) are adjusted to produce an acceptable match between simulated and observed groundwater levels. Typical model outcomes depend on several different parameters and combinations leading to the non-uniqueness problem where different sets of model inputs produce nearly identical model outputs. To reduce this possibility and increase the reliability of the model, it is preferred that as many model variables or inputs as possible are accurately determined, and the model is calibrated using both steady state and transient simulations. However, for this model, only one set of water level data (groundwater levels measured on the 13 and 16 February 2011) was available for the calibration. Hence, a transient calibration was not possible.

The steady state calibration of the model was aimed at reproducing the observed groundwater levels in boreholes MB12, MB13, MB14 and MB16, and the expected flow patterns given the geometry of the aquifer. The model calibration was carried out using a manual calibration.

During the calibration process, the aquifer parameters were limited to the following ranges:

- Hydraulic conductivity between 2.5 m/day and 10 m/day;
- Lower Hydraulic conductivity zone beneath the tidal wetland area of 0.5 m/day and 1.0 m/day; and
- Recharge between 30% (or 321 mm/year) and 50% (or 535 mm/year) of average annual rainfall.

During the calibration process a separate and lower hydraulic conductivity zone was required to be simulated for the tidal wetland area in order to simulate a better match with the observed head at MB12. Geological mapping supports this zonation of aquifer permeability as it is mapped as a separate geological unit containing more clayey estuarine sediments.

A summary of the measured and simulated groundwater levels for the final calibration run at the monitoring bore locations is shown in Table 6, and the *Visual MODFLOW* calibration curve and statistics are shown in Drawing 7. The simulated steady state water table contours from this calibration run are shown on Drawing 8 and are considered to compare well with the geometry of the observed groundwater contours.

Table 6: Model Calibration Results

Bore	K_H (m/day)	Recharge (% of Rainfall)	Observed SWL (mAHD)	Simulated Heads (mAHD)	Difference (m)
MB12	8	40	6.47	5.49	-0.98
MB13	8	40	10.44	10.19	-0.25
MB14	8	40	12.04	12.18	+0.14
MB16	8	40	12.68	12.52	-0.16
RMS (m)					**0.51**

A measure of the success of model calibration can be evaluated using the root mean square error (RMS) expressed as:

$$RMS = [1/n\sum(h_m-h_s)^2]^{0.5}$$

where
- n = number of measurements
- h_m = measured head
- h_s = simulated head

The calculated RMS error for the model was 0.51 m. This calibration result is considered acceptable for the size of the model domain, limited calibration data, and the dynamic system that was modelled.

Final adopted model parameters following completion of the steady state calibration were:

- Hydraulic conductivity = 8 m/day
- Recharge = 40% average rainfall

7.7 Predictive Modelling – Central Dune Sand Aquifer

To evaluate the optimum borefield design and sustainable yield, the calibrated model was run for various transient simulations with different extraction scenarios. To be conservative, the long-term predictive simulations to identify the maximum sustainable yield were run over a 15 year period (January 1992 to December 2006) which contained one of the driest periods on record between 1991 and 2007 where the residual mass balance and five year running average continually decreased (Figure A.2, Appendix A).

Hydraulic heads obtained from the calibrated steady state simulation were incorporated into the transient model as the initial heads. The simulations comprised 180 monthly stress periods to allow for changes in the monthly rainfall to be simulated.

7.7.1 Sustainable Yield Criteria

The sustainable yield was assessed at the maximum extraction rate that did not cause the following:

- Excessive drawdown causing the aquifer to dry out in the vicinity of the bore field or extraction well; and
- Reversal of the hydraulic gradient near the tidal wetlands and Leeke's Beach (constant head boundaries), thereby inducing salt water intrusion and significantly decreasing the volume of groundwater discharge into the wetland.

To assess if a reversal of the hydraulic gradient occurred during the simulations, the simulated head was recorded at every stress period (i.e. monthly) at the location of MB12 located in the middle of the aquifer approximately 200 m from the boundary of the tidal wetland (Drawing 8). If the extraction from the bore field caused the groundwater at this location to be lower than the water level within the wetlands, then it would reverse the natural gradient thereby reducing the volume of groundwater discharging into the wetland ecosystem and cause salt water to potentially flow into the aquifer.

To be conservative, the specific criteria adopted to assess the sustainability of the simulated borefield extraction also included:

- Groundwater level within MB12 must remain above the ground surface level along the edge of the wetland i.e. ~3.0 mAHD to ensure a positive gradient is maintained at all times; and
- Simulated drawdown must not exceed 0.7 m within MB12. This is considered conservative as the natural fluctuation of the groundwater level is approximately 2-3 m between a wet and dry season.

7.7.2 Predictive Modelling Results

The production bores were located towards the middle of the aquifer and at a maximum distance from the constant head boundaries to minimise any potential impact of extraction on the water levels along the tidal wetlands (Drawing 8). Multiple pumping simulations were run allowing the pumping rates and bore locations to be changed in order to assess the sustainable yield of the aquifer system.

The following predictive scenarios were run under transient conditions using the historical set of monthly rainfall from January 1992 to December 2006:

Run 1 (Non-pumping case):
Predictive Run 1 was a non-pumping scenario carried out to obtain the simulated rise and fall of the groundwater levels with variation in rainfall only. The simulated heads were saved at the end of stress periods to validate that the calibration of the model was reasonable; ie. the model did not dry out under natural rainfall conditions and that fluctuations of the water table in response to rainfall were within likely bounds. This also allowed a better assessment of the impact of pumping from the bore field. The results are presented as a hydrograph for each monitoring bore in Appendix E, Figure E.1. This

hydrograph shows the groundwater levels fluctuate by 2-3 m over the simulated period and generally show a gradual decline in levels over the 16 year period which is similar to the decline in the CRRMB curve provided in Figure A-1 (Appendix A). This confirms that the steady state calibration of the model is reasonable.

Runs 2 to 4:

Predictive Run 2 simulated a total extraction of 400 kL/day from two production bores. Each bore was set to extract 200 kL/day. The two production bores were separated by approximately 200 m, one located between MB14 and MB16, the other to the west of MB14 in the centre of the aquifer. The production bores had the following coordinates:

- PB1 – E291514, N7435400; and
- PB2 – E292329, N7435460

During the Run 2 simulation the aquifer dried out around both bore locations, thus the pumping simulated from the bore field was considered to be not sustainable.

For Run 3 the pumping rate was reduced to 100 kL/day in both bores for a total extraction of 200 kL/day. However the aquifer at both bore locations dried out during the simulation. Thus the pumping simulated from the bore field was also considered to be not sustainable.

For Run 4 the pumping rates for both bores was reduced further to 50 kL/day for a total extraction of 100 kL/day, however the aquifer dried out at PB1 and PB2 dried out during the simulation. Thus the pumping simulated from the bore field was again considered to be not sustainable.

Run 5-6:

For Predictive Run 5 the production bore locations were moved into a deeper section of the aquifer near MB16 and closer towards the eastern boundary (Drawing 9). The bore field comprised two production bores, PB1 was located near MB16 and PB2 approximately 100 m to the southwest with the following coordinate locations:

- PB1 – E291534, N7435387; and
- PB2 – E291473, N7435319.

Predictive Run 5 simulated a total extraction of 120 kL/day, 80 kL/day from PB1 and 40 kL/day from PB2. Both bores dried out during the simulation and it was therefore not considered sustainable.

For Run 6 the total extraction was reduced to 90 kL/day, with PB1 extracting 70 kL/day and PB2 20 kL/day. Neither of the bores dried out satisfying the first sustainable yield criteria. The simulated drawdown reached its maximum at the end of the simulation. Groundwater head contours at this stage of the simulation are shown on Drawing 9 and indicate the natural hydraulic gradient has not been reversed around the tidal wetland or Leeke's Beach. The simulated hydrographs for MB12 showing the groundwater levels and drawdown throughout the simulation are shown on Figures E.2 and E.3 (Appendix E) respectively. Figure E.2 shows that the groundwater level did not fall below 3.0 mAHD at any occasion throughout the simulation and Figure E.3 shows that the drawdown did not exceed 0.7 m.

Drawing 10shows the drawdown induced by Run 6 across the aquifer at the end of the simulation when the drawdown recorded in MB12 reached its maximum. The drawing indicates that no significant drawdown affects the tidal wetland area as shown by the 0.5 m contour. This confirms the results simulated for MB12. The drawing shows that the drawdown within the aquifer reaches a maximum of 3.5 m within the bore field between PB1 and PB2.

The extraction simulated during Run 6 from the bore field is therefore considered to be sustainable, as it satisfied all the appropriate criteria indicating there would be no significant impact to the aquifer system or tidal wetland at any time during the simulation

Run 7-8:
To attempt to increase the aquifer sustainable yield a third production bore was located approximately 150 m to the west of PB2. This third bore PB3 was located at E291335, N7435310. Run 7 simulated an extraction of 50 kL/day from PB3 to increase the total bore field extraction to 140 kL/day. However PB3 and the aquifer surrounding it became dry during the simulation, therefore the extraction was considered to be not sustainable.

For Predictive Run 8 the extraction from PB3 was reduced to 20 kL/day, however the aquifer around the bore still became dry probably due to the thin saturated thickness of the aquifer in this area. Therefore the extraction was considered to be unsustainable and further simulations with a third extraction bore were not considered feasible.

7.8 Predictive Modelling Summary

In summary, the predictive modelling identified that the aquifer sustainable yield was limited first by the aquifer's low permeability and relatively thin saturated thickness before the drawdown from the bore field extraction impacted upon the tidal wetland or caused salt water intrusion. The saturated aquifer thickness is shown in cross section on Drawing 5 developed from the drilling of the monitoring bores. These bores recorded a saturated thickness of between 3.0 m and 10 m during a high rainfall period when the saturated thickness would be expected to be at its highest. The pumping rates simulated from the production bores were required to be significantly reduced in order to prevent the drying out of the model cells containing the production bores.

Run 6 indicated that a sustainable yield of 90 kL/day was capable of being extracted from the aquifer using the two production bores, PB1 (70 kL/day) and PB2 (20 kL/day), at the locations described above and shown on Drawing 9 and Drawing 10. The extraction rates remained constant and were extracted from the bore field continuously each day over the 15 year period.

The sustainable yield represents the average long-term yield for the aquifer. Higher extraction rates maybe possible if they were extracted during the wetter months of the year and for shorter time periods instead of continuously. Additional modelling would be required to confirm short-term sustainable yields or variable extraction rates from the bore field.

8. Conclusions

The groundwater investigation carried out within the central dune sand deposit of Great Keppel Island identified a potential groundwater supply resource within the sand deposit. The dune sand deposit contains an unconfined or water table aquifer over the area shown on Drawing 3.

The CHM was developed for the aquifer and is illustrated on Drawing 5 in cross-section. The aquifer extends from Leeke's Beach and the tidal wetland/estuary to approximately half way across the valley to Clam Bay. Its saturated thickness is relatively thin in parts and the monitoring bores installed indicates its thickness varies between 3.0 m and 10 m. The basement is residual sandy clay or weathered bedrock belonging to the Shoalwater Formation. The aquifer receives the majority of its recharge through the direct infiltration of rainfall across the permeable ground surface and run-off from the higher topography surrounding the aquifer to the north, south, and west. It will discharge groundwater into Leeke's Beach and the tidal wetland.

The groundwater quality is generally fresh (MB12, MB14, and MB16) however was found to be become slightly brackish, and non potable at MB13. The groundwater is acidic, which is typical for coastal sand aquifers, and indicates it would require treatment prior to being used as a potable water supply. Levels of chloride exceeded the ADWG in the three samples tested and hardness exceeded the aesthetic ADWG guideline in MB13. None of the other water quality parameters or heavy metals tested reported levels which exceeded the drinking water guidelines, with the exception of nickel in MB13. Generally the groundwater quality was better at MB16. The suitability of the groundwater quality as a potable water supply should be confirmed with further water quality testing after the production bores have been installed.

A numerical groundwater flow model was developed for the aquifer as one layer models using the pre-processor *Visual MODFLOW t*o assess the sustainability of extracting groundwater. A reasonable steady state calibration of the flow model was achieved by comparison of observed and simulated groundwater elevations. This data however is limited to one data point in time and could be improved in the future when additional groundwater monitoring data becomes available.

Predictive modelling scenarios were run over a 15 year rainfall record from 1992 to 2006 which included one of the most driest periods on record. Predictive modelling indicated the following average sustainable yield for the central dune sand aquifer:

- 90 kL/day (90 m^3/day) as simulated by predictive Run 6 (Section 7.7.2) using a bore field comprising two production bores, PB1 pumping at 70 kL/day and PB2 pumping at 20 kL/day, located near MB16 as shown on Drawing 10.

This sustainable yield is less in comparison to the other two dune sand aquifers (DP, 2007a) because of its smaller size, i.e. the surface areal extent is smaller, its saturated thickness is also thinner, and its permeability is lower compared to the other two aquifer systems. The numerical modelling found that the key sustainability criteria which restricted the bore field yield was the drying out of the aquifer around the simulated production bores.

The sustainable yield of 90 kL/day represents the average long-term yield for the aquifer. Higher extraction rates maybe possible when varied between the wet and dry months of the year, or if extraction occurs over shorter time periods instead of the bore field operating continuously throughout each year. Additional modelling would be required to confirm short-term sustainable yields.

8.1 Preliminary Bore Field Design

If the groundwater resource within the central dune sand deposit was to be used by the proposed resort, the bore field should be constructed at the locations simulated by the predictive scenario Run 6 to extract the maximum long-term sustainable yield. The two production bores should be established with the following coordinates:

- PB1 – E291534, N7435387; and
- PB2 – E291473, N7435319.

The volumes extracted from the individual production bores should not exceed those simulated. The modelling has shown that distribution of the pumping rates within the bore field affects the sustainable yield. If more water was pumped from the bore closer to the coastline or wetland, then the yield would not be sustainable.

9. Recommendations

It is recommended the following be carried out, if the proposed bore field is constructed:

- The bore field is constructed in accordance with the design outlined in Section 9.1 to obtain the long term sustainable yields;
- Step drawdown and 24-hour constant rate pumping tests are carried out on each production bore installed in the bore field. Analysis of the pumping test data should be undertaken to assess the individual sustainable bore yields and allow comparison with the simulated bore yields;
- Further assessment of potential impacts to the tidal wetland be carried out;
- Groundwater samples be collected at the end of the pumping tests and water quality testing (TDS, cations, anions, alkalinity, heavy metals, nutrients, and bacteriological including *E. Coli*) be carried out to confirm its suitability for irrigation and/or as a potable water supply;
- Data loggers should be installed into two monitoring bores MB12 and MB16 within the aquifer to allow more accurate monitoring data to be collected and used to re-calibrate the numerical model;
- Monitoring of water levels and electrical conductivity should be undertaken for monitoring bores MB12, MB13, MB14, and MB16 every three months.

9.1 Production Bore Construction Requirements

It is recommended that all bores be constructed in accordance with the Agriculture and Resource Management Council of Australia and New Zealand's *'Minimum Construction Requirements For Water Bores In Australia',* dated September 2003.

Construction requirements for the two new production (extraction) bores are:

- Borehole diameter of at approximately 254 mm (10 inch) drilled to 2 m below the base of the dune sand deposit. Drilling to 2 m below the base of the sands will be required to allow for some collapsing of the borehole and to ensure the screen is set opposite the base of the aquifer;
- Stainless steel screens, 3 m in length, 150 mm (6 inch) in diameter, and with an aperture 0.5 mm should be used;
- Bore casings should comprise Class 12 uPVC casing, of 150 mm (6 inch) diameter;
- Gravel pack consisting of 2-3 mm graded sand/gravel should be placed adjacent to well screens;
- A 2 metre bentonite seal should be placed within the annulus above the water table; and
- Lockable protective steel bore covers should be cemented in at the surface and a suitable protective fence constructed around each bore location.

10. References

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11. Limitations of this Report

Douglas Partners (DP) has prepared this report for this project on Great Keppel Island in accordance with DP's proposal BNE100871dated 10 December 2010 dated 3 February 2011 and acceptance received from Mr. Anthony Aiossa of GKI Resort Pty Ltd on 11 January 2011. This report is provided for the exclusive use of GKI Resort Pty Ltd for the specific project and purpose as described in the report. It should not be used by or relied upon for other projects or purposes on the same or other site or by a third party.

This report must be read in conjunction with any attached explanatory notes and should be kept in its entirety without separation of individual pages or sections. DP cannot be held responsible for interpretations or conclusions from review by others of this report or test data, which are not otherwise supported by an expressed statement, interpretation, outcome or conclusion stated in this report. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

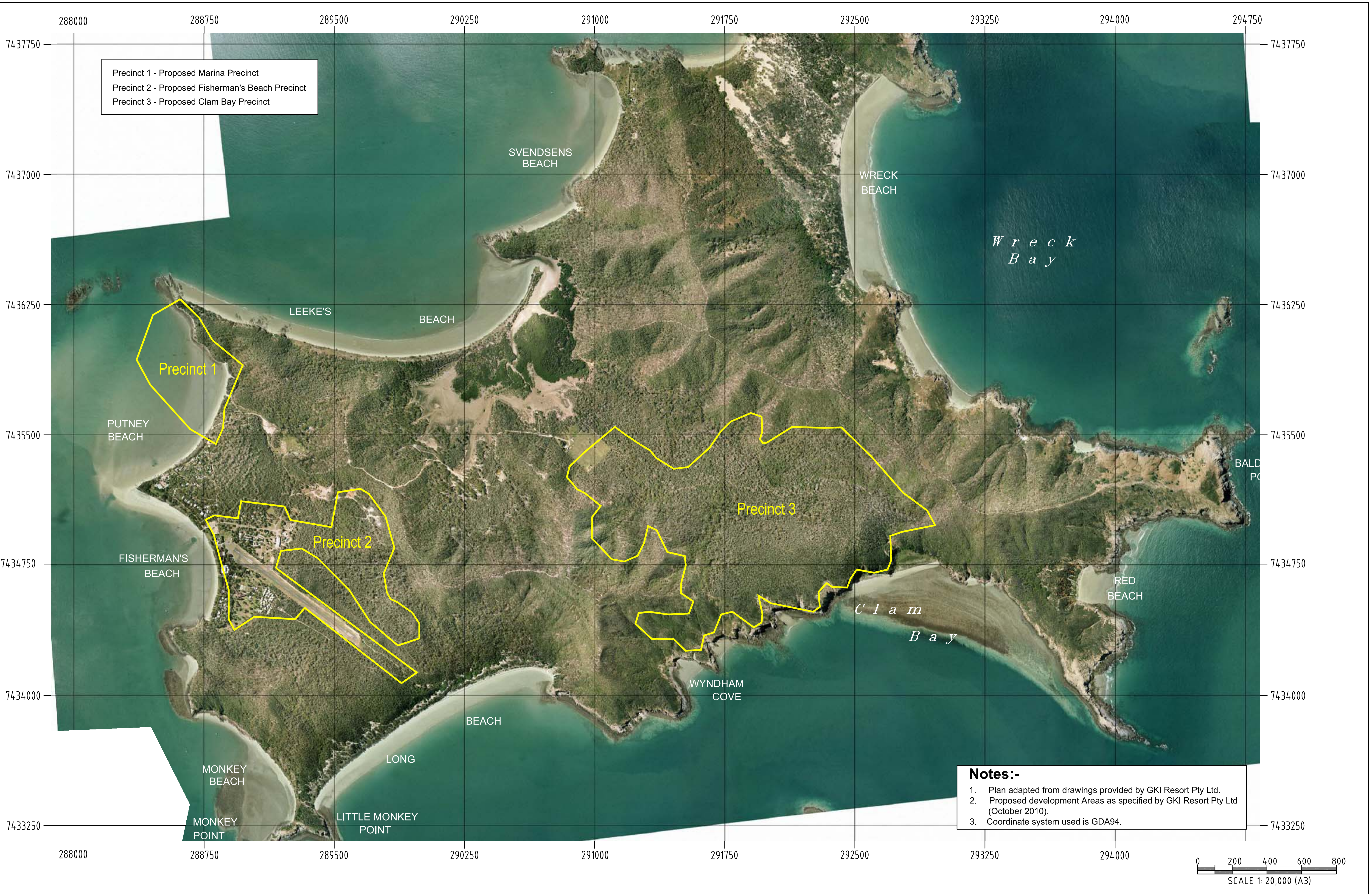
The results provided in the report are indicative of the sub-surface conditions only at the specific sampling or testing locations, and then only to the depths investigated and at the time the work was carried out. Sub-surface conditions can change abruptly due to variable geological processes and also as a result of anthropogenic influences. Such changes may occur after DP's field testing has been completed.

DP's advice is based upon the conditions encountered during this investigation. The accuracy of the advice provided by DP in this report may be limited by undetected variations in ground conditions between sampling locations. The advice may also be limited by budget constraints imposed by others or by site accessibility.

This report, or sections from this report, should not be used as part of a specification for a project, without review and agreement by DP. This is because this report has been written as advice and opinion rather than instructions for construction.

Douglas Partners Pty Ltd

Drawings



Douglas Partners
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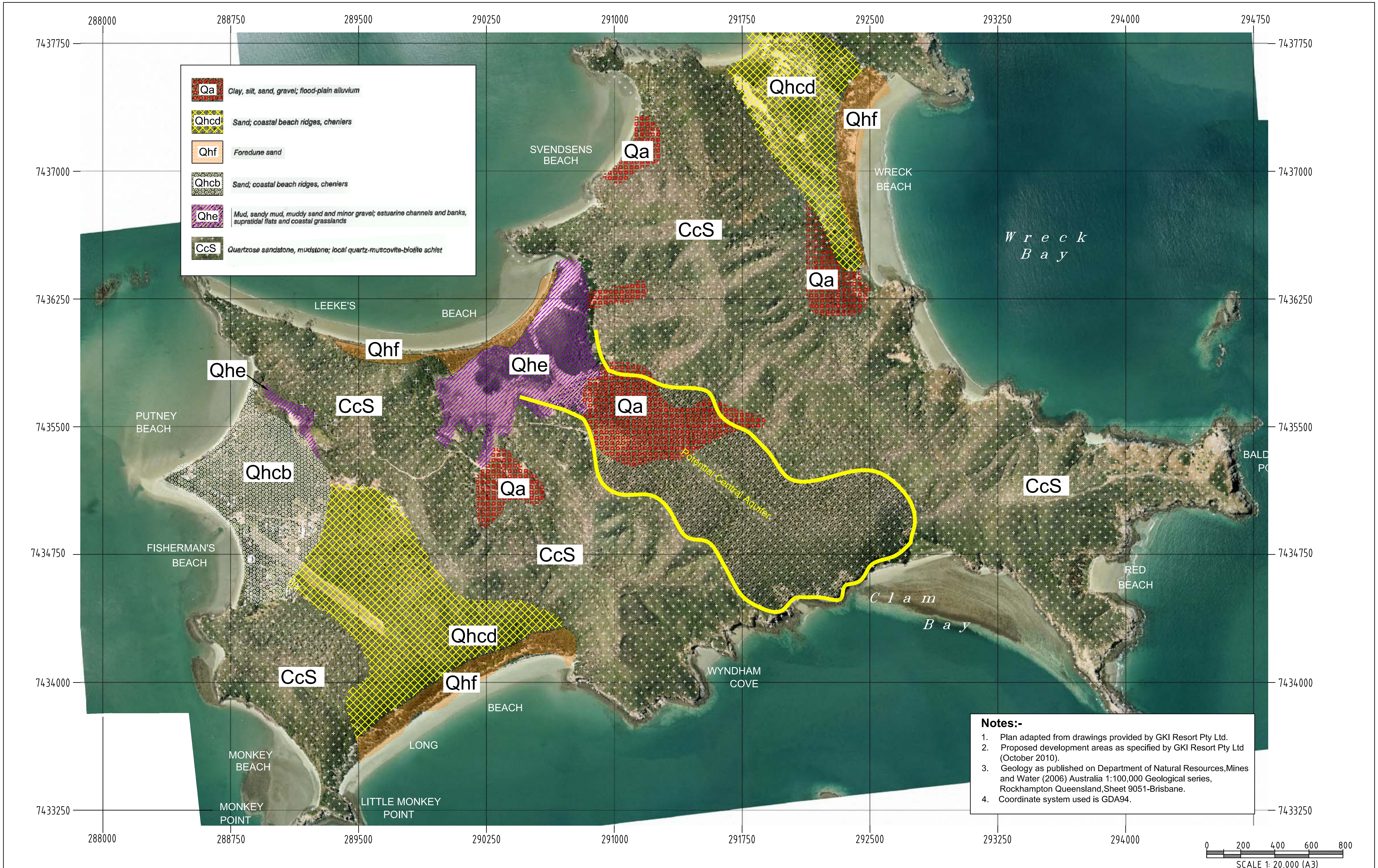
CLIENT: GKI Resort Pty Ltd		TITLE: **Proposed Precincts of Development**	PROJECT No: 74586.01
OFFICE: Brisbane	DRAWN BY: JT	**Additional Groundwater Investigation**	DRAWING No: 1
SCALE: As shown	DATE: 1 September 2011	**Central Dune Sand Deposit, Great Keppel Island**	REVISION: 1

P:\Groundwater Projects\74586.01 GKI Additional Groundwater Investigation\Drawings\Rev.01\Drawing 1 - Additional GW Investn.dwg



Notes:-

1. Plan adapted from drawings provided by GKI Resort Pty Ltd.
2. Proposed development areas as specified by GKI Resort Pty Ltd (October 2010).
3. Geology as published on Department of Natural Resources,Mines and Water (2006) Australia 1:100,000 Geological series, Rockhampton Queensland,Sheet 9051-Brisbane.
4. Coordinate system used is GDA94.

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CLIENT: GKI Resort Pty Ltd		TITLE: **Great Keppel Island Geology**	PROJECT No: 74586.01
OFFICE: Brisbane	DRAWN BY: JT	**Additional Groundwater Investigation**	DRAWING No: 2
SCALE: As shown	DATE: 1 September 2011	**Central Dune Sand Deposit, Great Keppel Island**	REVISION: 1

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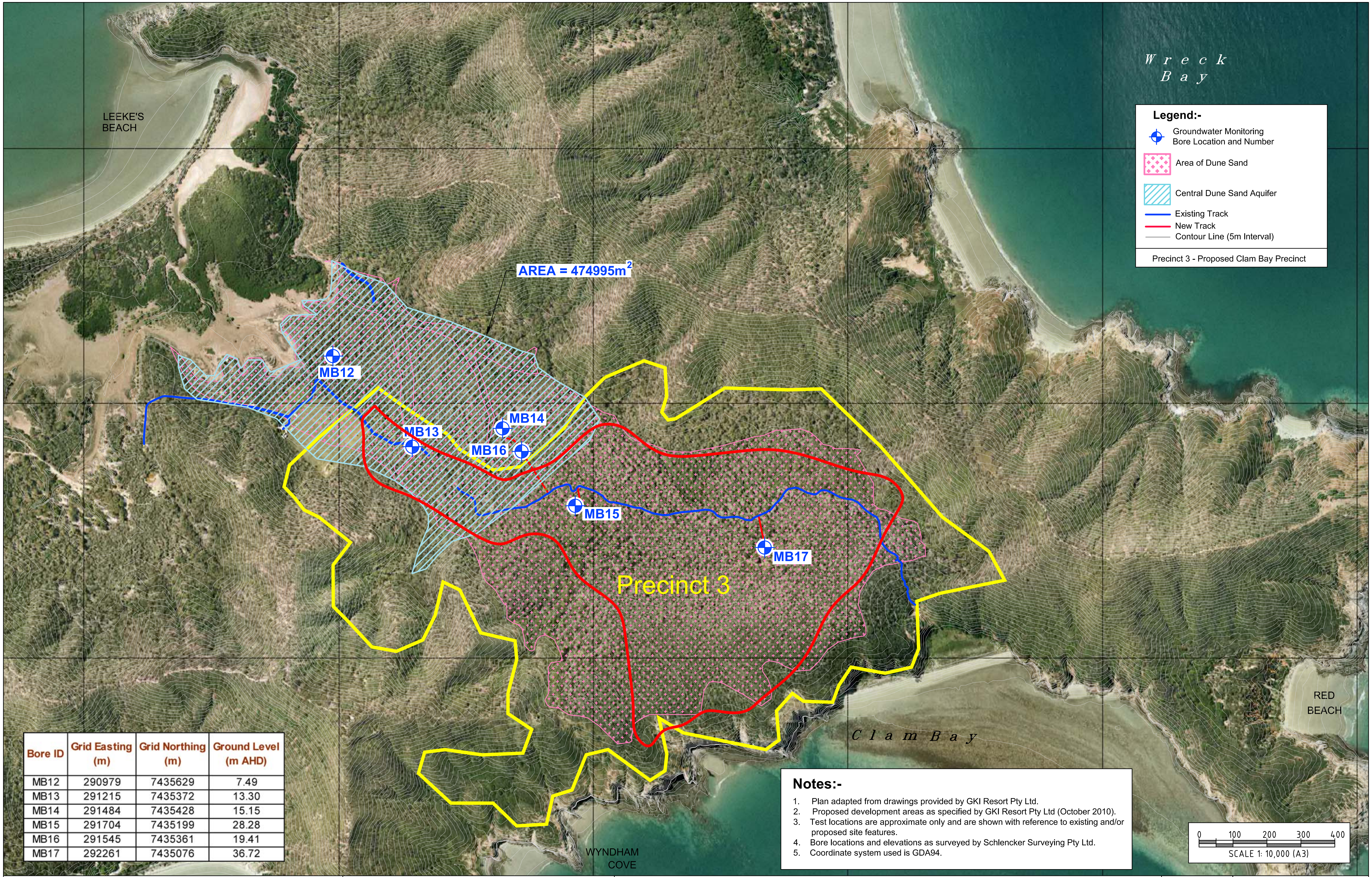

Bore ID	Grid Easting (m)	Grid Northing (m)	Ground Level (m AHD)
MB12	290979	7435629	7.49
MB13	291215	7435372	13.30
MB14	291484	7435428	15.15
MB15	291704	7435199	28.28
MB16	291545	7435361	19.41
MB17	292261	7435076	36.72

Notes:-

1. Plan adapted from drawings provided by GKI Resort Pty Ltd.
2. Proposed development areas as specified by GKI Resort Pty Ltd (October 2010).
3. Test locations are approximate only and are shown with reference to existing and/or proposed site features.
4. Bore locations and elevations as surveyed by Schlencker Surveying Pty Ltd.
5. Coordinate system used is GDA94.

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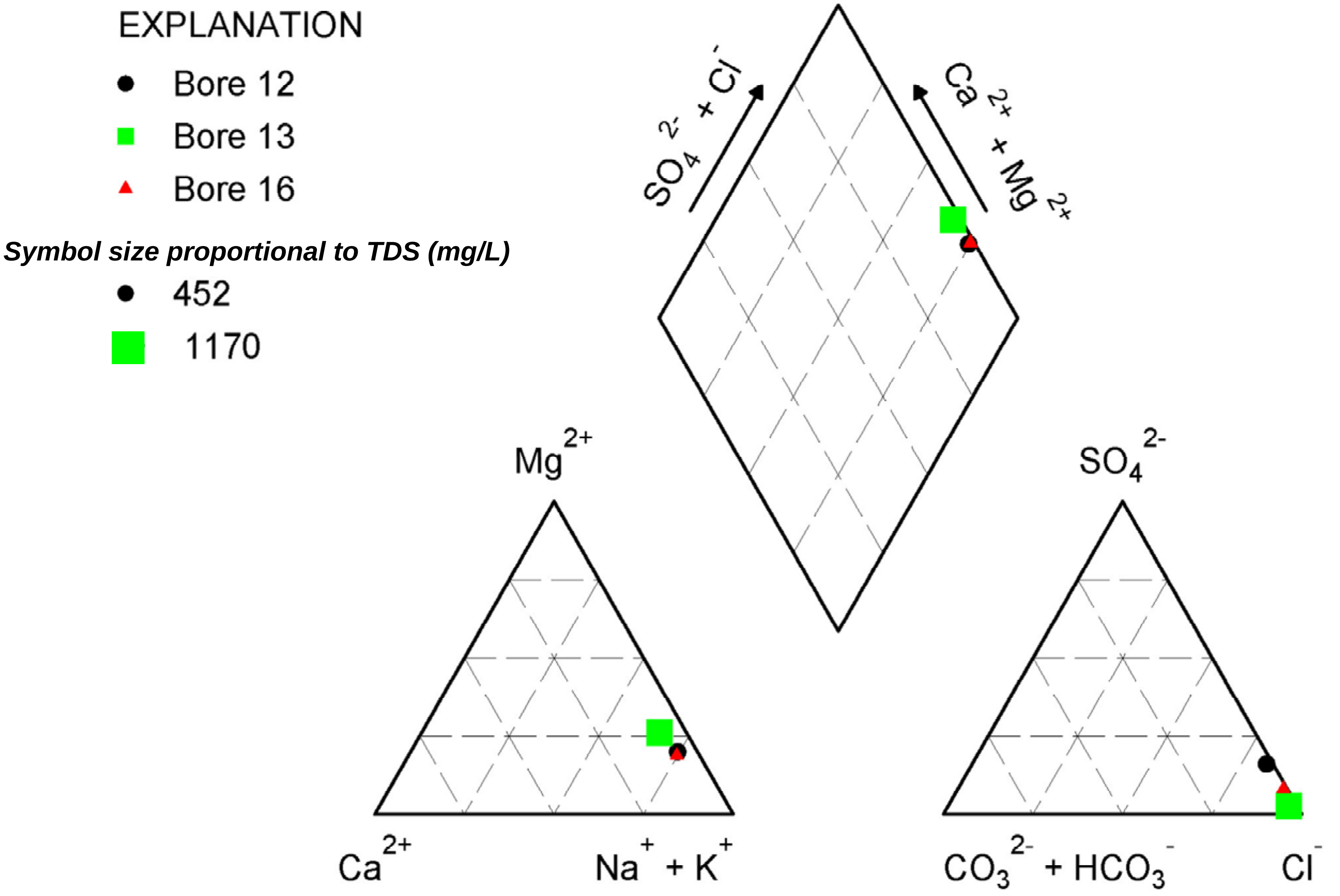
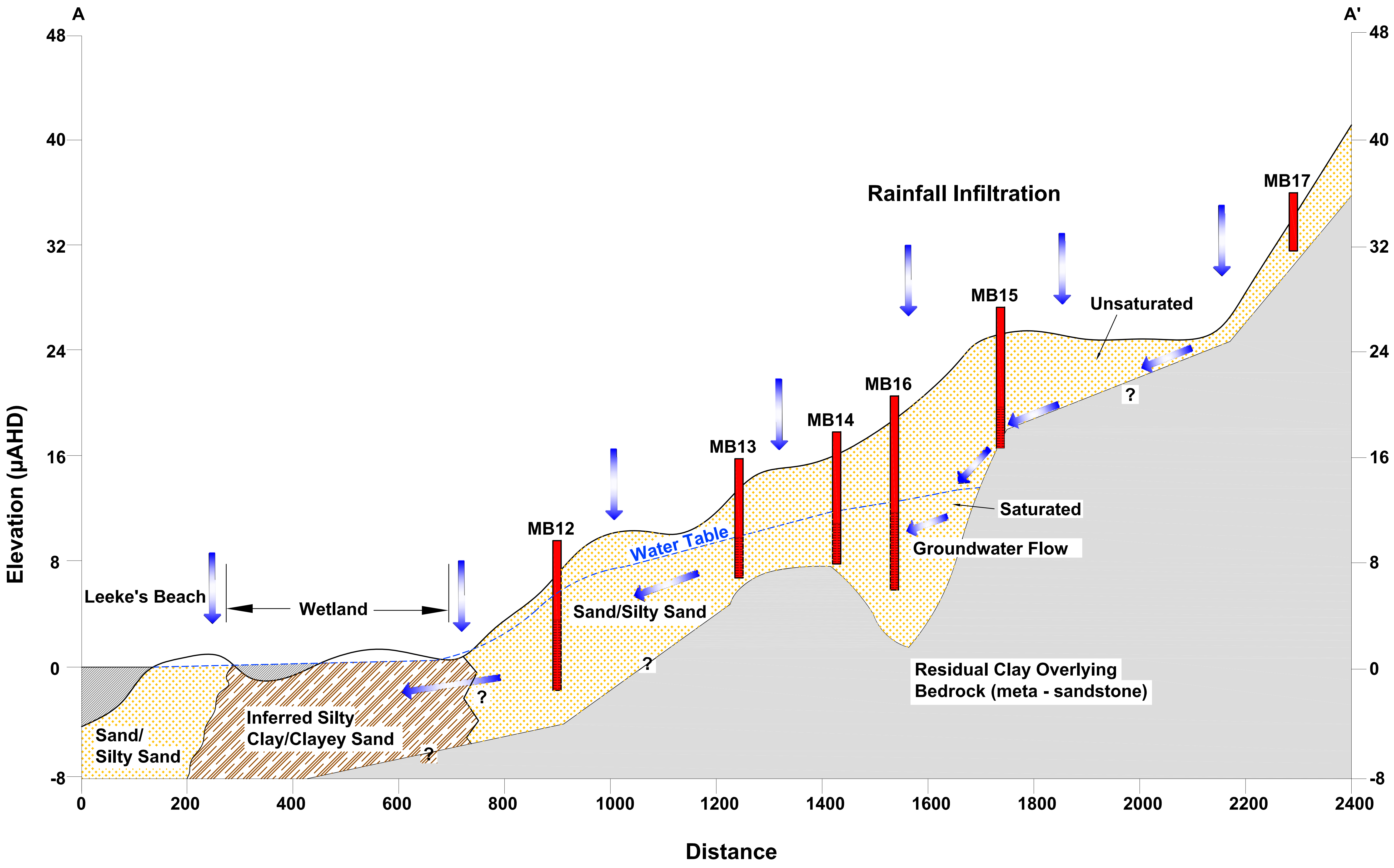
CLIENT: GKI Resort Pty Ltd		TITLE: Extent of Central Dune Sand Aquifer and Bore Location Plan	PROJECT No: 74586.01
OFFICE: Brisbane	DRAWN BY: JT	Additional Groundwater Investigation	DRAWING No: 3
SCALE: As shown	DATE: 1 September 2011	Central Dune Sand Deposit, Great Keppel Island	REVISION: 1

P:\Groundwater Projects\74586.01 GKI Additional Groundwater Investigation\Drawings\Rev.01\Drawing 3 - Additional GW Investn.dwg



Douglas Partners Geotechnics / Environment / Groundwater	CLIENT: GKI Resorts Pty Ltd		TITLE **PIPER DIAGRAM - GROUNDWATER QUALITY** **Additional Groundwater Investigation** **Central Dune Deposit, Great Keppel Island**	PROJECT No: 74586.01
	OFFICE: Brisbane	DRAWN BY: AMP		DRAWING No: 4
		DATE: Aug 2011		REVISION: 2



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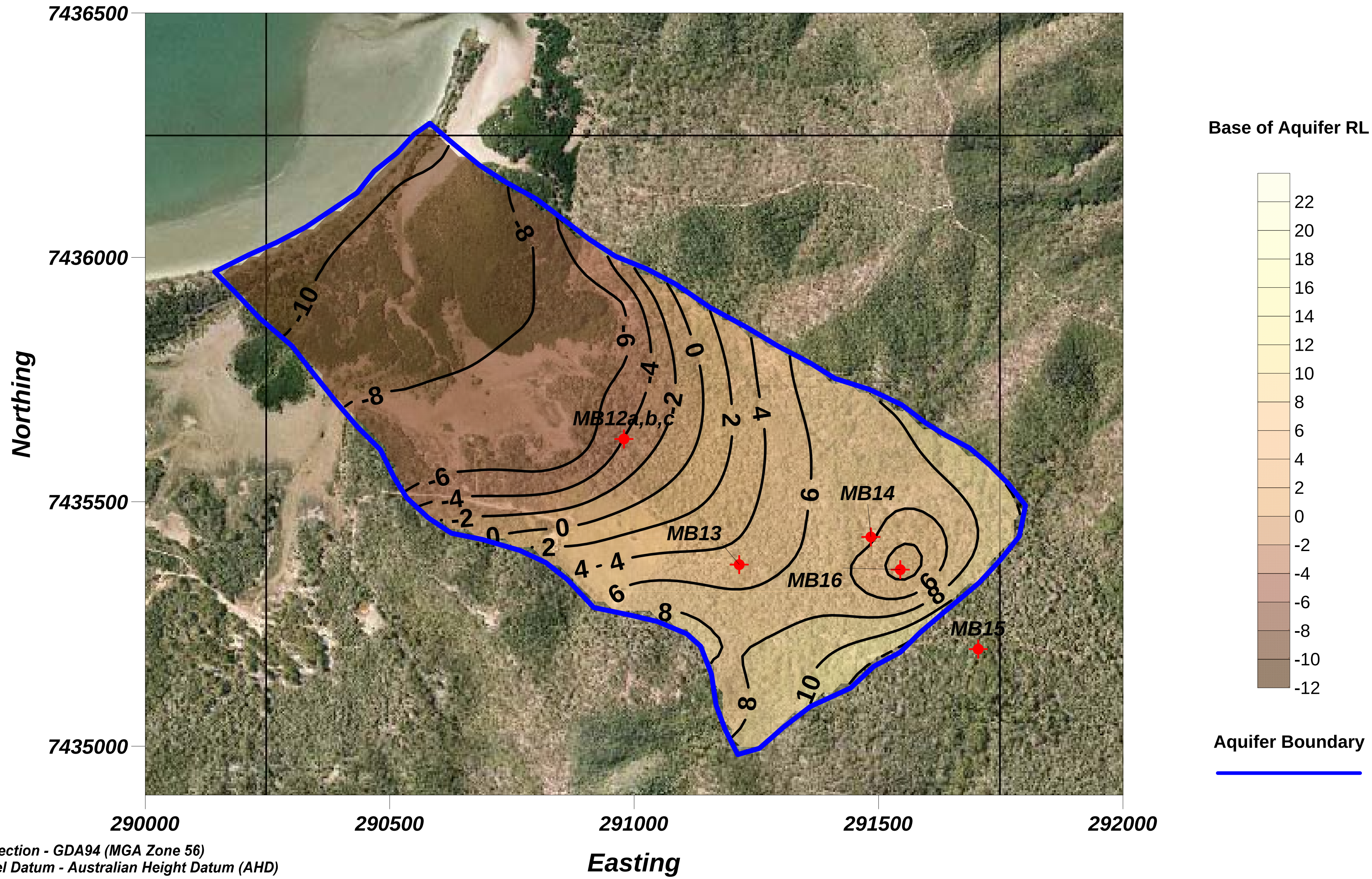
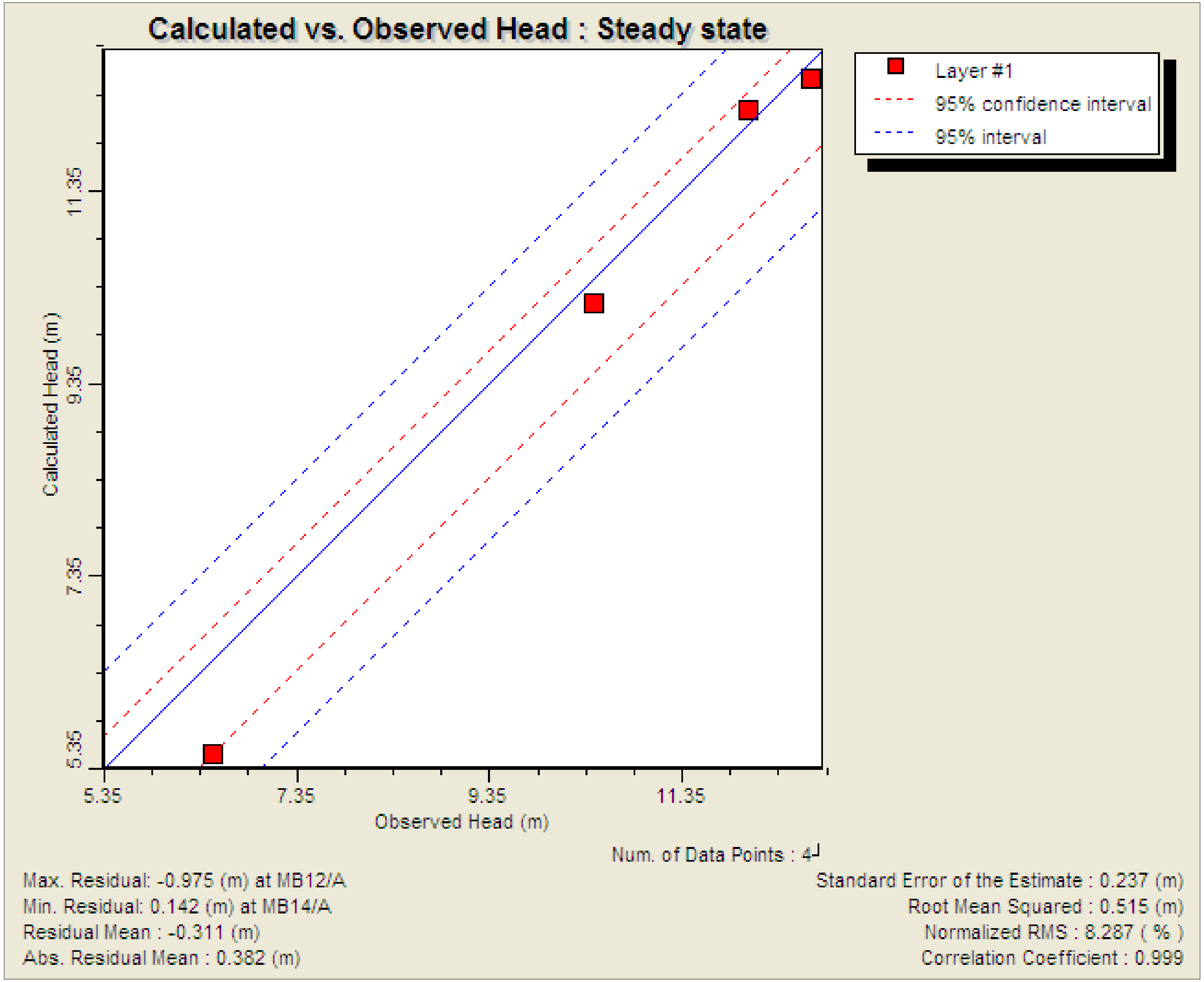
CLIENT: GKI Resort Pty Ltd		TITLE: Conceptual Hydrological Model Cross-Section Additional Groundwater Investigation Central Dune Sand Deposit, Great Keppel Island	PROJECT No: 74586.01
OFFICE: Brisbane	DRAWN BY: JT		DRAWING No: 5
SCALE: As shown	DATE: 1 September 2011		REVISION: 1

P:\Groundwater Projects\74586.01 GKI Additional Groundwater Investigation\Drawings\Rev.01\Drawing 5 Cross Section.dwg



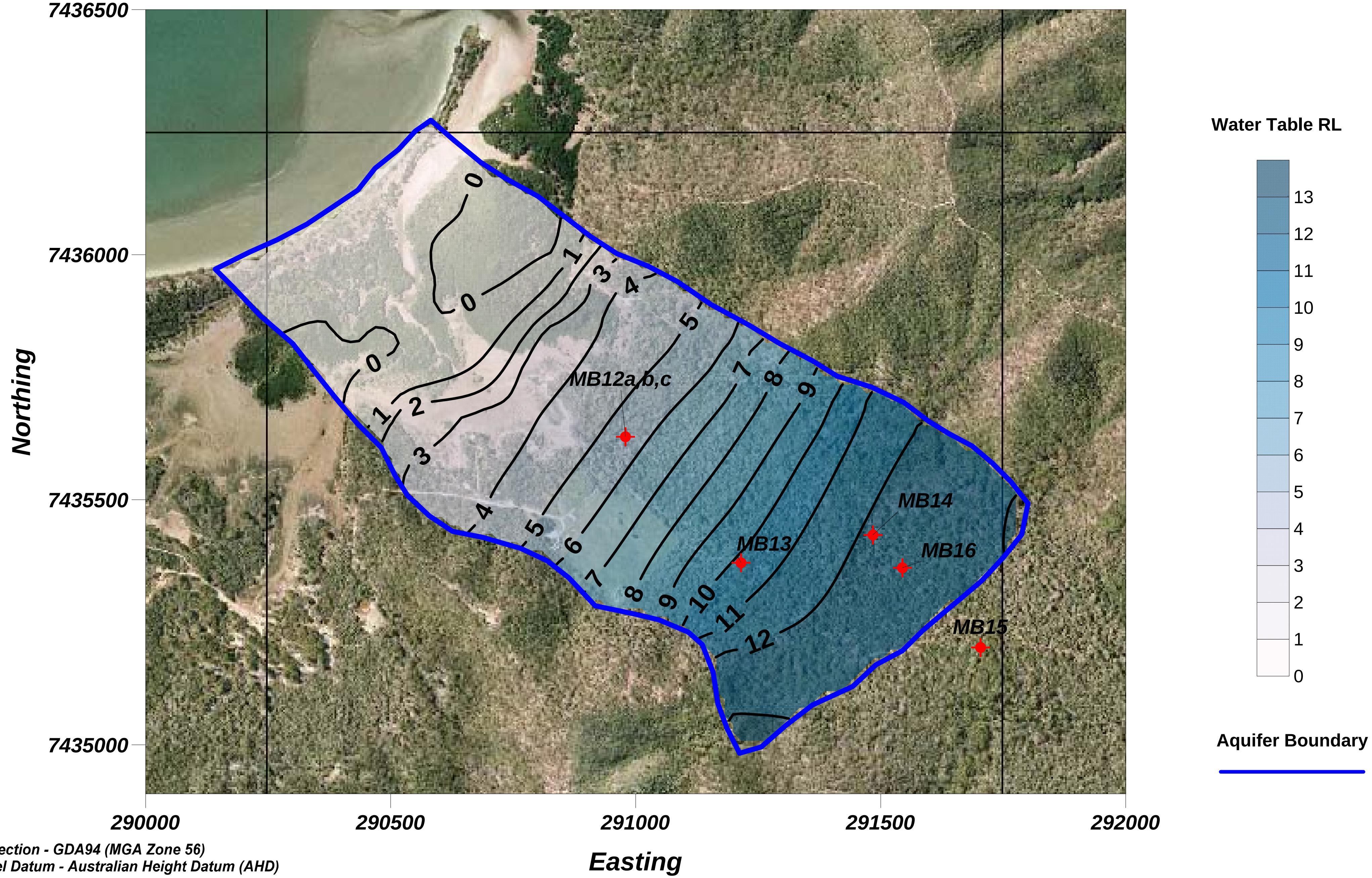
Projection - GDA94 (MGA Zone 56)
Level Datum - Australian Height Datum (AHD)

Douglas Partners Geotechnics / Environment / Groundwater	CLIENT: GKI Resorts Pty Ltd		TITLE **Inferred Base of Central Dune Sand Aquifer Additional Groundwater Investigation Central Dune Sand Deposit, Great Keppel Island**	PROJECT No: 74586.01
	OFFICE: Brisbane	DRAWN BY: CD		DRAWING No: 6
	SCALE: 1:15 000	DATE: Aug 2011		REVISION: 2



Douglas Partners
Geotechnics | Environment | Groundwater

CLIENT: GKI Resorts Pty Ltd		TITLE **Steady State Calibration Curve and Statistics** **Additional Groundwater Investigation** **Central Dune Sand Deposit, Great Keppel Island**	PROJECT No: 74586.01
OFFICE: Brisbane	DRAWN BY: CD		DRAWING No: 7
SCALE: NTS	DATE: Aug 2011		REVISION: 2



Projection - GDA94 (MGA Zone 56)
Level Datum - Australian Height Datum (AHD)

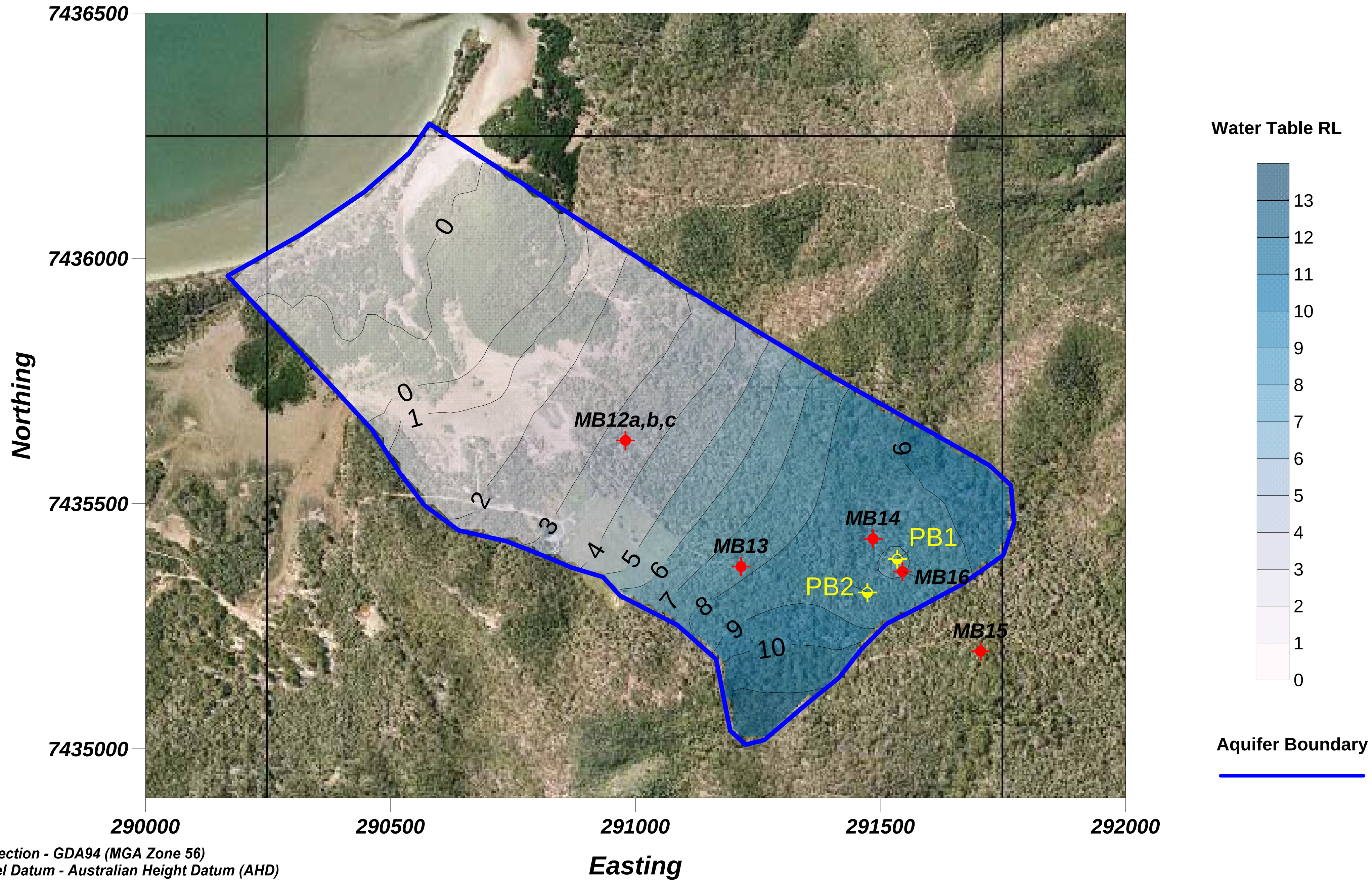
Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT: GKI Resorts Pty Ltd		
OFFICE: Brisbane	DRAWN BY: CD	
SCALE: 1:15 000	DATE: Aug 2011	

TITLE
Steady State Calibrated Heads
Additional Groundwater Investigation
Central Dune Sand Deposit, Great Keppel Island

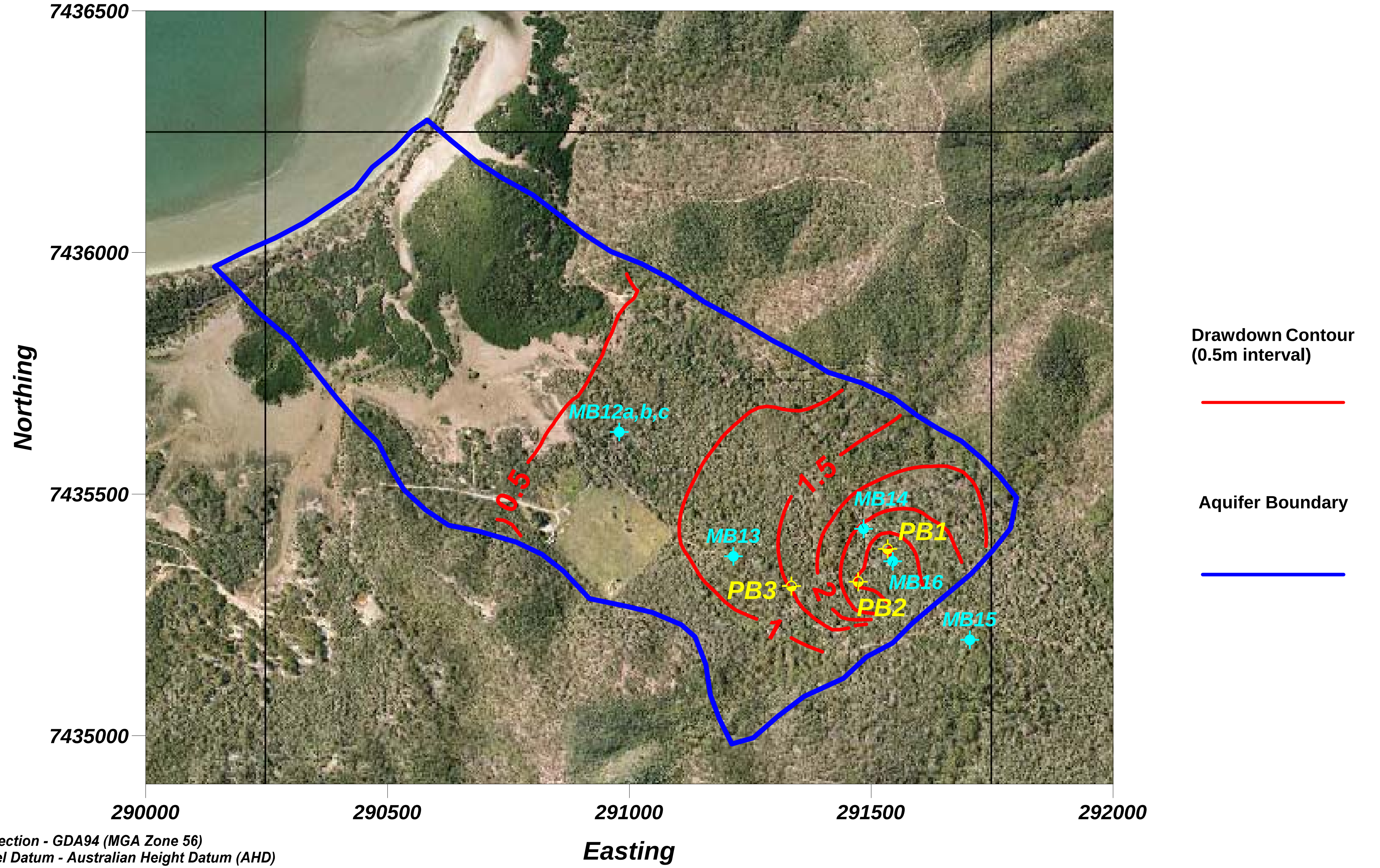
N

PROJECT No:	74586.01
DRAWING No:	8
REVISION:	2



Projection - GDA94 (MGA Zone 56)
Level Datum - Australian Height Datum (AHD)

Douglas Partners Geotechnics / Environment / Groundwater	CLIENT: GKI Resorts Pty Ltd		TITLE Run 6 Simulated Groundwater Levels – Extraction of 90 kL/day Additional Groundwater Investigation Central Dune Sand Deposit, Great Keppel Island	PROJECT No: 74586.01
	OFFICE: Brisbane	DRAWN BY: CD		DRAWING No: 9
	SCALE: 1:15 000	DATE: Aug 2011		REVISION: 2



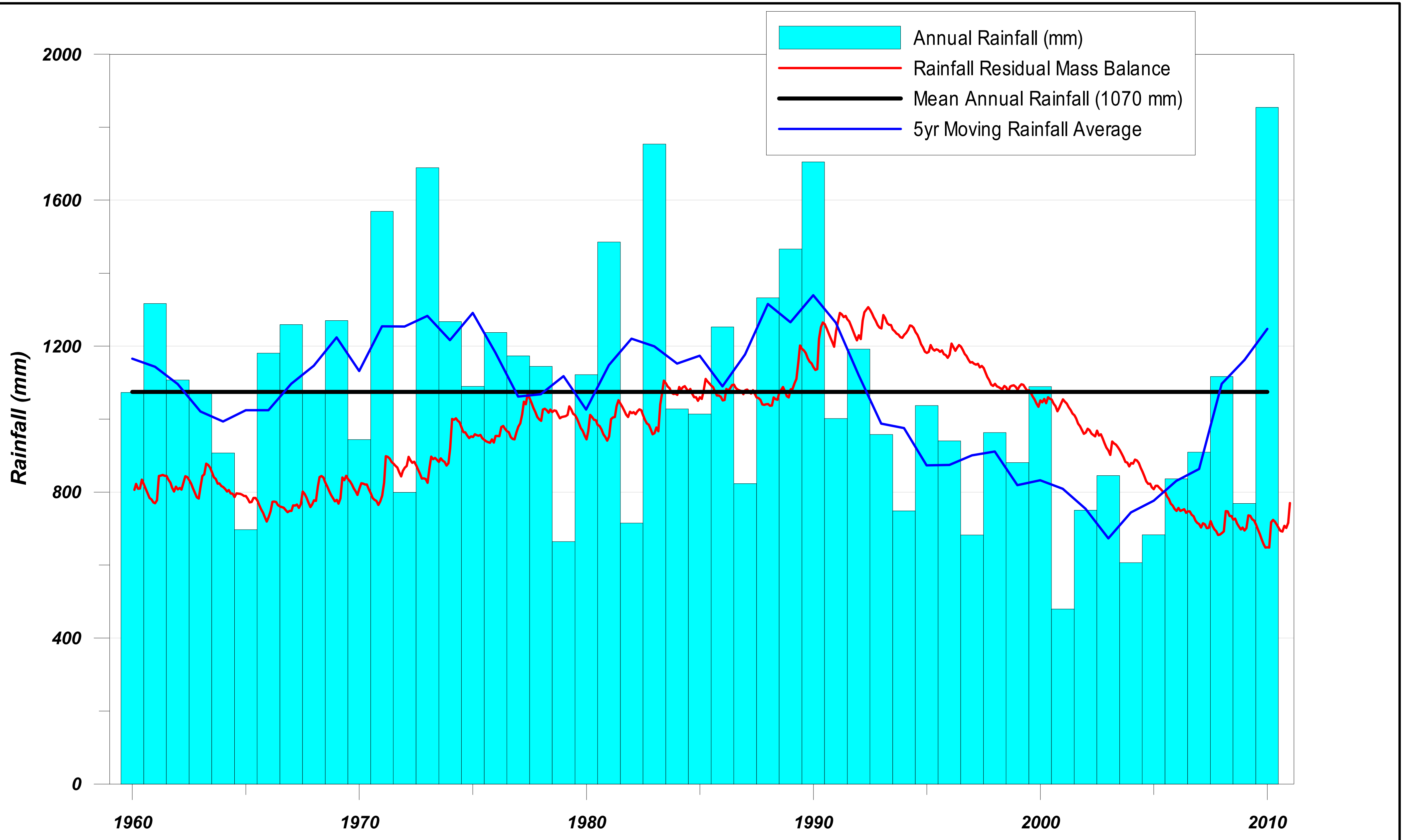
Projection - GDA94 (MGA Zone 56)
Level Datum - Australian Height Datum (AHD)

Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT: GKI Resorts Pty Ltd		TITLE: Run 6 Simulated Aquifer Drawdown, Extraction of 90 kL/day Additional Groundwater Investigation Central Dune Sand Deposit, Great Keppel Island	PROJECT No: 74586.01
OFFICE: Brisbane	DRAWN BY: CD		DRAWING No: 10
SCALE: 1:15 000	DATE: Aug 2011		REVISION: 2

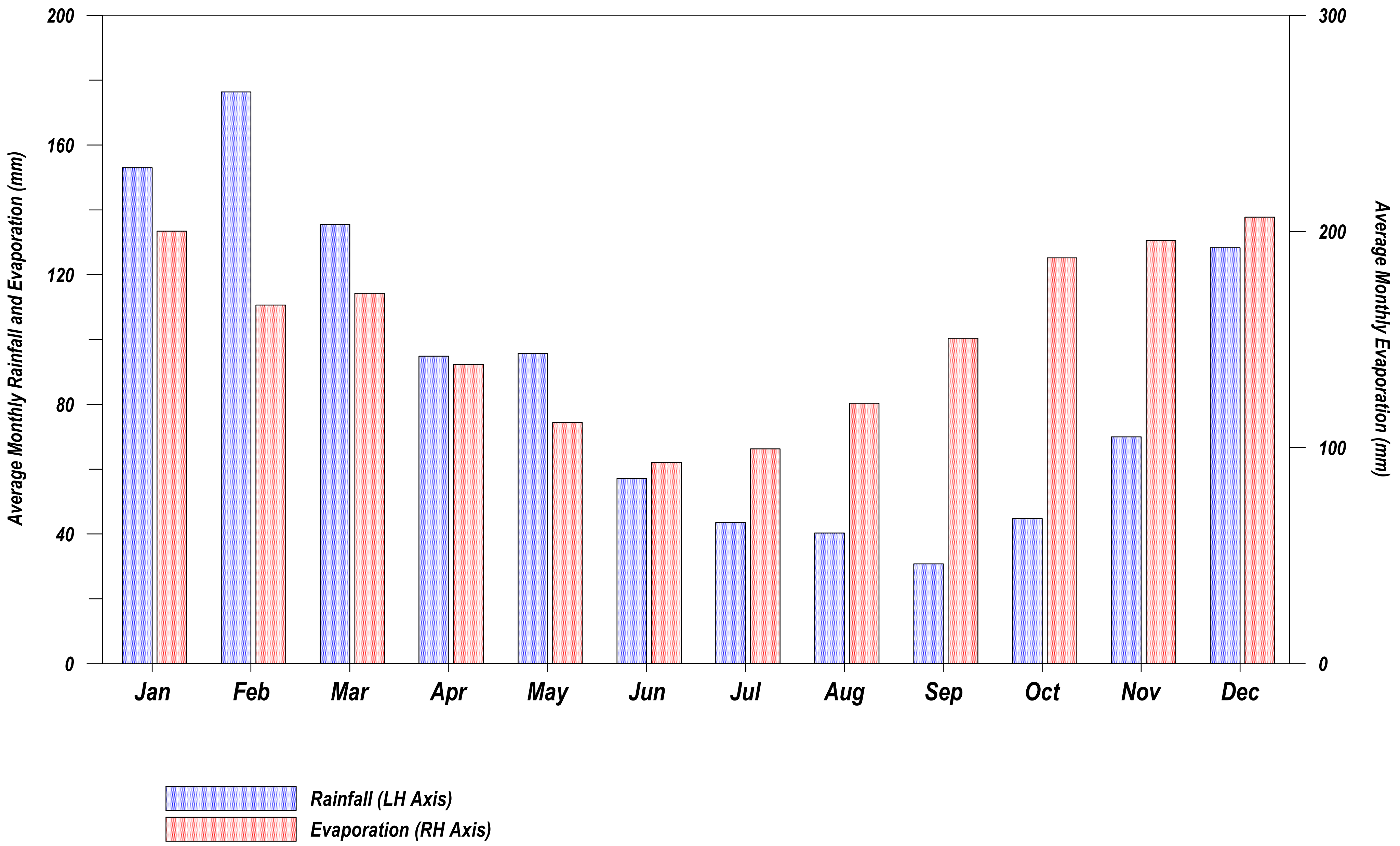
Appendix A

Rainfall and Evaporation Histograms



Douglas Partners
Geotechnics | Environment | Groundwater

CLIENT: GKI Resorts Pty Ltd		TITLE RAINFALL RESIDUAL MASS BALANCE Additional Groundwater Investigation Central Dune Sand Deposit, Great Keppel Island	PROJECT No: 74586.01
OFFICE: Brisbane	DRAWN BY: AMP		DRAWING No: A-1
	DATE: Aug 2011		REVISION: 2



Douglas Partners Geotechnics / Environment / Groundwater	CLIENT: GKI Resorts Pty Ltd		TITLE **AVERAGE MONTHLY RAINFALL AND EVAPORATION** **Additional Groundwater Investigation** **Central Dune Sand Deposit**	PROJECT No: 74586.01
	OFFICE: Brisbane	DRAWN BY: CD		DRAWING No: A-2
		DATE: Aug 2011		REVISION: 2

Appendix B

Borehole Reports and Explanatory Notes About This Report

About this Report

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Introduction

These notes have been provided to amplify DP's report in regard to classification methods, field procedures and the comments section. Not all are necessarily relevant to all reports.

DP's reports are based on information gained from limited subsurface excavations and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

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Borehole and Test Pit Logs

The borehole and test pit logs presented in this report are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on frequency of sampling and the method of drilling or excavation. Ideally, continuous undisturbed sampling or core drilling will provide the most reliable assessment, but this is not always practicable or possible to justify on economic grounds. In any case the boreholes and test pits represent only a very small sample of the total subsurface profile.

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes or pits, the frequency of sampling, and the possibility of other than 'straight line' variations between the test locations.

Groundwater

Where groundwater levels are measured in boreholes there are several potential problems, namely:

- In low permeability soils groundwater may enter the hole very slowly or perhaps not at all during the time the hole is left open;
- A localised, perched water table may lead to an erroneous indication of the true water table;
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report; and
- The use of water or mud as a drilling fluid will mask any groundwater inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water measurements are to be made.

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from a perched water table.

Reports

The report has been prepared by qualified personnel, is based on the information obtained from field and laboratory testing, and has been undertaken to current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal, the information and interpretation may not be relevant if the design proposal is changed. If this happens, DP will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface conditions, discussion of geotechnical and environmental aspects, and recommendations or suggestions for design and construction. However, DP cannot always anticipate or assume responsibility for:

- Unexpected variations in ground conditions. The potential for this will depend partly on borehole or pit spacing and sampling frequency;
- Changes in policy or interpretations of policy by statutory authorities; or
- The actions of contractors responding to commercial pressures.

If these occur, DP will be pleased to assist with investigations or advice to resolve the matter.

About this Report

Site Anomalies

In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, DP requests that it be immediately notified. Most problems are much more readily resolved when conditions are exposed rather than at some later stage, well after the event.

Information for Contractual Purposes

Where information obtained from this report is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. DP would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

The company will always be pleased to provide engineering inspection services for geotechnical and environmental aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.

Sampling

Sampling is carried out during drilling or test pitting to allow engineering examination (and laboratory testing where required) of the soil or rock.

Disturbed samples taken during drilling provide information on colour, type, inclusions and, depending upon the degree of disturbance, some information on strength and structure.

Undisturbed samples are taken by pushing a thin-walled sample tube into the soil and withdrawing it to obtain a sample of the soil in a relatively undisturbed state. Such samples yield information on structure and strength, and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Test Pits

Test pits are usually excavated with a backhoe or an excavator, allowing close examination of the in-situ soil if it is safe to enter into the pit. The depth of excavation is limited to about 3 m for a backhoe and up to 6 m for a large excavator. A potential disadvantage of this investigation method is the larger area of disturbance to the site.

Large Diameter Augers

Boreholes can be drilled using a rotating plate or short spiral auger, generally 300 mm or larger in diameter commonly mounted on a standard piling rig. The cuttings are returned to the surface at intervals (generally not more than 0.5 m) and are disturbed but usually unchanged in moisture content. Identification of soil strata is generally much more reliable than with continuous spiral flight augers, and is usually supplemented by occasional undisturbed tube samples.

Continuous Spiral Flight Augers

The borehole is advanced using 90-115 mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or in-situ testing. This is a relatively economical means of drilling in clays and sands above the water table. Samples are returned to the surface, or may be collected after withdrawal of the auger flights, but they are disturbed and may be mixed with soils from the sides of the hole. Information from the drilling (as distinct from specific sampling by SPTs or undisturbed samples) is of relatively low reliability, due to the remoulding, possible mixing or softening of samples by groundwater.

Non-core Rotary Drilling

The borehole is advanced using a rotary bit, with water or drilling mud being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from the rate of penetration. Where drilling mud is used this can mask the cuttings and reliable identification is only possible from separate sampling such as SPTs.

Continuous Core Drilling

A continuous core sample can be obtained using a diamond tipped core barrel, usually with a 50 mm internal diameter. Provided full core recovery is achieved (which is not always possible in weak rocks and granular soils), this technique provides a very reliable method of investigation.

Standard Penetration Tests

Standard penetration tests (SPT) are used as a means of estimating the density or strength of soils and also of obtaining a relatively undisturbed sample. The test procedure is described in Australian Standard 1289, Methods of Testing Soils for Engineering Purposes - Test 6.3.1.

The test is carried out in a borehole by driving a 50 mm diameter split sample tube under the impact of a 63 kg hammer with a free fall of 760 mm. It is normal for the tube to be driven in three successive 150 mm increments and the 'N' value is taken as the number of blows for the last 300 mm. In dense sands, very hard clays or weak rock, the full 450 mm penetration may not be practicable and the test is discontinued.

The test results are reported in the following form.

- In the case where full penetration is obtained with successive blow counts for each 150 mm of, say, 4, 6 and 7 as:

  4,6,7
  N=13

- In the case where the test is discontinued before the full penetration depth, say after 15 blows for the first 150 mm and 30 blows for the next 40 mm as:

  15, 30/40 mm

The results of the SPT tests can be related empirically to the engineering properties of the soils.

Dynamic Cone Penetrometer Tests / Perth Sand Penetrometer Tests

Dynamic penetrometer tests (DCP or PSP) are carried out by driving a steel rod into the ground using a standard weight of hammer falling a specified distance. As the rod penetrates the soil the number of blows required to penetrate each successive 150 mm depth are recorded. Normally there is a depth limitation of 1.2 m, but this may be extended in certain conditions by the use of extension rods. Two types of penetrometer are commonly used.

- Perth sand penetrometer - a 16 mm diameter flat ended rod is driven using a 9 kg hammer dropping 600 mm (AS 1289, Test 6.3.3). This test was developed for testing the density of sands and is mainly used in granular soils and filling.
- Cone penetrometer - a 16 mm diameter rod with a 20 mm diameter cone end is driven using a 9 kg hammer dropping 510 mm (AS 1289, Test 6.3.2). This test was developed initially for pavement subgrade investigations, and correlations of the test results with California Bearing Ratio have been published by various road authorities.

Soil Descriptions

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Description and Classification Methods

The methods of description and classification of soils and rocks used in this report are based on Australian Standard AS 1726, Geotechnical Site Investigations Code. In general, the descriptions include strength or density, colour, structure, soil or rock type and inclusions.

Soil Types

Soil types are described according to the predominant particle size, qualified by the grading of other particles present:

Type	Particle size (mm)
Boulder	>200
Cobble	63 - 200
Gravel	2.36 - 63
Sand	0.075 - 2.36
Silt	0.002 - 0.075
Clay	<0.002

The sand and gravel sizes can be further subdivided as follows:

Type	Particle size (mm)
Coarse gravel	20 - 63
Medium gravel	6 - 20
Fine gravel	2.36 - 6
Coarse sand	0.6 - 2.36
Medium sand	0.2 - 0.6
Fine sand	0.075 - 0.2

The proportions of secondary constituents of soils are described as:

Term	Proportion	Example
And	Specify	Clay (60%) and Sand (40%)
Adjective	20 - 35%	Sandy Clay
Slightly	12 - 20%	Slightly Sandy Clay
With some	5 - 12%	Clay with some sand
With a trace of	0 - 5%	Clay with a trace of sand

Definitions of grading terms used are:

- Well graded - a good representation of all particle sizes
- Poorly graded - an excess or deficiency of particular sizes within the specified range
- Uniformly graded - an excess of a particular particle size
- Gap graded - a deficiency of a particular particle size with the range

Cohesive Soils

Cohesive soils, such as clays, are classified on the basis of undrained shear strength. The strength may be measured by laboratory testing, or estimated by field tests or engineering examination. The strength terms are defined as follows:

Description	Abbreviation	Undrained shear strength (kPa)
Very soft	vs	<12
Soft	s	12 - 25
Firm	f	25 - 50
Stiff	st	50 - 100
Very stiff	vst	100 - 200
Hard	h	>200

Cohesionless Soils

Cohesionless soils, such as clean sands, are classified on the basis of relative density, generally from the results of standard penetration tests (SPT), cone penetration tests (CPT) or dynamic penetrometers (PSP). The relative density terms are given below:

Relative Density	Abbreviation	SPT N value	CPT qc value (MPa)
Very loose	vl	<4	<2
Loose	l	4 - 10	2 -5
Medium dense	md	10 - 30	5 - 15
Dense	d	30 - 50	15 - 25
Very dense	vd	>50	>25

Soil Descriptions

Soil Origin

It is often difficult to accurately determine the origin of a soil. Soils can generally be classified as:

- Residual soil - derived from in-situ weathering of the underlying rock;
- Transported soils - formed somewhere else and transported by nature to the site; or
- Filling - moved by man.

Transported soils may be further subdivided into:

- Alluvium - river deposits
- Lacustrine - lake deposits
- Aeolian - wind deposits
- Littoral - beach deposits
- Estuarine - tidal river deposits
- Talus - scree or coarse colluvium
- Slopewash or Colluvium - transported downslope by gravity assisted by water. Often includes angular rock fragments and boulders.

Symbols & Abbreviations

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Introduction

These notes summarise abbreviations commonly used on borehole logs and test pit reports.

Drilling or Excavation Methods

C	Core Drilling
R	Rotary drilling
SFA	Spiral flight augers
NMLC	Diamond core - 52 mm dia
NQ	Diamond core - 47 mm dia
HQ	Diamond core - 63 mm dia
PQ	Diamond core - 81 mm dia

Water

▷	Water seep
▽	Water level

Sampling and Testing

A	Auger sample
B	Bulk sample
D	Disturbed sample
E	Environmental sample
U_{50}	Undisturbed tube sample (50mm)
W	Water sample
pp	pocket penetrometer (kPa)
PID	Photo ionisation detector
PL	Point load strength Is(50) MPa
S	Standard Penetration Test
V	Shear vane (kPa)

Description of Defects in Rock

The abbreviated descriptions of the defects should be in the following order: Depth, Type, Orientation, Coating, Shape, Roughness and Other. Drilling and handling breaks are not usually included on the logs.

Defect Type

B	Bedding plane
Cs	Clay seam
Cv	Cleavage
Cz	Crushed zone
Ds	Decomposed seam
F	Fault
J	Joint
Lam	lamination
Pt	Parting
Sz	Sheared Zone
V	Vein

Orientation

The inclination of defects is always measured from the perpendicular to the core axis.

h	horizontal
v	vertical
sh	sub-horizontal
sv	sub-vertical

Coating or Infilling Term

cln	clean
co	coating
he	healed
inf	infilled
stn	stained
ti	tight
vn	veneer

Coating Descriptor

ca	calcite
cbs	carbonaceous
cly	clay
fe	iron oxide
mn	manganese
slt	silty

Shape

cu	curved
ir	irregular
pl	planar
st	stepped
un	undulating

Roughness

po	polished
ro	rough
sl	slickensided
sm	smooth
vr	very rough

Other

fg	fragmented
bnd	band
qtz	quartz

Symbols & Abbreviations

Graphic Symbols for Soil and Rock

General

- Asphalt
- Road base
- Concrete
- Filling

Soils

- Topsoil
- Peat
- Clay
- Silty clay
- Sandy clay
- Gravelly clay
- Shaly clay
- Silt
- Clayey silt
- Sandy silt
- Sand
- Clayey sand
- Silty sand
- Gravel
- Sandy gravel
- Cobbles, boulders
- Talus

Sedimentary Rocks

- Boulder conglomerate
- Conglomerate
- Conglomeratic sandstone
- Sandstone
- Siltstone
- Laminite
- Mudstone, claystone, shale
- Coal
- Limestone

Metamorphic Rocks

- Slate, phyllite, schist
- Gneiss
- Quartzite

Igneous Rocks

- Granite
- Dolerite, basalt, andesite
- Dacite, epidote
- Tuff, breccia
- Porphyry

BOREHOLE LOG

CLIENT: Tower Holdings Pty Ltd
PROJECT: Additional Groundwater Investigation
LOCATION: Great Keppel Island

SURFACE LEVEL: 7.49m AHD
EASTING: 290979.2
NORTHING: 7453628.9
DIP/AZIMUTH: 90°/--

BORE No: MB12
PROJECT No: 74586.01
DATE: 12/2/2011
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Type	Depth	Sample	Results & Comments	Water	Well Construction Details
	0.0	SAND - grey, fine to medium grained sand, with trace of silt							Concrete; Drilling Spoil; 50mm PVC Class No. 18 casing; Bentonite Seal
	~2.8	- moist						▼ (2.9m)	
	~3.0	- wet							
	~5.8	- pale brown-orange							Prepacked 50mm factory slotted in PVC screen 2.8m to 9.0m; Filter Sand; Piezometer installed to 9.0m depth
	9.0 – 9.2	SILTY CLAY - estimated 'stiff to firm', orange-brown and grey, silty clay, with a trace of medium to coarse grained quartz gravel, with some fine to medium grained sand							
	9.2	Bore discontinued at 9.2m due to refusal.							

RIG: Ezi Probe **DRILLER:** B & G Drilling **LOGGED:** KH **CASING:** Nil
TYPE OF BORING: Hollow flight auger.
WATER OBSERVATIONS: Groundwater observed at 2.9m.
REMARKS: SWL on construction: 1.03m BGL

SURVEY DATUM: GDA94 Zone 56 K

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: Tower Holdings Pty Ltd
PROJECT: Additional Groundwater Investigation
LOCATION: Great Keppel Island

SURFACE LEVEL: 7.49m AHD
EASTING: 290979.2
NORTHING: 7435628.9
DIP/AZIMUTH: 90°/--

BORE No: MB12a
PROJECT No: 74586.01
DATE: 10/2/2011
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Type	Depth	Sample	Results & Comments	Water	Well Construction Details
		SAND - grey and light grey, fine to medium grained sand, with a trace of silt							
		- moist to wet							
				B	3.5 / 4.0			▼ (4.0)	
		- wet							
		- saturated							
				B	6.0 / 6.5				
		- becoming pale brown-orange							
	8.3	SILTY SAND - pale brown and orange, silty sand, with some clay, wet							
		- becoming light brown							
		- becoming brown-orange							
		- with a trace of quartz fragments and trace of clay							
		- decreasing clay content, saturated							
				B	12.3 / 12.5				
		- with a trace of clay, wet							
		- saturated							
		- increasing clay content							
		- pale grey							
		- increasing clay content							
	16.8	SILTY CLAY - grey, silty clay, with some fine to medium grained sand and medium to coarse quartz gravel, wet		B	16.8 / 17.0				
	17.3	Bore discontinued at 17.3m due to refusal.							

RIG: Ezi Probe **DRILLER:** B & G Drilling **LOGGED:** KH **CASING:** Nil
TYPE OF BORING: Hollow flight auger.
WATER OBSERVATIONS: Groundwater observed at 4.0m.
REMARKS: No well installed due to screen damage and bore collapse. Redilled as MB12b

SURVEY DATUM: GDA94 Zone 56 K

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: Tower Holdings Pty Ltd
PROJECT: Additional Groundwater Investigation
LOCATION: Great Keppel Island

SURFACE LEVEL: 7.49m AHD
EASTING: 290979.2
NORTHING: 7435628.9
DIP/AZIMUTH: 90°/--

BORE No: MB12b
PROJECT No: 74586.01
DATE: 11/2/2011
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Type	Depth	Sample	Results & Comments	Water	Well Construction Details
	0.0	SAND - grey, fine to medium grained sand, with trace of silt							
		- moist							
		- wet						▼ (2.9m)	
		- pale brown-orange							
	9.5	SILTY CLAY - estimated 'stiff to firm', orange-brown and grey, silty clay, with trace of medium to coarse grained quartz gravel, with some fine to medium grained sand							
	10.3	Bore discontinued at 10.3m due to refusal.							

RIG: Ezi Probe **DRILLER:** B & G Drilling **LOGGED:** KH **CASING:** Nil
TYPE OF BORING: Hollow flight auger.
WATER OBSERVATIONS: Groundwater observed at 2.9m.
REMARKS: No well installed due to non-release of auger plug. Redrilled as MB12

SURVEY DATUM: GDA94 Zone 56 K

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: Tower Holdings Pty Ltd
PROJECT: Additional Groundwater Investigation
LOCATION: Great Keppel Island

SURFACE LEVEL: 13.3m AHD
EASTING: 291215.1
NORTHING: 7435371.8
DIP/AZIMUTH: 90°/--

BORE No: MB13
PROJECT No: 74586.01
DATE: 13/2/2011
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Well Construction Details
	0.0	SAND - brown, fine to medium grained sand							Concrete; Backfill (1); 50mm PVC Class No. 18 casing
	2.0	SILTY CLAYEY SAND - brown, silty clayey sand, fine to medium grained sand, with some fine to coarse grained quartz gravel, moist							Bentonite Seal (2)
	2.8	SILTY SAND - pale orange-brown, silty sand, fine to medium grained sand, moist to wet - increasing clay content - brown and orange-brown mottled with some clay, some medium to coarse grained quartz gravel, trace of tree roots, moist to wet		D	3.0 3.5			Water seep (2.8); Water level (~3.2)	Filter Sand; Prepacked 50mm factory slotted in PVC screen 3.0m to 6.10m
	5.0	SILTY CLAYEY SAND - red-brown, silty clayey sand, fine to medium grained sand, moist to wet							
	5.5	SILTY SANDY CLAY - estimated 'stiff to very stiff', orange-brown and grey mottled, medium plasticity, silty sandy clay, fine to medium grained sand, moist - increasing moisture content							Piezometer installed to 6.10m depth
	8.0	CLAYEY SAND - orange-brown, clayey sand, fine to medium grained sand, wet							
	8.5	SILTY CLAY - very stiff, red-brown, medium to high plasticity, silty clay, with some fine grained sand, some fine to medium grained quartz gravel - increasing gravel content - band of grey silty clayey sand, fine to medium grained sand							
	11.4	Bore discontinued at 11.4m due to refusal.							

RIG: Ezi Probe **DRILLER:** B & G Drilling **LOGGED:** KH **CASING:** Nil
TYPE OF BORING: Hollow flight auger.
WATER OBSERVATIONS: Groundwater seepage observed at 2.8m BGL and at 8.0m BGL.
REMARKS: SWL on completion: 2.57m BGL

SURVEY DATUM: GDA94 Zone 56 K

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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BOREHOLE LOG

CLIENT: Tower Holdings Pty Ltd
PROJECT: Additional Groundwater Investigation
LOCATION: Great Keppel Island

SURFACE LEVEL: 15.15m AHD
EASTING: 291484.3
NORTHING: 7435428.5
DIP/AZIMUTH: 90°/--

BORE No: MB14
PROJECT No: 74586.01
DATE: 14/2/2011
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Type	Depth	Sample	Results & Comments	Water	Well Construction Details
		SAND - dark brown/black, sand, mixed with organic matter, with some fine to medium grained sand, with some silt							Concrete
	1	- becoming dark brown and grey, no organic matter							Drilling Spoil
		- dark grey, no clay, moist							50mm PVC Class No. 18 casing
		- pale grey							
	2			B	2.0 – 2.5				Bentonite Seal
	3			B	3.0 – 3.6			▼ (3.12)	
		- grey							
	4	- becoming pale brown, with some clay, moist to wet						▷ (4.0)	Prepacked 50mm factory slotted in PVC screen 3.50m to 6.60m
	5	- pale brown, increasing clay content							Filter Sand
	6.0	SILTY SANDY CLAY - pale brown, silty sandy clay, fine to medium grained sand, moist							Piezometer installed to 6.60m depth
	6.6	- increasing resistance Bore discontinued at 6.6m due to refusal.							

RIG: Ezi Probe **DRILLER:** B & G Drilling **LOGGED:** KH **CASING:** Nil
TYPE OF BORING: Hollow flight auger.
WATER OBSERVATIONS: Groundwater seepage observed at 4.0m.
REMARKS: SWL on completion: 3.12m BGL

SURVEY DATUM: GDA94 Zone 56 K

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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BOREHOLE LOG

CLIENT: Tower Holdings Pty Ltd
PROJECT: Additional Groundwater Investigation
LOCATION: Great Keppel Island

SURFACE LEVEL: 28.28m AHD
EASTING: 291703.9
NORTHING: 7435198.9
DIP/AZIMUTH: 90°/--

BORE No: MB15
PROJECT No: 74586.01
DATE: 14 - 15/2/2011
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Type	Depth	Sample	Results & Comments	Water	Well Construction Details
		SAND - brown, fine to medium grained sand, with silt and organic matter			0.1				Concrete; Drilling Spoil
		- pale red-brown, fine grained sand, with some silt		B					Bentonite Seal
		- light red-brown, fine to medium grained sand		B	2.0				50mm PVC Class No. 18 casing
		- red-brown, with a trace of clay		B	3.0				
		- increasing clay content, with a trace of fine to medium gravel		B	4.0				Drilling Spoil
					5.0				
				B	9.0				Prepacked 50mm factory slotted in PVC screen 7.80m to 10.90m
	9.4	SANDY CLAY - red-brown, sandy clay, with some medium to coarse gravel, fine to medium grained sand			9.5				Filter Sand
		- increasing clay content							Piezometer installed to 10.90m depth
	11.0	Bore discontinued at 11.0m due to refusal.							

RIG: Ezi Probe **DRILLER:** B & G Drilling **LOGGED:** KH **CASING:** Nil
TYPE OF BORING: Hollow flight auger.
WATER OBSERVATIONS: No free groundwater seepage observed whilst drilling.
REMARKS: Well dry on construction.

SURVEY DATUM: GDA94 Zone 56 K

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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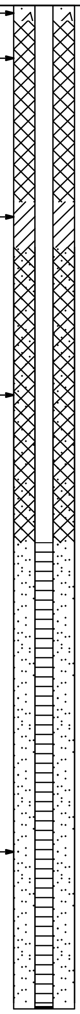
BOREHOLE LOG

CLIENT: Tower Holdings Pty Ltd
PROJECT: Additional Groundwater Investigation
LOCATION: Great Keppel Island

SURFACE LEVEL: 19.41m AHD
EASTING: 291544.5
NORTHING: 7435361.5
DIP/AZIMUTH: 90°/--

BORE No: MB16
PROJECT No: 74586.01
DATE: 16/2/2011
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Well Construction Details
		SAND - brown and grey, fine to medium grained sand, with some silt and organic matter							Concrete
		- light grey, fine grained sand		B	0.5–1.2				Drilling Spoil
	1	- pale grey, fine to medium grained sand							50mm PVC Class No. 18 casing
	2								
	3	- pale orange-brown							Bentonite Seal
	4	- light orange-brown		B	4.0–4.2				
	5								Drilling Spoil
	6	- pale orange-brown						▼ (approx. 6.7)	
	7	- orange-brown, moist		B	7.0–7.2				
	8	- light orange-brown, increasing moisture content							
	9	- moist to wet		B	9.0–9.2			▷	Prepacked 50mm factory slotted in PVC screen 7.10m to 13.30m
	10								
	11								Filter Sand
	12								
	13	- light grey, moist							Piezometer installed to 13.30m depth
	14	- moist to wet		B	13.8–14.0				
	15	- moist							
	16	- moist to wet							
	17								
	17.7	Bore discontinued at 17.7m due to refusal.							
	18								
	19								



RIG: Ezi Probe **DRILLER:** B & G Drilling **LOGGED:** KH **CASING:** Nil
TYPE OF BORING: Hollow flight auger.
WATER OBSERVATIONS: Groundwater seepage observed at 9.3m and 14.0m.
REMARKS: SWL on construction: 6.68m BGL

SURVEY DATUM: GDA94 Zone 56 K

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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BOREHOLE LOG

CLIENT: Tower Holdings Pty Ltd
PROJECT: Additional Groundwater Investigation
LOCATION: Great Keppel Island

SURFACE LEVEL: 36.72m AHD
EASTING: 292260.7
NORTHING: 7435076
DIP/AZIMUTH: 90°/--

BORE No: MB17
PROJECT No: 74586.01
DATE: 15/2/2011
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Well Construction Details
		SAND - pale grey and grey, fine to medium grained sand, with some organic matter - pale brown							
				B	0.7 1.0				
		- pale orange-brown, with some clay							
	2.5 2.6	SILTY CLAY - estimated 'stiff to very stiff', orange-brown, silty clay, with some fine to medium grained sand		B	2.5 2.6				
		Bore discontinued at 2.6m due to refusal.							

Depth scale: 1, 2, 3, 4

RIG: Ezi Probe **DRILLER:** B & G Drilling **LOGGED:** KH **CASING:** Nil
TYPE OF BORING: Hollow flight auger.
WATER OBSERVATIONS: No free groundwater and seepage observed whilst drilling.
REMARKS: No well installed.

SURVEY DATUM: GDA94 Zone 56 K

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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Appendix C

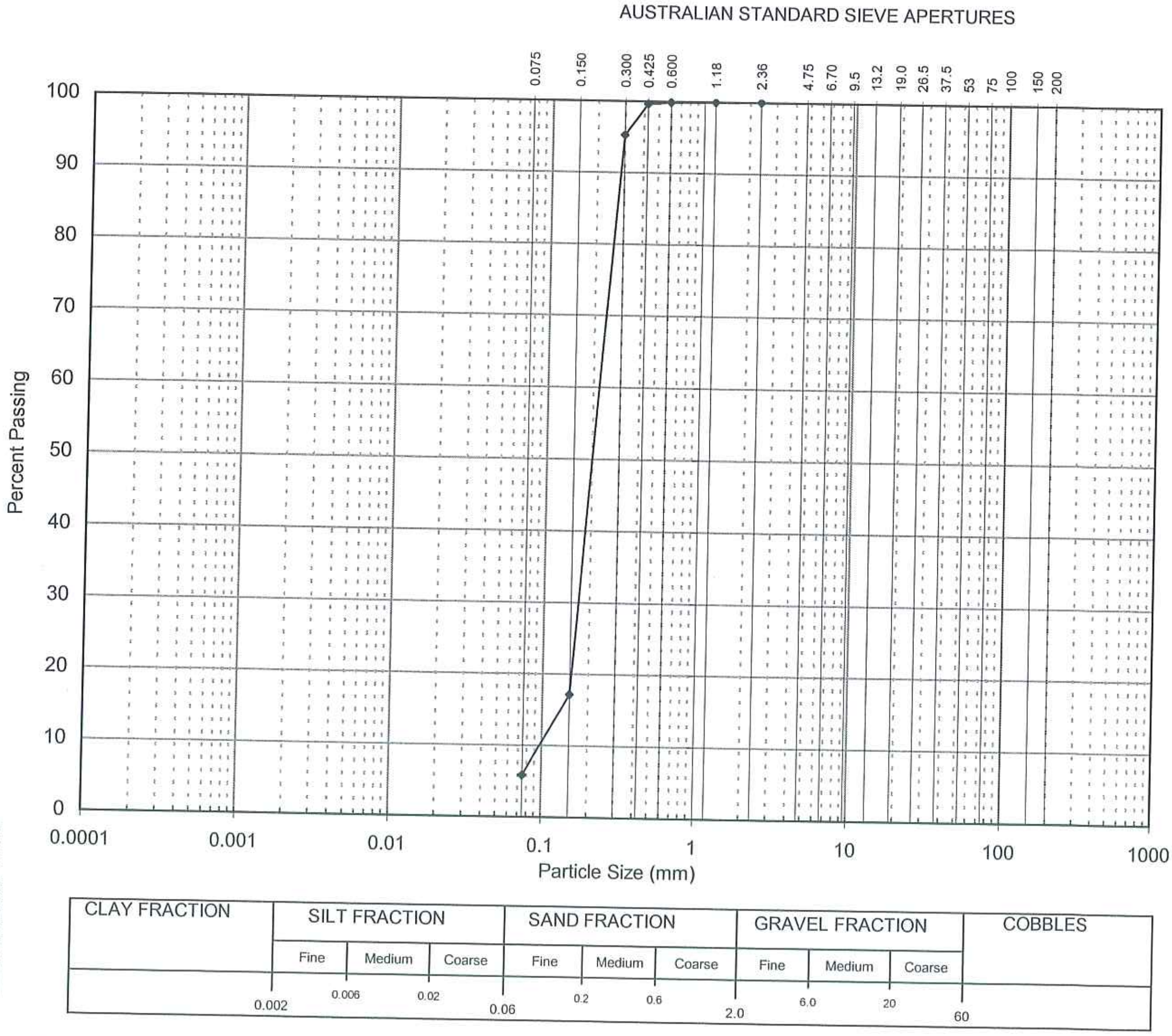
Laboratory Results – PSD Testing

Douglas Partners
Geotechnics / Environment / Groundwater

Douglas Partners Pty Ltd
ABN 75 053 980 117
www.douglaspartners.com.au
439 Montague Road
West End QLD 4101
Phone (07) 3237 8900
Fax (07) 3237 8999

Results of Particle Size Distribution

Client :	Tower Holdings Pty Ltd			**Project No. :**	74586.01
				Report No. :	BO11-193
Project :	Additional Groundwater Investigations			**Report Date :**	08-Mar-11
				Date Sampled:	10-16/02/2011
Location :	Great Keppel Island			**Date of Test:**	07-Mar-11
Road No:	-	**Sample / Pit No:**	Bore 12	**Depth / Layer:**	4.0m
Chainage:	-	**Section / Lot No:**	-	**Test Request No:**	-
				Page:	1 of 1



Sieve Size (mm)	% Passing
75.0	~
53.0	~
37.5	~
26.5	~
19.0	~
13.2	~
9.5	~
6.7	~
4.75	~
2.36	100%
1.18	100%
0.600	100%
0.425	100%
0.300	95%
0.150	17%
0.075	6%

Description: Sand with some silt

Test Method(s): AS 1289.3.6.1

Sampling Method(s): Sampled by DP Environmental

Remarks:

Tested:	SG
Checked:	SG

S. Gibbons
Sue-Ellen Gibbons
Senior Soil Technician

Douglas Partners
Geotechnics / Environment / Groundwater

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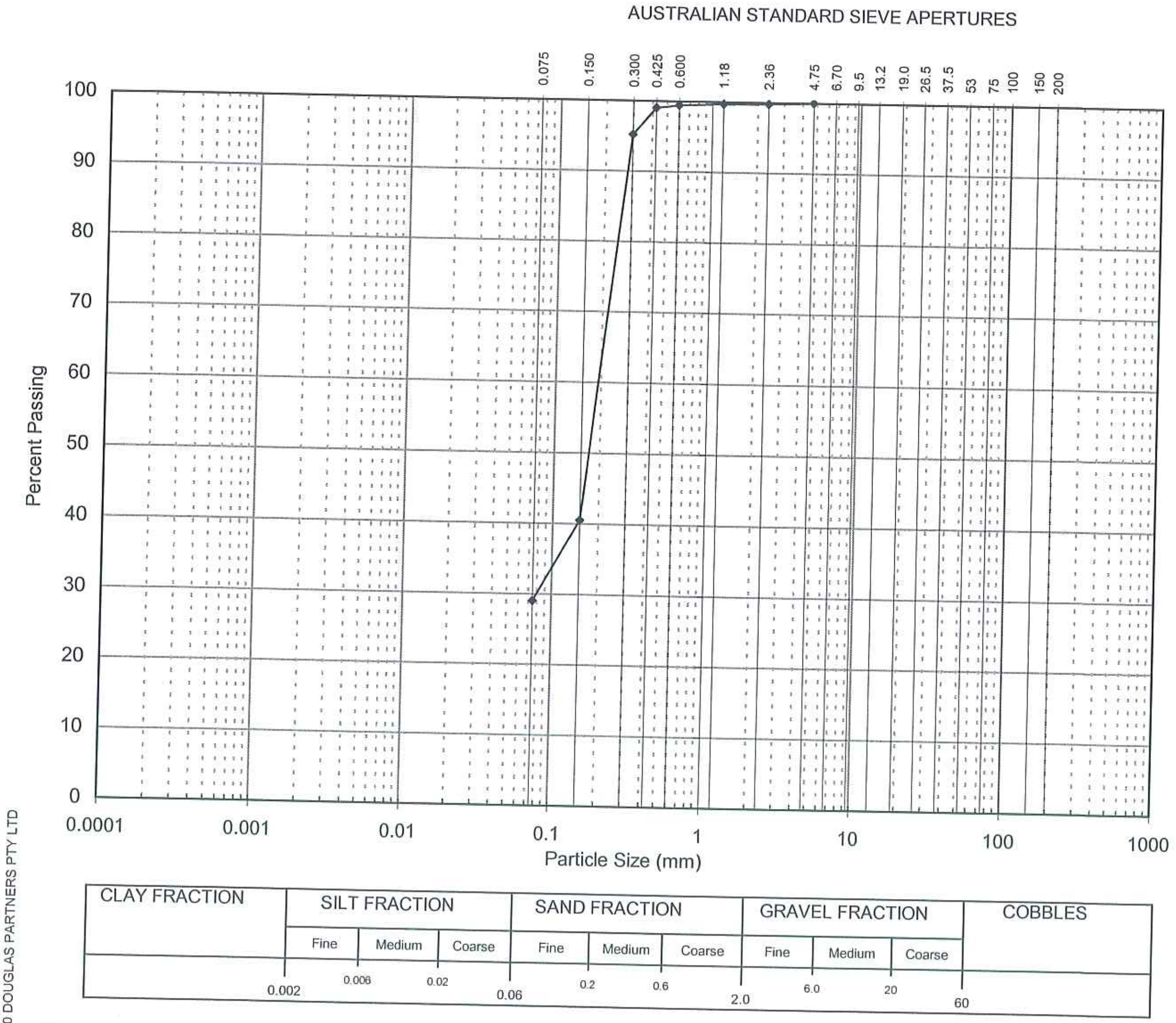
439 Montague Road
West End QLD 4101
Phone (07) 3237 8900
Fax (07) 3237 8999

Results of Particle Size Distribution

Client :	Tower Holdings Pty Ltd	**Project No. :**	74586.01
Project :	Additional Groundwater Investigations	**Report No. :**	BO11-194
		Report Date :	08-Mar-11
Location :	Great Keppel Island	**Date Sampled:**	10-16/02/2011
		Date of Test:	07-Mar-11
Road No:	- **Sample / Pit No:** Bore 13	**Depth / Layer:**	3.5m
Chainage:	- **Section / Lot No:** -	**Test Request No:**	-
		Page:	1 of 1



Sieve Size (mm)	% Passing
75.0	~
53.0	~
37.5	~
26.5	~
19.0	~
13.2	~
9.5	~
6.7	~
4.75	100%
2.36	100%
1.18	100%
0.600	99%
0.425	99%
0.300	95%
0.150	41%
0.075	29%

Description: Silty sand

Test Method(s): AS 1289.3.6.1

Sampling Method(s): Sampled by DP Environmental

Remarks:

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

NATA Accredited Laboratory Number: 828
This Document is issued in accordance with NATA's accreditation requirements.
Accredited for compliance with ISO/IEC 17025

Tested:	SG
Checked:	SG

S. Gibbons
Sue-Ellen Gibbons
Senior Soil Technician

Douglas Partners
Geotechnics / Environment / Groundwater

Douglas Partners Pty Ltd
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www.douglaspartners.com.au
439 Montague Road
West End QLD 4101
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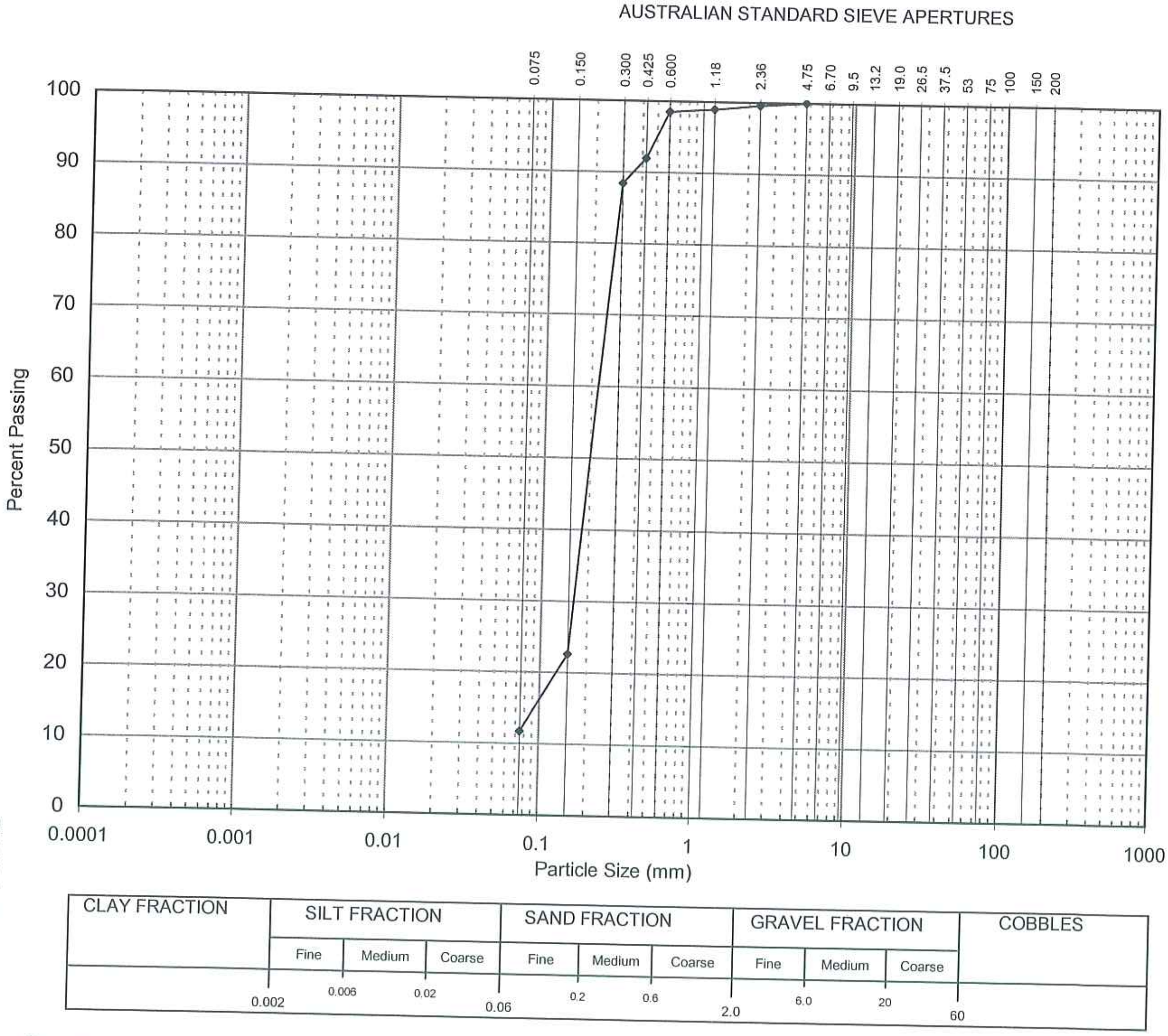
Fax (07) 3237 8999

Results of Particle Size Distribution

Client :	Tower Holdings Pty Ltd	**Project No. :**	74586.01
Project :	Additional Groundwater Investigations	**Report No. :**	BO11-195
		Report Date :	08-Mar-11
Location :	Great Keppel Island	**Date Sampled:**	10-16/02/2011
		Date of Test:	07-Mar-11
Road No:	- **Sample / Pit No:** Bore 14	**Depth / Layer:**	2.5m
Chainage:	- **Section / Lot No:** -	**Test Request No:**	-
		Page:	1 of 1



Sieve Size (mm)	% Passing
75.0	~
53.0	~
37.5	~
26.5	~
19.0	~
13.2	~
9.5	~
6.7	~
4.75	100%
2.36	100%
1.18	99%
0.600	99%
0.425	92%
0.300	88%
0.150	23%
0.075	12%

Description: Slightly silty sand

Test Method(s): AS 1289.3.6.1

Sampling Method(s): Sampled by DP Environmental

Remarks:

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Tested:	SG
Checked:	SG

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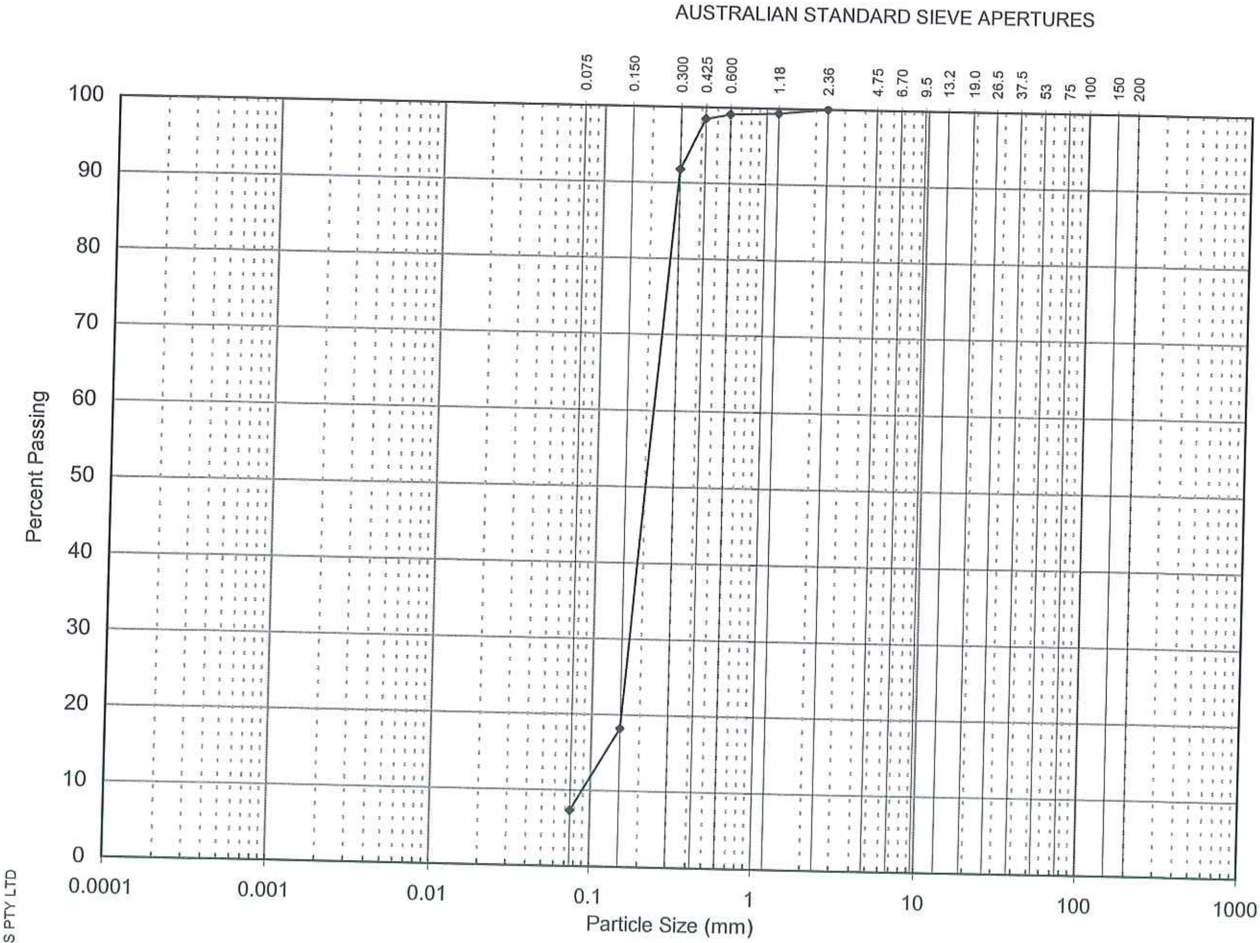
Results of Particle Size Distribution

Client :	Tower Holdings Pty Ltd	**Project No. :**	74586.01
Project :	Additional Groundwater Investigations	**Report No. :**	BO11-196
		Report Date :	08-Mar-11
Location :	Great Keppel Island	**Date Sampled:**	10-16/02/2011
		Date of Test:	07-Mar-11
Road No:	- **Sample / Pit No:** Bore 16	**Depth / Layer:**	9.2m
Chainage:	- **Section / Lot No:** -	**Test Request No:**	-
		Page:	1 of 1



Sieve Size (mm)	% Passing
75.0	~
53.0	~
37.5	~
26.5	~
19.0	~
13.2	~
9.5	~
6.7	~
4.75	~
2.36	100%
1.18	99%
0.600	99%
0.425	98%
0.300	92%
0.150	18%
0.075	7%

CLAY FRACTION	SILT FRACTION			SAND FRACTION			GRAVEL FRACTION			COBBLES
	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse	

Boundaries: 0.002, 0.006, 0.02, 0.06, 0.2, 0.6, 2.0, 6.0, 20, 60

Description: Sand with some silt

Test Method(s): AS 1289.3.6.1

Sampling Method(s): Sampled by DP Environmental

Remarks:

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

NATA Accredited Laboratory Number: 828
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Tested:	SG
Checked:	SG

S. Gibbons
Sue-Ellen Gibbons
Senior Soil Technician

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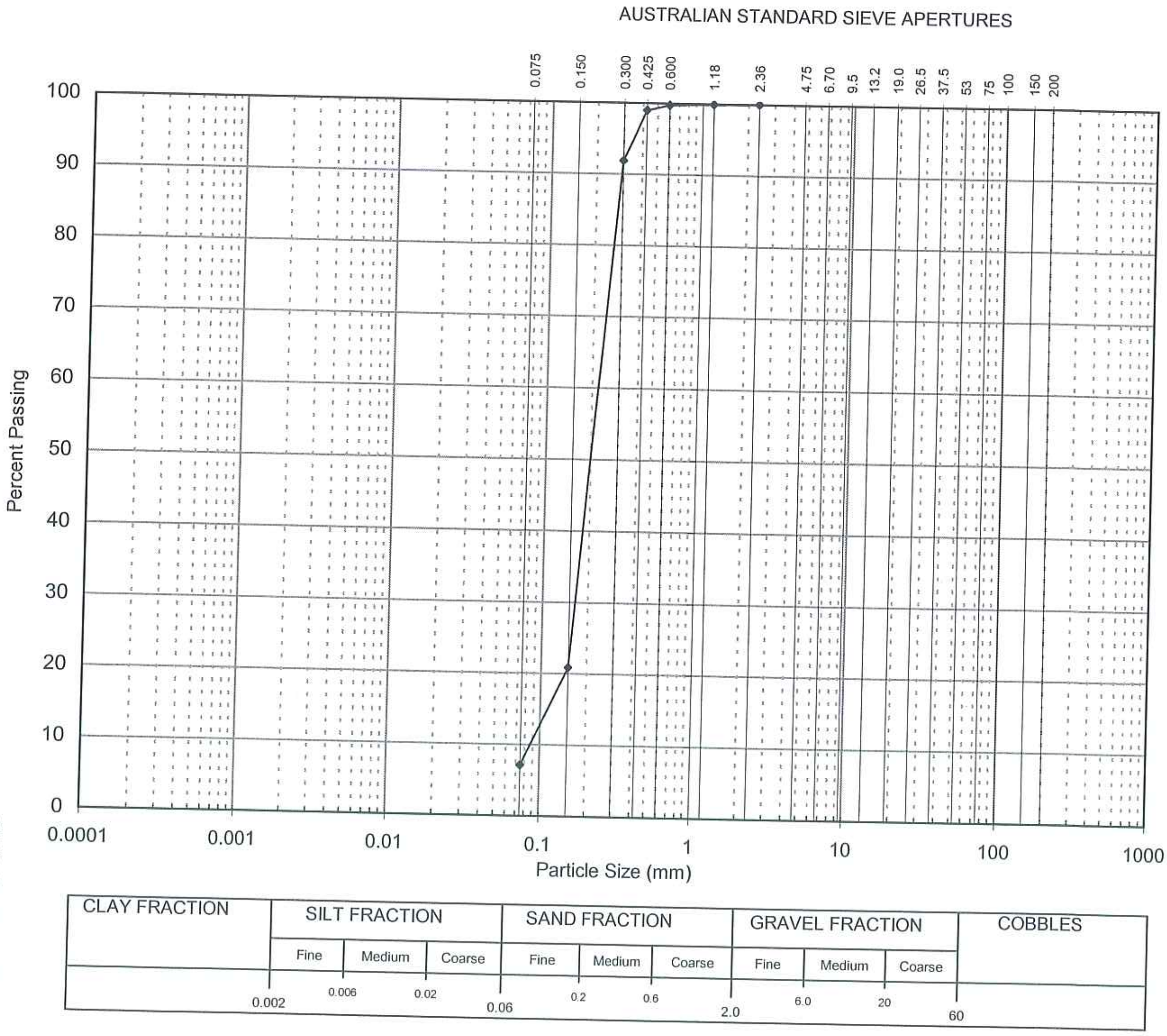
439 Montague Road
West End QLD 4101
Phone (07) 3237 8900
Fax (07) 3237 8999

Results of Particle Size Distribution

Client :	Tower Holdings Pty Ltd	**Project No. :**	74586.01
Project :	Additional Groundwater Investigations	**Report No. :**	BO11-197
		Report Date :	08-Mar-11
Location :	Great Keppel Island	**Date Sampled:**	10-16/02/2011
		Date of Test:	07-Mar-11
Road No:	- **Sample / Pit No:** Bore 16	**Depth / Layer:**	14.0m
Chainage:	- **Section / Lot No:** -	**Test Request No:**	-
		Page:	1 of 1



Sieve Size (mm)	% Passing
75.0	~
53.0	~
37.5	~
26.5	~
19.0	~
13.2	~
9.5	~
6.7	~
4.75	~
2.36	100%
1.18	100%
0.600	100%
0.425	99%
0.300	92%
0.150	21%
0.075	7%

Description: Sand with some silt

Test Method(s): AS 1289.3.6.1

Sampling Method(s): Sampled by DP Environmental

Remarks:

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

NATA Accredited Laboratory Number: 828
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Tested:	SG
Checked:	SG

S. Gibbons
Sue-Ellen Gibbons
Senior Soil Technician

Appendix D

Chain of Custody Documentation and Laboratory Results

ALS Batch EB1103074

CHAIN OF CUSTODY DOCUMENTATION

Australian Laboratory Services Pty Ltd

CLIENT:	Douglas Partners	SAMPLER:	Karen Hager
ADDRESS / OFFICE:	439 Montague Road WEST END 4101	MOBILE:	0417 544 122
PROJECT MANAGER (PM):	Carl Deegan	PHONE:	(07) 3237 8900
PROJECT ID:	74586.01	EMAIL REPORT TO:	karen.hager@douglaspartners.com.au
SITE: GKI	P.O. NO.:	EMAIL INVOICE TO: (if different to report)	donna.pyke@douglaspartners.com.au
RESULTS REQUIRED (Date): 24/2/2011	QUOTE: EN-020-10		

FOR LABORATORY USE ONLY
COOLER SEAL (circle appropriate)
Intact: Yes No N/A
SAMPLE TEMPERATURE
CHILLED: Yes No

COMMENTS / SPECIAL HANDLING / STORAGE OR DIPOSAL:
Keep chilled

ANALYSIS REQUIRED including SUITES (note - suite codes must be listed to attract suite prices)

ALS ID	SAMPLE ID	MATRIX	DATE	Time	Type / Code	Total bottles	TDS	Mg, Ca, Na, K	Cl, CO3, HCO3, SO4	Total hardness	8 metals	SAR	Iron	Total N, Total P	Turbidity, TSS	
1	MB12	W	13/2/11		P,N,S	3	X	X	X	X	X	X	X	X	X	
2	MB13	W	14/2/11		P,N,S	3	X	X	X	X	X	X	X	X	X	Please log as separate Batch
3	MB14	W	14/2/11		P,N,S	3	HOLD SAMPLE									
4	MB16	W	16/2/11		P,N,S.	3	X	X	X	X	X	X	X	X	X	

URGENT

Environmental Division
Brisbane
Work Order
EB1103074
Telephone : +61-7-3243 7222

RELINQUISHED BY:		RECEIVED BY		METHOD OF SHIPMENT
Name: Karen Hager	Date: 17/2/2011	Name: L. ANGELES.	Date: 18.2.11	Con' Note No: 671831728
Of: Douglas Partners	Time:	Of: ALS	Time: 1300.	
Name:	Date:	Name:	Date:	Transport Co: TNT.
Of:	Time:	Of:	Time:	

Water Container Codes: P = Unpreserved Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cd Preserved; S = Sodium Hydroxide Preserveed Plastic; AG = Amber Glass Unpreserved; V = VOA Vial HCl Preserved; VS = VOA Vial Sulphuric Preserved; SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass; Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bad for Acid Sulphate Soils; B = Unpreserved Bag.

ALS Environmental

SAMPLE RECEIPT NOTIFICATION (SRN)

Comprehensive Report

Work Order	: **EB1103074**		
Client	: **DOUGLAS PARTNERS PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR CARL DEEGAN	Contact	: Milan Pavasovic
Address	: 439 MONTAGUE ROAD WEST END QLD, AUSTRALIA 4101	Address	: 32 Shand Street Stafford QLD Australia 4053
E-mail	: carl.deegan@douglaspartners.com.au	E-mail	: milan.pavasovic@alsglobal.com
Telephone	: +61 32378900	Telephone	: +61 7 3243 7129
Facsimile	: +61 07 32378999	Facsimile	: +61 7 3243 7218
Project	: 74586 01	Page	: 1 of 3
Order number	: ----		
C-O-C number	: ----	Quote number	: ES2010DOUPAR0245 (EN/020/10)
Site	: GKI		
Sampler	: Karen Hager	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement

Dates

Date Samples Received	: 18-FEB-2011	Issue Date	: 21-FEB-2011 09:35
Client Requested Due Date	: 24-FEB-2011	Scheduled Reporting Date	: **25-FEB-2011**

Delivery Details

Mode of Delivery	: Carrier	Temperature	: 8.9°C
No. of coolers/boxes	: 1 MEDIUM	No. of samples received	: 4
Security Seal	: Intact.	No. of samples analysed	: 3

General Comments

- This report contains the following information:
  - Sample Container(s)/Preservation Non-Compliances
  - Summary of Sample(s) and Requested Analysis
  - Requested Deliverables
- Samples received in appropriately pretreated and preserved containers.
- Turnaround times have been extended due to laboratory capacity.
- **Samples received in appropriately pretreated and preserved containers.**
- **Breaches in recommended extraction / analysis holding times have occurred.**
- **The recommended holding time for turbidity +/or chlorophyll-A +/or colour analysis is 48 hours from the time of sampling.**
- Discounted Package Prices apply only when specific ALS Group Codes ('W', 'S', 'NT' suites) are referenced on COCs.
- Please direct any turn around / technical queries to the laboratory contact designated above.
- Please direct any queries related to sample condition / numbering / breakages to Matt Goodwin.
- Analytical work for this work order will be conducted at ALS Brisbane.
- Sample Disposal - Aqueous (14 days), Solid (90 days) from date of completion of work order.

Sample Container(s)/Preservation Non-Compliances

All comparisons are made against pretreatment/preservation AS, APHA, USEPA standards.

- **No sample container / preservation non-compliance exist.**

Summary of Sample(s) and Requested Analysis

Some items described below may be part of a laboratory process neccessary for the execution of client requested tasks. Packages may contain additional analyses, such as the determination of moisture content and preparation tasks, that are included in the package.
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.

Matrix: **WATER**

Laboratory sample ID	Client sampling date / time	Client sample ID	(On Hold) WATER No analysis requested	WATER - EA006 Sodium Adsorption Ratio	WATER - EA015H Total Dissolved Solids - High Level	WATER - EA025H Suspended Solids (High Level)	WATER - EA045 Turbidity	WATER - EA065 Total Hardness as CaCO3	WATER - EG020F Dissolved Metals by ICPMS	WATER - EK062G Total Nitrogen as N (TKN + NOx reported) By Discrete Analyser
EB1103074-001	13-FEB-2011 15:00	MB12		✓	✓	✓	✓	✓	✓	✓
EB1103074-002	14-FEB-2011 15:00	MB13		✓	✓	✓	✓	✓	✓	✓
EB1103074-003	14-FEB-2011 15:00	MB14	✓							
EB1103074-004	16-FEB-2011 15:00	MB16		✓	✓	✓	✓	✓	✓	✓

Matrix: **WATER**

Laboratory sample ID	Client sampling date / time	Client sample ID	WATER - EK067G Total Phosphorus as P By Discrete Analyser	WATER - EN055 - DA Ionic Balance (DA)	WATER - NT-01 Major Cations (Ca, Mg, Na, K)	WATER - NT-02 (EB) Major Anions (Cl, SO4, Alkalinity)	WATER - W-02 8 Metals
EB1103074-001	13-FEB-2011 15:00	MB12	✓	✓	✓	✓	✓
EB1103074-002	14-FEB-2011 15:00	MB13	✓	✓	✓	✓	✓
EB1103074-004	16-FEB-2011 15:00	MB16	✓	✓	✓	✓	✓

Requested Deliverables

MR CARL DEEGAN

- *AU Certificate of Analysis - NATA (COA)	Email	carl.deegan@douglaspartners.com.au
- *AU Interpretive QC Report - DEFAULT (Anon QCI Rep) (QCI)	Email	carl.deegan@douglaspartners.com.au
- *AU QC Report - DEFAULT (Anon QC Rep) - NATA (QC)	Email	carl.deegan@douglaspartners.com.au
- A4 - AU Sample Receipt Notification - Environmental (SRN)	Email	carl.deegan@douglaspartners.com.au
- Chain of Custody (CoC) (COC)	Email	carl.deegan@douglaspartners.com.au
- EDI Format - ENMRG (ENMRG)	Email	carl.deegan@douglaspartners.com.au
- EDI Format - XTab (XTAB)	Email	carl.deegan@douglaspartners.com.au

MS DONNA PYKE

- A4 - AU Tax Invoice (INV)	Email	donna.pyke@douglaspartners.com.au

MS KAREN HAGER

- *AU Certificate of Analysis - NATA (COA)	Email	karen.hager@douglaspartners.com.au
- *AU Interpretive QC Report - DEFAULT (Anon QCI Rep) (QCI)	Email	karen.hager@douglaspartners.com.au
- *AU QC Report - DEFAULT (Anon QC Rep) - NATA (QC)	Email	karen.hager@douglaspartners.com.au
- A4 - AU Sample Receipt Notification - Environmental (SRN)	Email	karen.hager@douglaspartners.com.au
- Chain of Custody (CoC) (COC)	Email	karen.hager@douglaspartners.com.au
- EDI Format - ENMRG (ENMRG)	Email	karen.hager@douglaspartners.com.au
- EDI Format - XTab (XTAB)	Email	karen.hager@douglaspartners.com.au

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **EB1103074**	Page	: 1 of 4
Client	: **DOUGLAS PARTNERS PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR CARL DEEGAN	Contact	: Milan Pavasovic
Address	: 439 MONTAGUE ROAD WEST END QLD, AUSTRALIA 4101	Address	: 32 Shand Street Stafford QLD Australia 4053
E-mail	: carl.deegan@douglaspartners.com.au	E-mail	: milan.pavasovic@alsglobal.com
Telephone	: +61 32378900	Telephone	: +61 7 3243 7129
Facsimile	: +61 07 32378999	Facsimile	: +61 7 3243 7218
Project	: 74586 01	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 18-FEB-2011
Sampler	: Karen Hager	Issue Date	: 28-FEB-2011
Site	: GKI		
		No. of samples received	: 4
Quote number	: EN/020/10	No. of samples analysed	: 3

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

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA WORLD RECOGNISED ACCREDITATION

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Dilani Fernando	Senior Inorganic Chemist	Inorganics
Kim McCabe	Senior Inorganic Chemist	Inorganics

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 insuffient sample for analysis.

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

When 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

- **EA025 (Suspended Solids): LCS recovery falls outside Dynamic Control Limits. It is however within ALS Static Control Limits and hence deemed acceptable.**
- **EA025 (Suspended Solids): Unable to perform analysis on samples 1 (MB12) and 4 (MB16) due to insufficient volume.**

Analytical Results

Sub-Matrix: **WATER**			Client sample ID	MB12	MB13	MB16	----	----
			Client sampling date / time	13-FEB-2011 15:00	14-FEB-2011 15:00	16-FEB-2011 15:00	----	----
Compound	CAS Number	LOR	Unit	EB1103074-001	EB1103074-002	EB1103074-004	----	----
EA006: Sodium Adsorption Ratio (SAR)								
^ Sodium Absorption Ratio	----	0.01	-	**6.23**	**7.21**	**5.86**	----	----
EA015: Total Dissolved Solids								
Total Dissolved Solids @180°C	GIS-210-010	5	mg/L	**528**	**1170**	**452**	----	----
EA025: Suspended Solids								
^ Suspended Solids (SS)	----	5	mg/L	----	**1750**	----	----	----
EA045: Turbidity								
Turbidity	----	0.1	NTU	**2200**	**1700**	**2700**	----	----
EA065: Total Hardness as CaCO3								
^ Total Hardness as CaCO3	----	1	mg/L	**116**	**345**	**99**	----	----
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	**10**	**29**	**5**	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**10**	**29**	**5**	----	----
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	**70**	**27**	**31**	----	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	**264**	**709**	**253**	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**10**	**31**	**10**	----	----
Magnesium	7439-95-4	1	mg/L	**22**	**65**	**18**	----	----
Sodium	7440-23-5	1	mg/L	**154**	**308**	**134**	----	----
Potassium	7440-09-7	1	mg/L	**2**	**7**	**3**	----	----
EG020F: Dissolved Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	**0.0009**	<0.0001	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Copper	7440-50-8	0.001	mg/L	**0.006**	**0.046**	**0.001**	----	----
Nickel	7440-02-0	0.001	mg/L	**0.004**	**0.038**	**0.004**	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	**0.001**	<0.001	----	----
Zinc	7440-66-6	0.005	mg/L	**0.030**	**0.119**	**0.202**	----	----
Iron	7439-89-6	0.05	mg/L	**0.08**	**0.14**	<0.05	----	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	**0.34**	<0.01	**5.16**	----	----

Analytical Results

Sub-Matrix: **WATER**			Client sample ID	MB12	MB13	MB16	----	----
			Client sampling date / time	13-FEB-2011 15:00	14-FEB-2011 15:00	16-FEB-2011 15:00	----	----
Compound	CAS Number	LOR	Unit	EB1103074-001	EB1103074-002	EB1103074-004	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	1.5	1.2	1.7	----	----
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ Total Nitrogen as N	----	0.1	mg/L	1.8	1.2	6.9	----	----
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	0.60	0.86	1.29	----	----
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	9.12	21.1	7.89	----	----
^ Total Cations	----	0.01	meq/L	9.03	20.5	7.92	----	----
^ Ionic Balance	----	0.01	%	0.49	1.58	0.16	----	----

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

QUALITY CONTROL REPORT

Work Order	: **EB1103074**	Page	: 1 of 7
Client	: **DOUGLAS PARTNERS PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR CARL DEEGAN	Contact	: Milan Pavasovic
Address	: 439 MONTAGUE ROAD WEST END QLD, AUSTRALIA 4101	Address	: 32 Shand Street Stafford QLD Australia 4053
E-mail	: carl.deegan@douglaspartners.com.au	E-mail	: milan.pavasovic@alsglobal.com
Telephone	: +61 32378900	Telephone	: +61 7 3243 7129
Facsimile	: +61 07 32378999	Facsimile	: +61 7 3243 7218
Project	: 74586 01	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Site	: GKI		
C-O-C number	: ----	Date Samples Received	: 18-FEB-2011
Sampler	: Karen Hager	Issue Date	: 28-FEB-2011
Order number	: ----		
		No. of samples received	: 4
Quote number	: EN/020/10	No. of samples analysed	: 3

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

This Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

NATA
WORLD RECOGNISED
ACCREDITATION

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Dilani Fernando	Senior Inorganic Chemist	Inorganics
Kim McCabe	Senior Inorganic Chemist	Inorganics

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 insuffient sample for analysis.

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

Key : Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
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
RPD = Relative Percentage Difference
# = Indicates failed QC

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR:- No Limit; Result between 10 and 20 times LOR:- 0% - 50%; Result > 20 times LOR:- 0% - 20%.

Sub-Matrix: **WATER**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
EA015: Total Dissolved Solids (QC Lot: 1684714)									
EB1102835-004	Anonymous	EA015H: Total Dissolved Solids @180°C	GIS-210-010	5	mg/L	1160	1150	0.8	0% - 20%
EB1102925-002	Anonymous	EA015H: Total Dissolved Solids @180°C	GIS-210-010	5	mg/L	218	180	19.1	0% - 20%
EA025: Suspended Solids (QC Lot: 1684511)									
EB1102956-001	Anonymous	EA025H: Suspended Solids (SS)	----	5	mg/L	44	48	8.7	No Limit
EB1102979-008	Anonymous	EA025H: Suspended Solids (SS)	----	5	mg/L	<5	<5	0.0	No Limit
EA045: Turbidity (QC Lot: 1677902)									
EB1103050-003	Anonymous	EA045: Turbidity	----	0.1	NTU	75.0	75.0	0.0	0% - 20%
EB1103074-004	MB16	EA045: Turbidity	----	0.1	NTU	2700	2800	3.6	0% - 20%
ED037P: Alkalinity by PC Titrator (QC Lot: 1684407)									
EB1102973-008	Anonymous	ED037-P: Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	0.0	No Limit
		ED037-P: Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	0.0	No Limit
		ED037-P: Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	38	39	2.6	0% - 20%
		ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	38	39	2.6	0% - 20%
EB1103074-001	MB12	ED037-P: Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	0.0	No Limit
		ED037-P: Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	0.0	No Limit
		ED037-P: Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	10	11	9.5	0% - 50%
		ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	10	11	9.5	0% - 50%
ED040F: Dissolved Major Anions (QC Lot: 1683024)									
EB1102879-016	Anonymous	ED040F: Sulfate as SO4 2-	14808-79-8	1	mg/L	475	470	0.9	0% - 20%
EB1103074-004	MB16	ED040F: Sulfate as SO4 2-	14808-79-8	1	mg/L	31	32	0.0	0% - 20%
ED045G: Chloride Discrete analyser (QC Lot: 1683026)									
EB1102879-016	Anonymous	ED045G: Chloride	16887-00-6	1	mg/L	209	208	0.5	0% - 20%
EB1103074-004	MB16	ED045G: Chloride	16887-00-6	1	mg/L	253	253	0.0	0% - 20%
ED093F: Dissolved Major Cations (QC Lot: 1683025)									
EB1102879-016	Anonymous	ED093F: Calcium	7440-70-2	1	mg/L	32	32	0.0	0% - 20%
		ED093F: Magnesium	7439-95-4	1	mg/L	41	41	0.0	0% - 20%
		ED093F: Sodium	7440-23-5	1	mg/L	154	155	0.0	0% - 20%
		ED093F: Potassium	7440-09-7	1	mg/L	2	2	0.0	No Limit
EB1103074-004	MB16	ED093F: Calcium	7440-70-2	1	mg/L	10	10	0.0	0% - 50%
		ED093F: Magnesium	7439-95-4	1	mg/L	18	18	0.0	0% - 50%
		ED093F: Sodium	7440-23-5	1	mg/L	134	133	0.0	0% - 20%
		ED093F: Potassium	7440-09-7	1	mg/L	3	3	0.0	No Limit
EG020F: Dissolved Metals by ICP-MS (QC Lot: 1677401)									
EB1102828-002	Anonymous	EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	0.0	No Limit

Sub-Matrix: **WATER**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
				Laboratory Duplicate (DUP) Report					
EG020F: Dissolved Metals by ICP-MS (QC Lot: 1677401) - continued									
EB1102828-002	Anonymous	EG020A-F: Arsenic	7440-38-2	0.001	mg/L	0.001	<0.001	0.0	No Limit
		EG020A-F: Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	0.0	No Limit
		EG020A-F: Copper	7440-50-8	0.001	mg/L	0.011	0.010	0.0	0% - 50%
		EG020A-F: Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	0.0	No Limit
		EG020A-F: Nickel	7440-02-0	0.001	mg/L	0.002	<0.001	0.0	No Limit
		EG020A-F: Zinc	7440-66-6	0.005	mg/L	0.011	<0.005	74.3	No Limit
		EG020A-F: Iron	7439-89-6	0.05	mg/L	0.08	0.08	0.0	No Limit
EB1102973-002	Anonymous	EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	0.0	No Limit
		EG020A-F: Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	0.0	No Limit
		EG020A-F: Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	0.0	No Limit
		EG020A-F: Copper	7440-50-8	0.001	mg/L	0.001	0.001	0.0	No Limit
		EG020A-F: Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	0.0	No Limit
		EG020A-F: Nickel	7440-02-0	0.001	mg/L	<0.001	<0.001	0.0	No Limit
		EG020A-F: Zinc	7440-66-6	0.005	mg/L	<0.005	<0.005	0.0	No Limit
		EG020A-F: Iron	7439-89-6	0.05	mg/L	<0.05	<0.05	0.0	No Limit
EG035F: Dissolved Mercury by FIMS (QC Lot: 1677400)									
EB1102796-005	Anonymous	EG035F: Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	0.0	No Limit
EB1102973-001	Anonymous	EG035F: Mercury	7439-97-6	0.0001	mg/L	0.0001	0.0002	0.0	No Limit
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser (QC Lot: 1685677)									
EB1102835-008	Anonymous	EK059G: Nitrite + Nitrate as N	----	0.01	mg/L	14.1	13.6	3.3	0% - 20%
EB1102850-002	Anonymous	EK059G: Nitrite + Nitrate as N	----	0.01	mg/L	<0.01	<0.01	0.0	No Limit
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser (QC Lot: 1682492)									
EB1102821-003	Anonymous	EK061G: Total Kjeldahl Nitrogen as N	----	0.1	mg/L	0.3	0.5	34.0	No Limit
EB1102837-001	Anonymous	EK061G: Total Kjeldahl Nitrogen as N	----	0.1	mg/L	0.8	0.8	0.0	No Limit
EK067G: Total Phosphorus as P by Discrete Analyser (QC Lot: 1682493)									
EB1102835-010	Anonymous	EK067G: Total Phosphorus as P	----	0.01	mg/L	<0.01	0.02	0.0	No Limit
EB1102837-001	Anonymous	EK067G: Total Phosphorus as P	----	0.01	mg/L	0.09	0.06	37.7	No Limit

Method Blank (MB) and Laboratory Control Spike (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Sample (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **WATER**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EA015: Total Dissolved Solids (QCLot: 1684714)								
EA015H: Total Dissolved Solids @180°C	GIS-210-010	5	mg/L	<5	2000 mg/L	91.8	86	106
EA025: Suspended Solids (QCLot: 1684511)								
EA025H: Suspended Solids (SS)	----	5	mg/L	<5	150 mg/L	# 117	86	108
EA045: Turbidity (QCLot: 1677902)								
EA045: Turbidity	----	0.1	NTU	<0.1	40.0 NTU	100	96	104
ED037P: Alkalinity by PC Titrator (QCLot: 1684407)								
ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	----	200 mg/L	85.0	83	111
ED040F: Dissolved Major Anions (QCLot: 1683024)								
ED040F: Sulfate as SO4 2-	14808-79-8	1	mg/L	<1	----	----	----	----
ED045G: Chloride Discrete analyser (QCLot: 1683026)								
ED045G: Chloride	16887-00-6	1	mg/L	<1	1000 mg/L	84.8	70	128
ED093F: Dissolved Major Cations (QCLot: 1683025)								
ED093F: Calcium	7440-70-2	1	mg/L	<1	----	----	----	----
ED093F: Magnesium	7439-95-4	1	mg/L	<1	----	----	----	----
ED093F: Sodium	7440-23-5	1	mg/L	<1	----	----	----	----
ED093F: Potassium	7440-09-7	1	mg/L	<1	----	----	----	----
EG020F: Dissolved Metals by ICP-MS (QCLot: 1677401)								
EG020A-F: Arsenic	7440-38-2	0.001	mg/L	<0.001	0.100 mg/L	100	85	124
EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	<0.0001	0.100 mg/L	98.3	88	117
EG020A-F: Chromium	7440-47-3	0.001	mg/L	<0.001	0.100 mg/L	107	88	127
EG020A-F: Copper	7440-50-8	0.001	mg/L	<0.001	0.200 mg/L	101	86	118
EG020A-F: Lead	7439-92-1	0.001	mg/L	<0.001	0.100 mg/L	104	89	113
EG020A-F: Nickel	7440-02-0	0.001	mg/L	<0.001	0.100 mg/L	100	88	119
EG020A-F: Zinc	7440-66-6	0.005	mg/L	<0.005	0.200 mg/L	102	85	130
EG020A-F: Iron	7439-89-6	0.05	mg/L	<0.05	0.50 mg/L	104	79	128
EG035F: Dissolved Mercury by FIMS (QCLot: 1677400)								
EG035F: Mercury	7439-97-6	0.0001	mg/L	<0.0001	0.010 mg/L	95.6	84	116
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser (QCLot: 1685677)								
EK059G: Nitrite + Nitrate as N	----	0.01	mg/L	<0.01	0.5 mg/L	94.4	73	121
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser (QCLot: 1682492)								
EK061G: Total Kjeldahl Nitrogen as N	----	0.1	mg/L	<0.1	10 mg/L	89.4	71.4	111
EK067G: Total Phosphorus as P by Discrete Analyser (QCLot: 1682493)								
EK067G: Total Phosphorus as P	----	0.01	mg/L	<0.01	4.42 mg/L	89.6	84.1	120

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

Sub-Matrix: **WATER**

				Matrix Spike (MS) Report			
				Spike	Spike Recovery (%)	Recovery Limits (%)	
Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Concentration	MS	Low	High
ED045G: Chloride Discrete analyser (QCLot: 1683026)							
EB1102966-007	Anonymous	ED045G: Chloride	16887-00-6	400 mg/L	93.4	70	130
EG020F: Dissolved Metals by ICP-MS (QCLot: 1677401)							
EB1102828-003	Anonymous	EG020A-F: Arsenic	7440-38-2	0.100 mg/L	105	70	130
		EG020A-F: Cadmium	7440-43-9	0.100 mg/L	99.7	70	130
		EG020A-F: Chromium	7440-47-3	0.100 mg/L	99.1	70	130
		EG020A-F: Copper	7440-50-8	0.200 mg/L	100	70	130
		EG020A-F: Lead	7439-92-1	0.100 mg/L	99.7	70	130
		EG020A-F: Nickel	7440-02-0	0.100 mg/L	100	70	130
		EG020A-F: Zinc	7440-66-6	0.200 mg/L	109	70	130
EG035F: Dissolved Mercury by FIMS (QCLot: 1677400)							
EB1102828-001	Anonymous	EG035F: Mercury	7439-97-6	0.010 mg/L	92.6	70	130
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser (QCLot: 1685677)							
EB1102835-009	Anonymous	EK059G: Nitrite + Nitrate as N	----	0.5 mg/L	110	70	130
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser (QCLot: 1682492)							
EB1102692-002	Anonymous	EK061G: Total Kjeldahl Nitrogen as N	----	25 mg/L	82.0	70	130
EK067G: Total Phosphorus as P by Discrete Analyser (QCLot: 1682493)							
EB1102835-011	Anonymous	EK067G: Total Phosphorus as P	----	5 mg/L	89.5	70	130

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

INTERPRETIVE QUALITY CONTROL REPORT

Work Order	: **EB1103074**	Page	: 1 of 10
Client	: DOUGLAS PARTNERS PTY LTD	Laboratory	: Environmental Division Brisbane
Contact	: MR CARL DEEGAN	Contact	: Milan Pavasovic
Address	: 439 MONTAGUE ROAD WEST END QLD, AUSTRALIA 4101	Address	: 32 Shand Street Stafford QLD Australia 4053
E-mail	: carl.deegan@douglaspartners.com.au	E-mail	: milan.pavasovic@alsglobal.com
Telephone	: +61 32378900	Telephone	: +61 7 3243 7129
Facsimile	: +61 07 32378999	Facsimile	: +61 7 3243 7218
Project	: 74586 01	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Site	: GKI		
C-O-C number	: ----	Date Samples Received	: 18-FEB-2011
Sampler	: Karen Hager	Issue Date	: 28-FEB-2011
Order number	: ----		
		No. of samples received	: 4
Quote number	: EN/020/10	No. of samples analysed	: 3

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

This Interpretive Quality Control Report contains the following information:

- Analysis Holding Time Compliance
- Quality Control Parameter Frequency Compliance
- Brief Method Summaries
- Summary of Outliers

Analysis Holding Time Compliance

The following report summarises extraction / preparation and analysis times and compares with recommended holding times. Dates reported represent first date of extraction or analysis and precludes subsequent dilutions and reruns. Information is also provided re the sample container (preservative) from which the analysis aliquot was taken. Elapsed period to analysis represents number of days from sampling where no extraction / digestion is involved or period from extraction / digestion where this is present. For composite samples, sampling date is assumed to be that of the oldest sample contributing to the composite. Sample date for laboratory produced leachates is assumed as the completion date of the leaching process. Outliers for holding time are based on USEPA SW 846, APHA, AS and NEPM (1999). A listing of breaches is provided in the Summary of Outliers.

Holding times for leachate methods (excluding elutriates) vary according to the analytes being determined on the resulting solution. For non-volatile analytes, the holding time compliance assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These soil holding times are: Organics (14 days); Mercury (28 days) & other metals (180 days). A recorded breach therefore does not guarantee a breach for all non-volatile parameters.

Matrix: **WATER** Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / *Container / Client Sample ID(s)*	*Sample Date*	*Extraction / Preparation*			*Analysis*		
		Date extracted	*Due for extraction*	*Evaluation*	*Date analysed*	*Due for analysis*	*Evaluation*
EA015: Total Dissolved Solids							
Clear Plastic Bottle - Natural MB12	**13-FEB-2011**	**----**	----	----	**25-FEB-2011**	20-FEB-2011	×
Clear Plastic Bottle - Natural MB13	**14-FEB-2011**	**----**	----	----	**25-FEB-2011**	21-FEB-2011	×
Clear Plastic Bottle - Natural MB16	**16-FEB-2011**	**----**	----	----	**25-FEB-2011**	23-FEB-2011	×
EA025: Suspended Solids							
Clear Plastic Bottle - Natural MB12	**13-FEB-2011**	**----**	----	----	**25-FEB-2011**	20-FEB-2011	×
Clear Plastic Bottle - Natural MB13	**14-FEB-2011**	**----**	----	----	**25-FEB-2011**	21-FEB-2011	×
Clear Plastic Bottle - Natural MB16	**16-FEB-2011**	**----**	----	----	**25-FEB-2011**	23-FEB-2011	×
EA045: Turbidity							
Clear Plastic Bottle - Natural MB12	**13-FEB-2011**	**----**	----	----	**21-FEB-2011**	15-FEB-2011	×
Clear Plastic Bottle - Natural MB13	**14-FEB-2011**	**----**	----	----	**21-FEB-2011**	16-FEB-2011	×
Clear Plastic Bottle - Natural MB16	**16-FEB-2011**	**----**	----	----	**21-FEB-2011**	18-FEB-2011	×
ED037P: Alkalinity by PC Titrator							
Clear Plastic Bottle - Natural MB12	**13-FEB-2011**	**---**	27-FEB-2011	----	**25-FEB-2011**	27-FEB-2011	✓
Clear Plastic Bottle - Natural MB13	**14-FEB-2011**	**---**	28-FEB-2011	----	**25-FEB-2011**	28-FEB-2011	✓
Clear Plastic Bottle - Natural MB16	**16-FEB-2011**	**---**	02-MAR-2011	----	**25-FEB-2011**	02-MAR-2011	✓

Matrix: **WATER**

Evaluation: ✘ = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)	Sample Date	Extraction / Preparation: Date extracted	Due for extraction	Evaluation	Analysis: Date analysed	Due for analysis	Evaluation
ED040F: Dissolved Major Anions							
Clear Plastic Bottle - Natural MB12	**13-FEB-2011**	---	13-MAR-2011	----	**24-FEB-2011**	13-MAR-2011	✓
Clear Plastic Bottle - Natural MB13	**14-FEB-2011**	---	14-MAR-2011	----	**24-FEB-2011**	14-MAR-2011	✓
Clear Plastic Bottle - Natural MB16	**16-FEB-2011**	---	16-MAR-2011	----	**24-FEB-2011**	16-MAR-2011	✓
ED045G: Chloride Discrete analyser							
Clear Plastic Bottle - Natural MB12	**13-FEB-2011**	---	13-MAR-2011	----	**24-FEB-2011**	13-MAR-2011	✓
Clear Plastic Bottle - Natural MB13	**14-FEB-2011**	---	14-MAR-2011	----	**24-FEB-2011**	14-MAR-2011	✓
Clear Plastic Bottle - Natural MB16	**16-FEB-2011**	---	16-MAR-2011	----	**24-FEB-2011**	16-MAR-2011	✓
ED093F: Dissolved Major Cations							
Clear Plastic Bottle - Natural MB12	**13-FEB-2011**	---	20-FEB-2011	----	**24-FEB-2011**	20-FEB-2011	✘
Clear Plastic Bottle - Natural MB13	**14-FEB-2011**	---	21-FEB-2011	----	**24-FEB-2011**	21-FEB-2011	✘
Clear Plastic Bottle - Natural MB16	**16-FEB-2011**	---	23-FEB-2011	----	**24-FEB-2011**	23-FEB-2011	✘
EG020F: Dissolved Metals by ICP-MS							
Clear Plastic Bottle - Nitric Acid; Filtered MB12	**13-FEB-2011**	---	12-AUG-2011	----	**21-FEB-2011**	12-AUG-2011	✓
Clear Plastic Bottle - Nitric Acid; Filtered MB13	**14-FEB-2011**	---	13-AUG-2011	----	**21-FEB-2011**	13-AUG-2011	✓
Clear Plastic Bottle - Nitric Acid; Filtered MB16	**16-FEB-2011**	---	15-AUG-2011	----	**21-FEB-2011**	15-AUG-2011	✓
EG035F: Dissolved Mercury by FIMS							
Clear Plastic Bottle - Nitric Acid; Filtered MB12	**13-FEB-2011**	---	13-MAR-2011	----	**23-FEB-2011**	13-MAR-2011	✓
Clear Plastic Bottle - Nitric Acid; Filtered MB13	**14-FEB-2011**	---	14-MAR-2011	----	**23-FEB-2011**	14-MAR-2011	✓
Clear Plastic Bottle - Nitric Acid; Filtered MB16	**16-FEB-2011**	---	16-MAR-2011	----	**23-FEB-2011**	16-MAR-2011	✓
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser							
Clear Plastic Bottle - Sulphuric Acid MB12	**13-FEB-2011**	---	13-MAR-2011	----	**27-FEB-2011**	13-MAR-2011	✓
Clear Plastic Bottle - Sulphuric Acid MB13	**14-FEB-2011**	---	14-MAR-2011	----	**27-FEB-2011**	14-MAR-2011	✓
Clear Plastic Bottle - Sulphuric Acid MB16	**16-FEB-2011**	---	16-MAR-2011	----	**27-FEB-2011**	16-MAR-2011	✓

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method Container / Client Sample ID(s)	Sample Date	Extraction / Preparation			Analysis		
		Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser							
Clear Plastic Bottle - Sulphuric Acid MB12	**13-FEB-2011**	**25-FEB-2011**	13-MAR-2011	✓	**28-FEB-2011**	13-MAR-2011	✓
Clear Plastic Bottle - Sulphuric Acid MB13	**14-FEB-2011**	**25-FEB-2011**	14-MAR-2011	✓	**28-FEB-2011**	14-MAR-2011	✓
Clear Plastic Bottle - Sulphuric Acid MB16	**16-FEB-2011**	**25-FEB-2011**	16-MAR-2011	✓	**28-FEB-2011**	16-MAR-2011	✓
EK067G: Total Phosphorus as P by Discrete Analyser							
Clear Plastic Bottle - Sulphuric Acid MB12	**13-FEB-2011**	**25-FEB-2011**	13-MAR-2011	✓	**28-FEB-2011**	13-MAR-2011	✓
Clear Plastic Bottle - Sulphuric Acid MB13	**14-FEB-2011**	**25-FEB-2011**	14-MAR-2011	✓	**28-FEB-2011**	14-MAR-2011	✓
Clear Plastic Bottle - Sulphuric Acid MB16	**16-FEB-2011**	**25-FEB-2011**	16-MAR-2011	✓	**28-FEB-2011**	16-MAR-2011	✓

Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(where) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **WATER**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	Method	QC	Regular	Actual	Expected	Evaluation	
Laboratory Duplicates (DUP)							
Alkalinity by PC Titrator	ED037-P	2	12	**16.7**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Chloride by Discrete Analyser	ED045G	2	11	**18.2**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Dissolved Mercury by FIMS	EG035F	2	20	**10.0**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Dissolved Metals by ICP-MS - Suite A	EG020A-F	2	17	**11.8**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Major Anions - Dissolved	ED040F	2	19	**10.5**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Major Cations - Dissolved	ED093F	2	11	**18.2**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Nitrite and Nitrate as N (NOx) by Discrete Analyser	EK059G	2	18	**11.1**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Suspended Solids (High Level)	EA025H	2	18	**11.1**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Dissolved Solids (High Level)	EA015H	2	20	**10.0**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Kjeldahl Nitrogen as N By Discrete Analyser	EK061G	2	15	**13.3**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Phosphorus as P By Discrete Analyser	EK067G	2	15	**13.3**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Turbidity	EA045	2	20	**10.0**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Laboratory Control Samples (LCS)							
Alkalinity by PC Titrator	ED037-P	1	12	**8.3**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Chloride by Discrete Analyser	ED045G	2	11	**18.2**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Dissolved Mercury by FIMS	EG035F	1	20	**5.0**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	17	**5.9**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Nitrite and Nitrate as N (NOx) by Discrete Analyser	EK059G	1	18	**5.6**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Suspended Solids (High Level)	EA025H	1	18	**5.6**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Dissolved Solids (High Level)	EA015H	1	20	**5.0**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Kjeldahl Nitrogen as N By Discrete Analyser	EK061G	1	15	**6.7**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Phosphorus as P By Discrete Analyser	EK067G	1	15	**6.7**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Turbidity	EA045	1	20	**5.0**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Method Blanks (MB)							
Chloride by Discrete Analyser	ED045G	1	11	**9.1**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Dissolved Mercury by FIMS	EG035F	1	20	**5.0**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	17	**5.9**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Major Anions - Dissolved	ED040F	1	19	**5.3**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Major Cations - Dissolved	ED093F	1	11	**9.1**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Nitrite and Nitrate as N (NOx) by Discrete Analyser	EK059G	1	18	**5.6**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Suspended Solids (High Level)	EA025H	1	18	**5.6**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Dissolved Solids (High Level)	EA015H	1	20	**5.0**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Kjeldahl Nitrogen as N By Discrete Analyser	EK061G	1	15	**6.7**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Phosphorus as P By Discrete Analyser	EK067G	1	15	**6.7**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Turbidity	EA045	1	20	**5.0**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Matrix Spikes (MS)							
Chloride by Discrete Analyser	ED045G	1	11	**9.1**	**5.0**	✓	ALS QCS3 requirement
Dissolved Mercury by FIMS	EG035F	1	20	**5.0**	**5.0**	✓	ALS QCS3 requirement
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	17	**5.9**	**5.0**	✓	ALS QCS3 requirement

Matrix: **WATER**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Matrix Spikes (MS) - Continued							
Nitrite and Nitrate as N (NOx) by Discrete Analyser	EK059G	1	18	**5.6**	**5.0**	✓	ALS QCS3 requirement
Total Kjeldahl Nitrogen as N By Discrete Analyser	EK061G	1	15	**6.7**	**5.0**	✓	ALS QCS3 requirement
Total Phosphorus as P By Discrete Analyser	EK067G	1	15	**6.7**	**5.0**	✓	ALS QCS3 requirement

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	Method	Matrix	Method Descriptions
Sodium Adsorption Ratio	EA006	WATER	APHA 21st ed., 3120 Ca, Mg, Na. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Total Dissolved Solids (High Level)	EA015H	WATER	APHA 21st ed., 2540C A gravimetric procedure that determines the amount of `filterable` residue in an aqueous sample. A well-mixed sample is filtered through a glass fibre filter (1.2um). The filtrate is evaporated to dryness and dried to constant weight at 180+/-5C. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Suspended Solids (High Level)	EA025H	WATER	APHA 21st ed., 2540D A gravimetric procedure employed to determine the amount of `non-filterable` residue in a aqueous sample. The prescribed GFC (1.2um) filter is rinsed with deionised water, oven dried and weighed prior to analysis. A well-mixed sample is filtered through a glass fibre filter (1.2um). The residue on the filter paper is dried at 104+/-2C . This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Turbidity	EA045	WATER	APHA 21st ed., 2130 B. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Hardness as CaCO3	EA065	WATER	APHA 21st ed., 2340 B. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Alkalinity by PC Titrator	ED037-P	WATER	APHA 21st ed., 2320 B This procedure determines alkalinity by automated measurement (e.g. PC Titrate) using pH 4.5 for indicating the total alkalinity end-point. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Major Anions - Dissolved	ED040F	WATER	APHA 21st ed., 3120. The 0.45um filtered samples are determined by ICP/AES for Sulfur and/or Silcon content and reported as Sulfate and/or Silica after conversion by gravimetric factor.
Chloride by Discrete Analyser	ED045G	WATER	APHA 21st ed., 4500 Cl - G.The thiocyanate ion is liberated from mercuric thiocyanate through sequestration of mercury by the chloride ion to form non-ionised mercuric chloride.in the presence of ferric ions the librated thiocynate forms highly-coloured ferric thiocynate which is measured at 480 nm APHA 21st edition seal method 2 017-1-L april 2003
Major Cations - Dissolved	ED093F	WATER	APHA 21st ed., 3120; USEPA SW 846 - 6010 The ICPAES technique ionises the 0.45um filtered sample atoms emitting a characteristic spectrum. This spectrum is then compared against matrix matched standards for quantification. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Dissolved Metals by ICP-MS - Suite A	EG020A-F	WATER	(APHA 21st ed., 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020): Samples are 0.45 um filtered prior to analysis. The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.
Dissolved Mercury by FIMS	EG035F	WATER	AS 3550, APHA 21st ed. 3112 Hg - B (Flow-injection (SnCl2)(Cold Vapour generation) AAS) Samples are 0.45 um filtered prior to analysis. FIM-AAS is an automated flameless atomic absorption technique. A bromate/bromide reagent is used to oxidise any organic mercury compounds in the filtered sample. The ionic mercury is reduced online to atomic mercury vapour by SnCl2 which is then purged into a heated quartz cell. Quantification is by comparing absorbance against a calibration curve. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Nitrite and Nitrate as N (NOx) by Discrete Analyser	EK059G	WATER	APHA 21st ed., 4500-NO3- F. Combined oxidised Nitrogen (NO2+NO3) is determined by Cadmium Reduction and direct colourimetry by Discrete Analyser. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Total Kjeldahl Nitrogen as N By Discrete Analyser	EK061G	WATER	APHA 21st ed., 4500-Norg D. 25mL water samples are digested using a traditional Kjeldahl digestion followed by determination by Discrete Analyser. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Total Nitrogen as N (TKN + Nox) By Discrete Analyser	EK062G	WATER	APHA 21st ed., 4500-Norg / 4500-NO3-. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)

Analytical Methods	Method	Matrix	Method Descriptions
Total Phosphorus as P By Discrete Analyser	EK067G	WATER	APHA 21st ed., 4500-P B&F This procedure involves sulphuric acid digestion of a 100mL sample to break phosphorus down to orthophosphate. The orthophosphate reacts with ammonium molybdate and antimony potassium tartrate to form a complex which is then reduced and its concentration measured at 880nm using Discrete Analyser. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Ionic Balance by PCT DA and ICPAES	EN055 - DA	WATER	APHA 21st Ed. 1030F. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)

Preparation Methods	Method	Matrix	Method Descriptions
TKN/TP Digestion	EK061/EK067	WATER	APHA 21st ed., 4500 Norg - D; APHA 21st ed., 4500 P - H. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)

Summary of Outliers

Outliers : Quality Control Samples

The following report highlights outliers flagged in the Quality Control (QC) Report. Surrogate recovery limits are static and based on USEPA SW846 or ALS-QWI/EN/38 (in the absence of specific USEPA limits). This report displays QC Outliers (breaches) only.

Duplicates, Method Blanks, Laboratory Control Samples and Matrix Spikes

Matrix: **WATER**

Compound Group Name	Laboratory Sample ID	Client Sample ID	Analyte	CAS Number	Data	Limits	Comment
Laboratory Control Spike (LCS) Recoveries							
EA025: Suspended Solids	1978917-026	----	**Suspended Solids (SS)**	----	117 %	86-108%	**Recovery greater than upper control limit**

- **For all matrices, no Method Blank value outliers occur.**
- **For all matrices, no Duplicate outliers occur.**
- **For all matrices, no Matrix Spike outliers occur.**

Regular Sample Surrogates

- **For all regular sample matrices, no surrogate recovery outliers occur.**

Outliers : Analysis Holding Time Compliance

This report displays Holding Time breaches only. Only the respective Extraction / Preparation and/or Analysis component is/are displayed.

Matrix: **WATER**

Method	*Extraction / Preparation*			*Analysis*		
Container / Client Sample ID(s)	*Date extracted*	*Due for extraction*	***Days overdue***	*Date analysed*	*Due for analysis*	***Days overdue***
EA015: Total Dissolved Solids						
Clear Plastic Bottle - Natural MB12	----	----	----	25-FEB-2011	20-FEB-2011	**5**
Clear Plastic Bottle - Natural MB13	----	----	----	25-FEB-2011	21-FEB-2011	**4**
Clear Plastic Bottle - Natural MB16	----	----	----	25-FEB-2011	23-FEB-2011	**2**
EA025: Suspended Solids						
Clear Plastic Bottle - Natural MB12	----	----	----	25-FEB-2011	20-FEB-2011	**5**
Clear Plastic Bottle - Natural MB13	----	----	----	25-FEB-2011	21-FEB-2011	**4**
Clear Plastic Bottle - Natural MB16	----	----	----	25-FEB-2011	23-FEB-2011	**2**
EA045: Turbidity						
Clear Plastic Bottle - Natural MB12	----	----	----	21-FEB-2011	15-FEB-2011	**6**

Matrix: **WATER**

Method	*Extraction / Preparation*			*Analysis*		
Container / Client Sample ID(s)	*Date extracted*	*Due for extraction*	***Days overdue***	*Date analysed*	*Due for analysis*	***Days overdue***
EA045: Turbidity - Analysis Holding Time Compliance						
Clear Plastic Bottle - Natural MB13	----	----	----	21-FEB-2011	16-FEB-2011	**5**
Clear Plastic Bottle - Natural MB16	----	----	----	21-FEB-2011	18-FEB-2011	**3**
ED093F: Dissolved Major Cations						
Clear Plastic Bottle - Natural MB12	----	----	----	24-FEB-2011	20-FEB-2011	**4**
Clear Plastic Bottle - Natural MB13	----	----	----	24-FEB-2011	21-FEB-2011	**3**
Clear Plastic Bottle - Natural MB16	----	----	----	24-FEB-2011	23-FEB-2011	**1**

Outliers : Frequency of Quality Control Samples

The following report highlights breaches in the Frequency of Quality Control Samples.

- **No Quality Control Sample Frequency Outliers exist.**

Appendix E

Predictive Simulation Bore Hydrographs

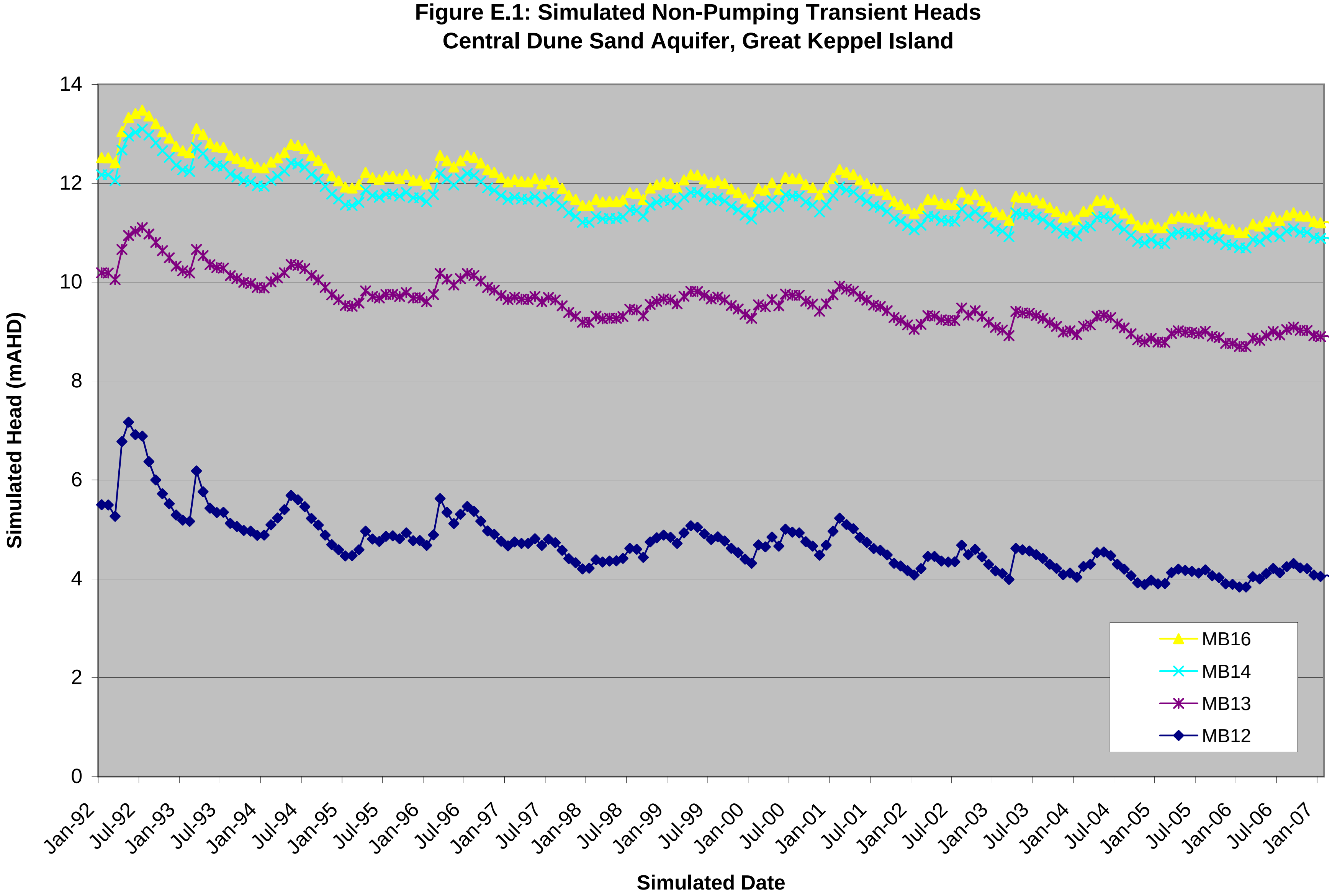

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Figure E.2: MB12 Simulated Heads During Run 6, Central Dune Sand Aquifer, Great Keppel Island

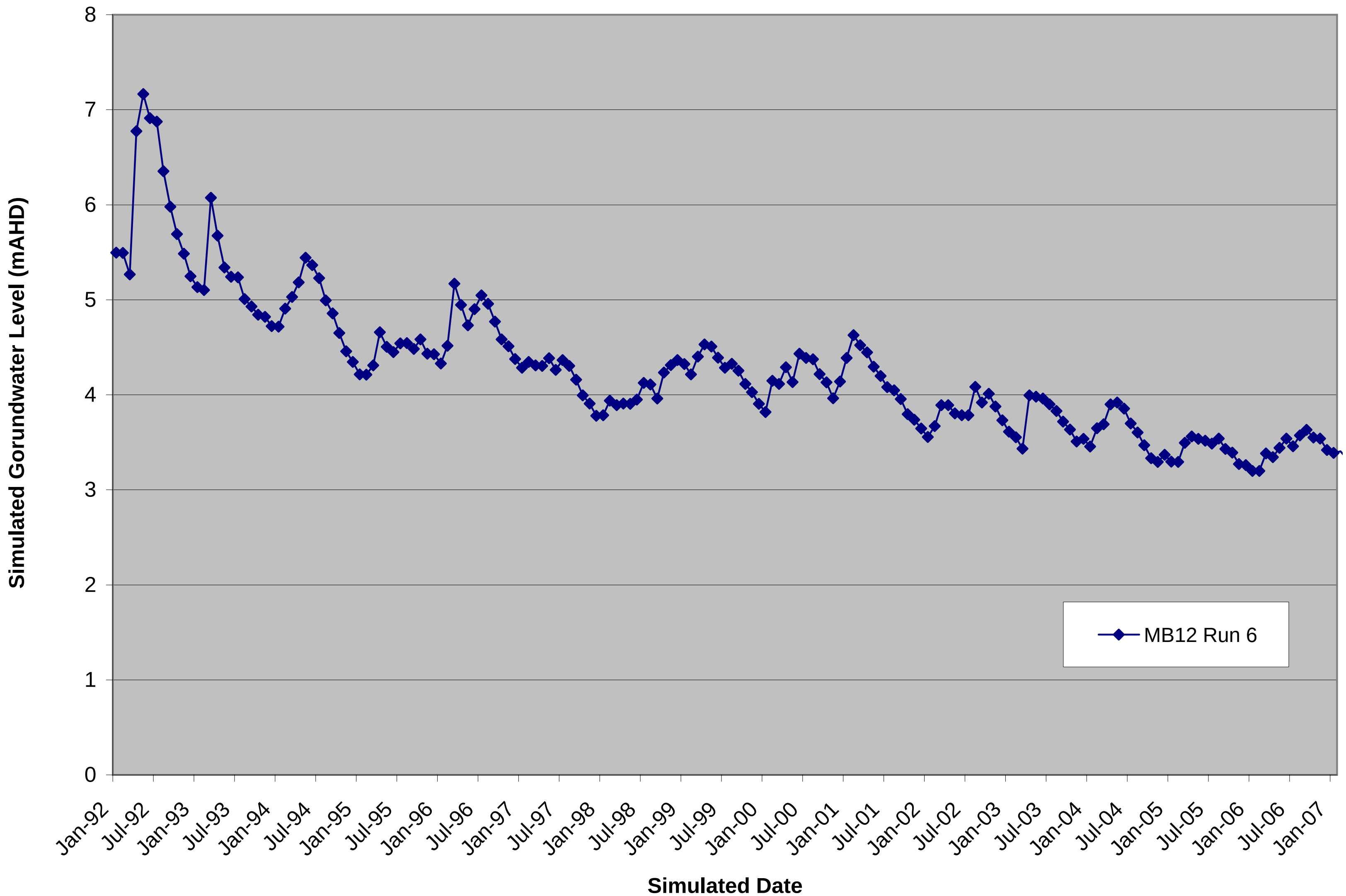

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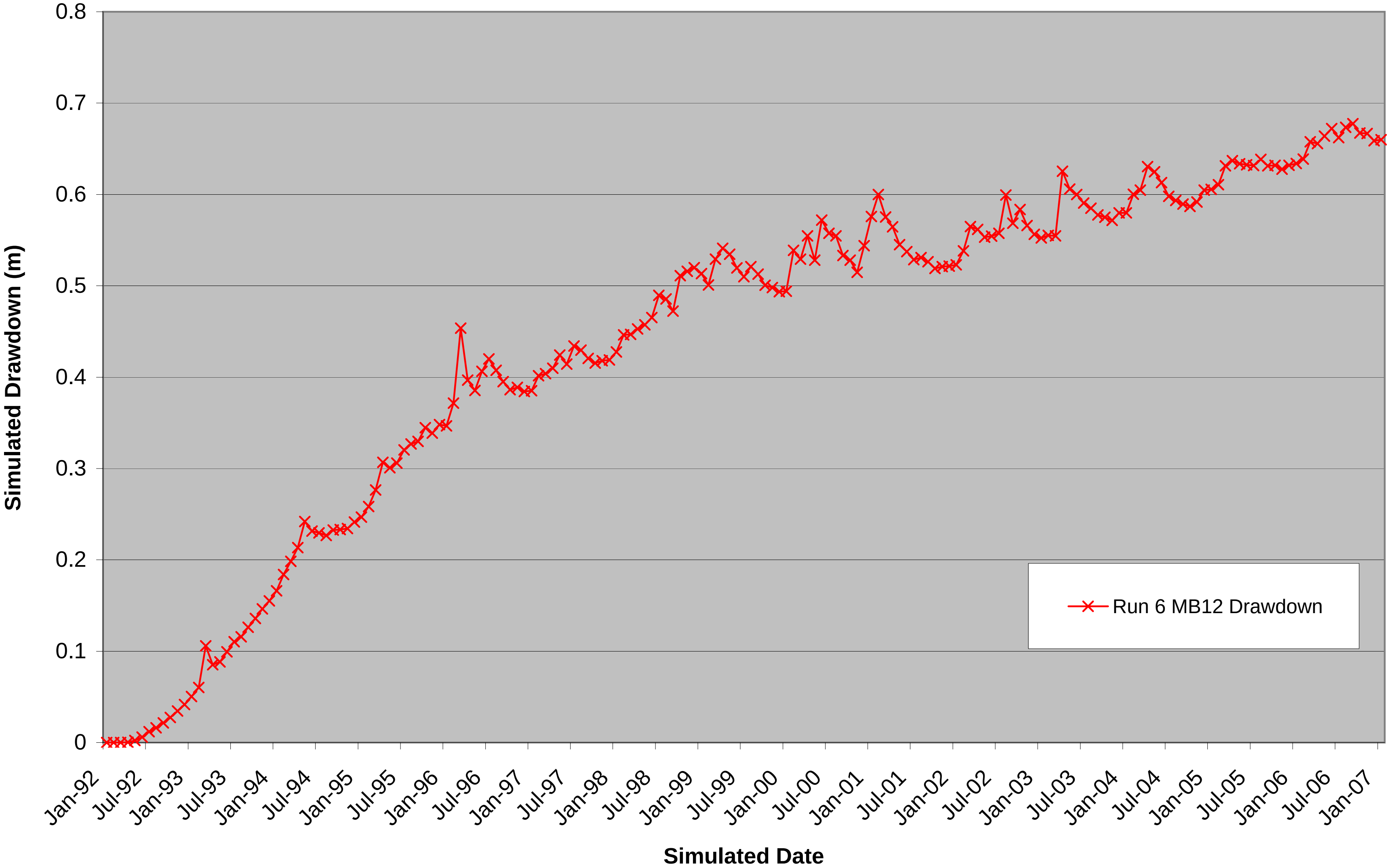
Figure E.3: MB12 Simulated Drawdown
Central Dune Sand Aquifer, Great Keppel Island



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