

SOVEREIGN WATERS ESTATE

Sedimentation Study

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Summary

Sovereign Waters Lake is situated in Redland City between Birkdale and Wellington Point on the coastline of Waterloo Bay. The lake and associated stormwater inlet control and wetland system are part of the water sensitive urban design within this catchment.

As is normal for these systems the wetland and lake are subject to sedimentation and nutrient build up. Redland City Council has identified the need to obtain an updated understanding of lake condition, the extent of sediment accumulation and future maintenance needs. Kellogg Brown & Root Pty Ltd was commissioned to review existing data, design drawings, reports and documentation to prepare a sedimentation study. This study is important for planning, costing and maintenance and its findings will be incorporated into an updated Lake Management Plan.

A sediment sampling program has been completed, involving the collection of 26 piston samples from the wetland and lake. The wetland samples had a mixture of catchment derived and stormwater inlet sediments. The characteristics of the sediments sampled from the lake bed were predominantly analogous to marine derived sediments. There is localised deposition at stormwater inlets to the lake. Indicative estimations of tidal and catchment inflow sources of total suspended solid (TSS) per annum were undertaken. From the observed sampling data and estimations it has been determined that the primary sediment source is the tidal exchange water from Waterloo Bay.

Sedimentation rates have been estimated for four zones within the lake based on the field data collected. The zones have been defined based on lake depth and sediment accretion rate. Table 1 shows the zones and estimated annual sedimentation rates.

Table 1 Lake zones and annual sedimentation rates

Zone	Definition	Average annual sedimentation rate (m/a)
1	General zone	3.5×10^{-3}
2	Western zone	2.9×10^{-2}
3	Deep zone	4.4×10^{-3}
4	Stormwater inlet zone	2.7×10^{-2}

The requirement to remove accumulated sediments from the lake was assessed by identifying the minimum lake depth at which the lake's ability to perform its recreational, aesthetics and

water treatment functions would be compromised. These lake functions and the associated minimum lake depth have been presented in Table 2.

Table 2 Lake functions and associated limiting depths

Objective	Function	Limiting depth (m)
Water Quality	• Secondary contact recreational standard (ANZECC, 2000). • Release of water at slow rate into perimeter channel. • Reduced velocities and turbulence at bed; higher removal of TSS. • Trapping and removal of pollutants from water column. • Support habitat functions.	1.5
Stormwater Treatment Facility	• Satisfactory detention period to allow fine particle sedimentation and removal of nutrients from water column. • Have enough volumetric capacity to facilitate flood events managed for within the design. • Keep above a depth which limits mixing (via surface wind shear) of bed sediments and consequential release of nutrients.	1.5
Habitat	• Provide a deep water habitat for fauna. • Refuge for aquatic animals during extended dry periods.	1.5–2.5
Aesthetics	• Maintain scenic amenity for residents, walkers and other members of the public. • Maintain non-odorous lake ecosystem. • Maintain clear and free open water surface throughout the lake. • Limit photosynthesis at the lake bed.	1.5
Recreation	• Non contact recreational amenity (uncompromised surface waters, free from growth). • Secondary contact recreational standard (ANZECC, 2000). • Use for kayaking and other non-powered vessels.	1–1.5

The minimum water depth of 1.5 m has been adopted as the basis for predicting when sediment removal would be required.

Projections of the change of lake water depth using the observed sedimentation rates showed future changes in water depth for each zone.

Across most of the lake bed the rate of accumulation is very slow and sediment removal operations in these areas of the lake should not need to occur within the foreseeable future. However, the projections identify the likely need for removal of sediment in the proximity of the stormwater inlets by approximately 2035. The volume of sediment to be removed is predicted to be small and it is likely it could be accessed from the shore. There is also a zone

along part of the western lake margin which is accreting sediment at a rate likely to require sediment removal by approximately 2065. The sediment accumulation observed in the wetland indicates sediment removal sediment is likely to be required within the next 10 years.

Based on the data available to date it is not expected that any large scale dredging operation to remove lake sediment will be required within the foreseeable future.

It will be important to schedule regular checks of sediment accumulation in the gross pollutant traps, wetland and lake to more accurately predict when sediment removal is needed.

1 Introduction

1.1 BACKGROUND

This sedimentation study is an input into the development of a Lake Management Plan for Redland City Council (RCC) and has been prepared by Kellogg Brown & Root Pty Ltd (KBR).

The Sovereign Waters constructed lake and wetland is an established aesthetic area for treating stormwater and urban run-off prior to its outflow into coastal waters.

The wetland and lake system is part of a water sensitive urban design (WSUD) within the catchment, which is approximately 2 km². The lake itself is designed to be brackish due to the tidal exchange system. Under normal operations the water level is regulated to fluctuate by 0.4 m and volumetric turnover of the lake is achieved within 24 days. If required the turnover time can be reduced to 10 days using a manually operated emergency outlet (Redland City Council, 2000).

Upstream of the wetland area there are several ponds built between 2005 and 2011 on the southern side of Birkdale Road in EGW Wood Park. These feed into the Sovereign Waters wetland area via five reinforced concrete box culverts (RCBCs). The wetland area consists of two ponds, which act as treatment areas for the removal of sediments and nutrients from the influent water. The wetland system has been designed to maintain acceptable water quality within the lake under normal conditions.

In August 2000 filling of the lake with water began and construction of over 80% of the surrounding housing had been completed. The development then moved into its operational phase. In July 2000 The Sovereign Waters Operations and Maintenance Manual was issued, and the Lake Management Plan was issued in August 2000.

Operations and maintenance is ongoing and Council has identified the requirement to update the documentation and assess the present state of the Sovereign Waters wetland and lake system. One of the items identified to be investigated so maintenance requirements are understood is the accretion of sediments in the lake.

1.2 SCOPE

This sedimentation study is a precursor to the development of a Lake Management Plan for RCC. The intent for this sedimentation study was:

- review survey data and conduct sediment sampling to identify the main sources of sediments and annual sedimentation rates
- review available water quality data and identify any links between lake function and sediment accumulation.

1.3 LOCATION AND GENERAL ARRANGEMENT

The Sovereign Waters Lake is situated in South East Queensland, on the coastline of Waterloo Bay. The urban development is between Birkdale and Wellington Point, adjacent to Birkdale Road (see Figure 1.1).

The Sovereign Waters lake and wetlands primary features can be seen in Figure 1.2 and are broken down into the following:

- upstream ponds (EGW Wood Park)
- two wetlands; 1 inlet zone and 1 macrophyte zone
- the lake
- boat ramp and overflow channel for flood events
- stormwater inlets and gross pollutant traps (GPTs)
- tidal exchange system which transfers via the adjacent perimeter channel.

Stormwater and run-off is distributed to the lake via stormwater drainage and gross pollutant traps (GPTs) in the immediate areas east and west of the lake. The approximate upstream catchment area is 2 km² and has been defined in Figure 1.3. This area has been derived by assessing stormwater drainage plans and land contours provided by RCC. The five RCBC's (dimensions 2,400 mm by 750 mm) situated under Birkdale Road deliver the catchment water into the wetland and lake system (Figure 1.4).



Figure 1.1
LOCATION OF THE SOVEREIGN WATERS LAKE



Figure 1.2
MAIN HYDRODYNAMIC COMPONENTS OF THE SOVEREIGN WATERS SYSTEM

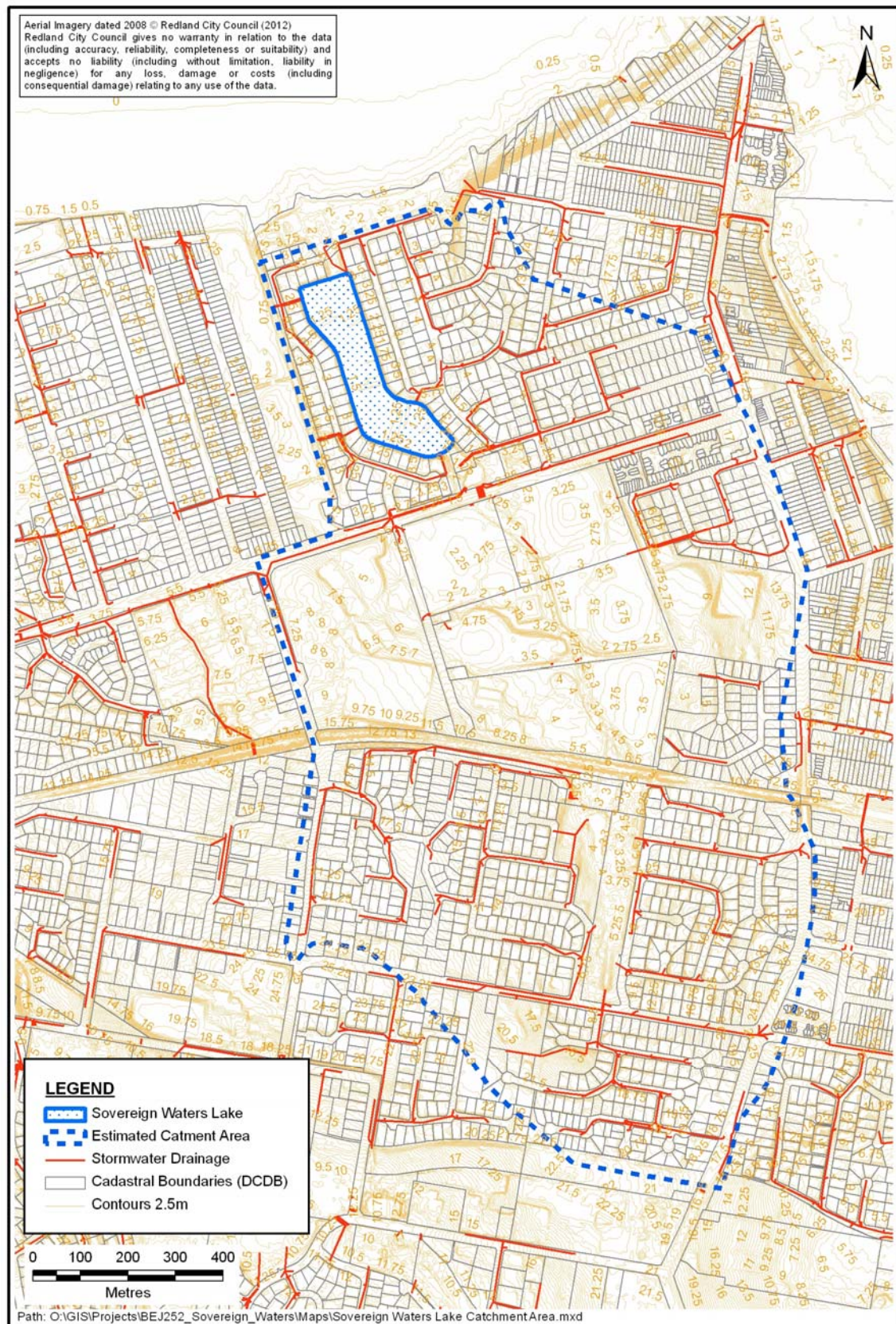


Figure 1.3
APPROXIMATE SOVEREIGN WATERS LAKE CATCHMENT AREA



Figure 1.4
CLOSE PROXIMITY STORMWATER SYSTEM AND GROSS POLLUTANT TRAPS (GPTs)

2 Methodology

This chapter describes the approach used to achieve the scope defined in Section 1.2.

2.1 DATA REVIEW

Lake bed survey data, water quality monitoring data and design drawings were studied to develop an understanding of the wetland and lake system from the information available. This process identified which data could contribute towards the sedimentation study. The data obtained and reviewed is discussed in Chapter 3.

2.2 SEDIMENT SAMPLING

Sampling of the both wetlands and the lake was conducted using a piston sampling method. Two sediment sampling events were completed.

2.2.1 Piston sampling

To extract the sediments a manual piston sampler was used. Piston sampling allows extraction of a sediment core which gives information regarding sediment layering. Since the sampler is manually operated depth of this sediment recovery is limited by how far the sampler can be pushed into the sediment.

The piston sampler was used from an anchored boat. The process to acquire a sample was as follows:

- anchor the boat on the identified sampling locations using a GPS
- measure water depth
- use the piston sampler to extract a sediment core as per the process outlined above
- extrude the sediment core from the piston sampler into a PVC observation tray
- photograph and record descriptions of the sediment sample
- place the appropriate sections of the sediment core into bags for possible future observation and analysis
- clean all sampling equipment in preparation for the next sampling location.

2.2.2 Sampling locations

Two wetland sampling locations and 23 lake sampling locations were selected. The sampling locations and the waypoints from the GPS system are tabulated in Table 4.1 and annotated on aerial imagery in Figure 2.1.

Locations SS07 to SS11 were sampled on 1 June 2012 and locations SS18 to SS40 were sampled on 31 July 2012.

Location SS07 was selected to determine if any accretion had occurred on the batter slopes along the lake margins. Locations SS18, SS19, SS21 and SS37 were selected to be in close proximity of catchment and/or stormwater discharge into the lake. All other locations are general lake bed samples.

Table 2.1 Piston sampling locations

Location Code	Easting	Northing
SS07	522680	6959911
SS08	522702	6959847
SS09	522741	6959764
SS10	522769	6959682
SS11	522874	6959596
SS18	522922	6959579
SS19	522862	6959644
SS20	522873	6959575
SS21	522719	6959895
SS22	522718	6959869
SS23	522734	6959835
SS24	522734	6959794
SS25	522762	6959744
SS26	522782	6959697
SS27	522810	6959643
SS28	522820	6959602
SS29	522663	6959879
SS30	522673	6959855
SS31	522696	6959827
SS33	522739	6959741
SS34	522748	6959698
SS35	522763	6959638
SS37	522713	6959903
SS39	522970	6959523
SS40	523002	6959498

Datum: GDA94 Projection, MGA Zone 56



Figure 2.1
PISTON SAMPLING LOCATIONS

2.3 SEDIMENTATION RATES

Historical lake bed survey data was analysed but because of the nature of the data it did not provide an adequate basis for the estimation of sediment accretion. Instead, data from the direct core recovery and measurement of sediment layers provided a dataset to estimate sedimentation rates.

The lake was segmented into four approximate zones based on water depth or dominant sedimentation processes. Annual sedimentation rates were estimated for each of the zones. The future change in water depth was projected using the rates. This provides an indication of when sediment accumulation would reduce lake water depth to the extent that it began to compromise lake functions or uses. It should be noted however that the available data only allows an estimation on the assumption that sediment accretion continues at the same rate, when in practice this may not be linear.

2.4 SEDIMENT SOURCES

Visual characterization of the sediments and their observed properties provided an understanding of the sources. Indicative calculations were also made to estimate the tidal inflow and catchment volumes entering the lake per annum. Total suspended solids (TSS) values in influent water have been measured over several months in 2011 by RCC (for water quality input data see Section 3.4 and for water quality review see Chapter 4). By using volumetric flow per annum and TSS averages comparative estimations were made as to the relative contributions of TSS from the catchment and from tidal exchange.

3 Input data

This chapter presents the data used in this study. The review of this data provided an understanding on the history of the site and of lake processes and sedimentation.

3.1 TIDAL PLANES AND DATUMS

Tidal plane data has been used to understand the change in lake water surface level and volumetric exchange via the tidal inlet and discharge system. Using tidal planes and datums provides consistent reference levels throughout the lifespan of the lake and wetland system.

The tide monitoring location of Wellington Point has been selected as it is the closest observation station to the Sovereign Waters lake. The semi-diurnal predicted tidal planes for 2012 have been extracted from the Queensland Tide Tables 2012 booklet. All references to water levels within this document will be to the tidal planes presented and to Australian Height Datum (AHD), seen in Table 3.1.

Table 3.1 Australian Height Datum

Tidal Plane	QT 2012 Tide Tables Wellington Point	
	Level (mLAT)	Level (mAHD)
HAT	2.84	1.51
MHWS	2.26	0.93
MHWN	1.85	0.52
MSL	1.26	-0.07
AHD	1.33	0.00
MLWN	0.79	-0.54
MLWS	0.38	-0.95
LAT	0.00	-1.33

3.2 DESIGN BED LEVELS

The design bed levels assisted in developing an understanding of the lake sedimentation processes after sampling was conducted and data analysis occurred. Caution has been used as the drawings provided have not been issued ‘as constructed’. The most descriptive and detailed drawing of the lake bed which has been used in this study is provided in Appendix A.

Notably the drawing shows an over excavated area in the northern end of the lake and a slightly deeper area of lake bed in the middle.

3.3 LAKE BED SURVEY DATA

Survey data taken over several annual periods can often be used to identify the patterns of sedimentation and accretion rates.

Prior to the lake being filled in August 2000 a survey was carried out to create a digital terrain model (DTM) of the lake bed, however the data from this survey is not available. Surveys of the lake bed level were then done annually from commencement of operation through to 2003. Table 3.2 lists the surveys which were carried out and the main focus of the data.

Table 3.2 Lake bed survey history

Survey Date	Drawing Number	Description of Data
Before 04 August 2000	unknown	Pre-filled lake bed survey
10–14 September 2001	B2295-001	Vertical displacement between 2001 surveyed surface and pre-filling DTM
9–13 September 2002	B2295-002	Vertical displacement between 2002 surveyed surface and pre-filling DTM
23–25 November 2003	B2295-004	Vertical displacement between 2003 surveyed surface and pre-filling DTM

The surveys were conducted by Jones Flint & Pike Pty Ltd using a Total Station set-up over shore control with a target and range pole in a vessel positioned in line with a rope across the lake (JF&P, 2003). The set-up defined an approximate 10 m spacing grid and from reviewing documentation it appears the method was consistent for all surveys. This produced measurements at 22 survey points in the lake.

Due to the time which has elapsed since the surveys were completed (over nine years ago) only hard copy reports with summarized data are available and the raw survey data could not be obtained.

The use of a range pole (which is placed on the bed to determine where the top of the sediment is) limits the accuracy of detecting the surface of soft unconsolidated sediment layers. This is because the end of the pole penetrates the sediment, and the amount it penetrates is unknown and varies depending on sediment stiffness. Re-analysis of the data was not possible without the raw (digital) data and original (constructed) bed levels taken pre-filling in July or August 2000. Therefore we were unable to verify the data and obtain clear measures of change in the surface of the accreted sediments.

3.4 WATER QUALITY MONITORING DATA

Water quality monitoring has occurred as part of the conditions of constructing the sub-development, lake and wetland.

The sampling methodology for all sampling events was to take surface water grab samples and observational notes on environmental and weather conditions. The in-situ water and laboratory analysis quality parameters which have been taken for the Water Quality Control Progress Reports are identified in Table 3.3.

Table 3.3 Water quality parameters

In-situ	Laboratory
Temperature	Suspended solids
pH	Faecal coliforms
DO	Algae count and identification
Turbidity	Total nitrogen
Salinity	Total phosphorous
Specific conductance	Chlorophyll a*
	Enterococci sp.*

* Analysis not required after April 2001, RCC authorised.

From information provided it is understood that water quality monitoring began in March 1999. From this point monthly Water Quality Control Progress Reports were developed until March 2002 (Report No.34). There were nine sample locations, which included the EGW Wood Park pond upstream of Birkdale Road, the wetlands, three lake locations, two perimeter channel locations and one location in the bay within the flow path of the channel.

The next available datasets are results from monitoring events from 2007 through to 2012. These were taken by RCC using similar methodology as previous sampling events. The locations of the sample points differ from previous studies, so comparisons between sampling programs needs to be done with an understanding of the difference in locations and effect to the results.

4 Lake water quality

4.1 OBJECTIVE

The water quality data available has been reviewed to obtain an understanding of lake condition, the lake processes which dominate and the suitability of lake water quality for the intended lake uses. The effects of rainfall and tidal exchange can also be seen.

The lake has been designed to allow secondary contact (e.g. recreation use of kayaks, canoes and other small non powered vessels). Swimming is not an intended use for the lake. It is also noted that recreational fishing has been observed at the lake and is reported by RCC and lake residents to be common practice, however, this also is not an intended use. The applicable water quality standards to be maintained for the lake are Australian and New Zealand Guidelines for Fresh and Marine Water Quality: recreational secondary contact guidelines (ANZECC, 2000). These guidelines define the water quality objectives for the various lake uses being discussed.

4.2 GUIDELINES

The guidelines for recreational secondary contact focus on less frequent body contact with the water. The third recreational category of visual aesthetics also applies to the Sovereign Waters site. Table 4.1 has been extracted from the guidelines and broadly identifies the characteristics relevant to recreational use.

Table 4.1 Water quality characteristics relevant to recreational use (extract from ANZECC, 2000. p.5-2)

Characteristics	Secondary contact (e.g. boating)	Visual use (no contact)
Microbiological guidelines	x	
Nuisance organisms (e.g. algae)	x	x
Physical and chemical guidelines:		
• Aesthetics	x	x
• Clarity	x	x
• Colour	x	x
• pH		
• Temperature		
• Toxic chemicals	x	
• Oil, debris	x	x

Specifically the guidelines recommend the following specific parameter values.

Table 4.2 Water Quality parameters guidelines for secondary and tertiary recreational standards

Parameter	Guideline value
pH	6.5–8.5
DO	>6.5 (>80% saturation)
Total Phosphorous	70 µg/L
Total Nitrogen	650 µg/L
Total Suspended Solids (TSS) - combined wet and dry periods	15 mg/L
Total Suspended Solids (TSS) - wet periods	90 th ile <100 mg/L
Faecal Coliforms	1000 organisms/100 mL

4.3 RAINFALL DATA

Daily rainfall data from two observation stations near the catchment have been obtained. This data has been looked at in comparison with water quality monitoring conducted by RCC in 2007 and 2011. This helped identify the effect of dry periods and/or rainfall runoff on lake water quality and mixing processes.

There are two Bureau of Meteorology (BOM) rainfall stations in the Redland area. Details for both stations and their distance from the most southern point of the catchment (beginning of the mainstream length) can be seen in Table 4.3.

Table 4.3 Nearest rainfall stations

Station Name	BOM Station Number	Latitude (decimal)	Longitude (decimal)	Station Height (m)	Distance from catchment (km)
Ormiston College	040770	-27.51	153.24	10	1.80
Redlands HRS	040265	-27.52	153.25	16	3.20

4.4 WATER QUALITY MONITORING DATA

The data is from surface grab samples. The water quality monitoring locations and the data for parameters of interest are presented in Appendix B. Therefore the changes in water quality with respect to depth within the lake cannot be seen in the data. This can be inferred from an understanding of lake processes. The parameters of most interest for this review are TSS, dissolved Oxygen (DO), turbidity and conductivity for locations SW3, SW4 and SW5.

4.5 LAKE WATER QUALITY

Water quality monitoring has occurred several times during or after a period of reported significant rainfall months (see Figure 4.1 and Figure 4.2). The data from these sampling events has been reviewed to identify any abnormal changes in TSS, dissolved Oxygen (DO) and turbidity values after heavy rainfall.

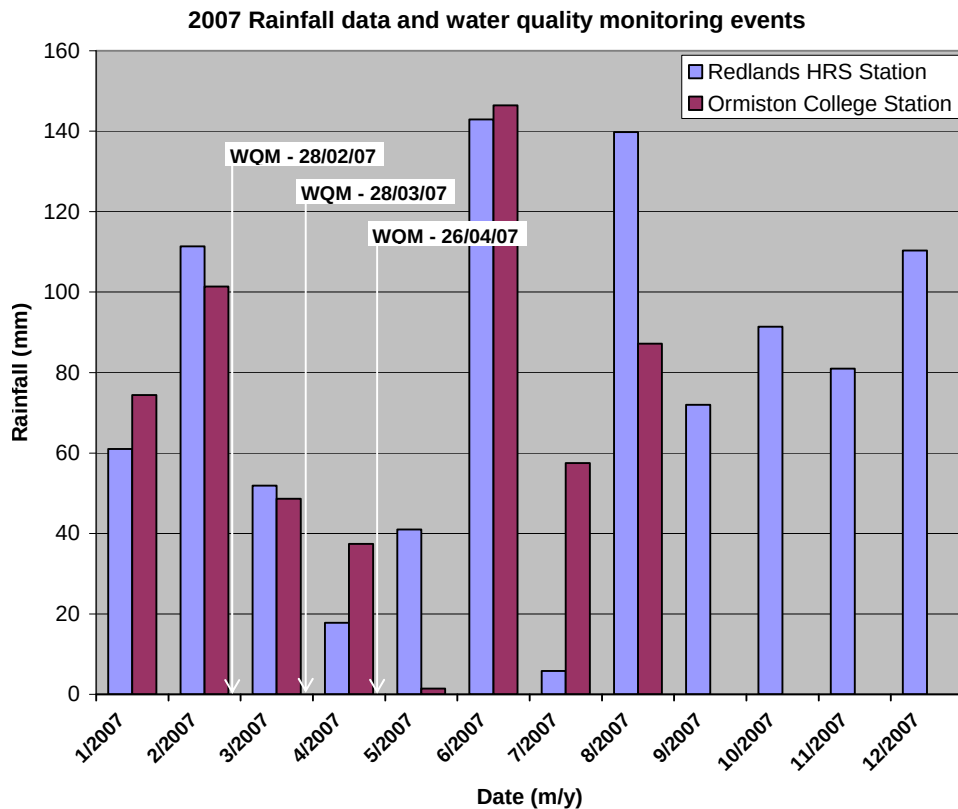


Figure 4.1
RAINFALL DATA AND WATER QUALITY MONITORING EVENTS FOR 2007

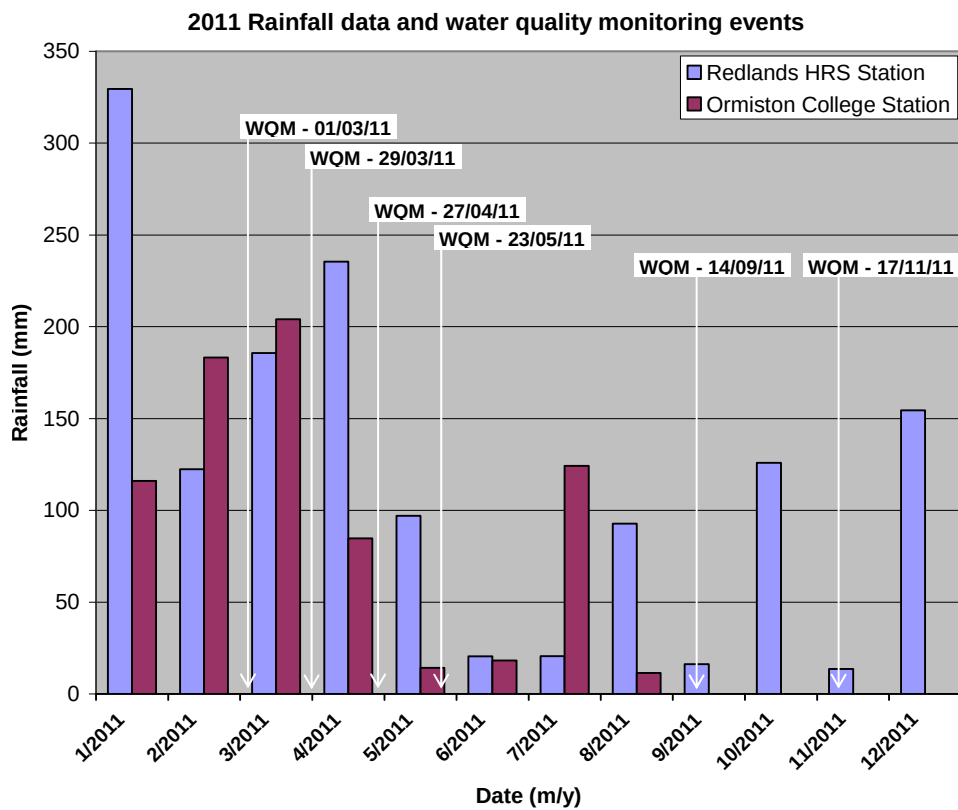


Figure 4.2
RAINFALL DATA AND WATER QUALITY MONITORING EVENTS FOR 2011

Tables 4.4 and 4.5 present the water quality data of principle interest, and identify the monitoring events which were carried out when the lake was influenced by a high rainfall period.

Table 4.4 Sampled lake water quality values

	Date	TSS (mg/l)	Thermotolerant Coliforms (CFU/100ml)	DO (%sat)	Turbidity (NTU)	Conductivity (mS/cm)
SW3	28/02/2007*			91	4	11.39
	28/03/2007*			123	6	12.07
	26/04/2007*			99	5	8.74
	22/05/2007			76	5	18.40
	1/03/2011*	14	10	91	4	11.39
	29/03/2011*	6	30	123	6	12.07
	27/04/2011*	5	180	99	5	8.74
	23/05/2011	3	180	76	5	18.40
	14/09/2011	3	<10	108	2	19.80
	17/11/2011	22	<10	102	2	23.90
SW4	28/02/2007*			95	4	11.41
	28/03/2007*			79	6	12.32
	26/04/2007*			89	3	7.91
	22/05/2007			72	5	15.20
	1/03/2011*	6	10	95	4	11.41
	29/03/2011*	4	60	79	6	12.32
	27/04/2011*	3	50	91	4	7.91
	23/05/2011	7	50	72	5	15.20
	14/09/2011	2	<10	108	2	20.00
	17/11/2011	23	10	101	2	23.60
SW5	28/02/2007*			90	3	11.84
	28/03/2007*			99	9	12.20
	26/04/2007*			89	3	32.10
	22/05/2007			71	7	15.90
	1/03/2011*	4	10	90	3	11.84
	29/03/2011*	6	150	99	9	12.20
	27/04/2011*	4	120	89	3	32.10
	23/05/2011	4	120	71	7	15.90
	14/09/2011	<2	<10	105	2	20.00
	17/11/2011	26	10	104	3	26.40

* denotes 'wet weather' lake condition monitoring events

Lake water clarity is generally quite good, and for the data available suspended solids and turbidity do not exhibit notable increases during periods of elevated rainfall.

In fact, the single instance of suspended solids concentration being above the applicable guideline value occurred during a low rainfall period when tidal exchanges would have been the strongest influence on lake water quality. This gives an indication that the inlet protection from the upstream ponds and wetland is effective, and that tidal inflows often have elevated suspended solids and turbidity.

As expected, there is a clearer relationship between rainfall and lake surface water salinity. This data also provides an indication that localised effects on lake surface water salinity can occur in the vicinity of stormwater drain inlets for short periods just after small to medium rainfall runoff inflows. These do not persist however, as broad-scale lake mixing processes re-establish uniform surface water salinity.

Although water quality data from different depths in the lake is not available, it can be seen that stratification (the formation of a fresher layer of water overlying a saltier layer of water) occurs after substantial freshwater inflows, and that the lake then gradually re-mixes as the dominance of saline tidal inflows returns.

Based on the data available, the bacteriological quality of lake surface waters is typically suitable for secondary contact use.

5 Sediment sampling results

This chapter presents the results of the piston sampling conducted on 1 June and 30 July in 2012 and also discusses visual observations from the field work completed.

Images of each sample and field description logs for the cores can be found in Appendix C.

5.1 PISTON SAMPLE RESULTS

During sampling it was possible to recover a core which included both the accreted sediment and the upper surface of the clay from the original constructed lake bed for most samples. This means that at most sampling locations the depth of sediment which has accreted since the lake was filled could be measured.

The northernmost sampling point data (SS07) indicates that no accretion is occurring on the shallow section of the batters, where there is higher turbulence from wind waves. This is likely to be representative of the upper batters for the entire lake within approximately 6 m of the perimeter wall.

5.1.1 Wetland sample results

Two samples were taken in the wetland, one in the inlet zone (Wetland 1) and one in the macrophyte zone (Wetland 2).

The inlet zone sample, SS40 had approximately 0.25 m of accreted sediment in two different layers. A clay constructed bed layer was not present in the sample, so the total depth of accumulated sediment at the location sampled may be greater. The first layer was fine black odorous silt and was approximately 0.03 m deep. The rest of the core was a low plasticity clay. It was not odorous and was dark grey in colour.

The macrophyte zone (Wetland 2) sample, SS39 had approximately 0.18 m of coarse grainy silt with some sand followed by a mottled plastic clay layer. The silt layer of accreted sediments had some detritus and was highly odorous.

Table 5.1 Wetland sediment samples summary

Sample Name	Water Depth (m)	Core Length (m)	Depth of Accreted Sediment (m)
SS39	1.00	0.20	0.18
SS40	0.50	0.25	0.25

5.1.2 Lake bed sample results

The least amount of accreted sediment sampled was 0.01 m and the most accretion was 0.40 m. In some areas several piston samples were attempted at the same location when there was little or no accreted sediment. 13 out of 18 of the lake bed samples had 0.10 m or less of accretion, one location had 0.13 m of accretion and three locations had between 0.30 m and 0.40 m of accreted sediment. The deepest accumulation of sediment occurred in the centre of the lake at locations SS09, SS34 and SS35.

The accreted material throughout was consistent in texture; generally very fine to fine silts, and layers containing a silt/clay mixture. In a few locations very small pebbles and rocks (all no greater than 0.02 m in diameter) were observed, but these are likely to have originated from placement of rock and gravel to protect lake edge batters. Most of the samples, particularly where these were less than 0.10 m sedimentation were highly liquidated and not consolidated. None of the lake bed samples were odorous. Only SS08 contained detritus or visible decayed organic matter. The colour of the deposited material varied slightly ranging from grey, greenish grey, greenish black to black.

Table 5.2 summarizes the water depth, core length and depth of accreted sediment. Images and further description can be seen in Appendix A.

Table 5.2 Lake bed sediment samples summary

Sample Name	Water depth (m)	Core length (m)	Depth of accreted sediment (m)
SS08	2.66	0.20	0.10
SS09	3.25	0.50	0.40
SS10	3.09	0.25	0.03
SS11	2.52	0.20	0.05
SS20	2.30	0.25	0.13
SS22	4.00	0.10	0.02
SS23	2.75	0.15	0.08
SS24	2.65	0.10	0.03
SS25	2.85	0.25	0.02
SS26	2.65	0.20	0.02
SS27	2.70	0.10	0.02
SS28	2.55	0.10	0.03
SS30	3.95	0.15	0.05
SS31	2.80	0.10	0.01
SS33	3.50	0.45	0.35
SS34	2.65	0.30	0.30
SS35	2.50	0.20	0.02

5.1.3 Tidal and catchment inlet sample results

Reported samples in this section are in proximity of a tidal inlet, stormwater inlets or a wetland inlet to the lake.

The sample taken at SS18, near the wetland inlet had 0.01 m of accreted silt; the rest of the 0.20 m core was stiff clay. The silt was fine and had liquid consistency, was not

odorous and did not have any detritus or visible decaying organic matter in the sampled sediment.

The tidal inlet consists of a submerged top hinged tide valve which feeds into the lake at a bed level of –1.6 mAHD. One sample was taken approximately 20 m east of the inlet. The deposited material was very fine silt, up to 0.04 m deep. The silt was greenish black in colour, contained some decaying leaves and had a slight odour.

Two sample locations were selected in front of stormwater inlets to the lake. One inlet is situated on the east side approximately 120 m from the southern end of the lake and the other is in the north east corner of the lake. These locations will be referred to as stormwater inlets 1 and 2 respectively. The location of the inlets and the areas of the catchment they service can be seen in the introduction (Figure 1.3 and Figure 1.4).

The sampled depth of accreted sediments at stormwater inlet 1 was 0.35 m. There were two layers of sediment; the top layer (0–0.10 m) was silt with some sand and pebbles and the second layer (0.10–0.30 m) was a less liquid, more consolidated silt. The core contained detritus and decayed organic matter throughout. The sediment was black and very odorous.

Two samples were taken near stormwater inlet 2, one being close to the inlet (SS37); which had 0.30 m of accreted sediment and one further away (SS21); which had 0.10 m of accreted sediment. The texture of deposited sediment at SS21 was very fine silt, it was greenish black in colour, had no detritus or visible decaying organic matter and was not odorous. This contrasted from deposited sediment at SS37, which had silt, sand and gravel throughout (<0.002 m in diameter), leaves, twigs, shells and decayed organic matter and was extremely odorous.

Table 5.3 details the sample name and location and summarizes the relevant depths and lengths.

Table 5.3 Stormwater inlet and catchment inlet samples summary

Sample name	Sample location	Water depth (m)	Core length (m)	Depth of accreted sediment (m)
SS18	Near wetland inlet	2.20	0.20	0.01
SS19	Near stormwater inlet	2.10	0.35	0.35
SS21	Near stormwater inlet	3.50	0.20	0.10
SS29	Near tidal inlet	3.80	0.10	0.04
SS37	Near stormwater inlet	2.15	0.30	0.30

6 Sediment sources

There are two potential sources for the sediment which accretes in the lake system. One is sediment derived from the catchment which enters with stormwater and the other is the suspended sediment in tidal exchange water which enters from Moreton Bay.

Clearly, sediment will enter the lake from both these sources, but it is of interest to understand the dominant source as this would focus the maintenance effort in the event that it was necessary to reduce sediment entry into the lake.

An indication of the origins of the accreted sediment in the lake was obtained from a review of the physical characteristics of the sediment, the concentrations of suspended solids reported in the lake monitoring water quality data and an estimation of the volumes of water entering the lake from these sources over a typical year.

Sediment transported from the catchment in stormwater contains a range of particle sizes and also contains organic material such as vegetation along with other debris. The design of the lake system is such that the upstream ponds, wetland zones and GPTs remove sediment from stormwater inflows, particularly debris and the coarse, heavy fraction of suspended sediment. Generally then, most of the sediment which persists in the inflow water which enters the lake is fine and takes longer to settle.

The physical characteristics of the sediment in the cores from the wetland and from the ponds upstream of the wetland confirm this is occurring.

The sediments in Moreton Bay waters are generally catchment derived and arrive via creek and river mouths within the bay. Coarse sediments settle out at estuary mouths whilst the complex oceanic and metrological processes within the bay entrain finer sediments within the water column for extended periods of time. The very fine clays undergo change due to salt ion interactions and form what is referred to as marine clays when they settle.

The suspended sediments arriving via the tidal inlet are therefore fine, typically in the range of coarse silts (~61 µm diameter) to very fine clays (~4 µm diameter) (Healthy Waterways, 2006).

The accreted sediment found across the floor of the lake had characteristics consistent with the marine clays derived from the fine sediments carried by tidal exchange water inflows. Exceptions to this were the small zones immediately adjacent to stormwater inlet pipes and the pipes entering from the wetland. At these locations accreted sediment contained a higher proportion of coarse sediment (e.g. sands) and fragments of vegetation as the result of some of this material persisting through the upstream treatment devices under certain flow conditions.

To obtain further indication of the dominant source of accreted sediment within the lake an estimate of the flows entering the lake from catchment runoff (for runoff events sufficient to transport sediment) and from tidal exchange was made. These

were then combined with representative suspended solids concentrations for each of these sources.

This estimation indicates that while sediment enters the lake from both sources, substantially more enters as fine suspended sediment in tidal water inflows. The estimation showed that because of the much higher frequency of tidal inflows the volume of water from this source was higher in a typical year, and the water quality data indicates that suspended solids concentration is also typically higher in this inflow source.

7 Sedimentation rates

In this section annual rates of sedimentation within the lake in a number of representative zones is derived using the sampling results from Chapter 5. Estimated projected deposition depths as also presented. The information within this section is important for lake management and planning purposes and will be used to develop certain sections of the Lake Management Plan.

7.1 LAKE ZONES

The lake has been divided into zones. This has been done to categorize the modes of sediment deposition and develop uniform rates within zones to reduce the data and provide useful and representative annual rates.

The annual sedimentation rates for these zones may not be linear over time. However, this approach allows an estimation to be made on both the volume of accreted sediment and the effect on lake depth.

There are 4 zones which have been selected and each zone has been described below;

- Zone 1 (General zone): Designed lake bed; based on the small range in depth of accretion within this area, and consistent lake depth. This is most of the lake bed.
- Zone 2 (Western zone): A zone with a deeper bed level and which has higher accretion of sediment.
- Zone 3 (Deep zone): An excavated zone with deeper water depths (equal to or greater than 3.5 m) but does not show higher accretion rates.
- Zone 4 (Stormwater inlet zone): Stormwater water inlet zones within approximately 20 m radius of stormwater inlets to the lake.

These zones can be seen in Figure 7.1 and the data on sediment accretion has been grouped according to these zones. Boundaries between the zones are inferred as they simply provide a framework for the identification of lake management actions and priorities. Tables 7.1 to 7.4 present the grouped data.

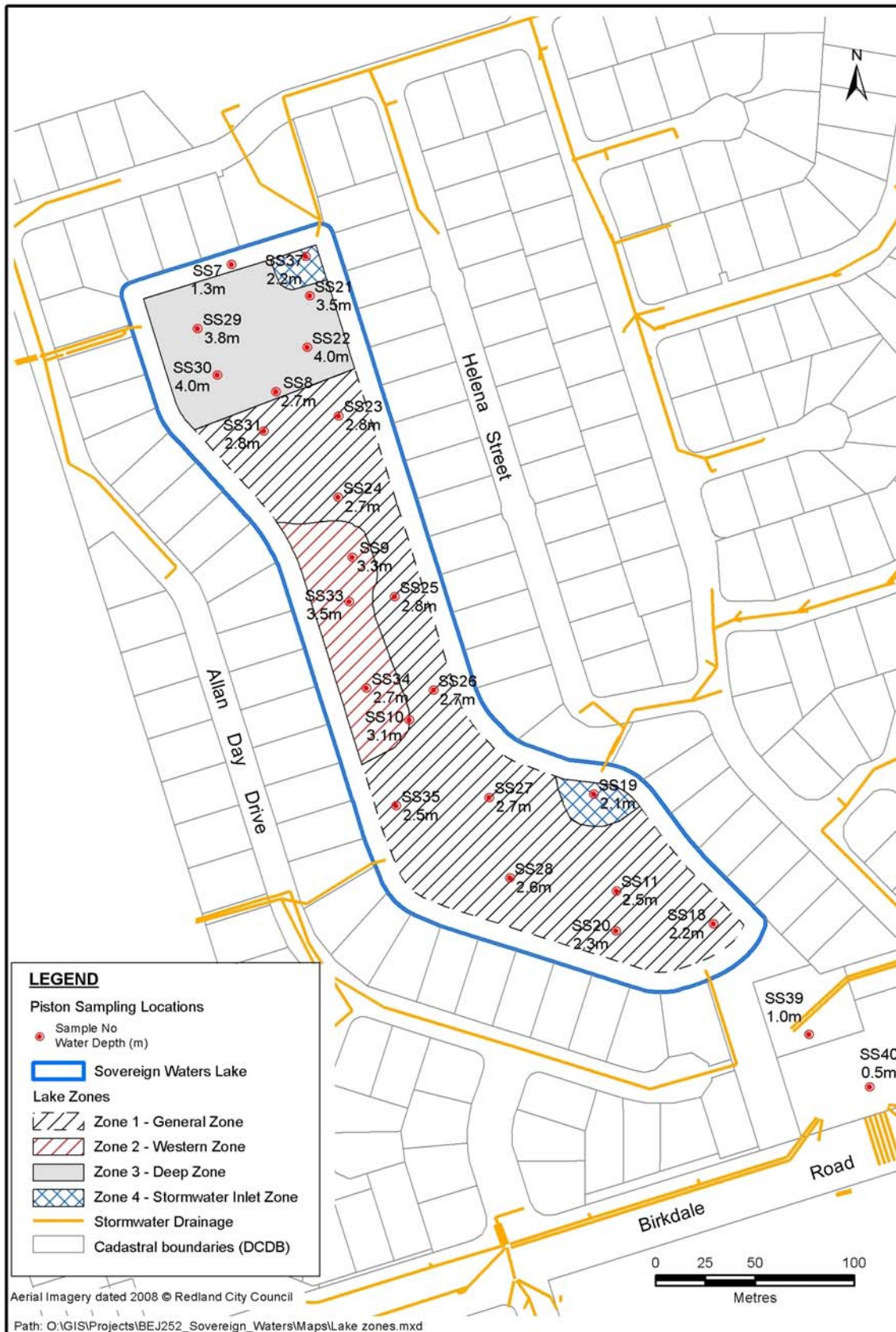


Figure 7.1
LAKE ZONES BASED ON ACCRETION RATES AND BED LEVEL

Table 7.1 Zone 1 – general zone

Sample name	Water depth (m)	Depth of accreted sediment (m)
SS08	2.66	0.10
SS10	3.09	0.03
SS11	2.52	0.05
SS18	2.20	0.01
SS20	2.30	0.13
SS23	2.75	0.08
SS24	2.65	0.03
SS25	2.85	0.02
SS26	2.65	0.02
SS27	2.70	0.02
SS28	2.55	0.03
SS31	2.80	0.01
SS35	2.50	0.02

Table 7.2 Zone 2 – Western zone

Sample name	Water depth (m)	Depth of accreted sediment (m)
SS09	3.25	0.40
SS33	3.50	0.35
SS34	2.65	0.30

Table 7.3 Zone 3 – Deep zone

Sample name	Water depth (m)	Depth of accreted sediment (m)
SS21	3.50	0.10
SS22	4.00	0.02
SS29	3.80	0.04
SS30	3.95	0.05

Table 7.4 Zone 4 – Stormwater inlet zone

Sample name	Water depth (m)	Depth of accreted sediment (m)
SS19	2.10	0.35
SS37	2.15	0.30

7.2 ANNUAL SEDIMENTATION RATES

The annual sedimentation rates have been estimated by grouping measured depths of accumulated sediment into the adopted zones. From filling of the lake in August 2000 to present it has been 12 years, therefore the values have been divided by the number of years to give an annual sedimentation rate for each zone. These values can be seen in Table 7.5.

Table 7.5 Annual sedimentation rates

Zone	Description	Total mean depth of accreted sediment (m)	Average annual sedimentation rate (m)
1	General zone	0.04	3.5×10^{-3}
2	Western zone	0.35	2.9×10^{-2}
3	Deep zone	0.05	4.3×10^{-3}
4	Stormwater inlet zone	0.33	2.7×10^{-2}

7.3 PROJECTED SEDIMENTATION AND WATER DEPTH

The estimated annual sedimentation rate for each zone was then multiplied by the time (in years) and added on to the lake bed level to project the change in depth. The projection assumes the present bed surface would continue to accrete at the measured rate in each zone. Figure 7.2 shows the projected change in water depth over time in the adopted lake zones.

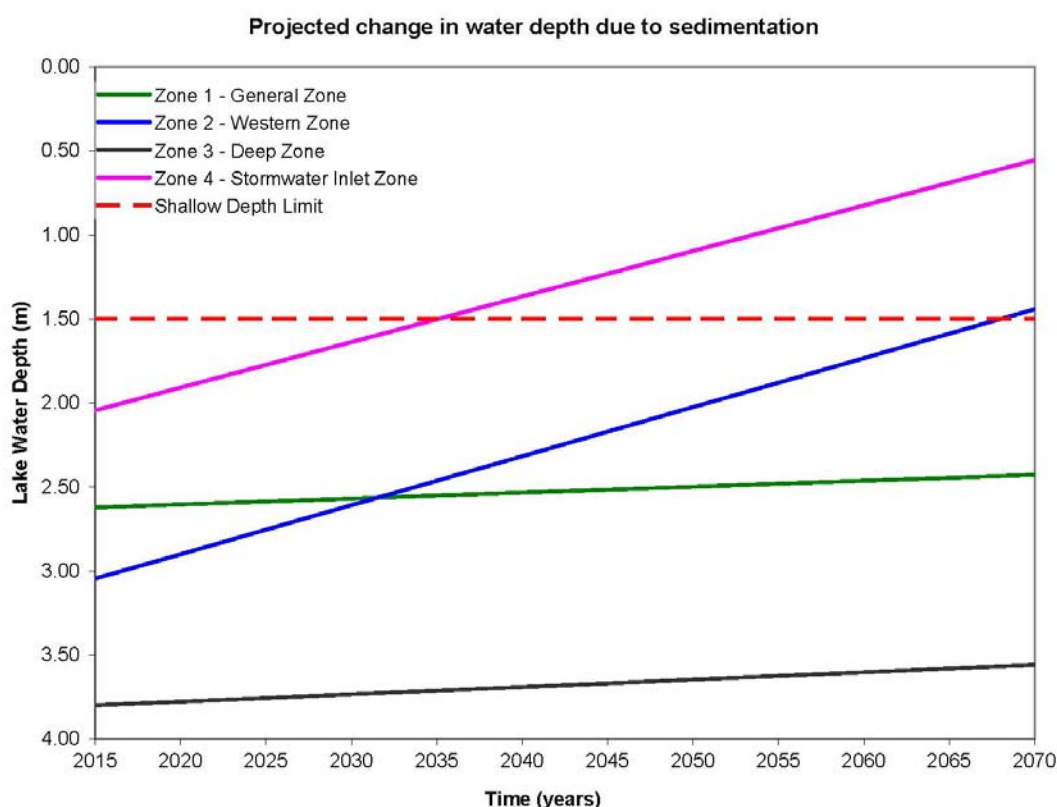


Figure 7.2
ESTIMATED CHANGE IN WATER DEPTH DUE TO SILTATION BETWEEN 2015 AND 2070

From these results it can be seen that sediment has been accreting in the ‘Western zone’ (Zone 2) and the ‘Stormwater inlet zone’ (Zone 4) at a higher rate than for the remainder of the lake. For the remainder of the lake (Zones 1 and 3) very little change in depth is predicted based on current data, even over a very long timeframe.

8 Sediment removal

The relationship between deposition of sediment over time and the potential for this to affect lake functions is discussed in this chapter. A key aspect of this is to determine how much sediment can accumulate before it is necessary to remove it. To determine this, sediment accretion rate is considered in terms of the change in lake depth, and the resulting lake depth is linked to the functions that the lake is to fulfill.

8.1 WETLAND AREA

The requirement to remove sediments from the wetlands is a function of their effectiveness at sediment removal. An inlet zone is designed to remove sediment and reduce flow velocity prior to the water entering the aquatic plant zone. The aquatic plant zone filters nutrients and removes further sediments by spreading the flow over purpose built shallow area planted with aquatic plants.

The requirement to remove sediment from these structures is triggered by a reduction in the intended function. For example, if there is sufficient sediment to reduce the further capture of sediment from inflows, or if it reduces the health or function of the aquatic plants, then there is a need to remove accumulated sediment. Sediment removal from inlet zone ponds is typically specified as being necessary once >50% of pond volume is filled within sediment. The frequency of this depends on the rate at which sediment accumulates. The present requirements for the wetland and sediment removal options will be identified in the Lake Management Plan.

8.2 LAKE AREA

The key functions and uses of the lake and the links to the water depth needed to preserve these are discussed in the following sections.

8.2.1 Stormwater treatment and water quality

The Sovereign Waters lake is a complex system within which water quality and ecological conditions are a function of physical, chemical and biological processes. The lake inherently functions as a sink for nutrients and sediments, even with effective upstream inlet protection systems. Run-off from surrounding areas, precipitation and influx of fine sediments from the tidal exchange is expected.

The lake is designed so that its full volume should be exchanged via the tidal exchange and overflow weir within 24 days (Redland City Council, 2000). This lake turnover rate is appropriate given that the Sovereign Waters lake environment is brackish. The water quality data available also indicates that the tidal exchange rate is preserving acceptable conditions.

Settling processes are a key component of the treatment of stormwater which occurs in the lake. The standing water volume within the lake needs to be sufficient to slow the

velocity of large runoff inflows, and maintain low energy non-turbulent conditions in the lake.

If sediment accumulation substantially reduces lake depth, the current velocity and turbulence from inflows would be higher and sediment settling reduced. This could reduce the level of treatment provided by the lake and therefore reduce the level of protection to downstream systems (in this case Moreton Bay Marine Park).

If the lake was allowed to become shallow turbulent mixing of the lake bed surface sediments could cause sediment resuspension with associated release of nutrients from the sediment into the water column where they can accelerate the growth of algae.

8.2.2 Recreational and habitat functions

The lake has been designed as an aesthetic recreational area, for both passive recreation and secondary contact recreation. More specifically, the uses it is intended to support are as follows:

- for kayaking, canoeing and other small non powered vessel use
- to provide visual amenity (specifically uncompromised surface waters, free from growth).

Safety should also be considered within the recreational framework, as the lake must maintain a depth which is safe for a kayak or canoe user to roll safely.

The lake also provides habitat for a range of estuarine and marine species (e.g. fish and crustaceans) and although artificial is quite productive in this regard. There is also bird usage of both the lake and the wetland area. Substantial filling of the lake with sediment would reduce the availability of open water habitat for these species.

8.3 MINIMUM WATER DEPTH

Defining a limit at which sediment removal should occur is intrinsic to ensuring that lake functions continue within a satisfactory range. The rationale is to maintain stormwater treatment, aesthetics, a healthy ecosystem and ANZECC secondary contact recreational standards (ANZECC, 2000).

Generally there will be a water depth range that is suitable for the optimum water quality and recreational functionality of the Sovereign Waters brackish lake. Several freshwater lake guidelines have water depth ranges based on ecological and recreational functions. These guides identify limiting depths for open water areas of artificial freshwater lakes. While the ecological processes in a freshwater lake are different to the Sovereign Waters brackish lake this information still provides some guidance. Table 8.1 summarises the lake functions and identifies the limiting depths for each function which is applicable to the Sovereign Waters Lake. The water depths identified in the table are therefore the depths that should trigger sediment removal from the lake.

Table 8.1 Lake functions and associated limiting depths

Objective	Function	Limiting depth (m)
Water Quality	• Secondary contact recreational standard (ANZECC, 2000) • Release of water at slow rate into perimeter channel • Reduced velocities and turbulence at bed; higher removal of TSS • Trapping and removal of pollutants from water column • Support habitat functions.	1.5
Stormwater Treatment	• Satisfactory detention period to allow fine particle sedimentation and removal of nutrients from water column • Have enough volumetric capacity to facilitate flood events managed for within the design • Keep above a depth which limits resuspension (via surface wind shear) of bed sediments and consequential release of nutrients.	1.5
Habitat	• Provide an open water habitat for fauna • Refuge for aquatic animals during extended dry periods.	1.5–2.5
Aesthetics	• Maintain scenic amenity for residents, walkers and other members of the public • Maintain non-odorous lake ecosystem • Maintain clear and free open water surface throughout the lake. • Limit photosynthesis at the lake bed (e.g. prevent algal scums).	1.5
Recreation	• Non contact recreational amenity (uncompromised surface waters, free from growth) • Secondary contact recreational standard (ANZECC, 2000) • Use for kayaking and other non-powered vessels.	1–1.5

The information from Table 8.1 indicates the minimum lake depth of water for continued functionality to be 1.5 m.

This has been adopted as the basis for estimating when sediment removal would be required to maintain or improve lake water quality and function given the observed sediment accretion rates to date. Furthermore, the minimum depth will be used as a trigger for sediment removal action in the Lake Management Plan.

Based on this, it is predicted that sediment removal from within the small areas near stormwater inlets (Zone 4) will be needed in approximately 20 years. It is likely that this sediment could be accessed using long reach excavator and loaded into trucks for disposal. Based on existing data the volume which accretes in this zone within this timeframe would not be expected to exceed approximately 600 m³.

The zone along the western margins of the lake (Zone 2) is not predicted to need sediment removal for more than 50 years. Access for removing this sediment is likely

to be more difficult and may require the use of a barge mounted excavator and unloading to shore, or alternatively an hydraulic dredging technique.

For the remaining areas of the lake it is not predicted that sediment removal will be needed within the foreseeable future.

On the other hand, sediment removal from GPTs, the inlet protection ponds upstream, and the wetland zones will be needed more frequently. The frequency of this is expected to be in the order of every few months for GPTs to every few years for inlet ponds.

Ultimately, periodic monitoring of the rate of sediment accumulation will be needed to confirm in advance when sediment removal is required.

9 References

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Appendix A

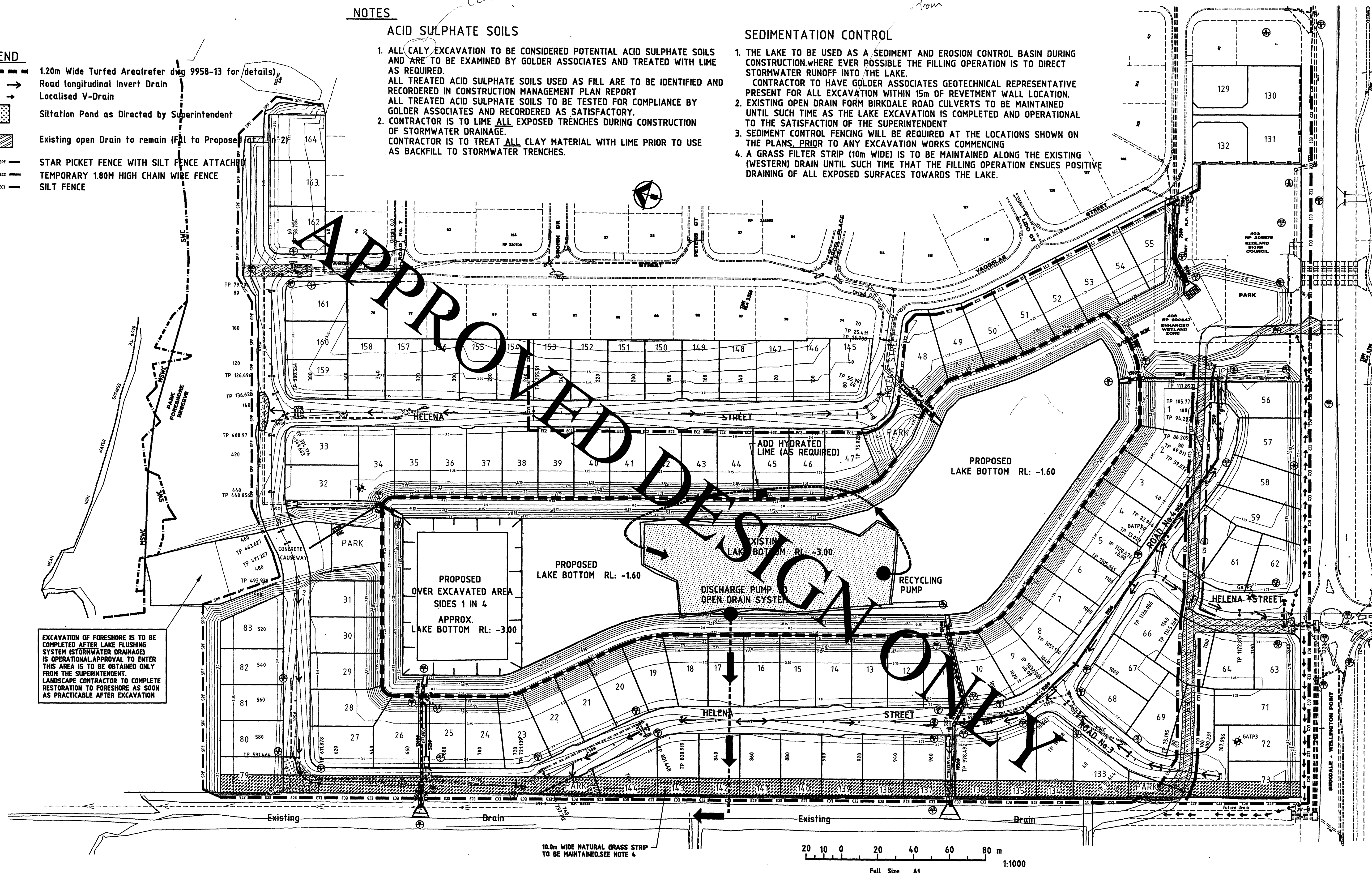
LAKE DESIGN DRAWING

1. ALL CALY EXCAVATION TO BE CONSIDERED POTENTIAL ACID SULPHATE SOILS AND ARE TO BE EXAMINED BY GOLDER ASSOCIATES AND TREATED WITH LIME AS REQUIRED.
ALL TREATED ACID SULPHATE SOILS USED AS FILL ARE TO BE IDENTIFIED AND RECORDED IN CONSTRUCTION MANAGEMENT PLAN REPORT
ALL TREATED ACID SULPHATE SOILS TO BE TESTED FOR COMPLIANCE BY GOLDER ASSOCIATES AND RECORDED AS SATISFACTORY.
2. CONTRACTOR IS TO LIME ALL EXPOSED TRENCHES DURING CONSTRUCTION OF STORMWATER DRAINAGE.
CONTRACTOR IS TO TREAT ALL CLAY MATERIAL WITH LIME PRIOR TO USE AS BACKFILL TO STORMWATER TRENCHES.

1. THE LAKE TO BE USED AS A SEDIMENT AND EROSION CONTROL BASIN DURING CONSTRUCTION, WHERE EVER POSSIBLE THE FILLING OPERATION IS TO DIRECT STORMWATER RUNOFF INTO THE LAKE.
CONTRACTOR TO HAVE GOLDER ASSOCIATES GEOTECHNICAL REPRESENTATIVE PRESENT FOR ALL EXCAVATION WITHIN 15m OF REVETMENT WALL LOCATION.
2. EXISTING OPEN DRAIN FORM BIRKDALE ROAD CULVERTS TO BE MAINTAINED UNTIL SUCH TIME AS THE LAKE EXCAVATION IS COMPLETED AND OPERATIONAL TO THE SATISFACTION OF THE SUPERINTENDENT
3. SEDIMENT CONTROL FENCING WILL BE REQUIRED AT THE LOCATIONS SHOWN ON THE PLANS, PRIOR TO ANY EXCAVATION WORKS COMMENCING
4. A GRASS FILTER STRIP (10m WIDE) IS TO BE MAINTAINED ALONG THE EXISTING (WESTERN) DRAIN UNTIL SUCH TIME THAT THE FILLING OPERATION ENSUES POSITIVE DRAINING OF ALL EXPOSED SURFACES TOWARDS THE LAKE.

1.20m Wide Turfed Area (refer dwg 9958-13 for details)
 Road longitudinal Invert Drain
 Localised V-Drain
 Siltation Pond as Directed by Superintendent
 Existing open Drain to remain (Fill to Proposed alignment)
 STAR PICKET FENCE WITH SILT FENCE ATTACHED
 TEMPORARY 1.80M HIGH CHAIN WIRE FENCE
 SILT FENCE

SPF
 EC2
 EC3



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Design	D.P.C
Drawn	D.P.C
Checked	J.M
Approved	<i>[Signature]</i>
RPEQ No.	1907
Date	NOV '99
Datum	A.H.D.
Scale	as shown

A	11/99	ORIGINAL ISSUE
No.	Date	Amendments

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Drawing No. 9958CONS

Drawing No. 995

9958-03A

Appendix B

WATER QUALITY MONITORING DATA SUMMARY

Appendix B
Water Quality Monitoring Data Summary

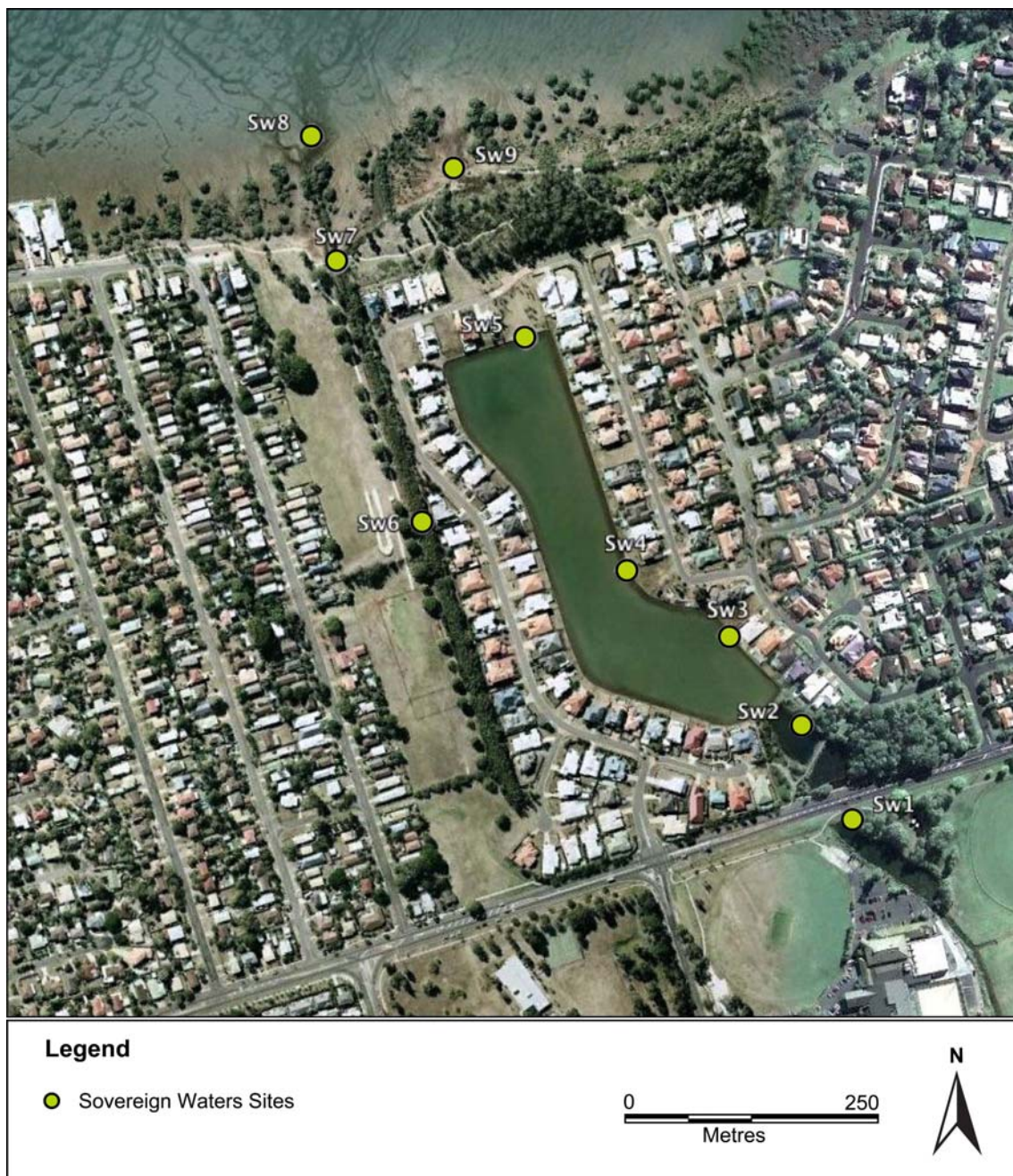


Figure B.1
REDLAND CITY COUNCIL SOVEREIGN WATERS WATER QUALITY MONITORING SITES

Table B1 Water Quality Monitoring Data Summary

	Date	TSS (mg/l)	Thermotolerant Coliforms (CFU/100ml)	DO (%sat)	Turbidity (NTU)	Conductivity (mS/cm)
SW1	28/02/2007	-	-	19.00	254.00	0.64
	28/03/2007	-	-	32.70	116.00	0.47
	26/04/2007	-	-	87.70	54.20	0.44
	22/05/2007	-	-	47.20	13.80	0.40
	1/03/2011	13	100	19.00	254.00	0.64
	29/03/2011	8	1800	32.70	116.00	0.47
	27/04/2011	8	9800	87.70	54.20	0.44
	23/05/2011	32	9800	47.20	13.80	0.40
	14/09/2011	10	110	110.00	7.50	0.50
	17/11/2011	38	900	102.00	9.00	0.70
SW2	28/02/2007	-	-	91.60	85.10	0.50
	28/03/2007	-	-	134.50	105.00	12.41
	26/04/2007	-	-	87.50	11.00	0.50
	22/05/2007	-	-	47.70	27.00	0.35
	1/03/2011	19	100	91.60	85.10	0.50
	29/03/2011	7	50	134.50	105.00	12.41
	27/04/2011	34	4000	87.50	11.00	0.50
	23/05/2011	39	70	47.70	27.00	0.35
	14/09/2011	5	300	36.00	7.90	2.30
	17/11/2011	26	300	101.00	9.30	13.13
SW3	28/02/2007	-	-	91.00	4.00	11.39
	28/03/2007	-	-	123.70	6.20	12.07
	26/04/2007	-	-	99.10	5.56	8.74
	22/05/2007	-	-	76.60	5.34	18.40
	1/03/2011	14	10	91.00	4.00	11.39
	29/03/2011	6	30	123.70	6.20	12.07
	27/04/2011	5	180	99.10	5.56	8.74
	23/05/2011	3	180	76.60	5.34	18.40
	14/09/2011	3	<10	108.60	2.40	19.80
	17/11/2011	22	<10	102.00	2.40	23.90
SW4	28/02/2007	-	-	95.00	3.80	11.41
	28/03/2007	-	-	79.80	6.40	12.32
	26/04/2007	-	-	89.40	2.90	7.91
	22/05/2007	-	-	72.80	4.60	15.20
	1/03/2011	6	10	95.00	3.80	11.41
	29/03/2011	4	60	79.80	6.40	12.32
	27/04/2011	3	50	91.80	4.51	7.91
	23/05/2011	7	50	72.80	4.60	15.20
	14/09/2011	2	<10	108.00	2.50	20.00
	17/11/2011	23	10	101.00	1.70	23.60

	Date	TSS (mg/l)	Thermotolerant Coliforms (CFU/100ml)	DO (%sat)	Turbidity (NTU)	Conductivity (mS/cm)
SW5	28/02/2007	-	-	90.70	3.30	11.84
	28/03/2007	-	-	99.00	9.20	12.20
	26/04/2007	-	-	89.40	2.88	32.10
	22/05/2007	-	-	71.90	6.62	15.90
	1/03/2011	4	10	90.70	3.30	11.84
	29/03/2011	6	150	99.00	9.20	12.20
	27/04/2011	4	120	89.40	2.88	32.10
	23/05/2011	4	120	71.90	6.62	15.90
	14/09/2011	<2	<10	105.00	1.90	20.00
	17/11/2011	26	10	104.00	2.60	26.40
SW6	28/02/2007	-	-	64.00	13.40	16.93
	28/03/2007	-	-	125.90	89.10	20.30
	26/04/2007	-	-	54.30	6.20	33.50
	22/05/2007	-	-	39.50	4.26	40.10
	1/03/2011	22	300	64.00	13.40	16.93
	29/03/2011	32	2200	125.90	89.10	20.30
	27/04/2011	15	230	54.30	6.23	33.50
	23/05/2011	45	230	39.50	4.26	40.10
	14/09/2011	27	200	78.00	21.20	46.20
	17/11/2011	49	<10	-	-	-
SW8	28/02/2007	-	-	-	-	-
	28/03/2007	-	-	70.40	19.60	45.43
	26/04/2007	-	-	70.70	69.70	45.90
	22/05/2007	-	-	95.90	7.15	47.70
	1/03/2011	53	200	45.00	66.30	17.12
	29/03/2011	-	10	70.40	19.60	45.43
	27/04/2011	54	160	85.30	15.70	32.10
	23/05/2011	22	160	95.90	7.15	47.70
	14/09/2011	22	<10	111.50	14.30	52.00
	17/11/2011	57	430	-	-	-

Appendix C

PISTON SAMPLING CORE LOGS AND IMAGES

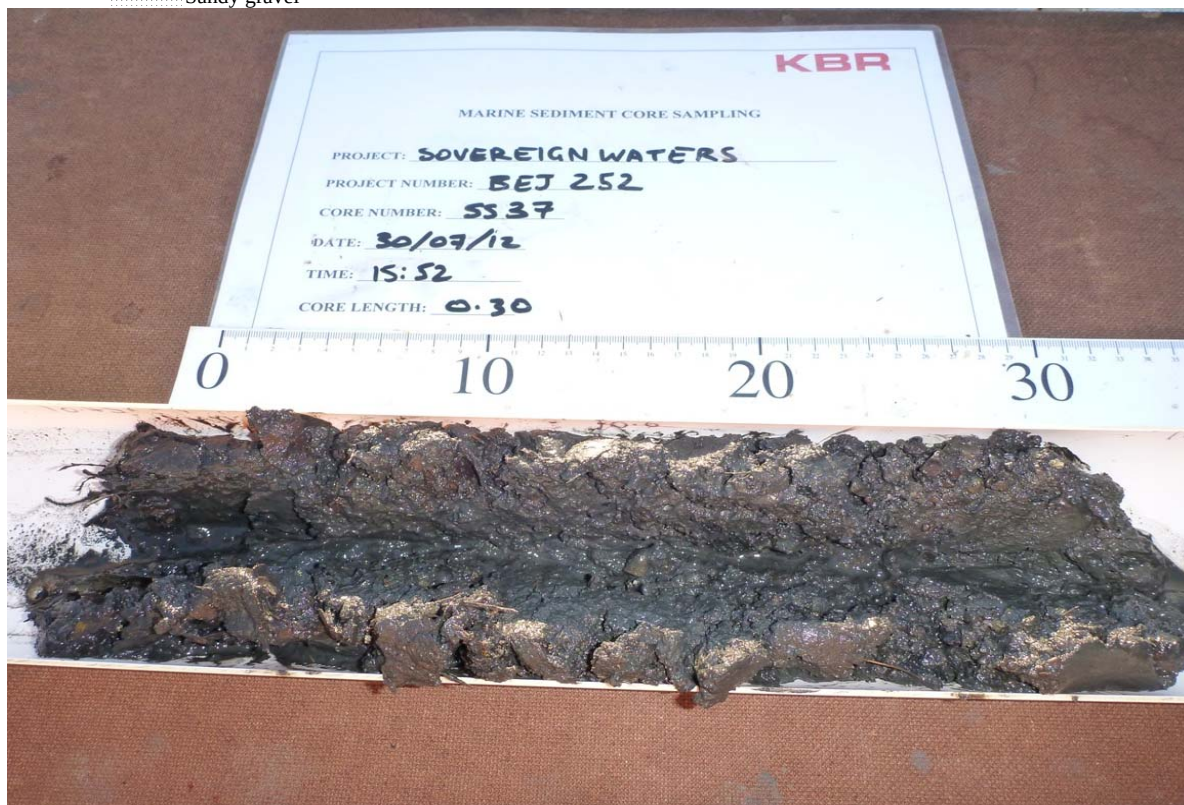
PROFILE LOG

CLIENT:	Redland City Council	Location:	WP45	Date:	30/07/2012
PROJECT:	Sovereign Waters	Easting	522712.7345	Logged by:	PCh
		Northing:	6959903.175		
		Datum:	GDA94		
		Water Depth (m):	2.15	Job No.	BEJ252
Investigation Method: Piston Sampling					

depth (m)	graphical log	Materials Description soil or rock type: colour, particle size or plasticity, density, origin, other features, classification (Unified)
-0.1		0-0.3 Gley 1 2.5/N Black. Sandy gravel, silty sand 1-2mm. Liquid. High amount leaves, twigs, shells and strong odour. Top half finer contents bottom half very coarse.
-0.2		
-0.3		
-0.4		
-0.5		

Note:

-  Clay
-  Silt
-  Sand
-  Rocks/pebbles
-  Sandy gravel



PROFILE LOG

CLIENT:	Redland City Council	Location:	SS08	Date:	15/06/2012
PROJECT:	Sovereign Waters	Easting	522702.48	Logged by:	PCh
		Northing:	6959846.72		
		Datum:	GDA94		
		Water Depth (m)	2.66	Job No.	BEJ252
Investigation Method: Piston Sampling					

depth (m)	graphical log	Materials Description soil or rock type: colour, particle size or plasticity, density, origin, other features, classification (Unified)
0 - 0.1		Gley 1 3/10Y very dark greenish grey. Very fine particles, dark grey, soft, some organic matter
0.1 - 0.2		10YR 8/4 pale brown. Constructed Bed - Stiff mottled clay
-0.1		
-0.2		
-0.3		
-0.4		
-0.5		

Note:

- Clay
- Silt
- Sand
- Rocks/pebbles
- Sandy gravel



PROFILE LOG

CLIENT:	Redland City Council	Location:	SS 09	Date:	15/06/2012
PROJECT:	Sovereign Waters	Easting	522740.76	Logged by:	PCh
		Northing:	6959763.57		
		Datum:	GDA94		
		Water Depth (m)	3.25	Job No.	BEJ252
Investigation Method: Piston Sampling					

depth (m)	graphical log	Materials Description soil or rock type: colour, particle size or plasticity, density, origin, other features, classification (Unified)	
-0.1		0 - 0.15	Gley 1 2.5/10Y greenish black. Fine silt, little cohesion, green/black, high moisture
-0.2		0.15 - 0.40	Gley 1 3/10Y very dark greenish grey. Fine silt, little cohesion, green/dark grey, high moisture
-0.3		0.4 - 0.5	10YR 5/6 yellowish brown. 10YR 7/1 light grey. Constructed Bed - Stiff mottled clay
-0.4			
-0.5			

Note:

-  Clay
-  Silt
-  Sand
-  Rocks/pebbles
-  Sandy gravel



PROFILE LOG

CLIENT:	Redland City Council	Location:	SS 10	Date:	15/06/2012
PROJECT:	Sovereign Waters	Easting	522769.35	Logged by:	PCh
		Northing:	6959681.66		
		Datum:	GDA94		
		Water Depth (m)	3.09	Job No.	BEJ252
Investigation Method: Piston Sampling					

depth (m)	graphical log	Materials Description soil or rock type: colour, particle size or plasticity, density, origin, other features, classification (Unified)	
-0.1		0 - 0.03	very fine silt sediment, black, some organic matter
-0.2		0.03 - 0.25	Constructed Bed - Stiff mottled clay
-0.3			
-0.4			
-0.5			

Note:

	Clay
	Silt
	Sand
	Rocks/pebbles
	Sandy gravel



PROFILE LOG

CLIENT:	Redland City Council	Location:	SS 10	Date:	
PROJECT:	Sovereign Waters	Easting:	522873.51	Logged by:	PCh
		Northing:	6959595.62		
		Datum:	GDA94		
		Water Depth (m)	2.52	Job No.	BEJ252
Investigation Method: Piston Sampling					

depth (m)	graphical log	Materials Description soil or rock type: colour, particle size or plasticity, density, origin, other features, classification (Unified)	
0		0 - 0.05	Fine silt layer, some clay
-0.1		0.05 - 0.20	Constructed Bed - Stiff mottled clay
-0.2			
-0.3			
-0.4			
-0.5			

Note:

-  Clay
-  Silt
-  Sand
-  Rocks/pebbles
-  Sandy gravel



PROFILE LOG

CLIENT:	Redland City Council	Location:	WP40	Date:	30/07/2012
PROJECT:	Sovereign Waters	Easting	522922.2991	Logged by:	PCh
		Northing:	6959579.092		
		Datum:	GDA94		
		Water Depth (m)	2.2	Job No.	BEJ252
Investigation Method: Piston Sampling					

depth (m)	graphical log	Materials Description soil or rock type: colour, particle size or plasticity, density, origin, other features, classification (Unified)
-0.1		0-0.01 Gley 1. 2.5/10Y Greenish Black Silt with liquid consistency. No detritus content or odour.
-0.2		0.01-0.20 10YR. 5/2 Greyish Brown. Stiff clay. Plastic. No Detritus content or odour.
-0.3		
-0.4		
-0.5		

Note:

-  Clay
-  Silt
-  Sand
-  Rocks/pebbles
-  Sandy gravel



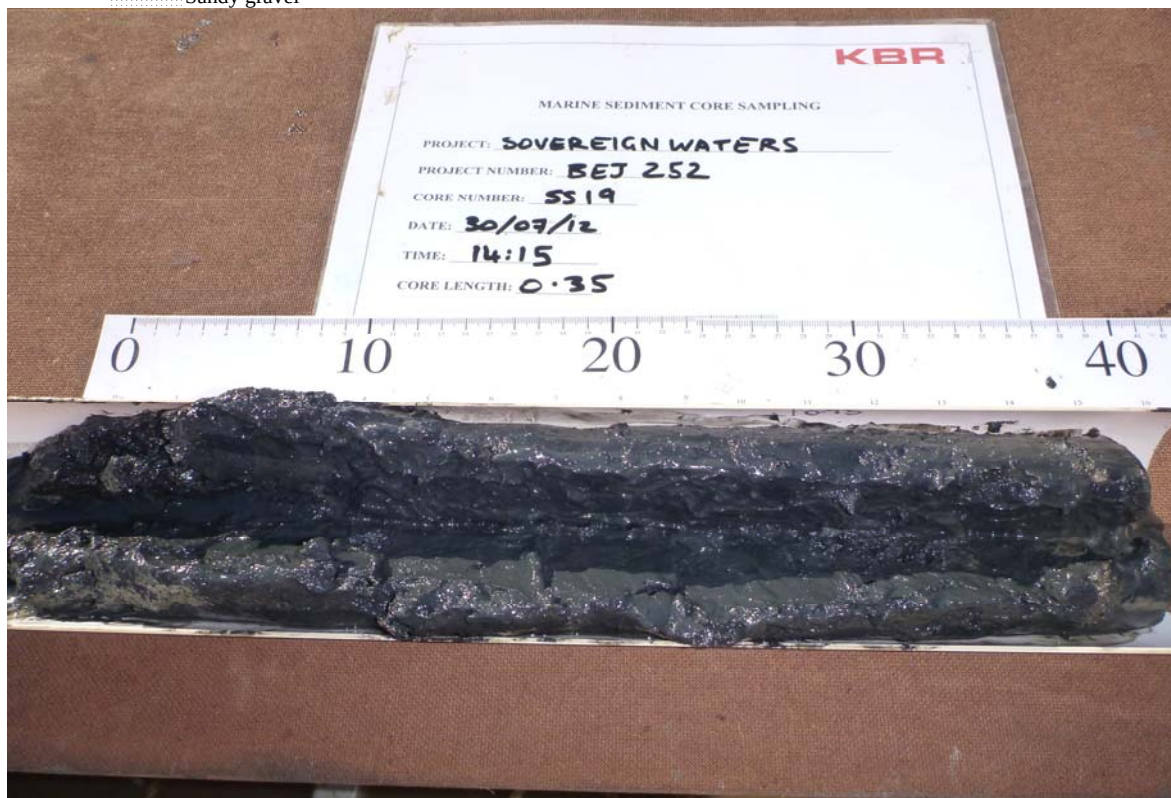
PROFILE LOG

CLIENT:	Redland City Council	Location:	WP39	Date:	30/07/2012
PROJECT:	Sovereign Waters	Easting	522862.0917	Logged by:	PCh
		Northing:	6959644.269		
		Datum:	GDA94		
		Water Depth (m):	2.1	Job No.	BEJ252
Investigation Method: Piston Sampling					

depth (m)	graphical log	Materials Description soil or rock type: colour, particle size or plasticity, density, origin, other features, classification (Unified)	
-0.1		0-0.1	Gley 1. 2.5/N. Black. Silt with sand, some pebbles <10mm. Liquid consistency. Highly organic. Odour.
-0.2		0.10-0.35	Gley 1. 2.5/N. Black. Silt. Liquid consistency. Highly organic. Odour.
-0.3			
-0.4			
-0.5			

Note:

	Clay
	Silt
	Sand
	Rocks/pebbles
	Sandy gravel



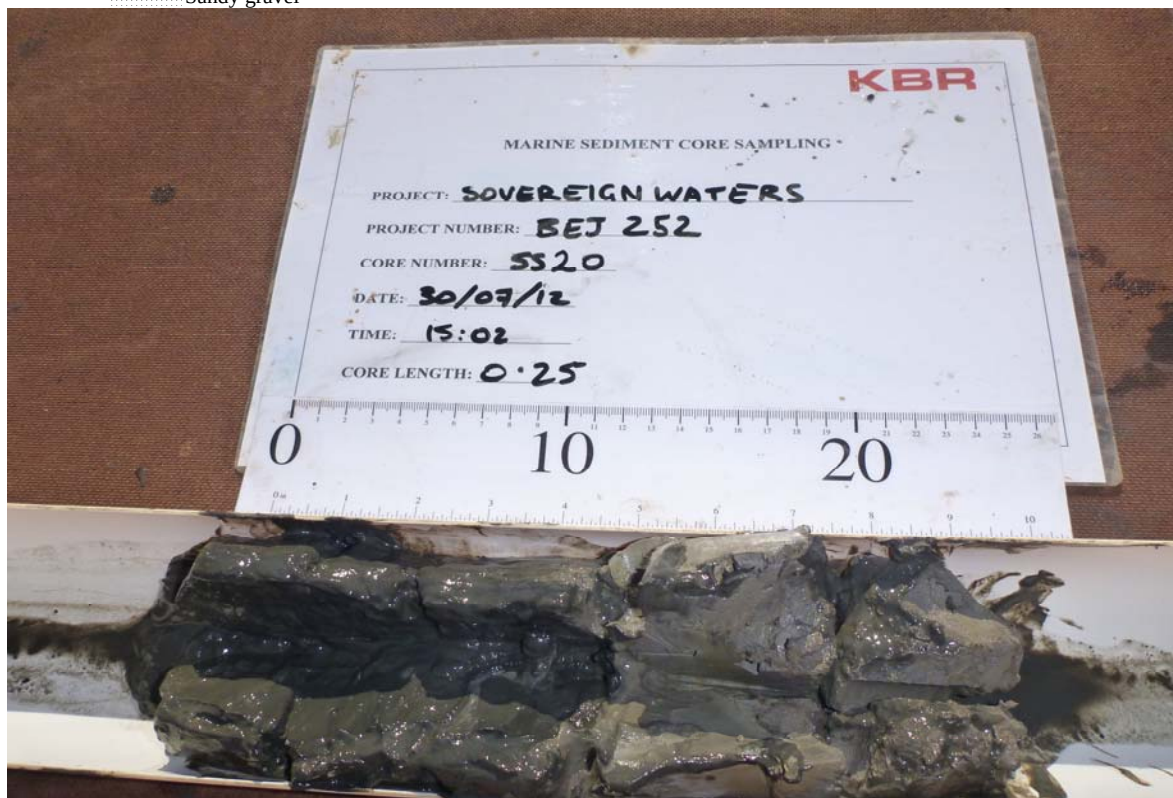
PROFILE LOG

CLIENT:	Redland City Council	Location:	WP41	Date:	30/07/2012
PROJECT:	Sovereign Waters	Easting	522873.3897	Logged by:	PCh
		Northing:	6959575.395		
		Datum:	GDA94		
		Water Depth (m):	2.3	Job No.	BEJ252
Investigation Method: Piston Sampling					

depth (m)	graphical log	Materials Description soil or rock type: colour, particle size or plasticity, density, origin, other features, classification (Unified)
-0.1		0-0.13 Gley 1. 2.5/10Y. Greenish Black. Very fine Silt. Very Liquid. No detritus or odour.
-0.2		0.13-0.25 10YR. 4/1. Dark grey. Stiff clay. Highly Plasticised. No detritus or odour.
-0.3		
-0.4		
-0.5		

Note:

-  Clay
-  Silt
-  Sand
-  Rocks/pebbles
-  Sandy gravel



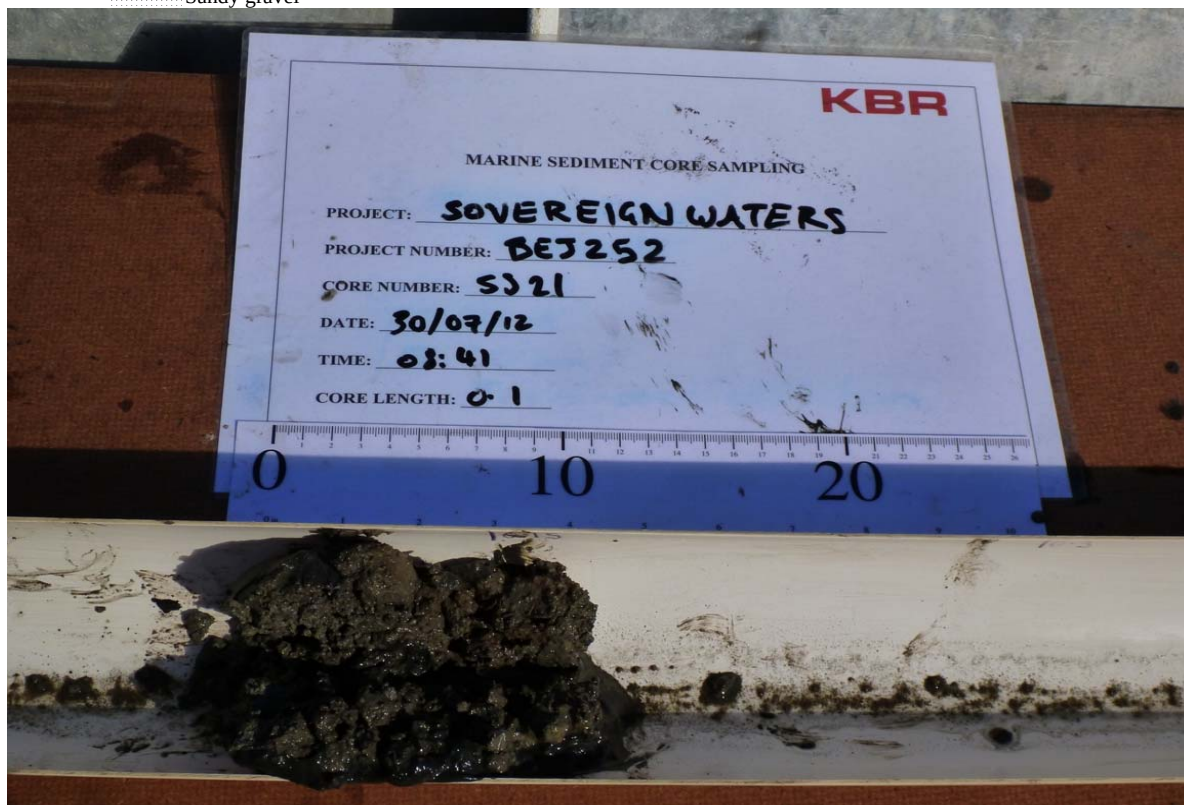
PROFILE LOG

CLIENT:	Redland City Council	Location:	WP22	Date:	30/07/2012
PROJECT:	Sovereign Waters	Easting:	522719.3354	Logged by:	PCh
		Northing:	6959895.103		
		Datum:	GDA94		
		Water Depth (m):	3.5	Job No.	BEJ252
Investigation Method: Piston Sampling					

depth (m)	graphical log	Materials Description soil or rock type: colour, particle size or plasticity, density, origin, other features, classification (Unified)
-0.1		Gley 2. 2.5/10G. Greenish black. Very fine silt. Highly liquid. No detritus or odour.
-0.2		Gley 2. 4/10BG. Dark greenish grey. Coarse grainy sandy clay. Plastic. No detritus or odour.
-0.3		
-0.4		
-0.5		

Note:

-  Clay
-  Silt
-  Sand
-  Rocks/pebbles
-  Sandy gravel



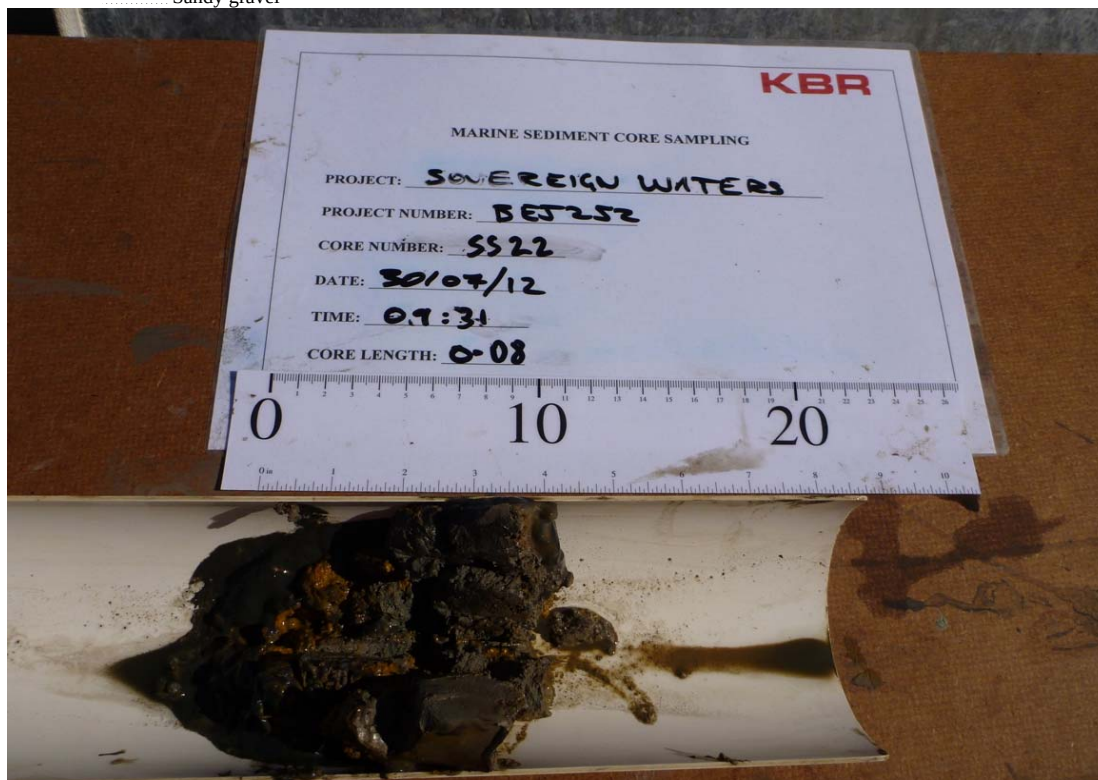
PROFILE LOG

CLIENT:	Redland City Council	Location:	WP27	Date:	30/07/2012
PROJECT:	Sovereign Waters	Easting:	522718.0704	Logged by:	PCh
		Northing:	6959869.211		
		Datum:	GDA94		
		Water Depth (m):	4	Job No.	BEJ252
Investigation Method: Piston Sampling					

depth (m)	graphical log	Materials Description soil or rock type: colour, particle size or plasticity, density, origin, other features, classification (Unified)
0-0.02		Gley 2. 2.5/10G. Greenish black. Very fine silt. Liquid. No detritus or odour.
0.02-0.1		10YR. 4/1. Dark grey. 10YR. 6/8. Brownish yellow. Mottled Subangular rocks <20mm. Very plastic. No detritus or odour.
-0.1		
-0.2		
-0.3		
-0.4		
-0.5		

Note:

-  Clay
-  Silt
-  Sand
-  Rocks/pebbles
-  Sandy gravel



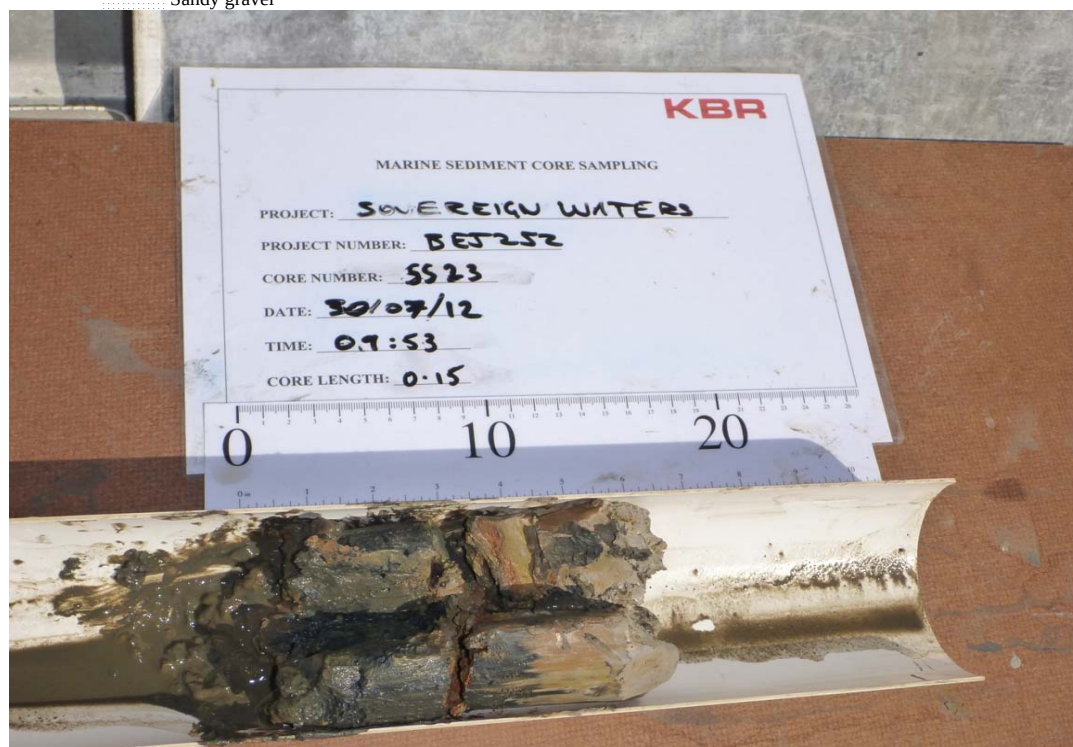
PROFILE LOG

CLIENT:	Redland City Council	Location:	WP28	Date:	30/07/2012
PROJECT:	Sovereign Waters	Easting	522733.9794	Logged by:	PCh
		Northing:	6959834.755		
		Datum:	GDA94		
		Water Depth (m):	2.75	Job No.	BEJ252
Investigation Method: Piston Sampling					

depth (m)	graphical log	Materials Description soil or rock type: colour, particle size or plasticity, density, origin, other features, classification (Unified)
0-0.01		Gley 2. 2.5/10G Greenish black. Silt with gravel/pebbles 2-4mm. Very liquid. No detritus or odour.
-0.1		Gley 2. 2.5/10G Greenish black. 10YR 7/3 very pale brown. Mottled silt/clay with small pebbles <5mm. Liquid/plastic. No detritus or odour.
-0.2		10YR 4/1 dark grey. 10YR 6/8 brownish yellow. Mottled clay. Plastic. No detritus or odour.
-0.3		
-0.4		
-0.5		

Note:

- Clay
- Silt
- Sand
- Rocks/pebbles
- Sandy gravel



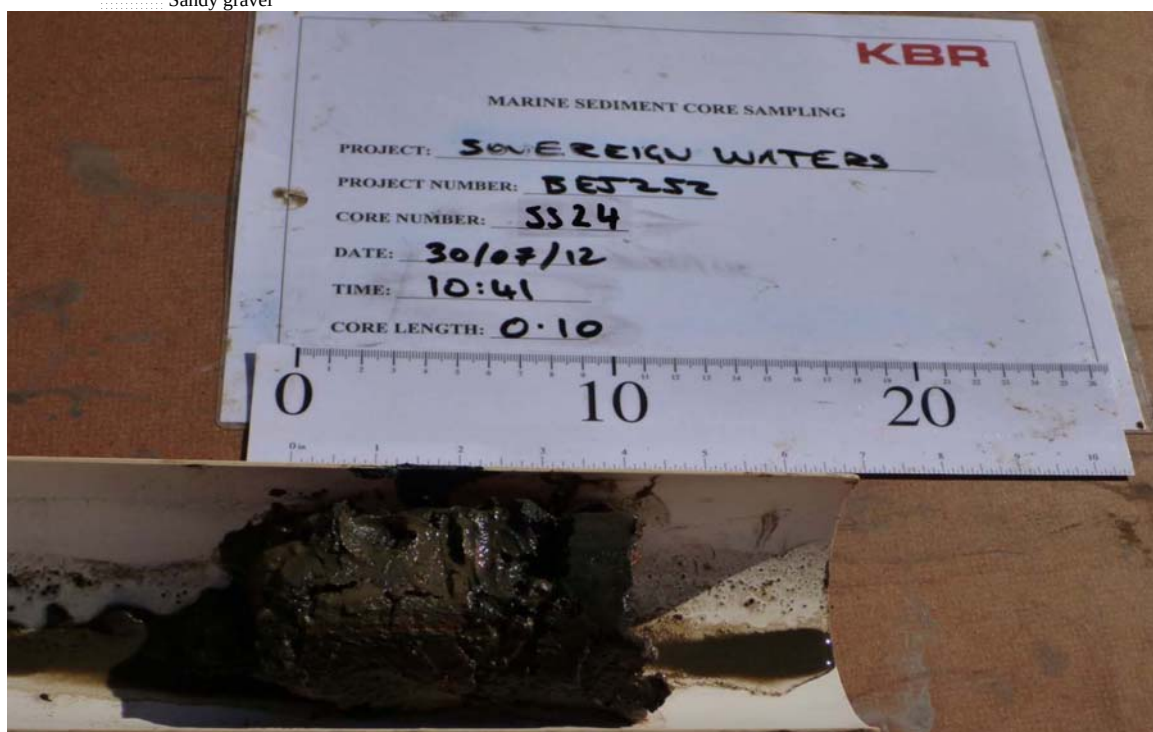
PROFILE LOG

CLIENT:	Redland City Council	Location:	WP30	Date:	30/07/2012
PROJECT:	Sovereign Waters	Easting	522733.6544	Logged by:	PCh
		Northing:	6959793.738		
		Datum:	GDA94		
		Water Depth (m):	2.65	Job No.	BEJ252
Investigation Method: Piston Sampling					

depth (m)	graphical log	Materials Description soil or rock type: colour, particle size or plasticity, density, origin, other features, classification (Unified)
0-0.01		Gley 1. 2.5/10Y greenish black. Very fine silt. Very liquid. No detritus or odour.
-0.1		Gley 1. 2.5/10Y greenish black. 10YR 7/3 very pale brown. Very fine silt with pebbles. Mottled. Plastic/liquid. No detritus or odour.
0.01-0.03		
0.03-0.1		10YR 4/1 dark grey. 10YR 6/8 brownish yellow. More pebbles, mottled clay. Plastic. No detritus or odour.
-0.2		
-0.3		
-0.4		
-0.5		

Note:

- Clay
- Silt
- Sand
- Rocks/pebbles
- Sandy gravel



PROFILE LOG

CLIENT:	Redland City Council	Location:	WP31	Date:	30/07/2012
PROJECT:	Sovereign Waters	Easting:	522762.104	Logged by:	PCh
		Northing:	6959743.706		
		Datum:	GDA94		
		Water Depth (m):	2.85	Job No.	BEJ252
Investigation Method: Piston Sampling					

depth (m)	graphical log	Materials Description soil or rock type: colour, particle size or plasticity, density, origin, other features, classification (Unified)
0-0.005		Gley 1 2.5/10Y greenish black. Very fine silt. Very liquid. No detritus or odour.
0.005-0.02		Gley 1 3/N very dark grey. Silty clay. Liquid/Platic. No detritus or odour.
0.02-0.25		7.5YR 5/1 grey. Some pebbles <20mm. Plastic. No detritus or odour.
-0.1		
-0.2		
-0.3		
-0.4		
-0.5		

Note:

-  Clay
-  Silt
-  Sand
-  Rocks/pebbles
-  Sandy gravel



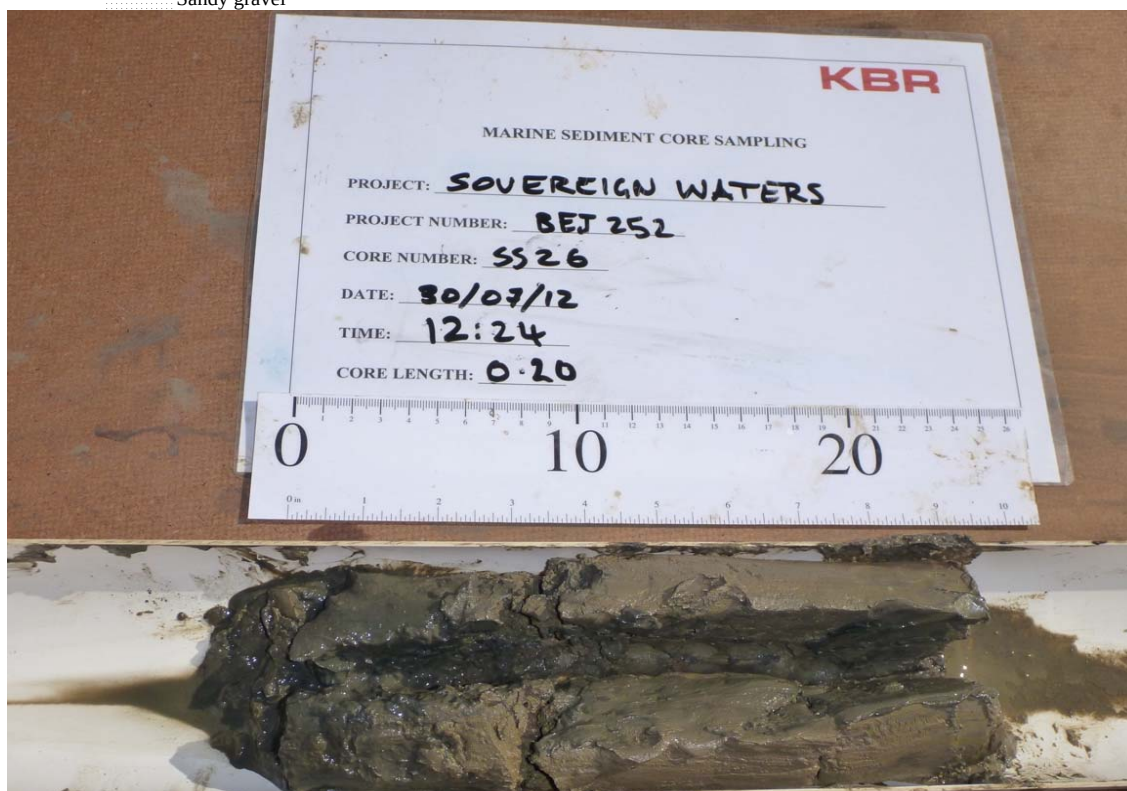
PROFILE LOG

CLIENT:	Redland City Council	Location:	WP35	Date:	30/07/2012
PROJECT:	Sovereign Waters	Easting	522781.5822	Logged by:	PCh
		Northing:	6959696.672		
		Datum:	GDA94		
		Water Depth (m):	2.65	Job No.	BEJ252
Investigation Method: Piston Sampling					

depth (m)	graphical log	Materials Description soil or rock type: colour, particle size or plasticity, density, origin, other features, classification (Unified)
0-0.02		Gley 1 3/1 very dark greenish grey. Fine silt. Liquid. No detritus or odour.
0.02-0.2		10YR 5/1 grey. A few pebbles <5mm. Highly plasticised. No detritus or odour.
-0.1		
-0.2		
-0.3		
-0.4		
-0.5		

Note:

-  Clay
-  Silt
-  Sand
-  Rocks/pebbles
-  Sandy gravel



PROFILE LOG

CLIENT:	Redland City Council	Location:	WP38	Date:	30/07/2012
PROJECT:	Sovereign Waters	Easting:	522809.5764	Logged by:	PCh
		Northing:	6959642.659		
		Datum:	GDA94		
		Water Depth (m):	2.7	Job No.	BEJ252
Investigation Method: Piston Sampling					

depth (m)	graphical log	Materials Description soil or rock type: colour, particle size or plasticity, density, origin, other features, classification (Unified)	
0-0.015		Gley 2.5/10 greenish black. Fine silt. Highly liquid. No detritus or odour.	
0.015 - 0.1		Gley 1 7/N light grey. 2.5YR reddish brown. 10.5YR 7/4 very pale brown. Mottled stiff clay. Very plastic. No detritus or odour.	
-0.1			
-0.2			
-0.3			
-0.4			
-0.5			

Note:

-  Clay
-  Silt
-  Sand
-  Rocks/pebbles
-  Sandy gravel



PROFILE LOG

CLIENT:	Redland City Council	Location:	WP43	Date:	30/07/2012
PROJECT:	Sovereign Waters	Easting	522819.909	Logged by:	PCh
		Northing:	6959602.159		
		Datum:	GDA94		
		Water Depth (m):	2.55	Job No.	BEJ252
Investigation Method: Piston Sampling					

depth (m)	graphical log	Materials Description soil or rock type: colour, particle size or plasticity, density, origin, other features, classification (Unified)
-0.1		
-0.2		
-0.3		
-0.4		
-0.5		

Note:

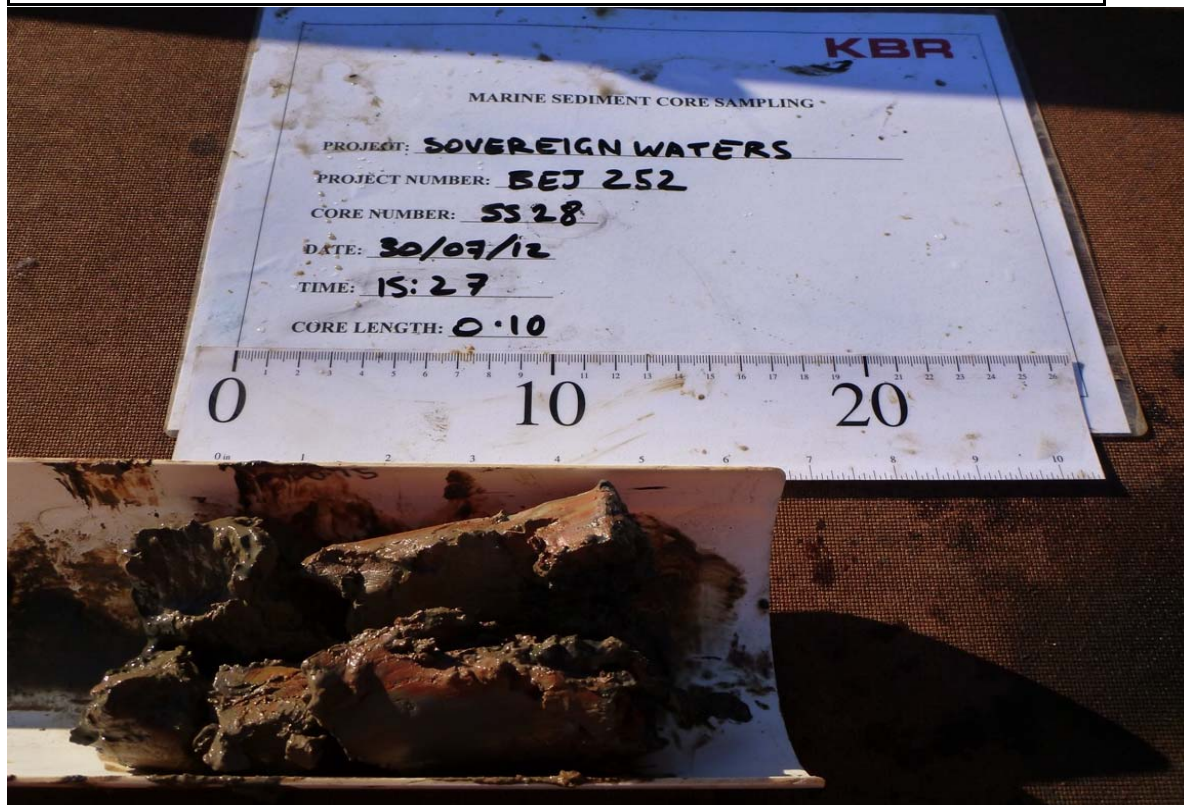
	Clay
	Silt
	Sand
	Rocks/pebbles
	Sandy gravel

PROFILE LOG

CLIENT:	Redland City Council	Location:	WP44	Date:	30/07/2012
PROJECT:	Sovereign Waters	Easting	522819.91	Logged by:	PCh
		Northing:	6959602.16		
		Datum:	GDA94		
		Water Depth (m):	2.55	Job No.	BEJ252
Investigation Method: Piston Sampling					

depth (m)	graphical log	Materials Description soil or rock type: colour, particle size or plasticity, density, origin, other features, classification (Unified)	
		0-0.03	Gley 1 3/N very dark grey. Pebbles and rocks <20mm, silty clay. Liquid/Plastic. Very little organic content and no odour.
-0.1		0.03-0.1	2.5YR 4/6 Red. 10YR 6/4 light yellow brown. 10YR 5/2 greyish brown. Stiff mottled clay. Plastic. No detritus or odour.
-0.2			
-0.3			
-0.4			
-0.5			

Note: 2 samples taken, the first had more silt but did not extrude correctly - one side remained in the sampler, had approx 3.5cm of silt. Second sample (above) had very little.



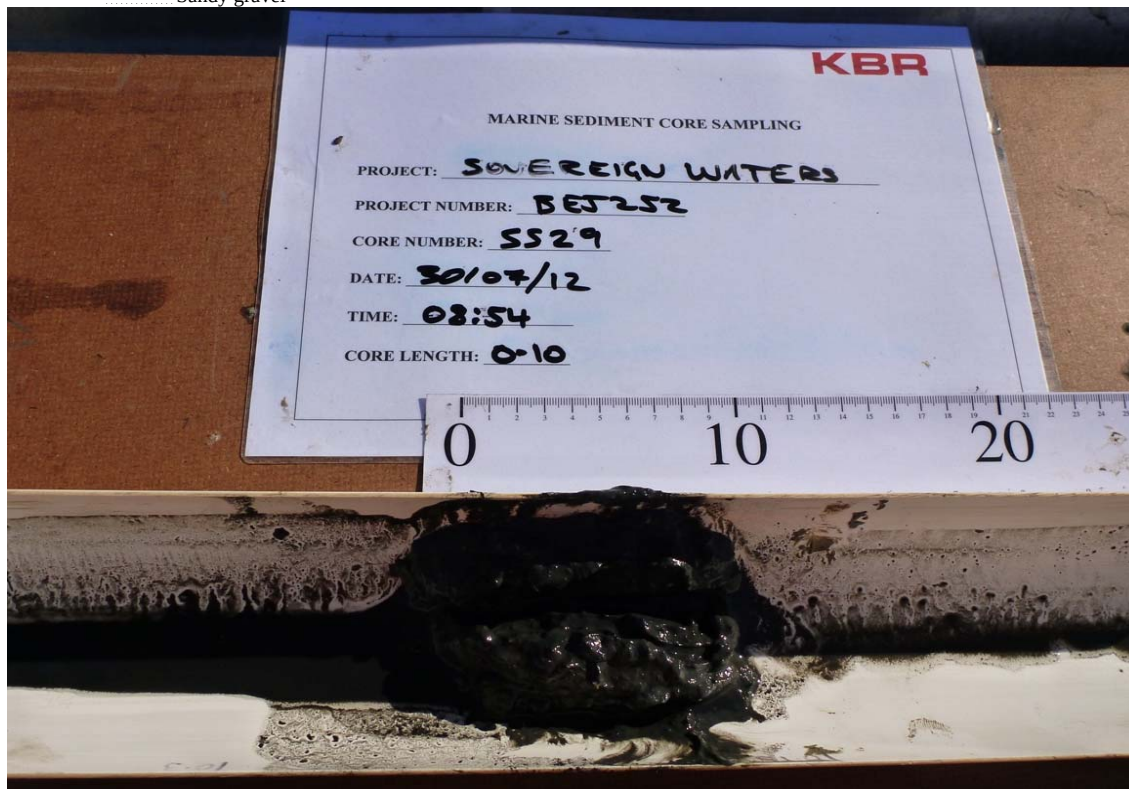
PROFILE LOG

CLIENT:	Redland City Council	Location:	WP25	Date:	30/07/2012
PROJECT:	Sovereign Waters	Easting	522662.98	Logged by:	PCh
		Northing:	6959878.62		
		Datum:	GDA94		
		Water Depth (m):	3.8	Job No.	BEJ252
Investigation Method: Piston Sampling					

depth (m)	graphical log	Materials Description soil or rock type: colour, particle size or plasticity, density, origin, other features, classification (Unified)
-0.1		0-0.03 Gley 2 2.5/10G greenish black. Very fine silt. Highly liquid. Some leaves and some odour.
-0.2		0.03-0.07 Plug fell out before sample could be recovered.
-0.3		
-0.4		
-0.5		

Note:

-  Clay
-  Silt
-  Sand
-  Rocks/pebbles
-  Sandy gravel



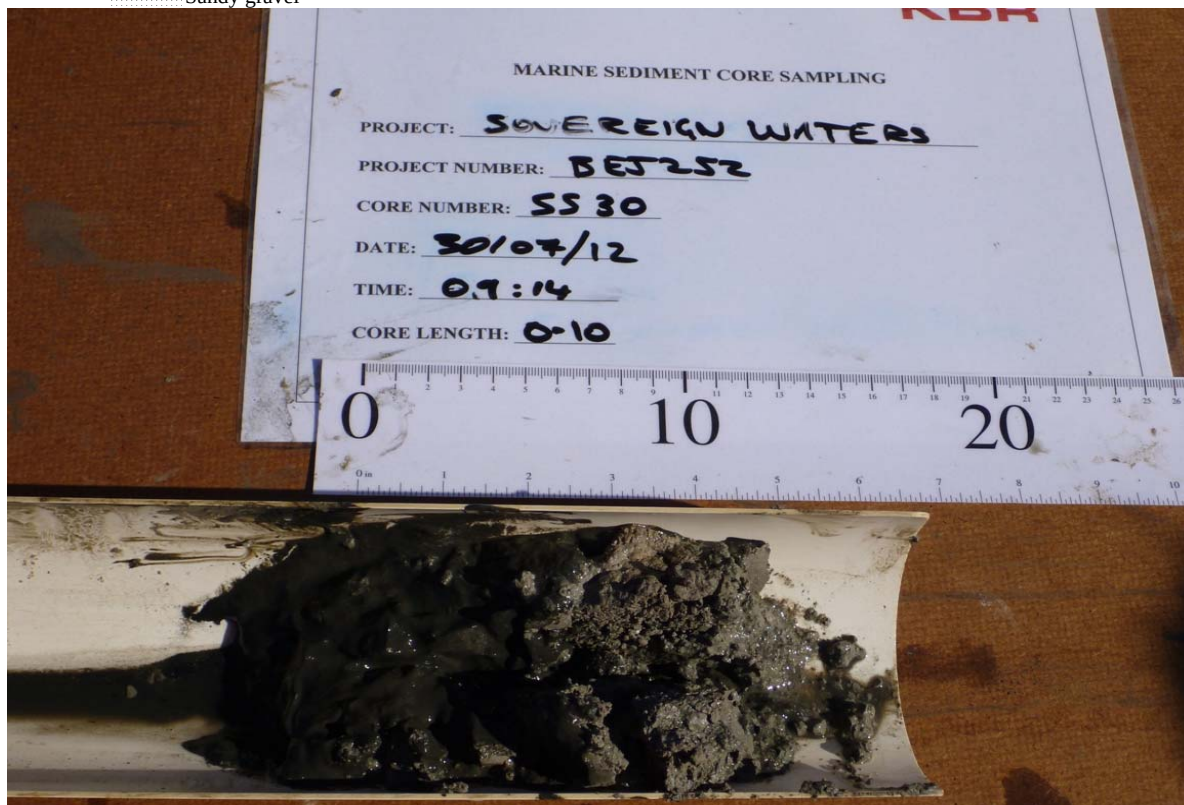
PROFILE LOG

CLIENT:	Redland City Council	Location:	WP26	Date:	30/07/2012
PROJECT:	Sovereign Waters	Easting	522672.801	Logged by:	PCh
		Northing:	6959855.22		
		Datum:	GDA94		
		Water Depth (m):	3.95	Job No.	BEJ252
Investigation Method: Piston Sampling					

depth (m)	graphical log	Materials Description soil or rock type: colour, particle size or plasticity, density, origin, other features, classification (Unified)	
-0.1		0-0.07	Gley 1 6/N grey. Coarse/medium. Plastic. No detritus and no odour.
-0.2		0.07-0.15	Gley 2 2.5/10G greenish black. Very fine silt. Highly liquid. No detritus and no odour.
-0.3			
-0.4			
-0.5			

Note:

-  Clay
-  Silt
-  Sand
-  Rocks/pebbles
-  Sandy gravel



PROFILE LOG

CLIENT:	Redland City Council	Location:	WP29	Date:	30/07/2012
PROJECT:	Sovereign Waters	Easting:	522696.3315	Logged by:	PCh
		Northing:	6959827.165		
		Datum:	GDA94		
		Water Depth (m):	2.8	Job No.	BEJ252
Investigation Method: Piston Sampling					

depth (m)	graphical log	Materials Description soil or rock type: colour, particle size or plasticity, density, origin, other features, classification (Unified)
0-0.01		Gley 2.5/10G greenish black. Silt with pebbles gravel 2-4mm. Very liquid, no detritus or odour.
0.01-0.07		Gley 2.5/10G greenish black. 10YR 7/3 very pale brown. Mottled silt/clay with small pebbles <5mm. Liquid/plastic, no detritus or odour.
0.07-0.1		10YR 4/1 dark grey. 10YR 6/8 Brownish yellow. Mottled clay. Plastic, no detritus or odour.
-0.1		
-0.2		
-0.3		
-0.4		
-0.5		

Note:

-  Clay
-  Silt
-  Sand
-  Rocks/pebbles
-  Sandy gravel



PROFILE LOG

CLIENT:	Redland City Council	Location:	WP33	Date:	30/07/2012
PROJECT:	Sovereign Waters	Easting:	522739.3203	Logged by:	PCh
		Northing:	6959741.27		
		Datum:	GDA94		
		Water Depth (m):	3.5	Job No.	BEJ252
Investigation Method: Piston Sampling					

depth (m)	graphical log	Materials Description soil or rock type: colour, particle size or plasticity, density, origin, other features, classification (Unified)
-0.1		0-0.2 Gley 1 2.5/N black. Very very fine silt. Very highly liquid. No detritus and no odour.
-0.2		0.2-0.35 Gley 1 3/10Y very dark greenish grey. Very fine silt more compressed. Highly liquid. No detritus and no odour.
-0.3		0.35-0.45 10YR 5/8 yellowish brown. Very fine clay/silt. Completely liquid, no cohesion. No detritus and no odour.
-0.4		
-0.5		

Note:

-  Clay
-  Silt
-  Sand
-  Rocks/pebbles
-  Sandy gravel



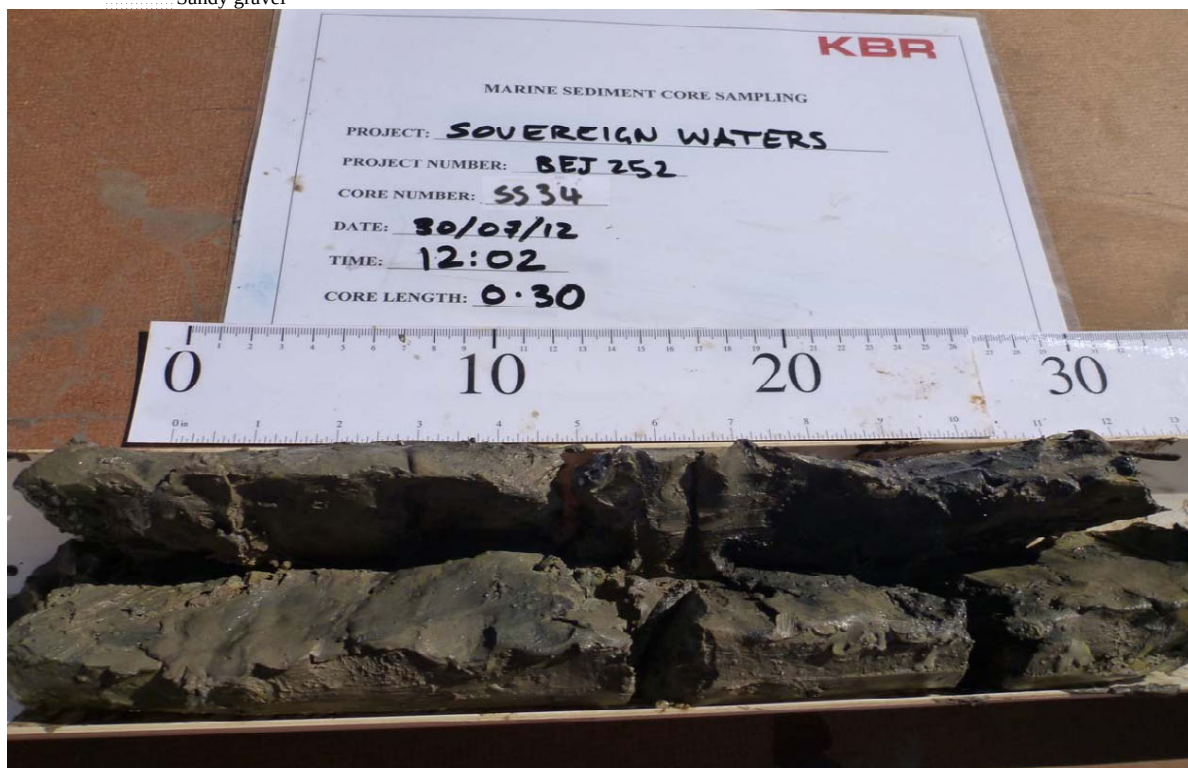
PROFILE LOG

CLIENT:	Redland City Council	Location:	WP34	Date:	30/07/2012
PROJECT:	Sovereign Waters	Easting:	522747.8339	Logged by:	PCh
		Northing:	6959697.71		
		Datum:	GDA94		
		Water Depth (m):	2.65	Job No.	BEJ252
Investigation Method: Piston Sampling					

depth (m)	graphical log	Materials Description soil or rock type: colour, particle size or plasticity, density, origin, other features, classification (Unified)
-0.1		0-0.3 Gley 1 5/10Y greenish grey.10YR 7/6 Yellow. Very small pebbles <10mm. Plastic. Some organic content in mid section (20cm into core) and no odour.
-0.2		
-0.3		
-0.4		
-0.5		

Note:

-  Clay
-  Silt
-  Sand
-  Rocks/pebbles
-  Sandy gravel



PROFILE LOG

CLIENT:	Redland City Council	Location:	WP37	Date:	30/07/2012
PROJECT:	Sovereign Waters	Easting:	522762.8767	Logged by:	PCh
		Northing:	6959638.474		
		Datum:	GDA94		
		Water Depth (m):	2.5	Job No.	BEJ252
Investigation Method: Piston Sampling					

depth (m)	graphical log	Materials Description soil or rock type: colour, particle size or plasticity, density, origin, other features, classification (Unified)
0-0.02		Gley 2 2.5/10G greenish black very fine silt. Highly liquid, no detritus or odour.
0.02-0.2		5YR 5/3 reddish brown. 5Y 6/4 pale olive. Gley 1 7/N light grey. Mottled. Rocks 10mm to 50mm. Highly plasticised. No detritus or odour.
-0.1		
-0.2		
-0.3		
-0.4		
-0.5		

Note:

-  Clay
-  Silt
-  Sand
-  Rocks/pebbles
-  Sandy gravel



PROFILE LOG

CLIENT:	Redland City Council	Location:	WP49	Date:	30/07/2012
PROJECT:	Sovereign Waters	Easting:	522970.3759	Logged by:	PCh
		Northing:	6959523.313		
		Datum:	GDA94		
		Water Depth (m):	1	Job No.	BEJ252
Investigation Method: Piston Sampling					

depth (m)	graphical log	Materials Description soil or rock type: colour, particle size or plasticity, density, origin, other features, classification (Unified)	
-0.1		0 - 0.18	Gley 1 2.5/N Black. Coarse, grainy silt with sand. Liquid/Plastic. Some organic content and odour.
-0.2		0.18 - 0.25	10YR 5/2 Greyish brown. 10YR 5/6 Yellowish brown. 10YR 3/2 very dark greyish brown. Mottled clay/fine. Plastic. Very little organic content and no odour.
-0.3			
-0.4			
-0.5			

Note:

-  Clay
-  Silt
-  Sand
-  Rocks/pebbles
-  Sandy gravel



PROFILE LOG

CLIENT:	Redland City Council	Location:		Date:	30/07/2012
PROJECT:	Sovereign Waters	Easting	523001.61	Logged by:	PCh
		Northing:	6959497.81		
		Datum:	GDA94		
		Water Depth (m):	0.3	Job No.	BEJ252
Investigation Method: Piston Sampling					

depth (m)	graphical log	Materials Description
		soil or rock type: colour, particle size or plasticity, density, origin, other features, classification (Unified)
0 - 0.03		Gley 1 2.5/N Black. Fine silt. Liquid. Some organic content and odour.
0.03 - 0.25		10YR 4/1 dark grey. Fine clay, some pebbles <5mm. Low plasticity. No detritus or odour.
-0.1		
-0.2		
-0.3		
-0.4		
-0.5		

Note:

-  Clay
-  Silt
-  Sand
-  Rocks/pebbles
-  Sandy gravel

