

AQUATIC PARADISE CANAL ESTATE

Siltation Study

Prepared for:

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Hydrographic Survey Data supplied by Port of Brisbane Corporation (POB)

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Information and data supplied by Redland City Council (RCC)

Limitations Statement

The sole purpose of this report and the associated services performed by Kellogg Brown & Root Pty Ltd (KBR) is to provide a siltation study in accordance with the scope of services set out in the contract between KBR and Redland City Council (RCC). That scope of services was defined by the requests of the Client, by the time and budgetary constraints imposed by the Client, and by the availability of access to the site.

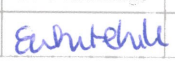
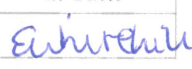
KBR derived the data in this report primarily from hydrographic survey data, visual inspections, examination of records in the public domain, interviews with individuals with information about the site and a limited amount of sub-surface explorations made on the dates indicated. The passage of time, manifestation of latent conditions or impacts of future events may require further exploration at the site and subsequent data analysis, and re-evaluation of the findings, observations and conclusions expressed in this report.

In preparing this report, KBR has relied upon and presumed accurate certain information (or absence thereof) relative to the waterway system and local catchment provided by government officials and authorities, the Client and others identified herein. Except as otherwise stated in the report, KBR has not attempted to verify the accuracy or completeness of any such information.

The findings, observations and conclusions expressed by KBR in this report are not, and should not be considered, an opinion concerning the correctness of the past hydrographic survey data and the suitability or otherwise of the design of Aquatic Paradise. No warranty or guarantee, whether express or implied, is made with respect to the data reported or to the findings, observations and conclusions expressed in this report. Further, such data, findings, observations and conclusions are based solely upon site conditions, information, data and drawings supplied by the Client in existence at the time of the investigation.

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CONTENTS

Section	Page	Section	Page
SUMMARY	v	APPENDICES	
1 INTRODUCTION		A Bed Level Digital Terrain Models	
1.1 Purpose	1-1	B Siltation Digital Terrain Models	
1.2 Scope	1-1	C Sediment Sampling Photographs	
		D Design Drawings	
2 PROJECT BACKGROUND			
2.1 Site location and description	2-1		
2.2 Background information	2-4		
3 INPUT DATA			
3.1 Survey data	3-1		
4 SILTATION MODELLING METHODOLOGY			
4.1 Survey data processing	4-1		
4.2 Estimating siltation	4-1		
5 SILTATION RATES			
5.1 Annual siltation	5-1		
5.2 Current siltation above design levels	5-2		
5.3 Siltation due to stormwater drain discharges	5-3		
5.4 Discussion	5-4		
6 SEDIMENT SAMPLING			
6.1 Introduction	6-1		
6.2 Sampling process and locations	6-1		
6.3 Summary of sampling results	6-3		
6.4 Interpretation	6-4		
7 SILTATION SOURCES AND PROCESSES			
7.1 Siltation sources	7-1		
7.2 Siltation processes	7-1		
8 CONCLUSION			
9 REFERENCES			

Summary

Kellogg Brown & Root Pty Ltd (KBR) was commissioned by Redland City Council (RCC) on 2 May 2012 to carry out a siltation study and develop a canal management plan for the Aquatic Paradise Canal System at Birkdale, Queensland.

This document provides an assessment of siltation in the canals and entrance channel by estimating siltation rates and volumes and identifying sources and processes of siltation.

The scope of works for the siltation study requested by RCC includes:

- a literature review of existing reports and studies on Aquatic Paradise
- identification of sources and processes of siltation
- estimation of siltation rates.

KBR assessed siltation rates using historical hydrographic survey data collected within the canals and entrance channel. Digital Terrain Models (DTMs) were developed to attain rates and volumes of siltation and quantify the volume of accumulated sediment in the canals. These DTMs were also used to identify siltation patterns, potential siltation sources and processes and assess the effectiveness of the siltation trap at the canal entrance. Sediment sampling was also undertaken at key locations in the canal system to broadly categorise the bed sediments and to gain an understanding of the possible sediment origins and processes.

The siltation study indicated an estimated average annual siltation rate of 32mm/annum and average annual net siltation volume of 10,200 m³/annum between 2000 and 2011. The estimated current siltation above design levels as of June 2011 is 65,400 m³.

This annual siltation within the Aquatic Paradise Canal Estate and entrance channel between 2000 and 2011 is attributable to two main sources:

- Waterloo Bay approximately 10,157 m³/annum = 99.6%.
- Stormwater outlets including Tarradarrapin Creek approximately 43 m³/annum = 0.4%.

Sediment sampling identified typical marine clays at sites throughout the canals and towards the canal entrance. Organic matter, apparently from upland sources, was also found in deposits

close to stormwater drain and creek inflow points. Interpretation of the DTMs indicates the highest level of siltation to be at the entrance to the canal system and around the first junction entering the canals (junction of John Goleby and Wood Canals). The analysis indicates that the siltation trap in a dredged condition is effective in reducing siltation in the canals.

The outcomes of this siltation study will inform the development of the canal management plan.

1 Introduction

1.1 PURPOSE

Kellogg Brown & Root Pty Ltd (KBR) was commissioned by Redland City Council (RCC) on 2 May 2012 to carry out a siltation study and develop a canal management plan for the Aquatic Paradise Canal System at Birkdale, Queensland.

Siltation has been occurring within the canals and entrance channel since its construction in 1987–88. There have been a number of dredging campaigns in various parts of the canal and entrance channel system since its construction. This dredging has formed a large part of the maintenance costs of the canal system.

This document provides an estimate of the siltation rates in the canals and entrance channel via analysis of past surveys. These rates are compared to sediment core sample stratigraphy. The nature of the sediment in the samples plus the siltation spatial pattern is also used to estimate the volumes of siltation from various sources (e.g. Waterloo Bay, Tarradarrapin Creek catchment).

This siltation study will inform the subsequent development of the canal management plan (CMP).

1.2 SCOPE

The scope of works for the siltation study requested by RCC includes:

- a literature review of existing reports and studies on Aquatic Paradise
- identification of sources and causes of siltation
- estimation of siltation rates.

To complete the scope of works KBR utilised an array of resources and tools. This included 3D mapping software to model siltation and a site visit to undertake sediment sampling.

Due to the nature of the study, the outcomes and findings do have limitations. The siltation rate estimate is reliant on the accuracy of the survey data provided to KBR. Silt origin estimates are reliant on the visual appearance of the silt (e.g. brown and organic for catchment derived and grey for bay derived) and the observed siltation pattern (e.g. deposits near culvert outlets → catchment derived).

More definitive silt origin studies require expensive and time consuming x-ray crystallography and/or trace element studies that have not been performed as part of this study.

Notwithstanding this, the completed analyses and the findings are considered appropriate for the forecasting and planning of the future dredging requirements required for the development of the CMP.

2 Project background

2.1 SITE LOCATION AND DESCRIPTION

The location of the Aquatic Paradise canal system is shown in Figure 2.1. This aerial image displays the canals and entrance channel with the canal estates broader locality being shown on the key map.

The canal system is located in Birkdale on the southern side of Waterloo Bay, which forms part of the greater Moreton Bay. The estate comprises approximately 3,000 m of inshore canals with a 2,950 m long access channel extending north into Waterloo Bay.

The system was constructed in 1987–88. The canals were excavated from dry land and the entrance channel was formed using a cutter suction dredge. The main and side canals have a design bed level of -1.9 mLAT; the entrance channel between the canal entrance at chainage 0 m (start) and 500 m a level of -2.5 mLAT, and between chainage 500 m and 2,950 m (end) a level of -1.9 mLAT. These typical design levels are contained in the design drawings contained in Appendix D. The maximum draught for boats entering Aquatic Paradise is defined by RCC to be 1.5 m. It appears that the canals and entrance channel were built close to the design levels.

Figure 2.2 is a close-up aerial image showing the layout of the canal system. There is only one entry/exit point for boat traffic, but there are a number of stormwater inflow points. The main source of runoff into the canals is Tarradarrapin Creek, which flows into the system at the southern end of Wood Canal. The canal estate has a total catchment area of approximately 4.5 km^2 , of which approximately 85% is suburban development, 5% is playing fields and parks, and the remainder is bush and wetland. In addition to Tarradarrapin Creek there are also three relatively large culverts which discharge into Wood Gate Canal, from William Taylor Park and the nearby cricket ground. Various other minor stormwater outlets also drain into the canals at locations throughout the system. In recent years RCC has installed sediment traps on some stormwater drains which flow into the canal system as a trial program.



Figure 2.1
LOCATION



Figure 2.2
CANALS LAYOUT

2.2 BACKGROUND INFORMATION

2.2.1 Constructed levels

The as-built survey drawings supplied by RCC describe ‘as constructed’ levels in the canals in comparison to the design profiles. It appears that most of the system was constructed at or just below the design levels, except for a couple of sections around the western end of Wood Gate Canal and in John Goleby Canal. These areas were excavated deeper than design levels, possibly to source fill.

2.2.2 Tide planes

Tide planes and datum levels play a crucial role in assessing the survey data and for understanding navigation in the area.

The most up-to-date tide planes for Wellington Point are provided in Table 2.1.

Table 2.1 Wellington Point Tide Planes (MSQ 2012)

		To LAT Datum (m)	To AHD Datum (m)
Highest Astronomical Tide	HAT	2.84	1.51
Mean High Water Springs	MHWS	2.26	0.93
Mean High Water Neaps	MHWN	1.85	0.52
Australian Height Datum	AHD	1.33	–0.00
Mean Sea Level	MSL	1.26	–0.07
Mean Low Water Neaps	MLWN	0.79	–0.54
Mean Low Water Springs	MLWS	0.38	–0.95
Lowest Astronomical Tide	LAT	0.00	–1.33

The survey datum stated in the hydrographic surveys provided to KBR is to LAT. This equates to –1.33 mAHD. This LAT datum has been adopted for all survey modelling and use in this report.

2.2.3 Dredging and surveying history

Since the canal system’s construction in 1987–88 there have been various surveys and dredging campaigns undertaken. In order to assess siltation, KBR needed to identify and quantify dredging campaigns between surveys. The timeline set out below indicates times when KBR has information that dredging and surveying has occurred. Dredging is shown in red text and surveying in blue.

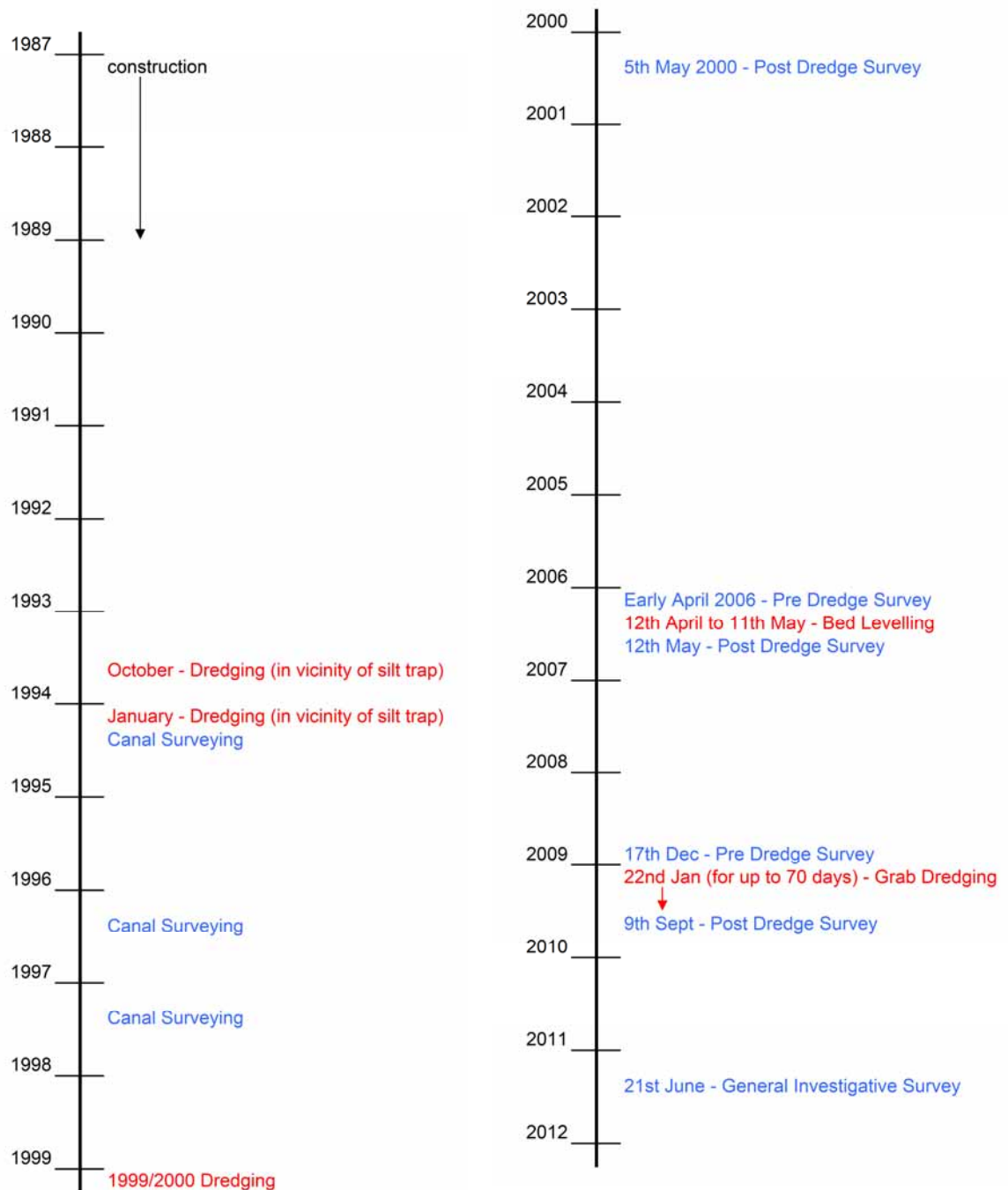


Figure 2.3
SURVEYS AND DREDGING OCCURRENCES

Note: The 'silt trap' is located between chainage 0m and 500m. These chainages of the inner entrance channel are shown in Appendix D.

KBR has been provided with survey data from the year 2000 onwards, hence this period will be used to estimate siltation rates. Dredging operations during this time are briefly summarised as follows.

Bed levelling

- occurred over three days between 12 April and 11 May 2006
- undertaken by 'Port of Brisbane Corporation'
- undertaken around silt trap/entrance to canals.

Grab dredging

- contracted dredging commencement date of 22 January 2009
- practical completion within 70 days of commencement date
- undertaken by 'Coastal Dredging & Construction Pty Ltd
- dredging extent:
 - Wood Channel Chainage –50 m to 300 m to depth –2.4 mLAT. Estimated insitu dredge volume of 19,885 m³ (as at June 2006)
 - Wood Channel Chainage 300 m to 1,000 m to depth –1.9 mLAT. Estimated in situ dredge volume of 22,765 m³ (as at June 2006)
- dredged material disposed at Mud Island via barge.

2.2.4 Existing reports and studies

The following reports and studies on the entrance channel and canal system were examined:

- 'Aquatic Paradise Canal Estate Siltation Study' November 1997 by Kinhill Pty Ltd: This report presents the findings of a siltation study on the canal system. The objective of the study was to examine possible sources of siltation, long term maintenance dredging requirements and costs, and the nature of any measures that could be employed to mitigate the costs of dredging. This report is a useful source of background information in developing this current report.
- University of New South Wales Water Research Laboratory (WRL) Study: This study was undertaken with the aim of understanding the sedimentation dynamics of Waterloo Bay. The Kinhill report summarised this study as *'the WRL report provides a reasonable insight into the future sedimentation behaviour of the development. While the predicted sedimentation volumes were extremely broad, the results are within the accepted accuracy ranges of the sedimentation prediction theories available at the time'*.
- Riedel & Byrne (R&B) Engineers Field Studies: During 1988 and 1989 R&B undertook field measurements and performed calculations aimed at estimating the likely siltation characteristics of the proposed Aquatic Paradise entrance channel. An important finding from this study was that during periods of observed heavy rain observed the suspended sediment levels in Waterloo Bay did not increase significantly..

3 Input data

3.1 SURVEY DATA

Siltation rates were estimated by comparing historical surveys after allowing for dredging. Survey data was provided by RCC and Port of Brisbane Pty Ltd. A summary of the survey data is provided in Table 3.1. All surveys were undertaken by the Port of Brisbane Pty Ltd.

Table 3.1 Survey data

Date	Title and Plan Number(s)	Sonar Beam	Grid Size	Class	Vertical and Horizontal Tolerances	Data Type Received	Datum
5 May 2000	Post Dredge 101383 101384 101514	Single Beam	5 m x 5 m	—	—	XYZ points (.TXT) file & PDF plans	LAT
12 April 2006	Pre Dredge	Single Beam	5 m x 5 m	C	Vertical = ± 0.10m Horizontal = ± 1.5m	XYZ points (.TXT) file	LAT (-1.31 mAHD)
12 May 2006	Post Dredge 113760	Single Beam	5 m x 5 m	C	Vertical = ± 0.10m Horizontal = ± 1.5m	XYZ points (.TXT) file & PDF plans	LAT (-1.31 mAHD)
17 Dec 2008	Pre Dredge	Multi Beam	0.2 m x 0.2 m	A	Vertical = ± 0.15m Horizontal = ± 0.5m	XYZ points (.PTS) file	LAT
9–11 Sept 2009	Post Dredge 122160	Multi Beam	0.2 m x 0.2 m	A	Vertical = ± 0.15m Horizontal = ± 0.5m	XYZ points (.PTS) file & PDF plans	LAT
21–22 June 2011	General Investigative 125528	Multi Beam	0.2 m x 0.2 m	A	Vertical = ± 0.15m Horizontal = ± 0.5m	XYZ points (.PTS) file	LAT (-1.31 mAHD)

4 Siltation modelling methodology

4.1 SURVEY DATA PROCESSING

The survey datasets were plotted for a rough check of their validity and verified against survey notes and datum levels. They were then converted from XYZ points to a DTM of the canal using 3D mapping and modelling software. This process facilitates subtraction of surveys to obtain siltation isopachs. The bed level DTMs are provided in Appendix A.

4.2 ESTIMATING SILTATION

Sequential bed level DTMs were overlayed to find the difference in height to estimate annual siltation rates and the current volume of siltation above design levels. This process is outlined below:

- Annual siltation rate (for a particular period) = newer survey minus older survey; then divided by the time (in years) between the two surveys.
- Current accumulated siltation above design levels = most current survey minus canal design levels.

All known dredging and bed levelling campaigns are also taken into account. This was done by estimating the dredged volumes using the pre and post dredge surveys and then adding this volume to the appropriate time period and areas as ‘siltation’.

Proposed dredge zones are based on observed siltation patterns; regions exhibiting similar siltation rates are grouped together with the intention that zone specific siltation volumes may be used to inform future dredge campaigns. The dredge zones are shown in Figure 4.1. Zones 1, 2 and 3 make up the entrance channel and Zones 4, 5, 6, 7, 8 and 9 make up the canals.

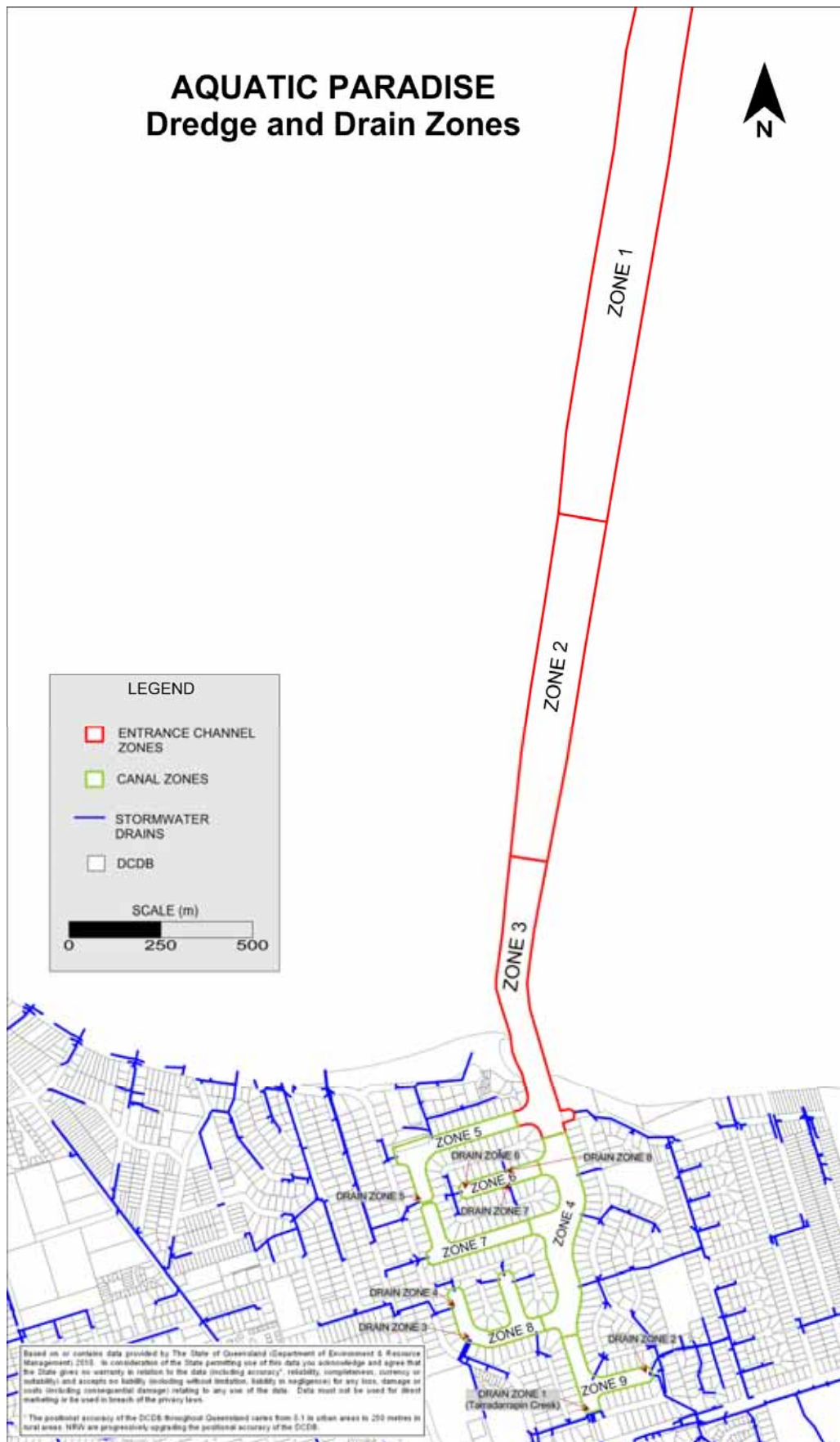


Figure 4.1
DREDGE ZONES

5 Siltation rates

5.1 ANNUAL SILTATION

This section details the estimated annual siltation across four time periods:

- May 2000 to May 2006 (partial extent model*).
- May 2006 to September 2009 (full extent overlayed model*).
- September 2009 to June 2011 (full extent model*).
- May 2000 to June 2011 (full extent model*).

* 'partial extent model' means that the hydrographic surveys were incomplete. 'Full extent model' means that the hydrographic surveys covered the entire canal estate and entrance channel. Whilst the 'full extent overlayed model' means that siltation was estimated by overlaying partially complete surveys to achieve a full extent model.

Each of these siltation maps are presented in Appendix B.

By applying a range of area and volume calculation functions to the annual siltation DTMs, the annual siltation rates have been estimated for each of the dredge zones. They are outlined in Table 5.1.

Table 5.1 Estimated average annual siltation rates

	Average annual siltation rate (mm/annum)			
	2000 to 2006	2006 to 2009	2009 to 2011	2000 to 2011
Entire Canal System	11	15	–8	32
Dredge Zone 1	–	–6	–20	4
Dredge Zone 2	8	15	–3	37
Dredge Zone 3	14	43	42	84
Dredge Zone 4	5	48	–11	41
Dredge Zone 5	5	36	–28	31
Dredge Zone 6	5	18	–22	31
Dredge Zone 7	–	–18	–30	20
Dredge Zone 8	–	11	–24	24
Dredge Zone 9	–	30	–35	25

Note: Negative values represent areas where the indicated rate of siltation is negative, i.e. 'erosion'. The indicated 'erosion' in the period 2009–2011 is due to apparent small changes in bed levels over large areas, these apparent level changes are within normal survey accuracy bounds.

Values represented by a '–' are due to partial survey coverage and hence data was not available for those time periods in those zones.

The same process was also undertaken to estimate the average annual siltation volumes. They are outlined below in Table 5.2. These volumes represent the net

siltation which is the siltation volume minus how much has eroded. However this net siltation is not necessarily the volume which should be dredged from the canals, since this also needs to consider where and how the siltation is deposited.

Table 5.2 Estimated average annual siltation volumes

	Annual siltation volume (m ³ /annum)			
	2000 to 2006	2006 to 2009	2009 to 2011	2000 to 2011
Entire Canal System	9,850	4,430	-3,200	10,200
Dredge Zone 1	–	-690	-3110	430
Dredge Zone 2	2,480	1,090	-250	2,710
Dredge Zone 3	6,660	2,230	2,180	4,760
Dredge Zone 4	450	1,320	-390	1,220
Dredge Zone 5	140	260	-410	340
Dredge Zone 6	120	50	-140	120
Dredge Zone 7	–	-130	-360	160
Dredge Zone 8	–	100	-340	260
Dredge Zone 9	–	200	-380	200
Canals	710	1,800	-2,020	2,300
Entrance Channel	9,140	2,630	-1,180	7,900

Note: Negative values represent areas where the indicated volume of siltation is reducing, i.e. 'erosion'. The indicated 'erosion' in the period 2009–2011 is due to apparent small changes in bed levels over large areas, these apparent level changes are within normal survey accuracy bounds.

5.2 CURRENT SILTATION ABOVE DESIGN LEVELS

This section describes the current estimated accumulated siltation above the canal system's design levels.

The resulting estimated volumes are outlined in Table 5.3. As various dredging operations have taken place during the time period between 1987/88 and the June 2011 survey, these volumes do not represent the total amount of siltation that has accumulated since construction; they simply show how much accumulated present in the canals above the design levels as of June 2011.

Table 5.3 Estimated accumulated siltation volumes

Canal Area	Accumulated siltation volume (m ³) (as of June 2011)
Entire Canal System	65,400
Dredge Zone 1	500
Dredge Zone 2	6,800
Dredge Zone 3	31,300
Dredge Zone 4	12,900
Dredge Zone 5	4,100
Dredge Zone 6	1,900
Dredge Zone 7	1,800
Dredge Zone 8	2,300
Dredge Zone 9	3,800
Entrance Channel (total)	38,600
Canals (total)	26,800

5.3 SILTATION DUE TO STORMWATER DRAIN DISCHARGES

The DTMs show isolated mounds of siltation at some locations where stormwater drains flow into the canals. A zoomed image showing a couple of these ‘stormwater drain siltation mounds’ from the 2009 to 2011 annual siltation DTM is shown in Figure 5.1.

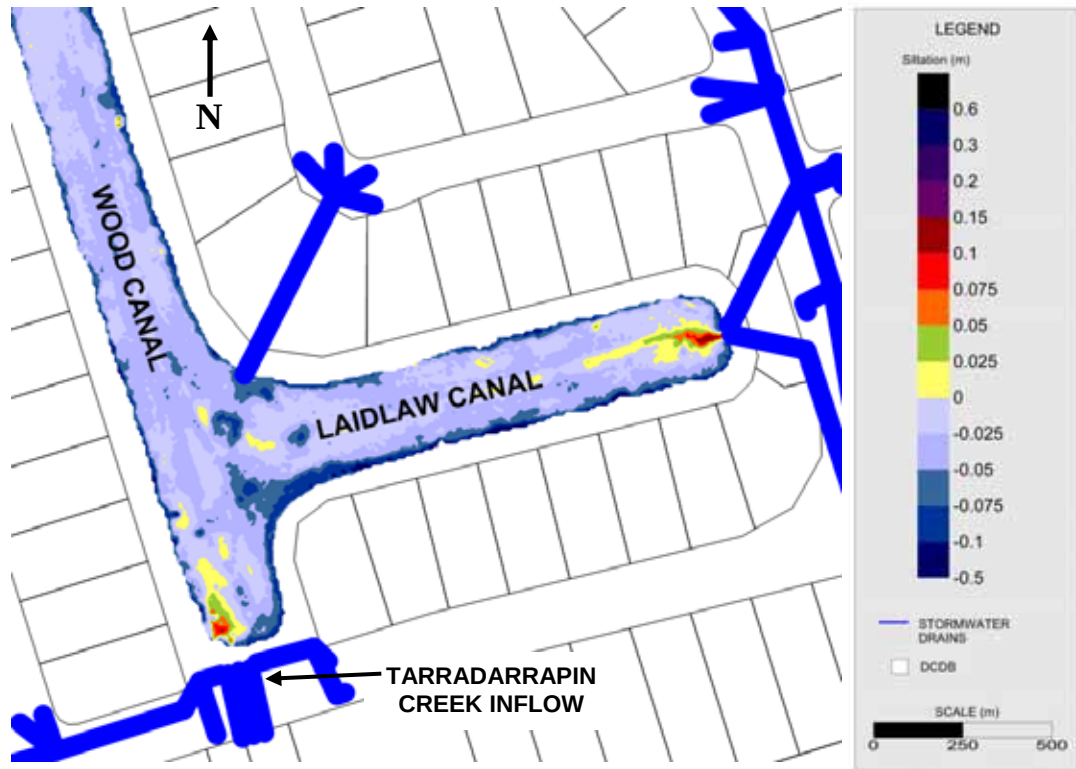


Figure 5.1
SILTATION MOUNDS (LAIDLAW AND WOOD CANALS)

Based on the 2000 to 2011 annual siltation DTM, each year approximately 43 m³ of sediment accumulates in the canals each year as a result of sediment and debris coming from stormwater drains. This represents approximately 0.4% of the total average annual siltation of 10,200 m³.

Table 5.4 outlines the estimated annual siltation at stormwater drain outlets over several surveyed time periods.

Table 5.4 Estimated annual siltation at stormwater drain outlets

	2006 to 2009 Annual siltation volume (m ³ /annum)	2009 to 2011 Annual siltation volume (m ³ /annum)	2000 to 2011 Annual siltation volume (m ³ /annum)
Drain Outlet Zone 1	16.5	4.5	6
Drain Outlet Zone 2	12.5	6.5	16
Drain Outlet Zone 3	2	4	16
Drain Outlet Zone 4	0.5	0.5	2
Drain Outlet Zone 5	1	0.5	–
Drain Outlet Zone 6	5.5	5.5	1
Drain Outlet Zone 7	0.5	–	–
Drain Outlet Zone 8	2.5	–	2
Total	41	21.5	43

The location of the drain zones is shown in Figure 4.1. Siltation volumes have been estimated only for stormwater drains that display an identifiable sediment deposit.

These results indicate a declining annual volume of silt depositing at stormwater drain outlets from 2006–2009 to 2009–2011.

Sediment samples taken from the deposits shown in Figure 5.1 show that these samples have a significant organic content, unlike other samples, confirming the hypothesis that these deposits have a significant catchment origin (refer Section 6).

5.4 DISCUSSION

Siltation is known to vary over space and time and this is reflected in the variation of the observed rates across the different dredge zones and time periods. Different factors could contribute to this rate deviation, including variation in rainfall events, turbidity levels, wind and wave action and direction, catchment runoff, tidal movements, survey accuracy, the depth of silt in the trap and an array of other factors, some of which are dependent upon each other.

KBR recommends that the 2000 to 2011 survey period is the most useful for analysing siltation patterns and identifying siltation sources and volumes. This is primarily due to its greater coverage and being over the longest time period, hence producing the most reliable long term siltation pattern estimate. The three other siltation periods (which fall in the 2000 to 2011 period) are still useful in assessing siltation patterns and origins in and between their respective time steps, however partial survey coverage, potential survey inaccuracies and shorter time frames means they were not adopted for KBR's assessment of siltation rates and volumes.

The consolidated average annual net siltation depths and volumes for the 2000 to 2011 period shown in Table 5.5:

Table 5.5 Consolidated average annual net siltation depths and volumes

	Annual siltation depths (mm/annum)	Annual siltation volume (m ³ /annum)
	2000 to 2011	2000 to 2011
Entire Canal System	32	10,200
Canals	42	2,300
Entrance Channel	29	7,900

The estimated volume of accumulated siltation above design levels as of June 2011 is:

- Entrance channel = 38,600 m³.
- Canals = 26,800 m³.
- Entire Canal System = 65,400 m³.

The estimated annual siltation at stormwater drain outlets is:

- 2006 to 2009 = 41 m³/a
- 2009 to 2011 = 21.5 m³/a
- 2000 to 2011 = 43 m³/a.

The average annual siltation depths and volumes temporal and spatial patterns have the following features:

- Greatest proportion of siltation is depositing in the inner entrance channel, silt trap and canal junction nearest the canal entrance. This volume is in the order of approximately 73% of the total annual siltation (2000–2011 survey).
- Over the 2000 to 2011 period the greatest rate of annual siltation accumulation is in the siltation trap and inner entrance channel.
- Much lower observed canal siltation after the Zone 3 ‘silt trap’ had been dredged (e.g. 2009–2011).
- A declining trend in siltation, possibly due to stabilisation of the areas surrounding the entrance channel. In theory, shallowing of canal bed levels may also result in declining siltation due to increased current flow and greater boat propeller jet action.
- Negative correlation with rainfall (2006–2009 which was dry has a higher siltation rate than the wet 2009–2011 period).
- Widespread and apparently even minor ‘erosion’ areas (negative siltation) indicated in the 2009 to 2011 survey are within the survey equipment error band [this survey period has a ± 0.15 m vertical tolerance, to a 95% confidence (Port of Brisbane survey plots; drawing 122160 1 to 4 and 125528 1 to 4)].

Dredging volumes and siltation volumes are related but not the same. Areas of low accretion rates can be allowed to accrete for many years without causing navigation problems. Localised high areas may require dredging even if the entire estate has minimal net average siltation. Note that ‘siltation’ refers to sediment accumulation of all types – gravel, sand, silt, clay and debris (organic matter).

6 Sediment sampling

6.1 INTRODUCTION

On 1 June 2012 KBR undertook preliminary sediment sampling in the Aquatic Paradise Canal System using a piston sampler. The purpose of this preliminary sampling was to qualitatively characterise the sediment and gain an understanding of the possible sediment origins and processes. No quantitative tests have been performed.

6.2 SAMPLING PROCESS AND LOCATIONS

A manual piston sampler was used to extract the sediments. This piston sampler consists of a metal tube with an inner plunger attached to a rope. The sampler is lowered down to the canal bed level (sediment surface) and the metal tube is pushed into the sediment. Whilst pushing the sampler down into the sediment the rope is held up, thus extracting a sediment core into the tube. Several metal pipes can be screwed together on top of the sampler to allow use in water of varied depths. As the sampler is non-mechanised the depth of this sediment core is determined by how far the user can push the piston into the sediment.

Each sample site was identified using a GPS. Sediment samples were extruded, photographed and some of the sediment was bagged for further inspection. This process was undertaken at six sediment sampling locations within the Aquatic Paradise canal system.

The sediment sampling locations were chosen based on analysis of the hydrographic surveys. These locations were at points of high sedimentation identified in the 2009 to 2011 Annual Siltation DTM. The sediment sampling locations can be seen in Figure 6.1. Sediment sample sites 1, 2 and 3 are at locations of high sedimentation which is expectedly due to sedimentation process from Moreton Bay. Whilst sample sites 4, 5 and 6 are at identified locations of localised sedimentation where stormwater drains enter the canal system.

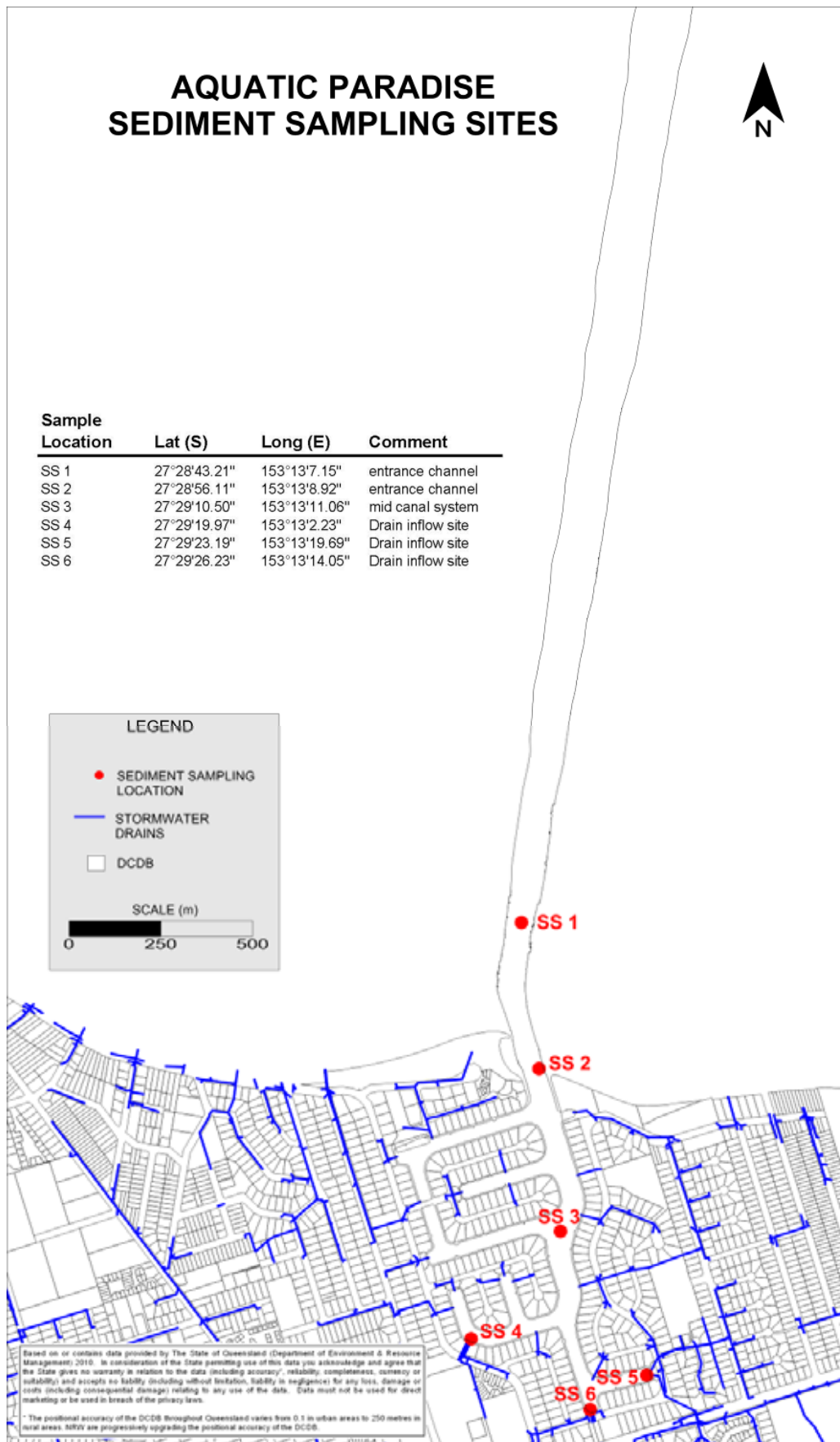


Figure 6.1
SEDIMENT SAMPLE SITES

6.3 SUMMARY OF SAMPLING RESULTS

Analysis of the samples was limited to visual inspection only. The colour of the sediment was assessed using the Munsell Colour Chart. Colour might be a guide to the origin of the sediment.

Table 6.1 summarises the sediment sample cores taken in the Aquatic Paradise Canal System. The table outlines sediment core length, sediment layering, sediment colour classification based on the Munsell Chart and general descriptions and comments of the sediments. Photos of each of the sediment cores are included in Appendix C.

Table 6.1 Sediment sample core summary

	Core Length (m)	Layers Separation (m)	Munsell Colour Description	Physical Descriptions/Comments
SS 1 (10:40am)	0.9	0 – 0.1	Gley 1 – 3/N (very dark grey)	Very fine marine clay Not as cohesive as SS2, although still fairly cohesive
		0.1 – 0.75	Gley 1 – 4/N (dark grey)	Fine marine clay Cohesive
		0.75 – 0.9	Gley 1 – 3/N (very dark grey)	Fine marine clay Cohesive Presence of granules (2–4 mm) and pebbles (up to 7mm)
SS 2 (10:15am)	0.75	0 – 0.1	Gley 1 – 2.5/N (black)	Fine marine clay Cohesive
		0.1 – 0.75	Gley 1 – 3/N (very dark grey)	Fine marine clay cohesive
SS 3 (09:45am)	0.75	0 – 0.1	Gley 1 – 2.5/N (black)	Fine marine clay Smooth texture and cohesive Noticeable salty odour
		0.1 – 0.75	Gley 1 – 4/1 10Y (dark greenish grey)	Fine marine clay Smooth texture and cohesive Noticeable salty odour More greyish colour than top layer
SS 4 (09:15am)	0.35	0 – 0.1	NA	Coarse sand / gravel 2–4mm granules, sub angular Very minimal fines, some quartz
		0.1 – 0.2	NA	Pebbles (average 15–20mm) Sub angular, no fines, some quartz
		0.2 – 0.35	Gley 2 – 5PB2.5/1 (blueish black)	Coarse sand with some silt Some organic matter and granules present (2–4mm)
SS 5 (08:40am)	0.7	0 – 0.3	Gley 2 – 5PB2.5/1 (blueish black)	Fine clayey silt Strong odour (possibly due to decomposing organic matter) Organic matter present – high level of leaves, sticks etc
		0.3 – 0.7	Gley 2 – 5PB2.5/1 (blueish black)	Fine clayey silt Slightly less odour than top layer Organic matter present – although less than top layer Gravel present (up to 10 mm, sub angular)
SS 6 (07:45am)	0.75	0 – 0.3	Gley 2 – 5PB2.5/1 (blueish black)	Fine clayey silt Organic matter present
		0.3 – 0.75	Gley 2 – 5PB2.5/1 (blueish black)	Fine clayey silt Small pebbles throughout (up to 10 mm, sub-angular) Vegetative debris and organic matter present

6.4 INTERPRETATION

Sediment samples from locations 1 and 2 are typical marine clay, ex Waterloo Bay and transported into the estate by the tide.

Sediment samples from location 3 appear to be from a similar origin to Samples 1 and 2. These samples appear slightly greyer than 1 and 2 for an unknown reason.

Sediment samples from location 4 have significant gravel and pebble content, with just a very shallow layer of black coloured sedimentation on top. This location is close to a stormwater discharge point, therefore it is possible that this region experiences erosion during times of high runoff, alternating with sedimentation during low runoff periods.

Sediment samples from locations 5 and 6 are from localised sedimentation mounds where stormwater drains flow into the canal system (based on the hydrographic survey interpretation). These samples appear to be fine clayey silt, very dark in colour and displaying a high organic content. The sample from site 5 also had a very strong odour, possibly due to anaerobic decomposition of organic matter. The organic matter indicates that these localised sedimentation deposit could have catchment origin.

7 Siltation sources and processes

This section discussed potential siltation sources and processes based on the siltation rates and patterns identified in Section 5 and the sediment characterisations described in Chapter 6.

7.1 SILTATION SOURCES

The two main sources of siltation of the Aquatic Paradise canal system appear to be offshore from Moreton Bay and upland sediment entering the canals at inflow points.

7.1.1 Offshore

As described in the DERM Moreton Bay Healthy Waterways reports and other references, sediment in western Moreton Bay is ultimately derived from catchment erosion. Course sediments are deposited at the mouth of rivers, especially Fisherman Islands, Brisbane River whereas fine sediments circulate in the bay for long periods of time due to tides, winds, waves, currents and an array of coastal processes. Due to the sand islands and shoals, such as Stradbroke and Moreton Islands and predominant south-easterly wind and waves, a large portion of this fine sediment is trapped within the bay. This trapped sediment undergoes a process of being circulated, deposited and then re-circulated throughout the bay, especially along the western side.

This circulation process transports suspended sediment into the entrance channel and canal system. How and where this sediment may come out of suspension is discussed in Section 7.2 ‘Siltation Processes’.

As this sediment has generally been in Moreton Bay for a long period of time it undergoes a salt alteration process into ‘marine clay’. This type of sediment was sampled from the Aquatic Paradise Canals as discussed in Chapter 6 of this report.

7.1.2 Upland

Other sources of siltation are the Tarradarrapin Creek inflow, various stormwater drain inflows around the canals and general surface runoff into the canals from the local catchment. These sources bring sediment and debris, such as organic matter into the canal system where it can be deposited. There are various points in the canal system where ‘siltation mounds’ have been identified close to stormwater outlets and creek inflows, as discussed in Section 5.3. Sediment sampling of these mounds which is discussed in Section 6 tends to confirm an upland origin for these ‘mounds’.

7.2 SILTATION PROCESSES

Surveyed siltation patterns (shown in Appendix B), plus the sediment sampling are consolidated into a siltation conceptual model as follows.

Due to the greater water depth in the entrance channel the combined wave–current seabed shear stresses decline, facilitating sedimentation. Moving into the canal estate, wave action disappears and current velocities also decline especially at canal ‘T’ junctions. Due to the decline in bed shear stresses and sediment transport rates, flocculated clay particles in suspension settle onto the bed especially at ‘T’ junctions. It is also noted that even though the tidal prism in the canals is generally expected to be the same for a flood and ebb tide (except in times of flood), the bed shear force to deposit siltation is appreciably less to the bed shear force required to erode siltation.

Further into the canal system siltation is reduced because the water turbidity has declined, leaving behind unflocculated particles in suspension that have an extremely slow settling rate.

In addition there are small fluvial deposits close to stormwater drain discharges. This pattern can be seen at various locations on the bed level and siltation DTMs shown in Appendix A.

The Aquatic Paradise Canal System has a ‘siltation trap’. This is the area from chainage 0 m to 500 m where the canal invert design level and hence re-dredge level is set at –2.5 mLAT, which is 0.6 m deeper than the rest of the canals and entrance channel. The purpose of this trap is for sediment to come out of suspension at this easy-to-dredge location, so that hard-to-dredge areas upstream of the trap experience less siltation. By comparing the 2006 to 2009 and 2009 to 2011 survey periods then the effectiveness of this siltation trap can be assessed as this trap was dredged between these two survey periods.

When the siltation trap was becoming full between 2006 and 2009, apparently more siltation accumulated throughout the entire canal system. Once the trap was dredged in 2009, then the 2009 to 2011 Annual Siltation DTM indicates less siltation throughout the canal system. The relevant DTMs can be found in Appendices A and B. It appears that a dredged silt trap is quite successful at reducing siltation throughout the canal system. Further investigations could also be undertaken to show potential benefits of dredging the siltation trap deeper than current design levels, and/or beam dragging sedimentation into the trap.

The apparent effectiveness of the siltation trap also reinforces the hypothesis that most siltation is coming from offshore. The DTMs show significant siltation upstream of the siltation trap when the trap is full, however there is generally much less siltation when it is empty. If the majority of siltation was coming from upland sources then significant siltation would be seen in both the 2006 to 2009 and 2009 to 2011 DTMs, which is not the case.

A possible influence on siltation processes within the canal system is suspected to be the Tarradarrapin Creek fresh water flow, especially during times of flood. In the absence of Tarradarrapin Creek flow it is expected that the flood and ebb tidal velocities in and out of the canals will be close to symmetric. Hence a fresh water outflow from Tarradarrapin Creek is expected to produce a net water flow out of the canal system into Moreton Bay. A net outward flow is expected to export sediment from the canal estate, or at least reduce the rate of siltation. This might partly explain the reduced rate of siltation and net erosion in the wet 2009–2011 period compared to the dryer 2006–2009. The indicated net erosion during the 2009 to 2011 period may

also be partly due to normal survey accuracy within the accepted tolerance levels, and hence may be less (or more) than in reality.

8 Conclusion

This Aquatic Paradise siltation study concludes that based on analysis of the 2000 to 2011 DTM there is an estimated average annual siltation rate of 32 mm/annum and average annual net siltation volume of 10,200 m³/annum. The estimated current siltation above design levels as of June 2011 is 65,400 m³.

Siltation within the Aquatic Paradise canal estate and entrance channel between 2000 and 2011 is attributed to two main sources; Waterloo Bay (approximately 10,157 m³/annum = 99.6% v/v long-term average) and the stormwater outlets including Tarradarrapin Creek (approximately 43 m³/a = 0.4% v/v long-term average).

For this 2000 to 2011 survey period approximately 73% of annual siltation by volume is depositing in the inner entrance channel, silt trap and canal junction nearest the canal entrance. The surveys indicate that a dredged siltation trap is effective at reducing siltation in the canals.

Sediment sampling identified typical marine clays at sites throughout the canals and towards the canal entrance and suggested sediments and organic matter found at stormwater drain and creek inflow points were from upland sources.

This siltation study informs the development of a CMP. This plan will guide the sustainable management of the canal system.

9 References

Kinhill Pty Ltd. 1997, *Aquatic Paradise Canal Estate Siltation Study – Final Report*, Ref: BC7905-001 Rev 0. 6 November 1997

Riedel & Byrne Consulting Engineers Pty Ltd. October 1989, *Waterloo Bay Canal Estate, Siltation Studies – Report*, ref: R350.

Riedel & Byrne Consulting Engineers Pty Ltd. June 1989, *Wellington Point Development – Channel Stability Studies Report*, ref: R324.

The State of Queensland (Department of Transport and Main Roads) 2011, *Queensland Tide Tables 2012*.

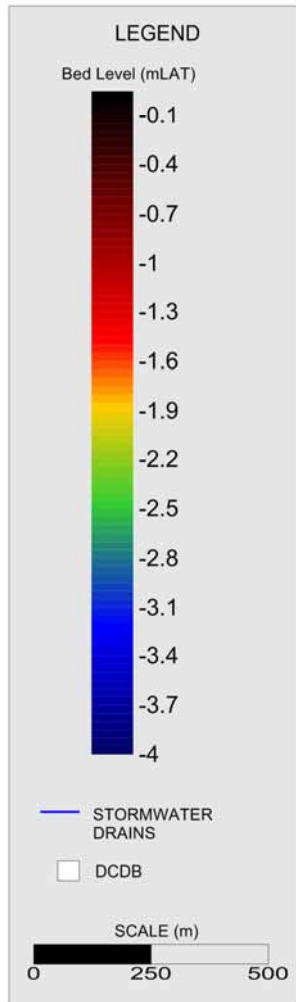
University of New South Wales Water Research Laboratory. 1982, *Sedimentation and Wave Penetration Studies for Aquatic Paradise Canal Estate Technical Report*, Ref: No, 82/21. November 1982.

Appendix A

BED LEVEL DIGITAL TERRAIN MODELS

AQUATIC PARADISE BED LEVELS

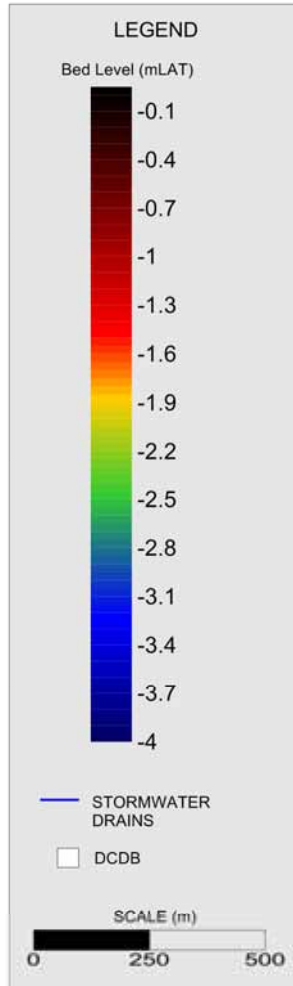
CANALS & ENTRANCE CHANNEL
May 2000 - Post Dredge Survey (LAT datum)



AQUATIC PARADISE BED LEVELS

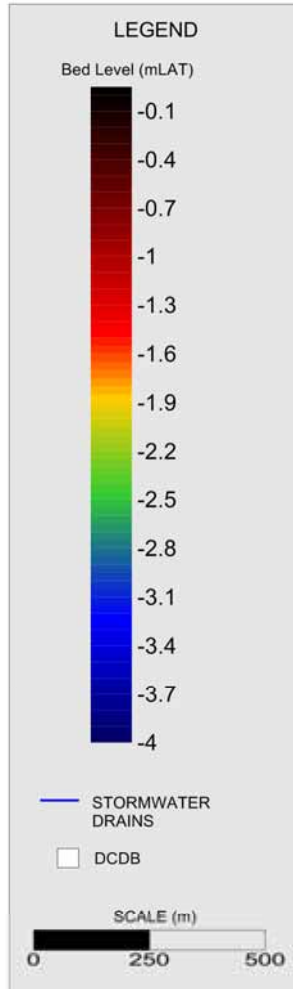
CANALS & ENTRANCE CHANNEL

April 2006 - Pre Dredge Survey (LAT datum)



AQUATIC PARADISE BED LEVELS

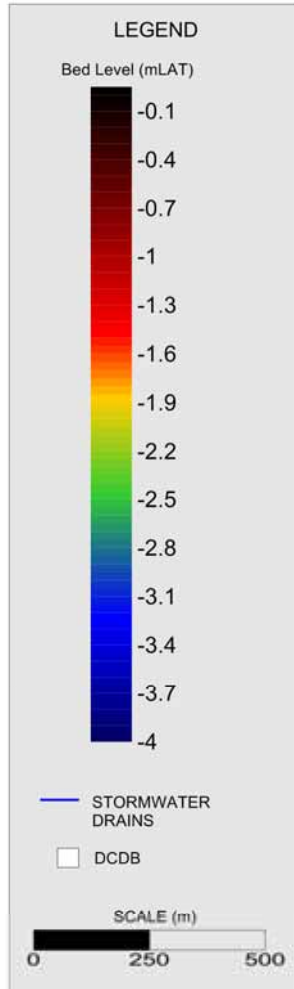
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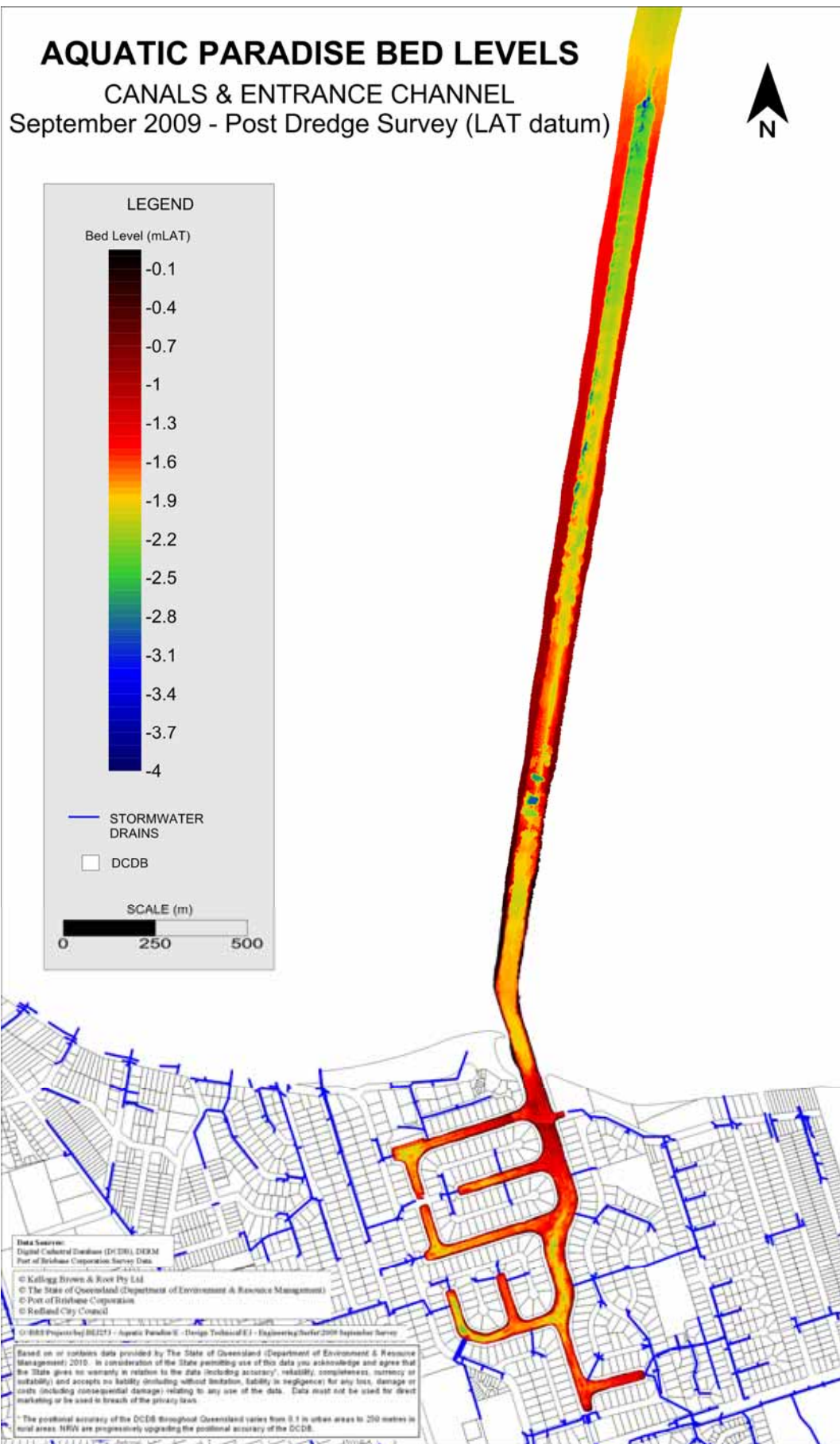


AQUATIC PARADISE BED LEVELS

CANALS & ENTRANCE CHANNEL

December 2008 - Pre Dredge Survey (LAT datum)

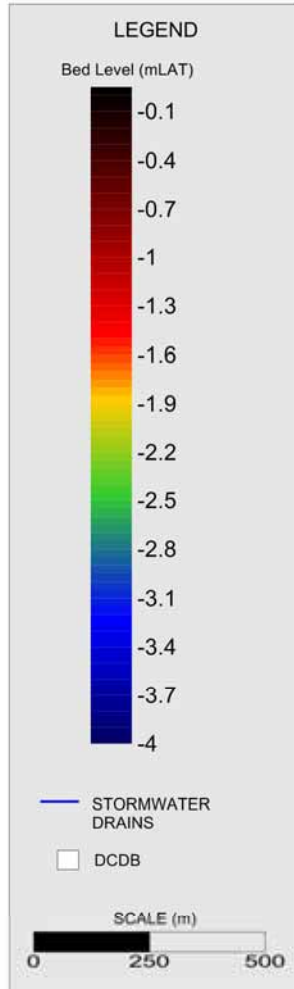




AQUATIC PARADISE BED LEVELS

CANALS & ENTRANCE CHANNEL

June 2011 - General Survey (LAT datum)

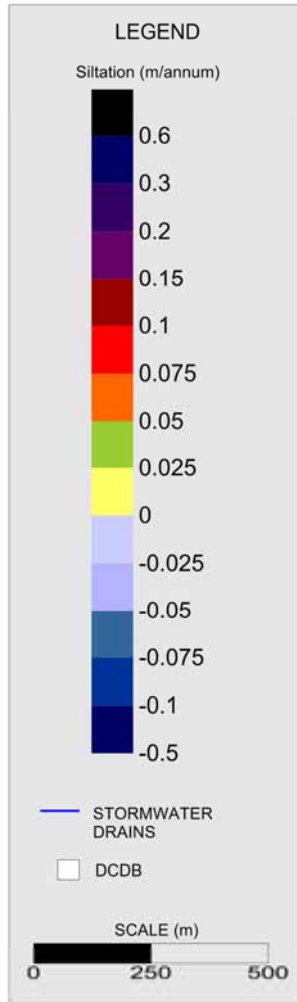


Appendix B

SILTATION DIGITAL TERRAIN MODELS

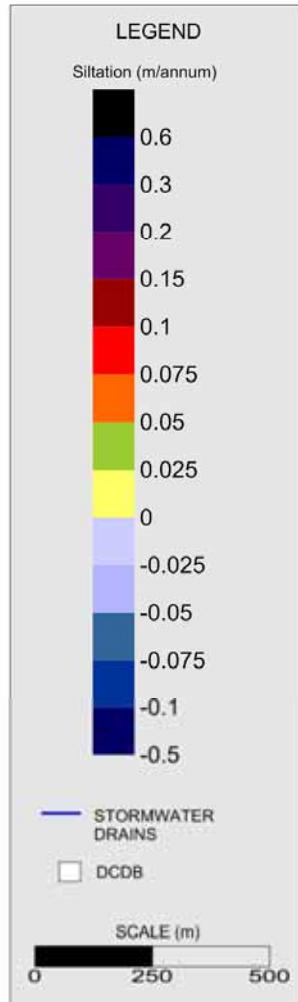
AQUATIC PARADISE ANNUAL SILTATION

CANALS & ENTRANCE CHANNEL
between May 2000 & May 2006



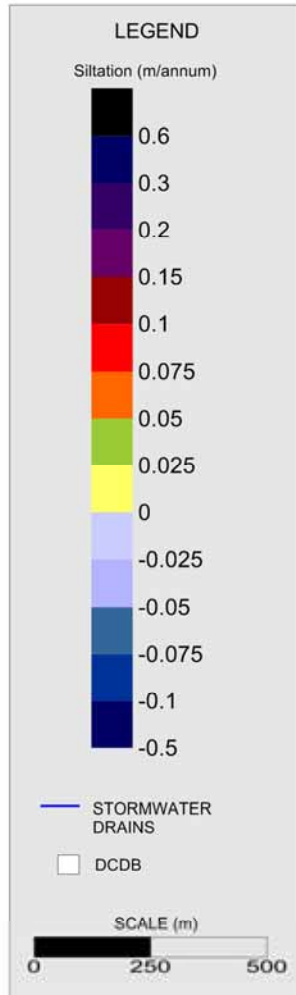
AQUATIC PARADISE ANNUAL SILTATION

CANALS & ENTRANCE CHANNEL
between May 2006 & September 2009



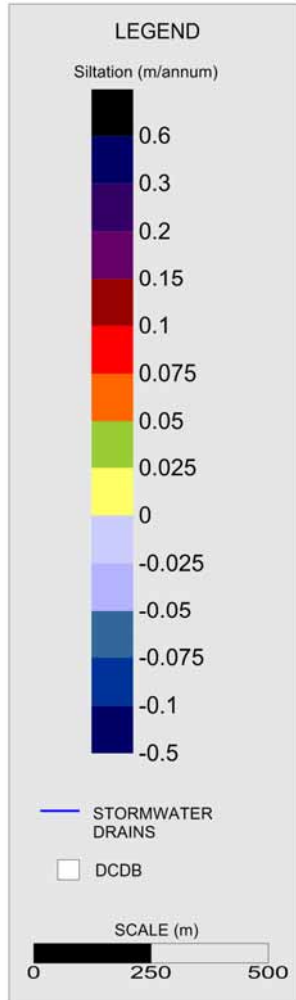
AQUATIC PARADISE ANNUAL SILTATION

CANALS & ENTRANCE CHANNEL
between September 2009 & June 2011

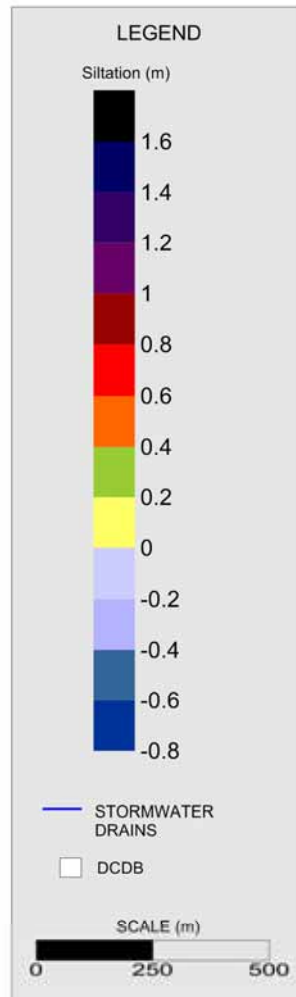


AQUATIC PARADISE ANNUAL SILTATION

CANALS & ENTRANCE CHANNEL
between May 2000 & June 2011



AQUATIC PARADISE SILTATION ABOVE DESIGN LEVELS CANALS & ENTRANCE CHANNEL between Design Bed Levels & June 2011



Appendix C

SEDIMENT SAMPLING PHOTOGRAPHS

Appendix C

Aquatic Paradise Canals – 1 June 2012
Piston sampling

SAMPLE SITE 1



Figure 1
SS 1 TOTAL CORE (0–0.9m)



Figure 2
SS 1 (1 of 6)



Figure 3
SS 1 (2 of 6)



Figure 4
SS 1 (3 of 6)



Figure 5
SS 1 (4 of 6)



Figure 6
SS 1 (5 of 6)



Figure 7
SS 1 (6 of 6)

SAMPLE SITE 2



Figure 8
SS2 TOTAL CORE (0 - 0.75m)

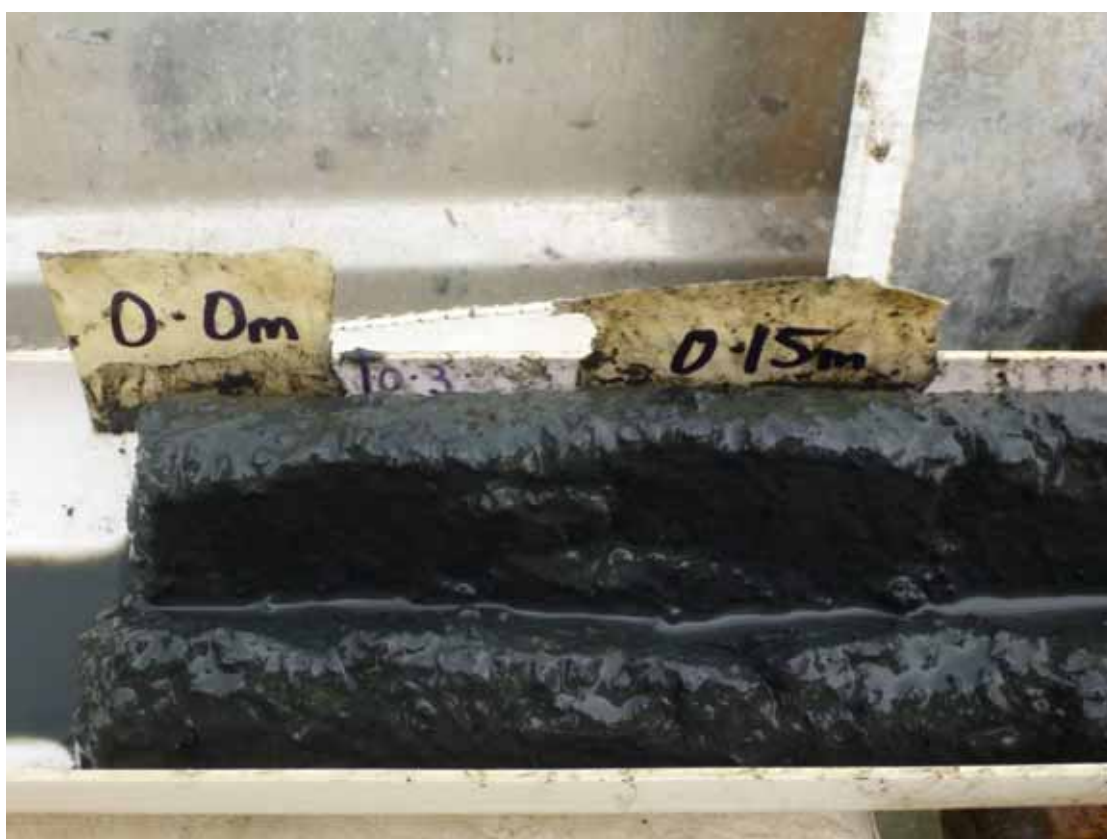


Figure 9
SS 2 (1 of 5)

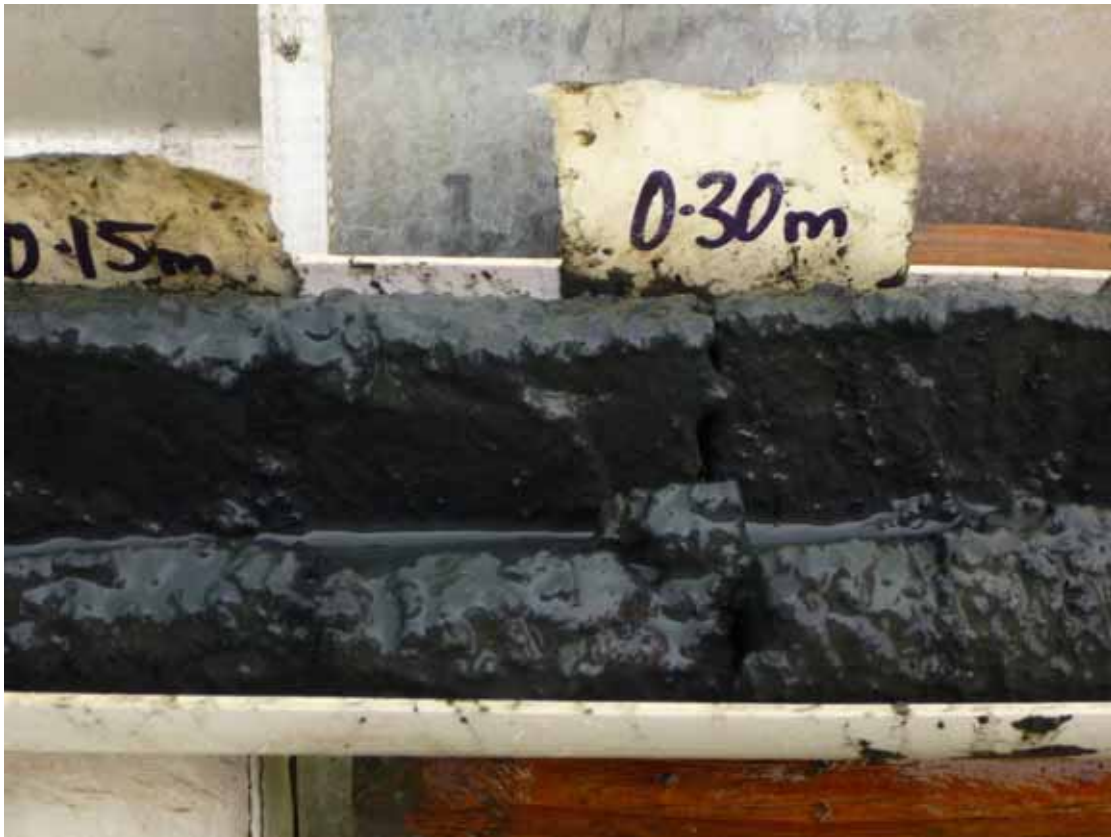


Figure 10
SS 2 (2 of 5)



Figure 11
SS 2 (3 of 5)

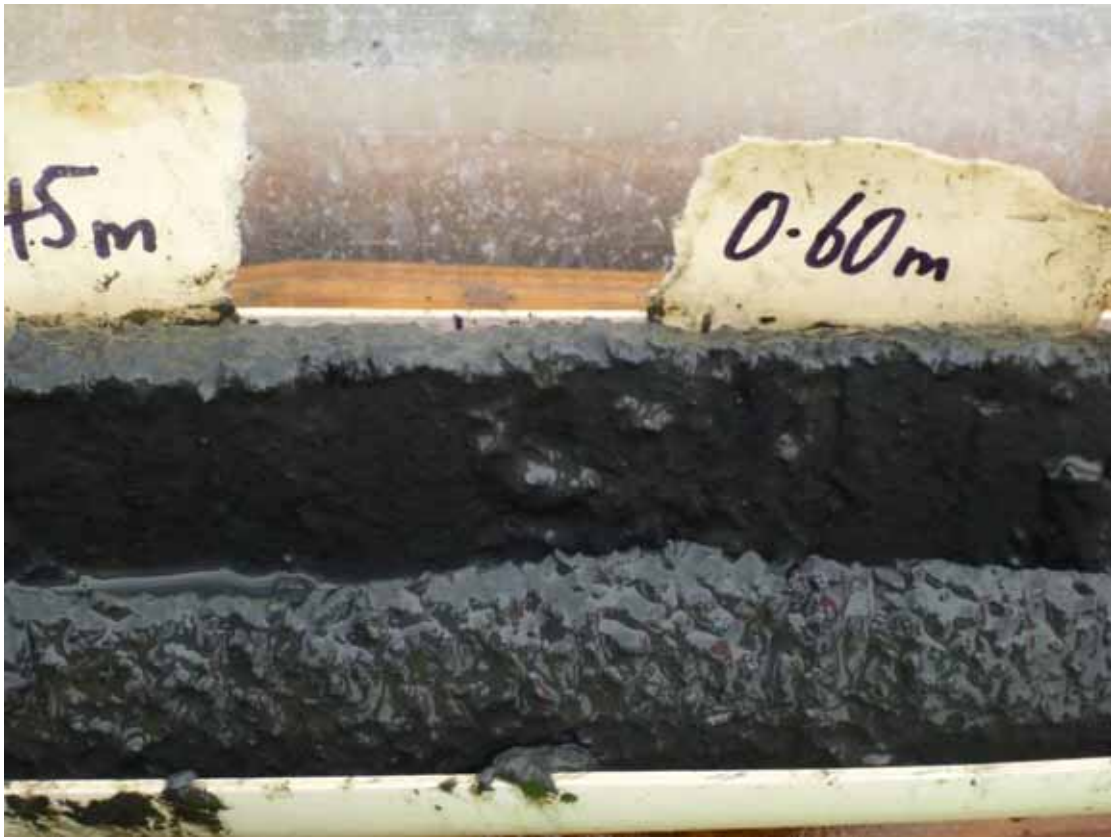


Figure 12
SS 2 (4 of 5)



Figure 13
SS 2 (5 of 5)

SAMPLE SITE 3



Figure 14
SS 3 TOTAL CORE (0 - 0.75m)



Figure 15
SS 3 (1 of 5)



Figure 16
SS 3 (2 of 5)



Figure 17
SS 3 (3 of 5)



Figure 18
SS 3 (4 of 5)

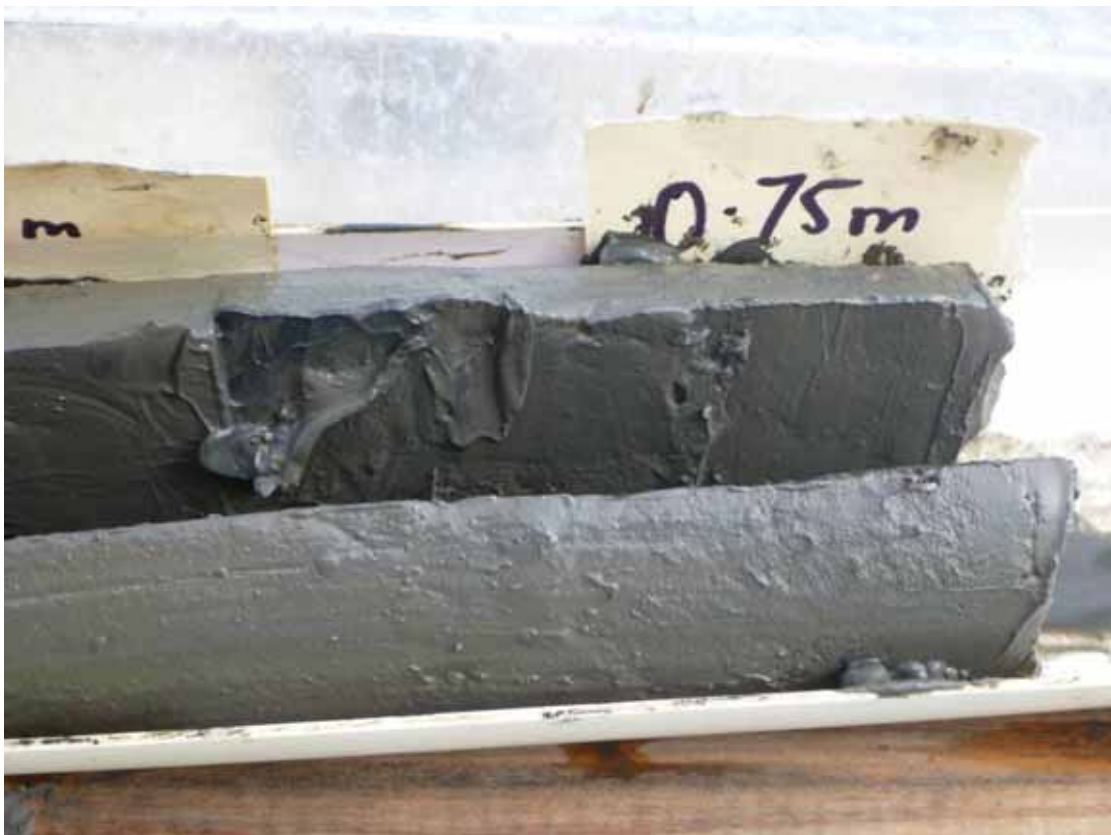


Figure 19
SS 3 (5 of 5)

SAMPLE SITE 4



Figure 20
SS 4 TOTAL CORE (0 - 0.35m)



Figure 21
SS 4 (1 of 3)



Figure 22
SS 4 (2 of 3)



Figure 23
SS 4 (3 of 3)

SAMPLE SITE 5



Figure 24
SS 5 TOTAL CORE (0 - 0.7m)



Figure 25
SS 5 (1 of 5)



Figure 26
SS 5 (2 of 5)



Figure 27
SS 5 (3of 5)



Figure 28
SS 5 (4 of 5)

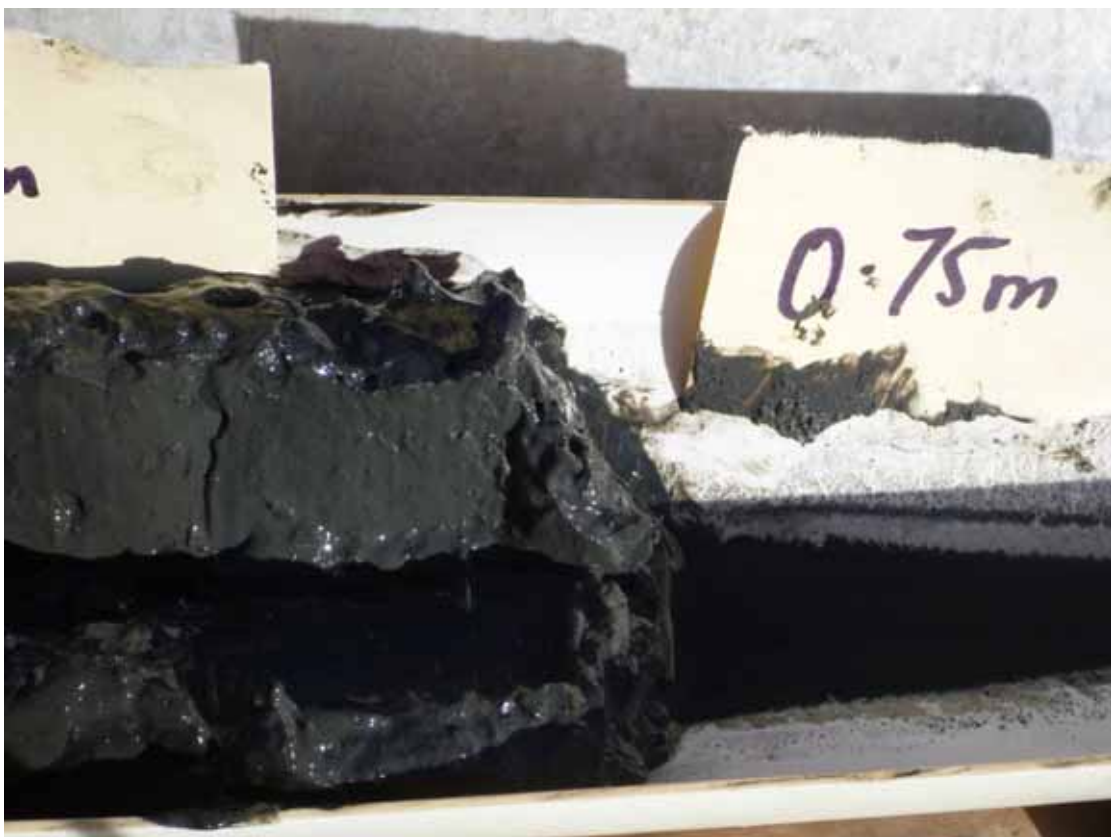


Figure 29
SS 5 (5 of 5)

SAMPLE SITE 6



Figure 30
SS 6 TOTAL CORE (0 - 0.75m)



Figure 31
SS 6 (1 of 5)

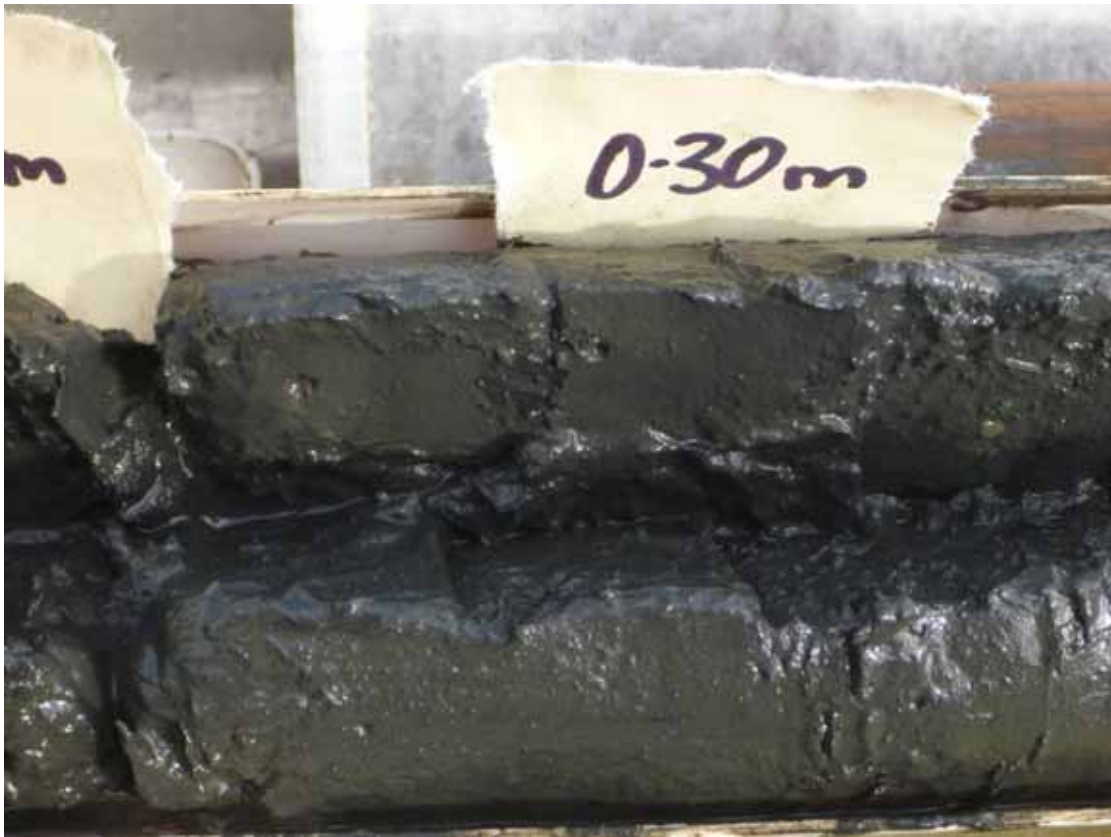


Figure 32
SS 6 (2 of 5)



Figure 33
SS 6 (3 of 5)

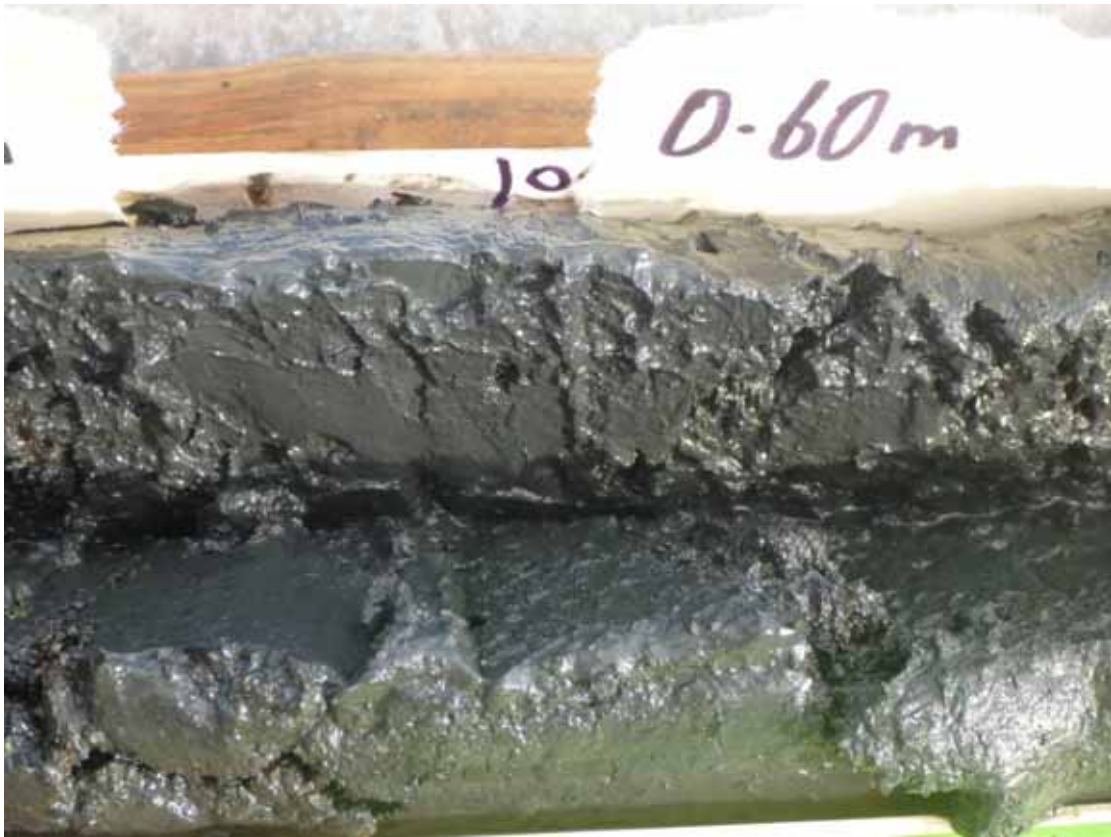


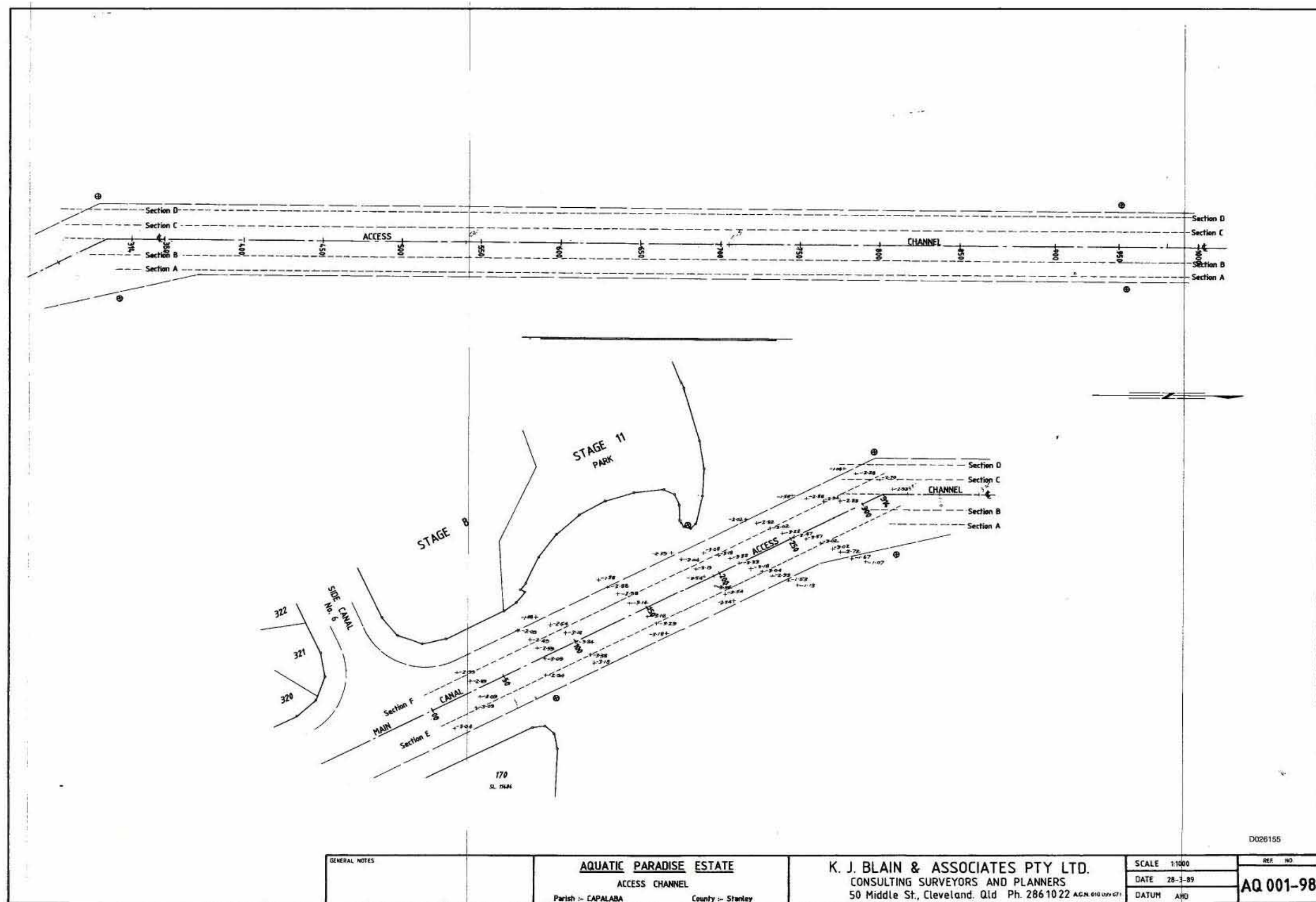
Figure 34
SS 6 (4 of 5)

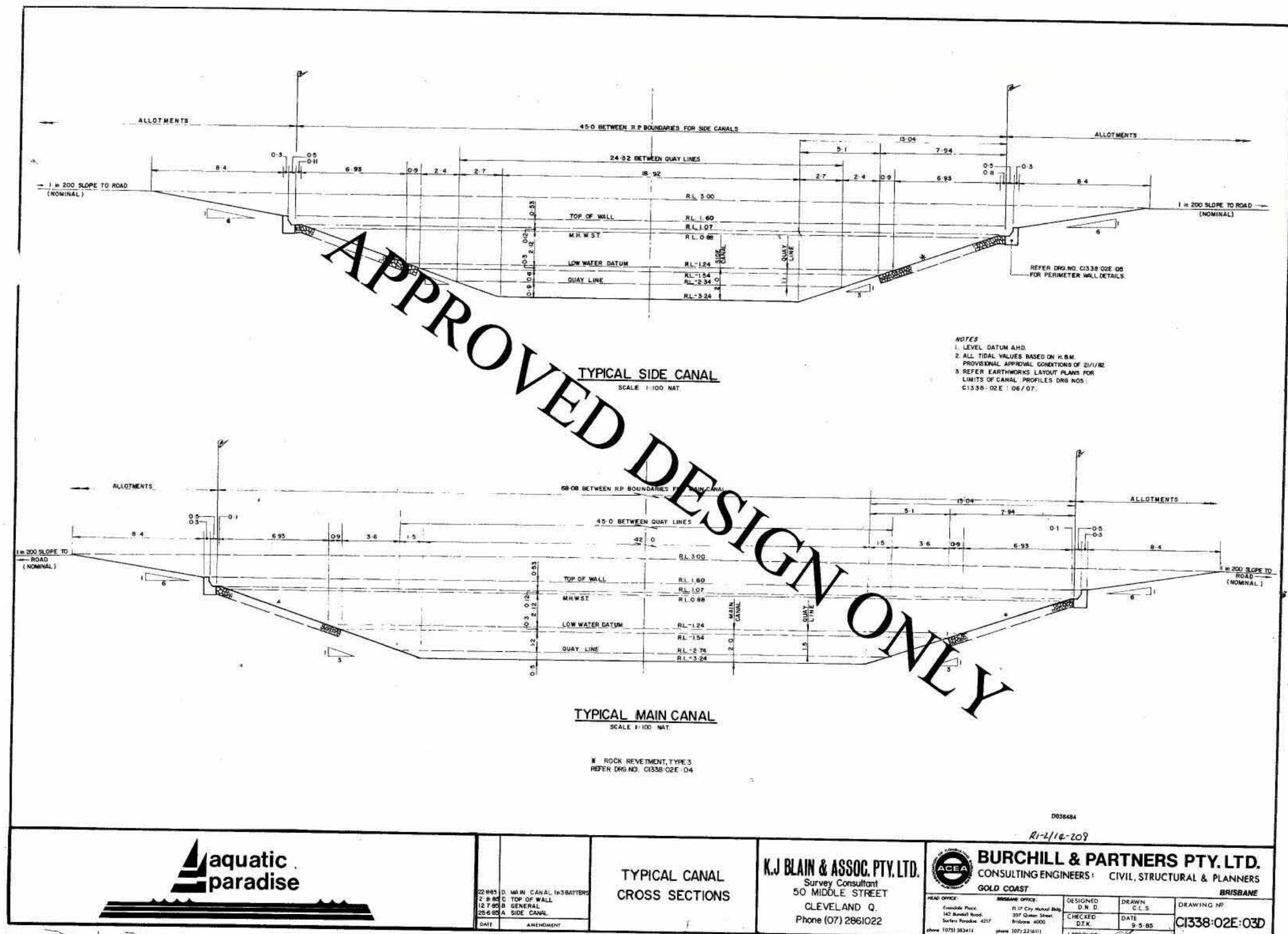


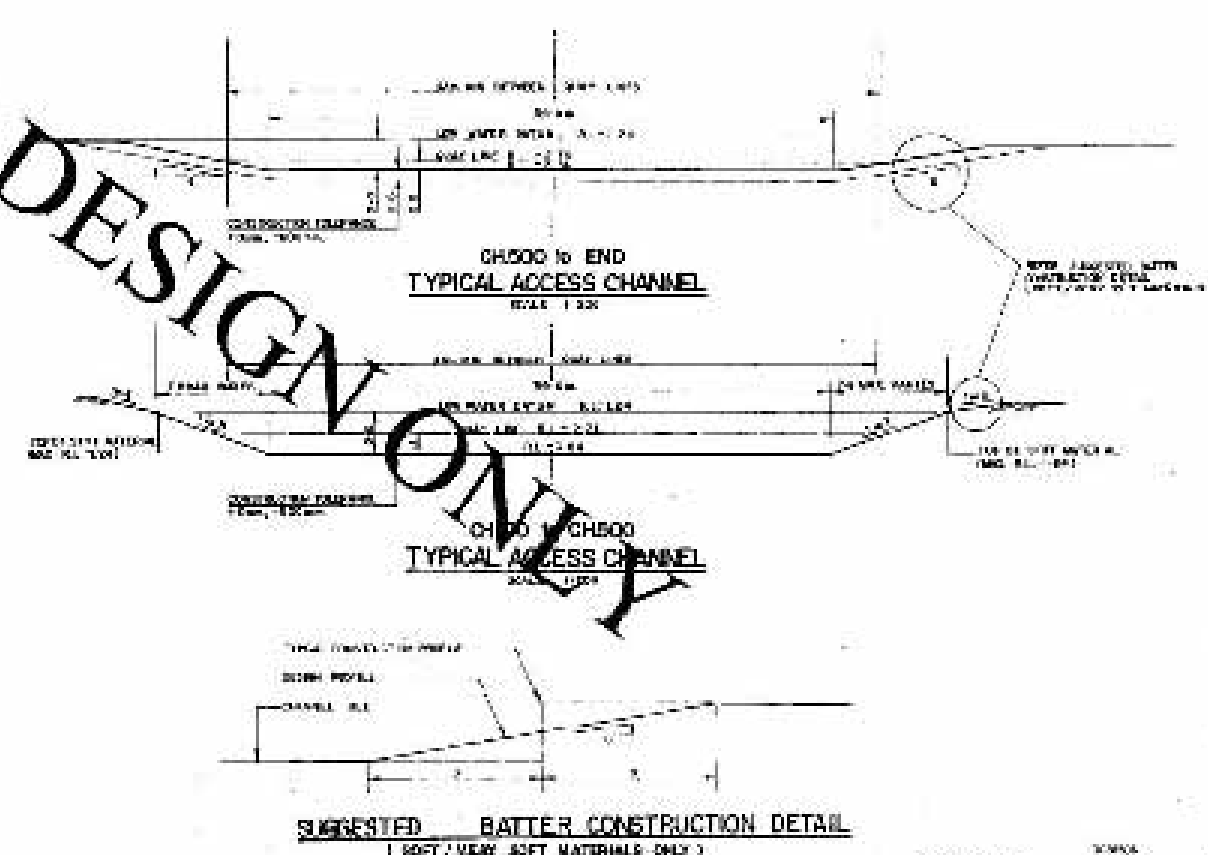
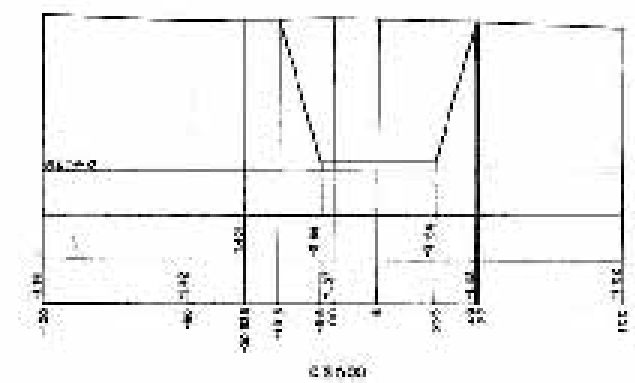
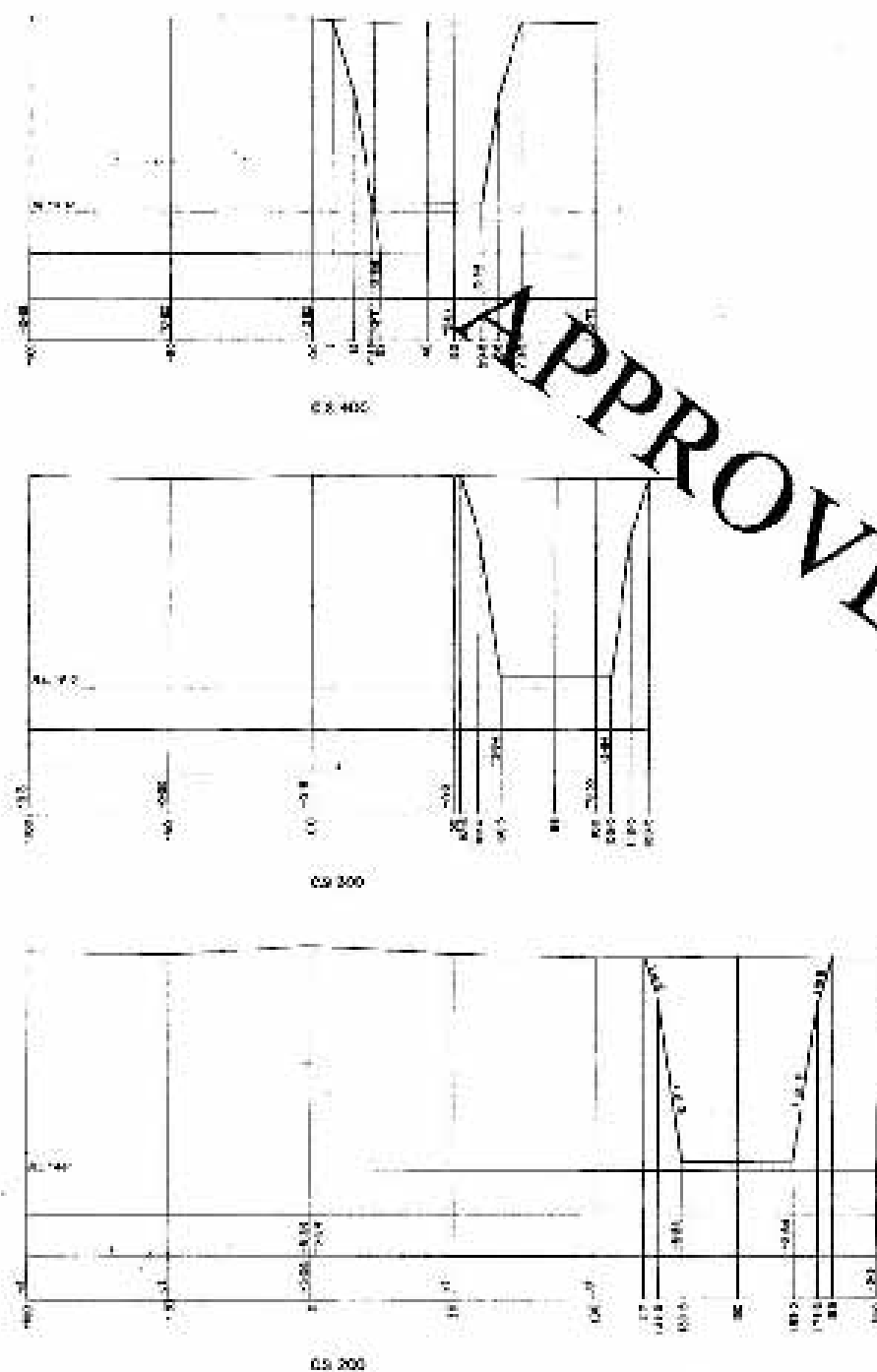
Figure 35
SS 6 (5 of 5)

Appendix D

DESIGN DRAWINGS







ACCESS CHANNEL
TYPICAL SECTIONS AND
CROSS SECTIONS
CH 200 to CH 500

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