G4 | Surface Water

Santos | PETRONAS

Report

Dredge Material Placement Facility
Dewatering Assessment and Preliminary Design

NOVEMBER 2009

Prepared for

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Abbreviations

Abbreviation	Description
AEP	Annual Exceedence Probability
ANRA	Australian Natural Resources Atlas
ANZECC	Australian and New Zealand Environment and Conservation Council
AR&R	Australian Rainfall and Runoff
ARI	Annual Reoccurrence Interval
AWBM	Australian Water Balance Model
BOD	Biological Oxygen Demand
CDFs	Confined Disposal Facilities
CSD	Cutter Suction Dredging
DERM	Queensland Department of Environment and Resources Management (previously EPA)
DMPF	Dredge Material Placement Facility
DO	Dissolved Oxygen
DPA	Dugong Protection Area
EIS	Environmental Impact Statement
EM	Engineering Manual
EPA	Queensland Environmental Protection Agency
GBR WHA	Great Barrier Reef World Heritage Area
GPC	Gladstone Ports Corporation
HAT	Highest Astronomical Tide
HEC-RAS	Hydrologic Engineering Centre River Analysis System
IEAust	Institute of Engineers Australia
LNG	Liquefied Natural Gas
RRL	Rainfall Runoff Library
TSHD	Trailing Suction Hopper Dredger
TSS	Total Suspended Solids
USACE	United State Army Corps of Engineers

Introduction

This report has been prepared as part of the Supplementary EIS to provide additional information on the design of the proposed dredge material placement facility (DMPF) at Laird Point and its impact on surface waters. This report builds on information provided on the material placement facility provided in EIS Section 8.17 and its purpose is to:

- Provide further detail on the DMPF design;
- Refine the surface water impact assessment on the basis of the revised design; and
- Address comments that were raised in government agency and public submissions on the EIS.

1.1 Scope of Work

URS has been engaged to undertake a preliminary design and surface water impact assessment of the proposed DMPF.

A fundamental component of the DMPF design is the dredge spoil dewatering process. This report and associated investigation evaluates settling performance and storage capacity of the facility during the placement process, and in so doing establishes the internal layout of the facility to show that the proposed DMPF design will be able to achieve the required dewatering objectives.

This report should be read in conjunction with Attachments G1-G9 of the EIS Supplement.

1.2 Objectives

The key objectives of the DMPF preliminary design are to:

- Provide adequate storage for the placement of dredged materials, including slurried seawater, during all stages of the dredging operation;
- Achieve required effluent discharge criteria, therefore having little to no impact on sensitive receptors, and
- Providing an efficient dewatering process, that overcomes both operational and constructability limitations.

These objectives are fundamentally interrelated and have been the basis for the preliminary design of the DMPF.

Project Description

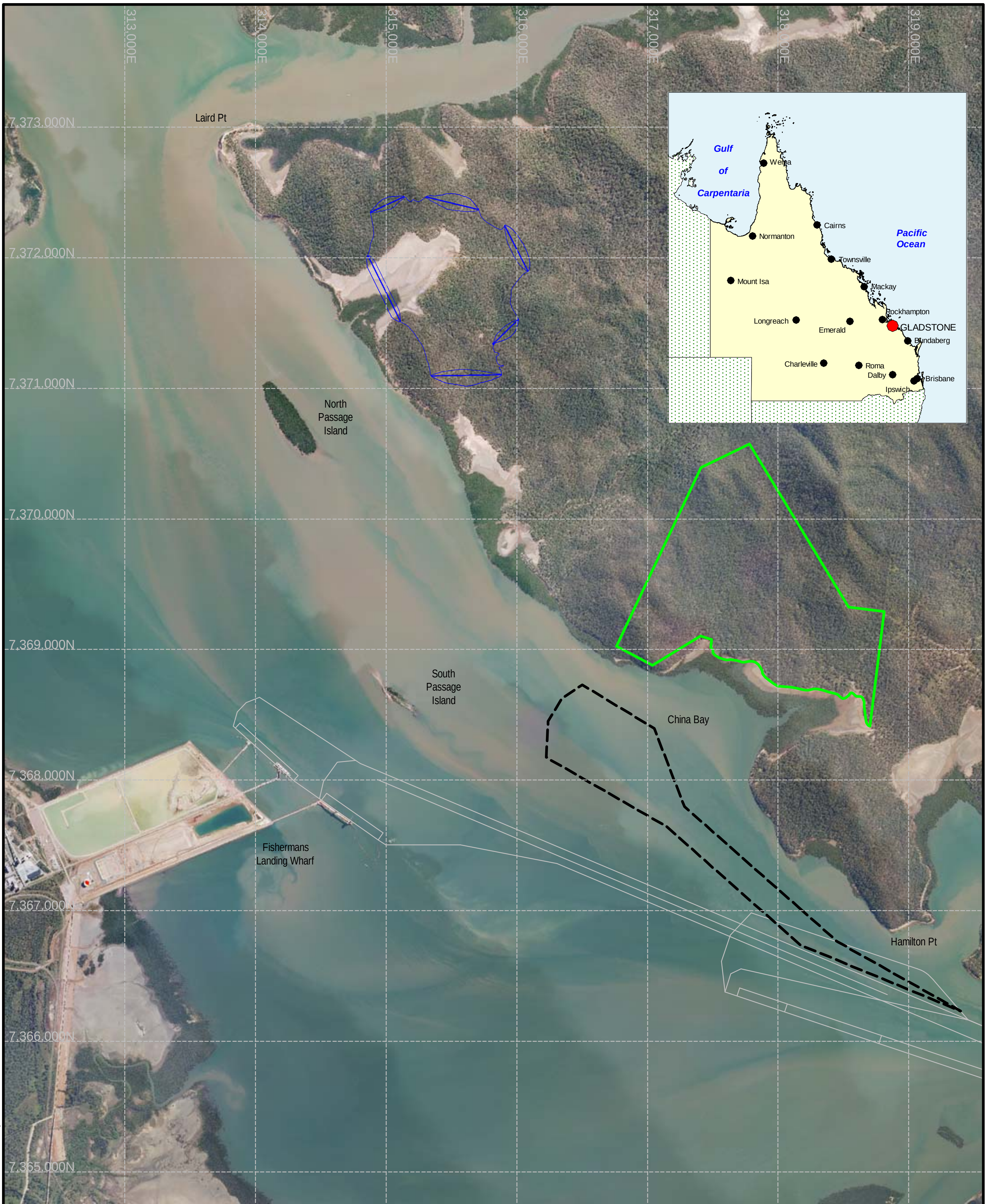
The capital dredging programme to develop an approach channel to the proposed LNG facility on Curtis Island and also to create a new berthing and manoeuvring area for LNG vessels comprises two elements as follows:

- Creation of an approach channel adjacent Hamilton Point and China Bay in Port Curtis to -13.5 m LAT; and
- Creation of a new berthing and manoeuvring area at the proposed LNG facility providing depths of -13.5 m LAT.

The location map shown as Figure 2-1 shows the LNG facility area, the capital dredging area and the dredge material placement facility footprint.

The DMPF will cover an area of approximately 120 ha, and have a capacity of 10.1 million m^3 of consolidated dredged material. The DMPF will also provide some capacity for ongoing maintenance dredging.

A more detailed description of the dredging project, proposed dredging equipment, and dredging scenarios envisaged is provided in Attachment G9.



N W E S

0 750 1500m

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Datum: GDA94

- Existing Channels
- Proposed Dredging Channel
- Dredge Material Placement Facility
- LNG Facility Indicative Site Boundary

Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Client: LNG	Project: GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT SUPPLEMENT — DREDGE MATERIAL PLACEMENT FACILITY DEWATERING ASSESSMENT AND PRELIMINARY DESIGN	Title: **LOCATION PLAN**
URS	Drawn: RG — Approved: JB — Date: 04-11-2009	Figure: **2-1** — Rev:B
	Job No: **4262 6440** /6220 — File No: 42626440-g-2170.wor	A4

Design Criteria and Constraints

3.1 Design Criteria

The design criteria adopted for the design of the DMPF are presented in Table 3-1. The design criteria were developed with reference to the Dredging and Dredged Material Disposal, Engineering Manual EM 11102-5025, Washington, D.C published by U.S Army Corps of Engineers (USACE) and information gathered during site visits.

Table 3-1 Design Criteria Summary

Item	Design Criteria	Source of Information
Design capacity	Initial embankment design to provide storage during dredging operation (48.8 weeks, 6.8 million m^3 of dredged materials)	HR Wallingford
Freeboard	Minimum of 0.6 m	USACE (EM 1110-2-5027)
Ponding depth	Minimum of 0.6 m	USACE (EM 1110-2-5027)
Surface area	120 ha	Shapefile
Effluent Quality	50 mg/L suspended solids concentrations	Consistency with recently approved and concurrent dredging projects in the Port of Gladstone
Length to width ratio to improve settlement efficiency	3:1	USACE (EM 1110-2-5027)
Rainfall	Highest rainfall event in 100 years commencing 1900 to 2000	Bureau of Meteorology

3.2 Constraints

The design of a DMPF requires careful evaluation of the design criteria in conjunction with design constraints. As part of the design approach, an evaluation of potential design constraints was performed. Section 3.2.1 to 3.2.5 discusses the potential design constraints that were considered in the design of the DMPF.

3.2.1 Facility Life

The proposed LNG facility is anticipated to have a lifespan of 20 years. In order to maintain the channel depth required for LNG vessels during the lifespan of the LNG facility, periodic additional maintenance dredging may be required. Therefore the DMPF will have the same lifespan as that of the proposed LNG facility.

3.2.2 Landform Constraints

The shape of the disposal area is constrained by the natural topographical and drainage constraints present on the site. Key landform constraints include the following:

- Footprint extent – Gas Transmission Pipeline (GTP) Corridor on the North and East boundary and Queensland Gas Company (QGC) property on South boundary (as shown in Figure 3.1);
- Proximity to shore; and
- Encroachment on Grahams Creek and adjacent catchments.

At this stage of DMPF design no constraints have been placed on the maximum allowable height for the embankments.

3.2.3 Future Land Use Constraints

The final landform of the DMPF is expected to be stable and free draining once rehabilitation works have been completed, but the nature of the dredge material and underlying soft clay foundation are potential key constraints on the future land use of the site. Potential future land uses could include possible commercial or industrial use or as native vegetation and habitat. While the DMPF area will become temporarily unsuitable as a habitat for flora and fauna during the construction and operation of the facility, it is anticipated that a short time after the capital dredging is completed and a majority of the area is rehabilitated, the area should quickly revegetate and regain productivity (Herbich, 1992).

3.2.4 Constructability

The availability of material for construction has constructability and cost implications. It is anticipated that construction materials will either be locally sourced, imported or utilise dredged materials. Potential constraints on construction material are as follows:

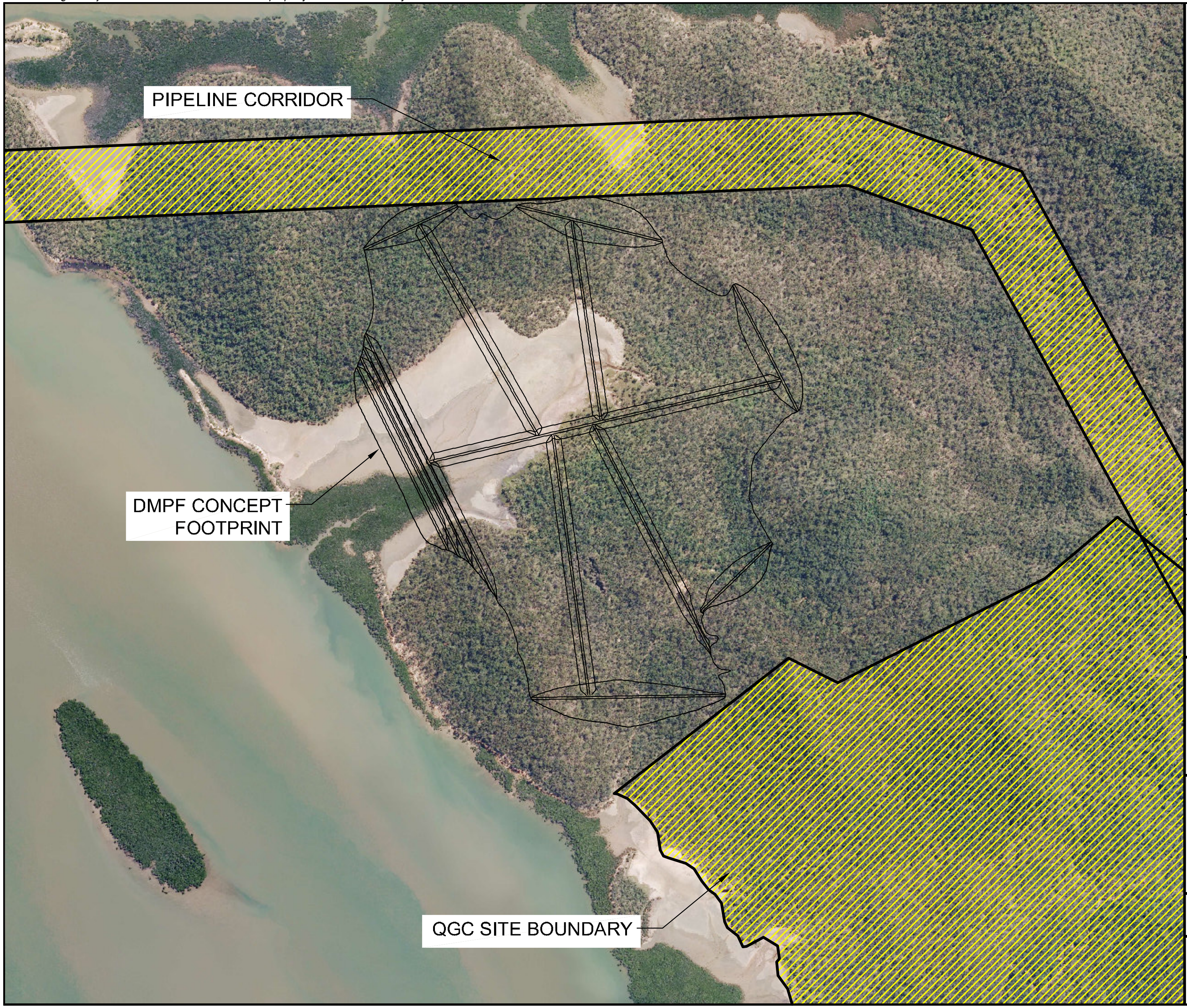
- Potential off-site sources;
- Availability of on-site rock borrow;
- Potential location for on-site quarry facility; and
- Barge access.

3.2.5 Access Requirements

Site access is essential for the construction, operation and management of the DMPF. Access to the facility is mainly constrained by the surrounding landform. Considerations for access include:

- Roads for earthmoving equipment;
- Barge access locations;
- Jetty location/use;
- Booster station; and
- Dredge slurry transfer pipeline.

Access to the site for both facility and workforce is proposed to be either via a causeway located on the existing tidal surface at the front of the facility or at the alternative landing point location indicated on Figure 3-2.



Source: 42626450	
Drawn: TMA	Approved: JW	Date: 28/10/2009
Job No.: 4262 6444 /6220	File No.: 42626440-g-2116.dwg

Client: LNG

Project: GLADSTONE LNG PROJECT ENVIROMENTAL IMPACT STATEMENT SUPPLEMENT DREDGE MATERIAL PLACEMENT FACILITY DEWATERING ASSESSMENT AND PRELIMINARY DESIGN

Title: LANDFORM CONSTRAINTS

Figure: 3-1 | Rev. A | A4

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LEGEND

PIPELINE ROUTE

PROPOSED DREDGING

150 0 150

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Source: 42626450

Drawn: TMA	Approved: JW	Date: 28/10/2009
Job No.: 4262 6444 /6220	File No.: 42626440-g-2120.dwg	

Client

LNG

Project
GLADSTONE LNG PROJECT
ENVIROMENTAL IMPACT STATEMENT
SUPPLEMENT
DREDGE MATERIAL PLACEMENT FACILITY
DEWATERING ASSESSMENT AND
PRELIMINARY DESIGN

Title
DREDGED MATERIAL TRANSPORT TO DMPF

Figure: **3-2** Rev. B A4

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Dredge Material Characteristics

The characteristics of the dredge material are a key consideration in the design and operation of the DMPF. The physical properties determine the storage capacity and detention time required for appropriate settlement. The presence of contaminants in dredge material will determine the potential surface water and groundwater impacts that may arise from the storage and dewatering of dredge material with the DMPF.

4.1 Dredge Volumes

There are broadly two types of material to be dredged, loose sandy silt and a small amount of rock. Table 4-1 shows the estimated proportions of sand and rock in the dredge areas.

Table 4-1 Dredge Material Volumes

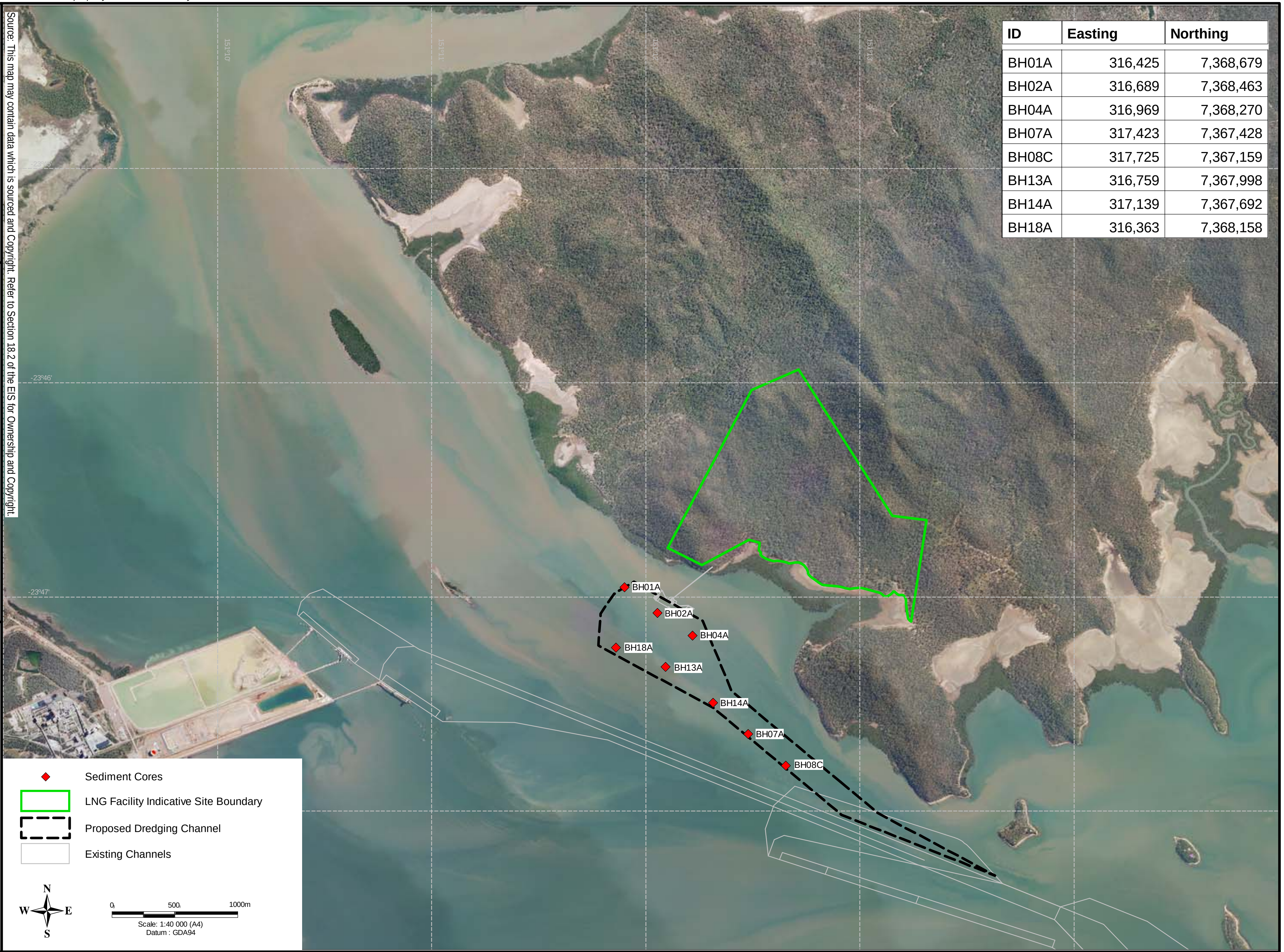
Dredge Area	Dredge volumes (m^3) in situ		Total Volume (m^3) in situ
	Sandy Silt	Rock	
GLNG basin	5,482,000	193,000	5,675,000
North China Bay Approach Channel	1,079,000	0	1,079,000
Total volume (m^3)	6,561,000	193,000	6,754,000

4.2 Laboratory Testing

A field sampling program was undertaken to supplement the assessment of dredge sediments presented in EIS Appendix R3.

Intact sediment cores were collected using a vibracorer from eight locations within the capital dredging area. The sampling locations are presented in Figure 4-1. Sampling locations were selected based on proximity to sites that had previously been sampled during the EIS as discussed in EIS Appendix R3. Sediment samples were taken from each sediment core at each change in lithology and submitted for laboratory analysis. The laboratory testing comprised the following:

- Particle Size Distribution;
- Zone settlement; and
- Sediment Quality
  - Metal Leachate.



ID	Easting	Northing
BH01A	316,425	7,368,679
BH02A	316,689	7,368,463
BH04A	316,969	7,368,270
BH07A	317,423	7,367,428
BH08C	317,725	7,367,159
BH13A	316,759	7,367,998
BH14A	317,139	7,367,692
BH18A	316,363	7,368,158

Client

URS

LNG

Project

GLADSTONE LNG PROJECT
ENVIRONMENTAL IMPACT STATEMENT
SUPPLEMENT
DREDGE MATERIAL PLACEMENT FACILITY
DEWATERING ASSESSMENT AND PRELIMINARY DESIGN

Drawn: RG | Approved: JB | Date: 04-11-2009

Job No: **4262 6440** /6220 | File No: 42626440-g-2165.wor

Title

SEDIMENT CORE INVESTIGATION

Figure: **4-1**

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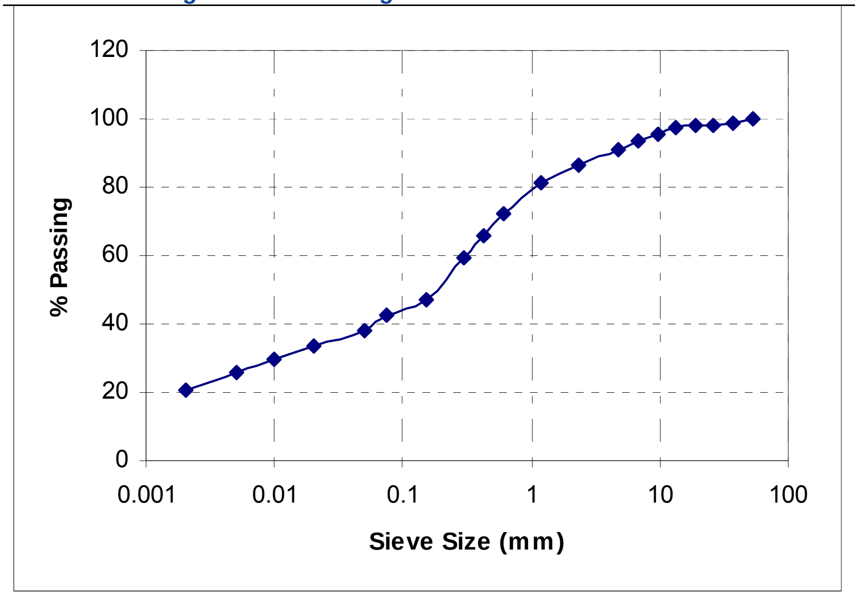
4.2.1 Particle Size Distribution (PSD)

PSD analysis was conducted by sieve and hydrometer by Australian Soil Testing laboratories in accordance with USACE EM 1110-2-5027. The laboratory results for the PSD analysis and a description of the material present in each sediment sample are presented in Appendix A.

The PSD results were combined to estimate the anticipated particle size distribution of dredge material that would expected for the duration of the dredging program. This average particle size distribution is provided in Figure 4-2.

Figure 4-2 Average Particle Size Distribution



The average PSD indicates that approximately 57 % of the dredged materials are coarse gained and 43 % are fine grained where USACE EM 1110-2-5027 defines coarse grained materials to be > 0.075 mm (>No. 200 sieve). The PSD of Borehole 07A (0-1.0 m) and 08C (4.74-5.6 m) most closely reflect this average PSD and are described as silty sand. This average PSD has been assumed for design purposes as representative of the material within the dredging channel.

4.2.2 Zone Settlement

Zone Settling analysis was conducted on samples of dredge material at Australian Soil Testing laboratories in accordance with the method described in USACE 1987.

An initial dry weight of 50 g from each borehole core layer was placed in a cylinder and filled with seawater (19°C) to a height of 344 mm (1 L). This equates to a ratio of approximately 1:10 to 1:20 of sediment (ranging from saturated to dry) to water. The interface between the supernatant and the settling materials was observed and recorded over time. The final settlement time was a visual observation, chosen conservatively as the time when zone settling was complete. Using the time to 100 % settlement and the change in height the zone settling velocity for each sample was calculated.

4 Dredge Material Characteristics

Analysis

Results of the zone settling tests are provided in Appendix A. In general the samples containing higher portions of sand and lower portions of clays/silts have a faster settling velocity shown with a steeper initial curve in the zone settling tests. The samples with increasing clay content settle at slower rates and flocculate together to have a higher final settlement height. The higher content of fines (i.e. the flatter the PSD curve) tends to increase the initial settling time and also the height of the sediment during zone settlement. Those with a sandy clay description have the highest final settlement height, compared to silty clay.

The zone settling results are summarised in Table 4-2.

Table 4-2 GLNG Sample Settling Rates

PSD	Time to 100% Settlement (min)	Settling Velocity, v_s (m/s)
Average Sample	620	5.16E-05
Sample with a larger proportion of fines	1440	3.32E-06
Sample with a larger proportion of coarse particles	15	3.48E-04

The zone settling results were compared with particle size settling velocities predicted by Stokes' Law to validate the testing results and also identify critical particle sizes for settling. This comparison found that the settling velocity for the average sample is equivalent to that for a particle sized between 0.005 mm – 0.01 mm whilst the slowest settling velocity corresponds to that for a 0.002 mm sized particle.

The 0.002 mm particle size was selected as the critical particle size for settlement of the samples with the slowest settling velocities. This is a conservative estimate as it does not allow for any flocculation of the clay/silt fraction within the facility.

4.2.3 Sediment Quality

The quality of marine sediment within the proposed capital dredge area was investigated as part of the EIS Marine Sediment Investigation report (EIS Appendix R3). This report found elevated concentrations of antimony, arsenic, chromium, copper, manganese, mercury and nickel within the dredge material. These levels were generally found at depths greater than 1.0 m BSB. It was concluded that it is likely that the presence of metals in marine sediments is naturally occurring as several metals were consistently present at higher concentrations in the residual material than the overlying sediment. It was also stated in the report that despite the likelihood of metals being naturally occurring, that metals present in the material may be mobilised during the dredging activity and potentially pose a risk to any receiving environment where dredging waters are released.

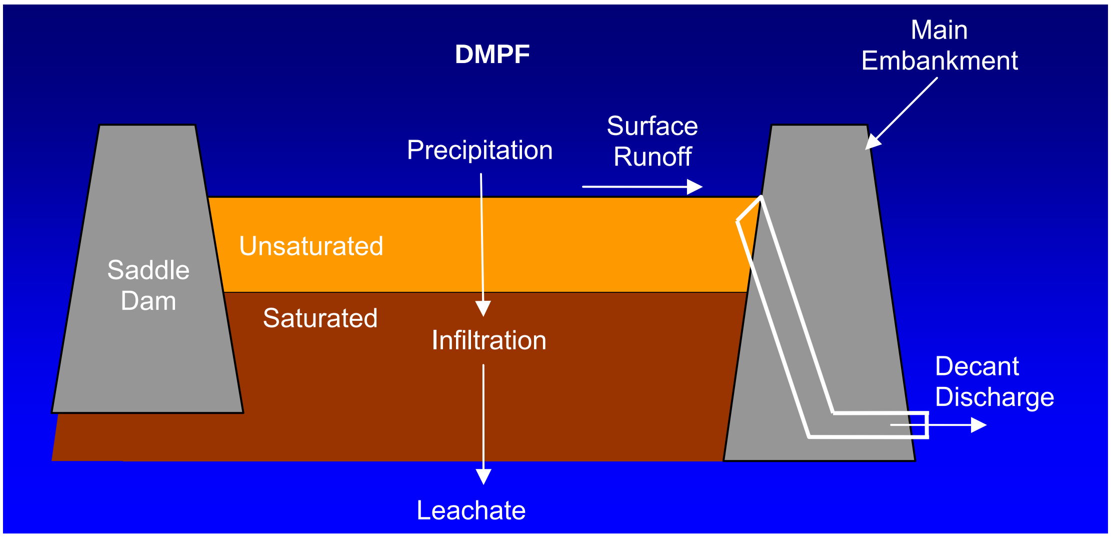
The US Army Corps of Engineers (USACE 2003) has defined three key pathways by which contaminants associated with dredge material may be mobilised and pose a risk to the receiving environment. These pathways are:

1. Decant discharges to surface water during filling operations and subsequent settling and dewatering
2. Precipitation surface runoff

3. Leachate into groundwater

The potential mobilisation pathways are represented in Figure 4 – 3 below.

Figure 4-3 Schematic of potential contaminant migration pathways for the DMPF (adapted from (USACE 2003)



In order to assess the potential for metals to be mobilised, and pose a risk to the receiving environment of the DMPF, intact sediment cores where collected using a vibracorer from eight locations within the capital dredging area and submitted for laboratory analysis. Sampling locations were selected based on proximity to sites that had previously been sampled during the EIS and discussed in Appendix R3. Sub-samples were taken from each sediment core at the changes lithology.

Laboratory Analysis

A total of 26 sediment samples were submitted to ALS laboratories for elutriate and leachate analysis for Aluminium, Arsenic, Cadmium, Chromium, Copper, Iron, Lead, Manganese, Nickel and Zinc.

- Elutriate Testing

Elutriate testing was undertaken in accordance with the methods described in the National Assessment Guidelines for Dredging 2009 (NAGD, 2009) to assess the potential for metals to be mobilised from dredge material and impact marine water quality through decant discharges from the DMPF during filling operations and subsequent settling and dewatering.

The elutriate test involves the mixing of sediment with seawater in a ratio of 1:4. The test simulates the effects of dredging on the release of bound contaminants near the dredge head and during the transfer from the dredger to the DMPF and subsequent decant discharge from the DMPF.

Test results are normally compared to the relevant Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ 2000a,b) trigger values for 95 percent protection.

- Leachate Testing

4 Dredge Material Characteristics

Leachate testing was undertaken in accordance with the Australian Standard Leaching Procedures (AS4439.3 and AS4439.2) using deionised water as leaching fluid. The purpose of the analysis was to assess the potential for metals to leach from stored sediment in the DMPF following rainfall and to cause environmental impacts through discharges to surface water in surface runoff or migration to groundwater.

Results and Discussion

The elutriate and leachate testing results are presented in Appendix D. .

- Elutriate Testing

The elutriate results are summarised in Table 4-3. Relevant ANZECC 2000 trigger values are provided, where available, for comparison purposes.

Table 4-3 Summary elutriate results

	Aluminium	Arsenic	Cadmium	Chromium	Copper
Minimum (µg/L)	<10	<0.5	<0.2	<0.5	<1
Maximum (µg/L)	260.0	14.4	0.8	0.6	4.0
Average (µg/L)	44.0	4.4	<0.2	<0.5	<1
ANZECC 2000 (Ambient WQ Sampling Results)	ID (170 – 1210)	ID (7 – 18)	5.5 (LD – 2.7)	27.4 (LD – 9)	1.3 (LD - 28)
	Iron	**Lead**	**Manganese**	**Nickel**	**Zinc**
Minimum	<5	<0.2	63.3	<0.5	<5
Maximum	688.0	<0.2	2520.0	4.9	22.0
Average	96.2	<0.2	1117.1	1.6	3.8
ANZECC 2000 (Ambient WQ Sampling Results	ID (460 - 2030)	4.4 (LD – 8)	ID (5-31)	70 (LD – 7)	15 (LD – 39)

- ID = Insufficient data is available to define a trigger value.
- (Ambient WQ Sampling Results) = Measured range for Port Curtis waters in the vicinity of the discharge location. These results are presented in Appendix E.

Aluminium

Aluminium results ranged from below detection limits to 260 µg/L with the average concentration being 44 µg/L. No ANZECC 2000 trigger value has been established for aluminium (due to insufficient data) to enable the significance of the measured results to be determined. However a comparison of the results with water quality monitoring data from the vicinity of the proposed discharge from the DMPF shows that the results are within the natural range (Appendix D).

Arsenic

Arsenic was detected at concentrations up to 14.4 µg/L with the average concentration being 4.4 µg/L. No ANZECC 2000 trigger value has been established for arsenic (due to insufficient data) to enable the significance of the measured results to be determined. However a comparison of the results with water quality monitoring data from the vicinity of the proposed discharge from the DMPF shows that the results are within the natural range (Appendix D).

Cadmium

Cadmium was generally absent from the elutriate samples. Only one sample recorded a result which was above detection limit and this was well below the ANZECC 2000 trigger value.

Chromium

Chromium was only detected in one sample and the concentration detected was well below the ANZECC 2000 trigger value.

Copper

Copper was generally absent from the samples with the exception of three samples for which concentrations ranged from 2 – 4 µg/L. These concentrations exceed the ANZECC 2000 trigger value however they are well within the natural range recorded during water quality sampling in the area (Appendix D).

Iron

Iron was detected in the majority of samples at concentrations ranging from 6 µg/L to 688 µg/L. An ANZECC 2000 trigger value has not been established for iron (due to insufficient data) to enable the significance of the measured results to be determined. However a comparison of the results with water quality monitoring undertaken in the vicinity of the proposed discharge from the DMPF shows that the results are within the natural range (Appendix D).

Lead

Lead was not detected in any of the elutriate samples.

Manganese

Manganese was detected in all samples at concentrations ranging from a low of 63 µg/L to a high of 2520 µg/L with average concentrations across all samples being approximately 1100 µg/L. No specific guideline levels for manganese are specified in the ANZECC 2000 guidelines due to insufficient data. Manganese is a naturally occurring element that is found in rock, soil and water. It is ubiquitous in the environment and comprises about 0.1 % of the

Earth's crust. Given the absence of specific guideline levels and the high levels present in sediment it is likely that manganese is naturally occurring in the area and will not pose a significant risk to the receiving environment

Nickel

Nickel was detected in the majority of elutriate samples. The maximum concentration recorded was 4.9 µg/L which is well below the ANZECC 2000 trigger value.

Zinc

Zinc was detected in three of the elutriate samples. The recorded concentration range from 6 µg/L to 22 µg/L. Whilst this maximum value exceeds the ANZECC 2000 trigger value it is well within the natural range recorded within Port Curtis (Appendix D).

The elutriate testing results indicate that there is a low potential for dredge materials to pose a risk to ambient water quality either at the dredge head or through the discharge of decanted seawater from the DMPF

4 Dredge Material Characteristics

- Leachate Testing

The leachate testing results are provided in Appendix D. Summary leach results are provided in Table 4-4.

Table 4-4 Summary leach results

	Aluminium	Arsenic	Cadmium	Chromium	Copper
Minimum (µg/L)	240.0	1.0	0.1	1.0	2.0
Maximum (µg/L)	17800.0	27.0	2.4	30.0	50.0
Average (µg/L)	4921.3	12.2	0.6	8.6	11.4
ANZECC 2000 (Ambient WQ Sampling Results)	ID (170 – 1210)	ID (7 – 18)	5.5 (LD – 2.7)	27.4 (LD – 9)	1.3 (LD - 28)
	Iron	**Lead**	**Manganese**	**Nickel**	**Zinc**
Minimum	110.0	1.0	8.0	1.0	15.0
Maximum	36800.0	200.0	296.0	15.0	526.0
Average	6344.6	17.3	70.8	5.2	120.5
ANZECC 2000 (Ambient WQ Sampling Results	ID (460 - 2030)	4.4 (LD – 8)	ID (5-31)	70 (LD – 7)	15 (LD – 39)

The results shown in Table 4-4 show that the dredge material has the potential to generate metal containing leachates following rainfall. As mentioned previously there are two main pathways by which leachates may migrate to the environment: surface runoff and migration to groundwater. Each of these pathways has been assessed separately to assess the potential for adverse impact on the receiving environment.

a. Surface Runoff

To interpret the potential impacts that may arise from surface runoff, the leach results have been compared against ANZECC (2000) guidelines as a highly conservative approach.

Aluminium

Aluminium leach results ranged from 240 µg/L to 17,800 µg/L with average concentrations being 4921 µg/L. No trigger values have been established for aluminium. However the results correspond with elevated aluminium concentrations that were detected in marine sediments and consequently are considered to be naturally occurring and therefore unlikely to pose a significant problem.

4 Dredge Material Characteristics

Arsenic

Arsenic was detected in leach samples from most locations sampled at concentrations ranging from 1.0 µg/L to 27 µg/L. No prescribed ANZECC (2000) limits have been established for arsenic. It is not expected that the concentrations detected would pose a significant environment risk. Arsenic leach results ranged from 1 to 27 µg/L. No trigger values have been established for arsenic. The concentrations detected are considered to be a naturally occurring problem.

Cadmium

Cadmium was detected in leachates from nine samples. All concentrations detected were below the ANZECC (2000) trigger value of 5.5 µg/L.

Chromium

Chromium was detected in leachates from 24 samples in generally low concentrations. Two leachates exceeded the ANZECC (2000) guideline of 27.4 µg/L.

Copper

Copper was detected in leachate from 22 samples. The concentrations generally exceeded the ANZECC (2000) guideline of 1.3 µg/L. Interestingly copper was only detected in low concentrations within the dredge sediment.

Lead

Lead was detected in leachates from 18 samples at generally low concentrations. Three samples exceeded the ANZECC (2000) guidelines for lead of 4.4 µg/L.

Manganese

Manganese was detected at moderate concentrations in leachates from all locations.

Nickel

Nickel was detected in low concentrations in 20 samples. All samples were below the ANZECC (2000) guideline value of 70 µg/L.

Zinc

Elevated zinc concentrations were detected in leach samples from all locations. The minimum concentration detected was equivalent to the ANZECC (2000) trigger value of 15 µg/L and the maximum was 526 µg/L. Elevated zinc levels have been reported for water samples collected from Port Curtis (see Appendix D). It is uncertain whether these levels are naturally occurring or whether they represent contamination of sediments and pose an environmental risk.

The results indicate that occasional exceedances of water quality guidelines may occur for copper and lead and regular exceedances for copper and zinc, should surface runoff concentrations mirror those detected in leach samples. However the likelihood of surface runoff being discharged at concentrations approaching leach results is extremely low. During operation of the facility any leachate generated from rainfall will be significantly diluted by transport water prior to discharge. Following closure, the DMPF will be transformed into a stable free-draining landform by reshaping the surface to promote controlled runoff and prevent ponding of water. The prevention of water from ponding on the surface will minimise the opportunity for the formation of metal containing leachates in surface runoff. Runoff from higher elevations around the periphery would be directed in a controlled manner along a network of surface drains toward the centre of the landform then to the spillway. The spillway would serve as a chute directing surface waters to Port Curtis.

b. Migration to groundwaters

The potential for leachate migration to groundwater is discussed in the Hydrogeological (Groundwater) Study undertaken for the DMPF (Attachment G3). The hydrogeology study found as a consequence of the short seepage period, slow groundwater migration, and limited alteration in groundwater patterns the impact of seepage on the groundwater resources and ocean (once groundwater reaches the ocean) will be reduced due to dilution, attenuation, and limited source. This suggests that the potential impacts of leachates forming within the facility will be low.

4.3 Consideration of Swell – Indicative Factor

When a dredger lifts material off the seabed, the volume which this material occupies in the DMPF can be larger than the volume it occupied in the ground. This increase in volume can be expressed by the ratio of the volume of the soil in the containment area after dredging to that volume of the soil in situ and is known as the bulking factor. In practice, a change in density is caused by the formation of additional voids in the soil or rock which reduces the dry density.

Bulking factors vary greatly for different types of soil, different particle size distributions and for different methods of dredging. In the majority of cases cited in literature, dredging operations rely heavily on practical experience to predict bulking factors. This is consistent with BS 6349 Part 5 which qualifies its guidance by noting that 'experienced judgement is required to provide reliable estimates on volumetric changes'.

When material is being dredged with a CSD, and in particular for soils with a low in situ density and relatively high fines content, a bulking factor of between 1.1 and 1.4 can be expected.

A bulking factor of 1.4 has been utilised for the purposes of this assessment as a conservative worst case scenario and the actual bulking factor may be smaller

Discharge Criteria

5.1 Overview

Discharges of seawater will occur from the DMPF through dewatering of the dredge spoil that has been deposited in the facility. It is estimated that the volume of seawater discharge will be approximately 170 ML/day. These discharges have the potential to have a negative impact on the receiving environment if the quality of the discharge is not appropriately controlled through adequate design.

5.2 Regulatory Requirements

In Queensland, effluent discharges to the marine environment are regulated by the Department of Environment and Resource Management (DERM). When new infrastructure is proposed, a licensing agreement is formed as part of the planning process, to permit offsite discharges.

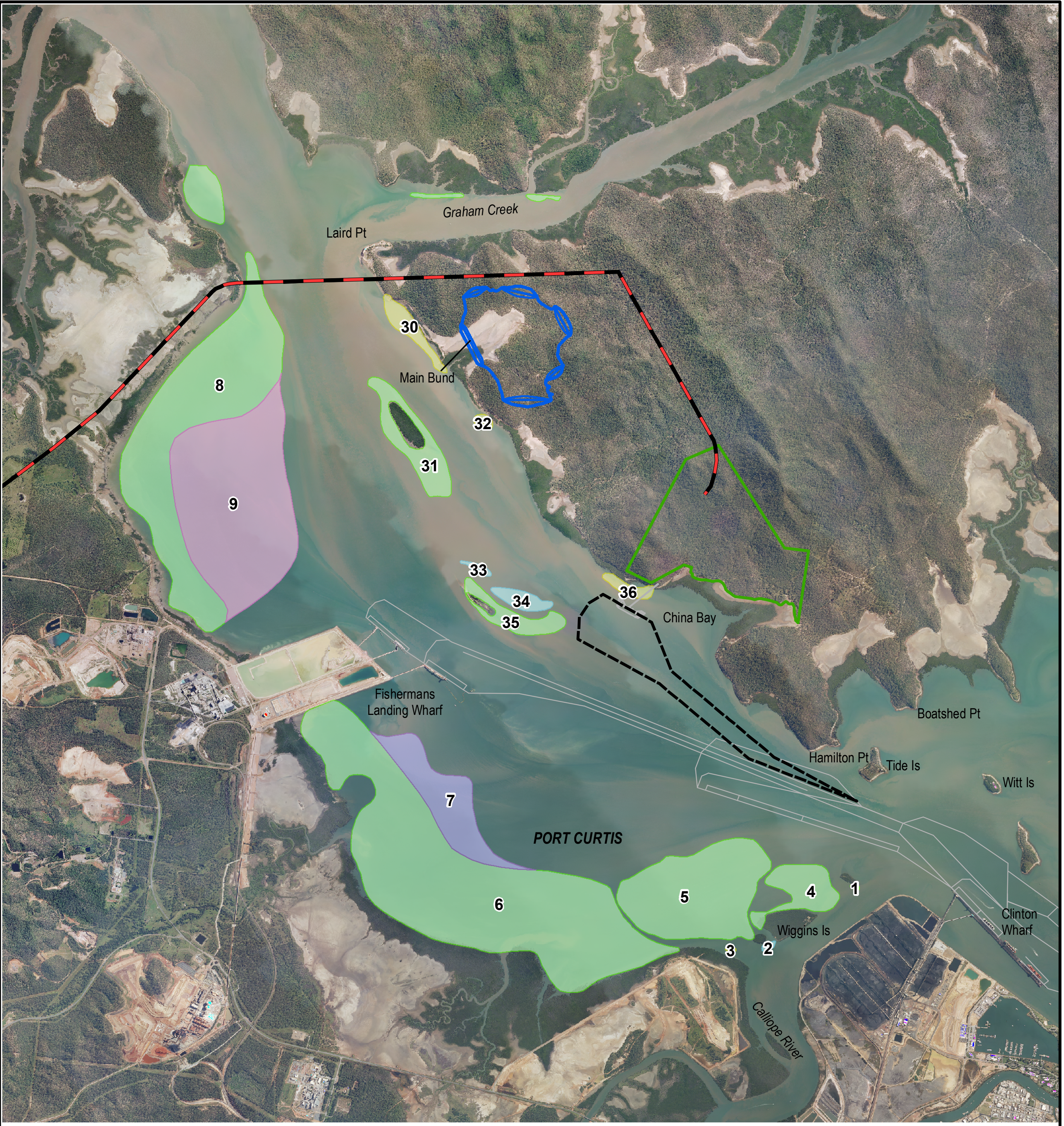
As yet, no instructions on water quantity and quality objectives for the DMPF have been established. It is however understood that the concentration of suspended solids must not exceed 50 mg/L, in the dewatering discharge from the current DMPF at Fishermans Landing and the recently approved DMPF at Wiggins Island

5.3 Sensitive Receptors

Seagrass communities have been identified as one of the main sensitive receptors in Port Curtis. The value of seagrasses in the Port Curtis area to dugong has been recognised by the declaration of the Rodds Bay Dugong Protection Area (DPA). Figure 5-1 below shows the seagrass communities within Port Curtis as belonging to *Zostera Capricorni* or *Halophila Ovalis*, with one usually dominant in each area (Rasheed *et. al.* 2003). Meadows in the receiving environment of the decant discharge from the DMPF include areas 30 – 36 and 124 – 125. However, these areas are mostly isolated or aggregated patches of seagrass growth, and represent an area which is small in comparison to the more established areas of cover on the mainland side of the estuary. These areas are summarised in Table 5-1 using information gathered from Rasheed *et. al*. (2003).

Table 5-1 Mean Biomass and Area of Seagrass Meadows in the receiving environment of the DMPF

Meadow ID	Community Type	Cover	Mean Biomass (g dw m^{-2})	Mean Area (ha)	No Sites
30	Light Zostera Capricorni	Aggregated patches	2.9 ± 1.5	14.9 ± 1.3	2
31	Light Zostera Capricorni with Halophila Ovalis	Aggregated patches	0.9 ± 0.2	40.0 ± 2.6	19
32	Zostera Capricorni	Isolated patches	Na	2.4 ± 0.3	0
33	Moderate Halophila Ovalis with Zostera Capricorni	Aggregated patches	2.0 ± 1.2	2.1 ± 0.4	3
34	Moderate Halophila Ovalis with Zostera Capricorni	Aggregated patches	1.0 ± 0.5	10.1 ± 0.8	6
35	Light Zostera Capricorni with Halophila Ovalis	Aggregated patches	0.7 ± 0.2	22.1 ± 2.0	18
36	Light Zostera Capricorni	Isolated patches	0.3 ± 0.3	6.5 ± 0.7	2
124	Zostera Capricorni	Isolated patches	Na	na	0
125	Zostera Capricorni	Isolated patches	Na	na	0



N
W E
S

Kilometers
0 0.4 0.8 1.6 2.4

Scale 1:70 000 (A4)
Datum : GDA 94

SEAGRASS

- Halophila decipiens
- Halophila decipiens with Halophila ovalis
- Halophila ovalis with Zostera Capricorni
- Zostera capricorni
- Zostera capricorni with Halophila ovalis

- GLNG Gas Transmission Pipeline (Sep. 2009)
- Existing Channels
- Proposed Dredging Channel
- Dredge Material Placement Facility
- LNG Facility Indicative Site Boundary

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DISTRIBUTION OF SEAGRASS BEDS WITHIN PORT CURTIS REPRODUCED FROM RASHEED ET AL (2003)

Drawn: MG	Approved: JL	Date: 19-11-2009	Figure: **5-1**	Rev. A
Job No.: **4262 6440**	File No.: 42626440-g-2191.mxd			A4

5.4 Receiving Environment Water Quality

URS conducted a marine water quality survey from 22 to 23 July 2009 to supplement marine water quality data previously gathered from other areas within Port Curtis. The findings of this survey are provided in Appendix E. The following is a summary of the baseline water quality of the immediate coastal vicinity of the proposed DMPF.

pH

The pH levels are generally within the QWQG 2006 limits and exhibit pH characteristic of seawater. In general the pH levels vary from 8.0 to 8.4 pH levels were not significantly different between low and high tide.

DO

Dissolved oxygen levels complied with the QWQG 2006 guideline levels during high tide. However during low tide dissolved oxygen levels were lower showing some signs of oxygen depletion at this time.

Conductivity and Salinity

Conductivity and salinity levels varied between low and high tide. Salinity levels in low tide ranged from approximately 32.5 g/L to 35 g/L, and were more saline than the levels observed during high tide, which generally ranged from 30 to 32 g/L. Typically, salinity levels may be expected to increase during high tide events with more saline water flooding in from the open ocean.

Temperature

The water temperature ranged between 19.4ºC to 21ºC with no thermal stratification expected.

Turbidity and Suspended Solids

The levels of turbidity and suspended solids exceeded the prescribed values under QWQG 2006 which are 6 NTU and 15 mg/L, respectively. Turbidity levels ranged from 3.1 NTU to 13.0 NTU while suspended solids varied from 17 mg/L to 88 mg/L. The elevated levels were consistent with the results of the previous BMT WBM (2008) survey. Such elevated levels were described to be consistent for high energy environments where current-driven sediment resuspension contributes to water column sediment load (BMT WBM, 2008).

Nutrients

Total nitrogen levels were elevated (200-300 μg/L) compared to the QWQG limit of 200 μg/L. The majority of the nitrogen present appears to be in organic form. This is apparent from the levels of Kjeldahl nitrogen, which is the total of organic and ammonium nitrogen, being similar to those of the total nitrogen levels. Ammonium nitrogen levels are comparatively lower with most of the reported concentrations being less than the analytical detection limit. However, detectable concentrations are elevated (20-140 μg/L) compared to the limit of 8 μg/L. Oxidisable nitrogen levels registered values that are mostly greater than the QWQG limit of 3 μg/L.

Total phosphorus levels were also found to be elevated (80-600 μg/L) compared to the QWQG limit of 20 μg/L. However reactive phosphorus levels were below detection limits.

5 Discharge Criteria

Metals

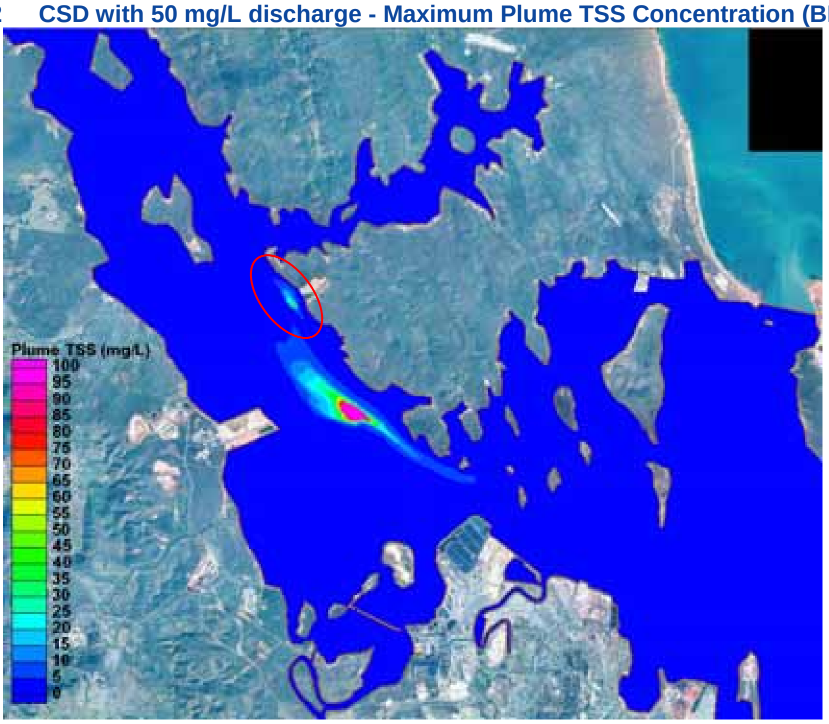
Elevated aluminium, iron, manganese, and arsenic concentrations were detected but were similar to levels found in other areas of Port Curtis based on the results of previous surveys. Cadmium, chromium, lead, mercury and nickel exhibited concentrations are within their respective ANZECC (2000) 95 % trigger values. Both total and dissolved levels of zinc and copper indicated exceedance to prescribed ANZECC (2000) 95 % trigger limits.

5.5 Modelling Turbidity and Deposition from Discharge

The discharge of seawater from the DMPF from dewatering of dredge spoil has the potential to generate sediment plumes and also contribute to the resuspension of bed material.

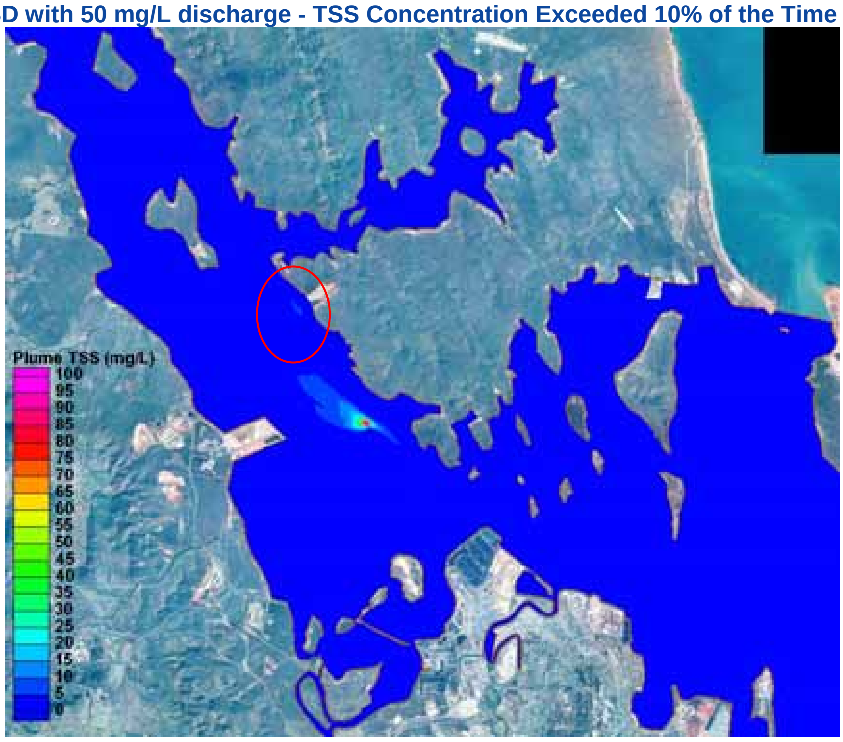
URS appointed BMT WBM to perform hydrodynamic modelling to evaluate the impact of the seawater discharge from the DMPF on the existing water quality. The full report is provided as Appendix A in Attachment G4 of the EIS Supplement. The discharge of effluent from the facility was modelled at a flow rate 2.8 m^3/s with a TSS concentration of 50 mg/L. The model simulation results for maximum TSS concentrations and 10 % exceedance are shown in Figure 5-2 and Figure 5-3. The figures show the plume extent arising from capital dredging using a Cutter Suction Dredge (CSD) with a 50mg/L (TSS) discharge occurring from the DMPF. The plume extent for the discharge from the DMPF is shown within the red circle in each case

Figure 5-2 CSD with 50 mg/L discharge - Maximum Plume TSS Concentration (BMT WBM)



5 Discharge Criteria

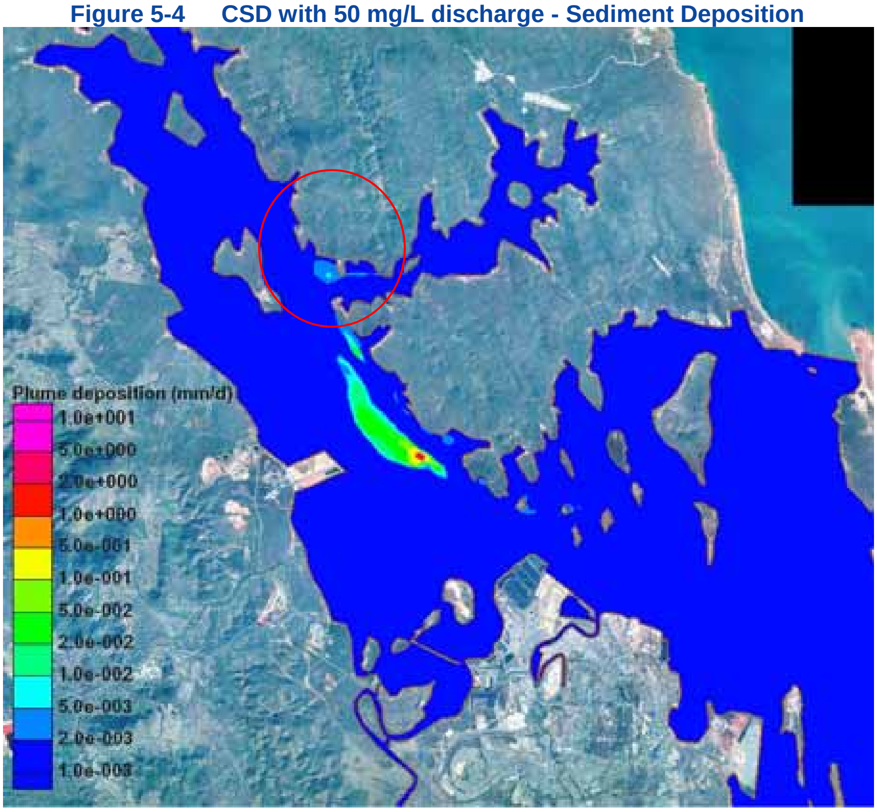
Figure 5-3 CSD with 50 mg/L discharge - TSS Concentration Exceeded 10% of the Time (BMT WBM)



The model simulation results for potential sediment deposition arising from capital dredging using a CSD and a 50 mg/L (TSS) discharge from the DMPF are provided in Figure 5-4 below.

5 Discharge Criteria

Figure 5-4 CSD with 50 mg/L discharge - Sediment Deposition



It can also be seen from the modelling results that the discharge from the DMPF has minimal impact and is not expected to have any detectable impacts on sensitive receptors. The modelling results indicate that the water quality impacts arising from the discharge from the DMPF would be localised and unlikely to pose a significant risk of environmental harm.

6

Conceptual Layout

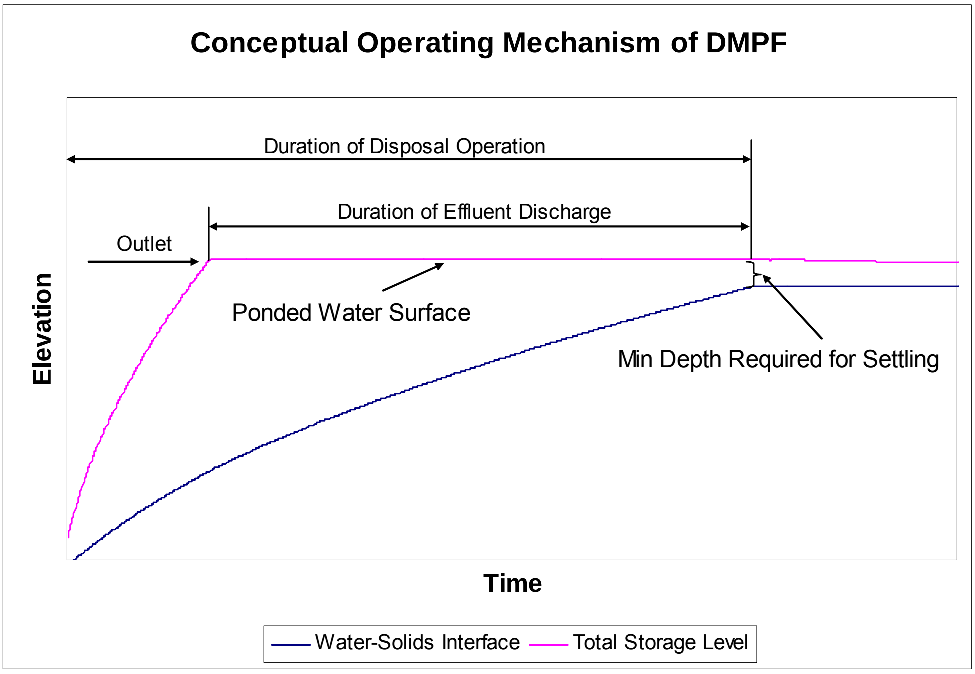
6.1 Concept Design

An initial concept design of the DMPF was provided in EIS Section 8.17. This design concept has been further developed to account for the construction and operational constraints that have been identified through the additional investigations discussed in the earlier sections of this report.

6.2 Proposed Operating Mechanism

The primary operating mechanism for the DMPF is the gravitational settling of suspended solids from the dredge slurry prior to discharge. As the dredging operation begins, dredged materials would be pumped into the facility and no discharge would occur until the water level reaches a preset level of sluice intake. The level of the sluice intake would be set to ensure that there is adequate surface area available to achieve the required concentration of suspended solids in the discharge. When the water level reaches the preset height, water will overflow through the sluice intake and discharge into the ocean. This concept is illustrated graphically in Figure 6-1.

Figure 6-1 Conceptual Operating mechanism of DMPF



The elevation of the water-solids interface increases with time until eventually there is an insufficient depth of water for the required settling to take place. Prior to the occurrence of this situation the disposal of the dredge material would either move to the next cell or alternatively the embankments and sluice intake would be raised to provide the required ponding depth.

6.3 Design Parameters

The preliminary design of the facility was developed on the basis of the anticipated dredge production rate, dredge material flow rate, site capacity, embankment height, sediment storage depth, ponding depth, freeboard, bulking factor and anticipate discharge water quality standard. The following are project conditions used in the design of the DMPF:

Table 6-1 Design Parameters

Design parameter	Value
Volume to dredge	6.8 million m^3
Total extraction time	48.8 weeks
Production hours per day	20
Effective production rate	19906 m^3/day
Solid to water ratio	14:86
Bulking factor	1.4
Slurry concentration	293 g/L
Minimum ponding depth	0.6 m
Freeboard	1.5 m
Minimum effluent water quality standard	50 mg/L

A minimum ponding depth of 0.6 m was adopted as it is recommend by USACE to prevent scouring, while the 1.5 m freeboard was adopted to provide adequate volume for direct rainfall during wet weather events which is well above the USACE recommend height.

6.4 Cell Sizing

As illustrated in Figure 6-2, the facility has been divided into six cells. Each cell is connected to the neighbouring cell by adjustable weirs. The main advantage of this configuration is that it allows drying and levelling to be occurring in some cells while dredge soil is being placed into operational cells (Herbich, 1992). This configuration also enables the velocity of the dredged slurry flows to be reduced to promote settlement of particles and improve discharge quality. Figure 6.-2 presents the sizing of each cell at each stage of operation.

Table 6-2 Cell sizing

Stage	Cell	Volume (ML)	Surface Area (ha)
Stage 1 (10m AHD)	-	4256	82.2
Stage 2 (14m AHD)	S1	747	15.5
	S2	768	15.9
	S3	626	14.4
	N1	824	15.7
	N2	857	16.4
	N3	814	16.0
Total:		4636	93.9
Stage 3 (18m AHD)	S1	860	16.6
	S2	923	17.7
	S3	855	16.8
	N1	864	16.3

6 Conceptual Layout

Stage	Cell	Volume (ML)	Surface Area (ha)
	N2	940	17.5
	N3	944	17.6
Total:		5386	102.5
Stage 4 (22 m AHD)	S1	907	16.9
	S2	1014	18.9
	S3	996	19.1
	N1	891	16.6
	N2	1004	18.3
	N3	1034	18.8
Total:		5846	108.6

Inlet and outlet Structures

The rate of discharge is regulated by the outlet structure. It is desirable that the discharge is released from the DMPF at approximately the same rate as the dredged materials are pumped into the facility. Proper design and operation can control the solids concentration in the discharge (Herbich 1992).

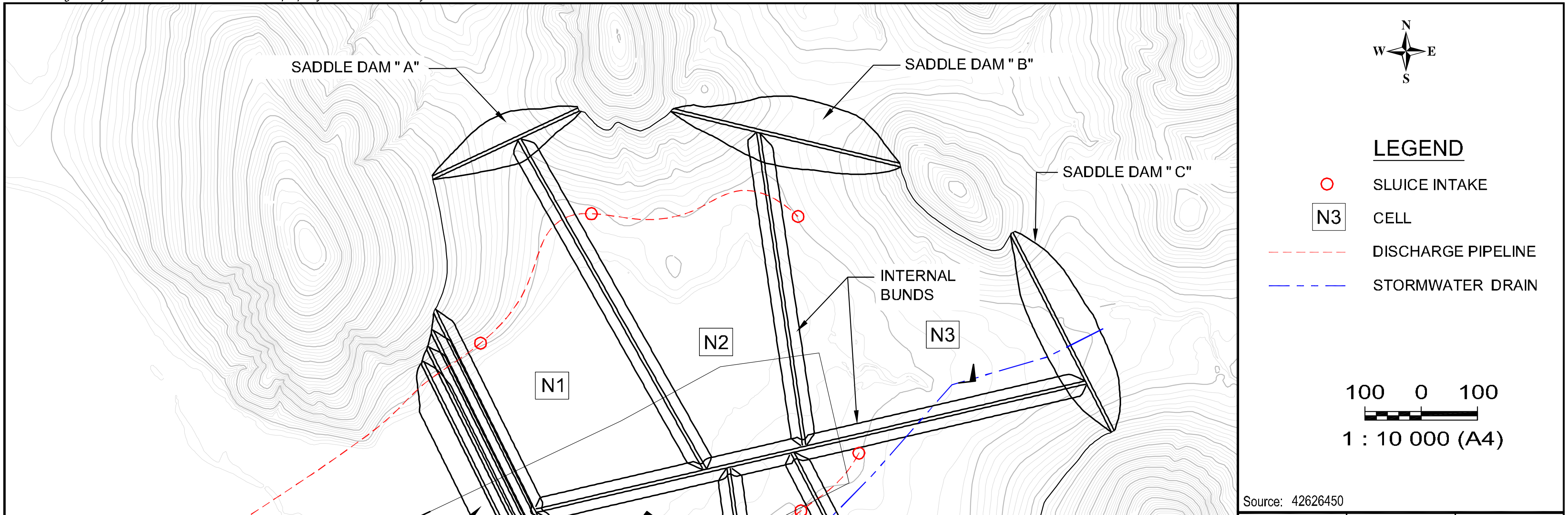
Sluice intakes would be used as the inlet structure within each cell with two separate pipes used to transport effluent from the Northern and Southern cells (as shown in Figure 6-2). The sluice intake levels for each stage of development are presented in Table 6-3. As discussed earlier, adjustable weirs would be used to enable water to flow from one cell to another.

The effective weir length and ponding depth are two key parameters in weir design. Only weir length has been considered for the preliminary design presented in this report. Assuming that effluent is released from the facility at the same rate as dredge spoil is pumped into the facility and a minimum ponding depth of 0.6 m, approximately 20 m of effective weir length is required in accordance with Figure 4.7 from the USACE (EM) 1110-2-5027.

Any further development on the weir design should follow the guidelines for weir design outlined in the USACE (EM) 1110-2-5027. Further investigation is required to ensure that position of the weirs will minimise short-circuiting and dead zones and maximise effective detention time. It is anticipated that due to the shape and landform of the facility more than one weir will be required for each cell to maximise the flow path and minimise short-circuiting as well as providing flexibility in relation the placement of the dredge transfer pipeline discharge. The current design is sufficient for feasibility and assessment purposes

Table 6-3 Sluice Intake Levels

Stage	Sluice Intake Levels
Stage 1	8.7 m AHD
Stage 2	13.2 m AHD
Stage 3	16.5 m AHD
Stage 4	19.9 m AHD



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CONCEPTUAL LAYOUT

Figure: **6-2** Rev. A A4

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6.5 Facility Staging and Development

The information discussed in this section has been developed to demonstrate the feasibility of the DMPF and is preliminary in nature. The dredging contractor who is appointed to undertake the capital dredging works, and to construct and operate the DMPF, may ultimately adopt another sequence / methodology so long as it meets the required discharge quality within the same footprint.

Embankments are required to confine the storage of dredged material and to separate the internal cells. The Main Embankment is needed to close off the tidal area and the remainder of the confinement for the facility is provided using saddle dams at low points around the periphery of the facility and the natural topography. It is proposed that the embankments be constructed in four stages:

Stage 1: the external embankment constructed to 10 m RL (internal bunds partially constructed using borrowed materials as shown in Figure 6-5).

Stage 2: the external and internal bunds constructed to 14 m RL

Stage 3: the external and internal bunds constructed to 18 m RL

Stage 4: the external and internal bunds constructed to 22 m RL

Dredging quantities for the proposed stages of the development are estimated to be as follows.

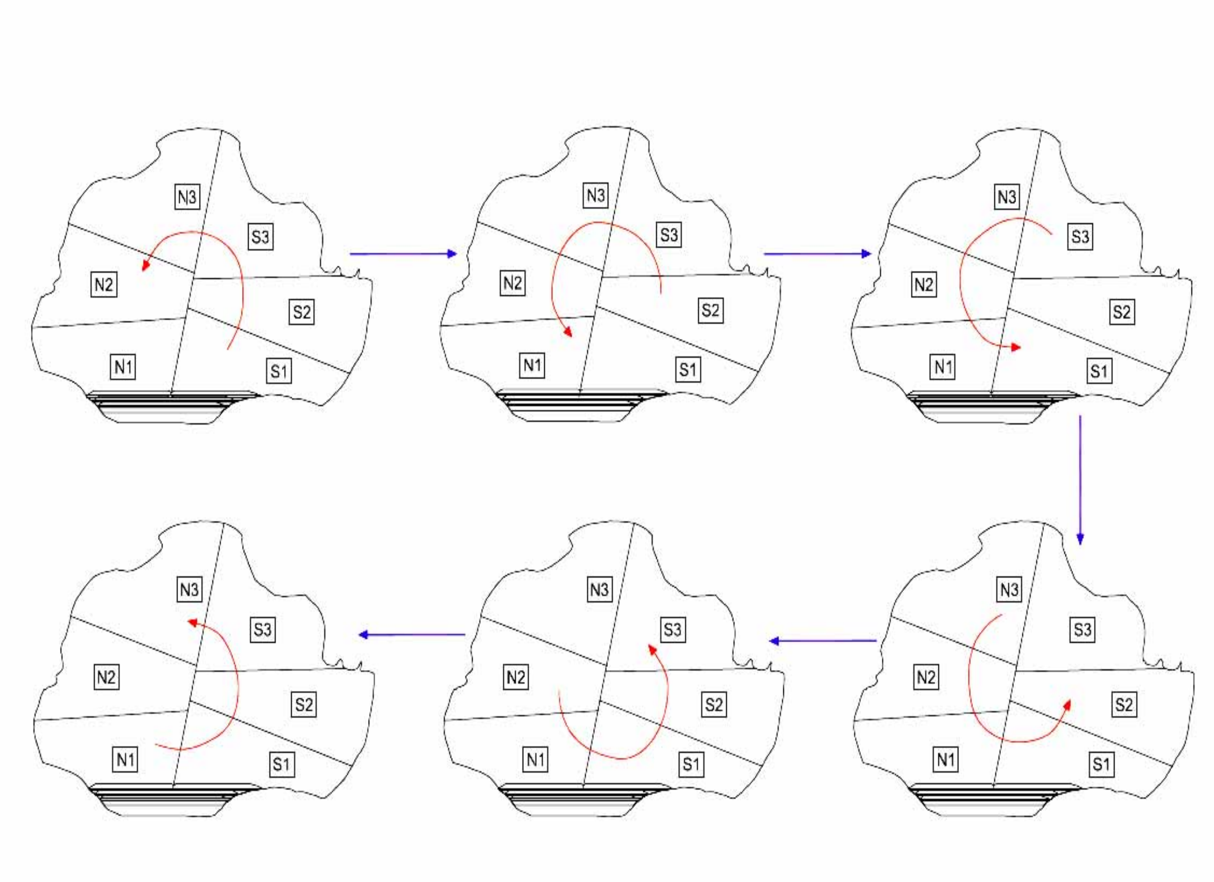
Table 6-4 Quantity of Dredged Material

Stage	Quantity of Dredge materials
Stage 1	1.53 million m^3
Stage 2	1.60 million m^3
Stage 3	1.92 million m^3
Stage 4	1.75 million m^3
Ultimate development	6.8 million m^3

Stage 2 to Stage 4 of the DMPF have been designed such that the cells will be operating in series, where at one time, five cells would be utilised in order to meet the effluent discharge quality. In this case, the first cell acts as a primary sedimentation basin while the remaining cells act as secondary, tertiary and polishing basins. Dredge slurry from the dredging site would be hydraulically pumped to the DMPF into the primary cell and effluent will overflow to the neighbouring cell through an adjustable weir until it reaches the fifth cell where it will overflow through a sluice intake and discharge back into the ocean. Once there is insufficient ponding depth available in the primary cell, the discharge pipe is then moved to the next cell where the same process occurs. The sequence for the proposed discharge operations is presented in Figure 6-3.

6 Conceptual Layout

Figure 6-3 Proposed DMPF Cell Sequencing



Effluent discharge will occur from sequential cells in line with sequence shown in Figure 6-3 and the discharge plan is shown in Figure 6-4. The exact location of the sluice intakes within each cell has not been finalised and this would be addressed during detailed design. The final operations will be determined by the dredging contractor keeping in mind that the sluice locations must be selected to ensure that sufficient surface area/flow path is available to achieve the required discharge quality.

6.5.1 Main Embankment

To close off the tidal area, a main embankment would be constructed. Construction of the main embankment will start after the completion of the foundation preparation. Details of main embankment design and construction options are presented in Attachment G6.

6.5.2 Saddle Dams

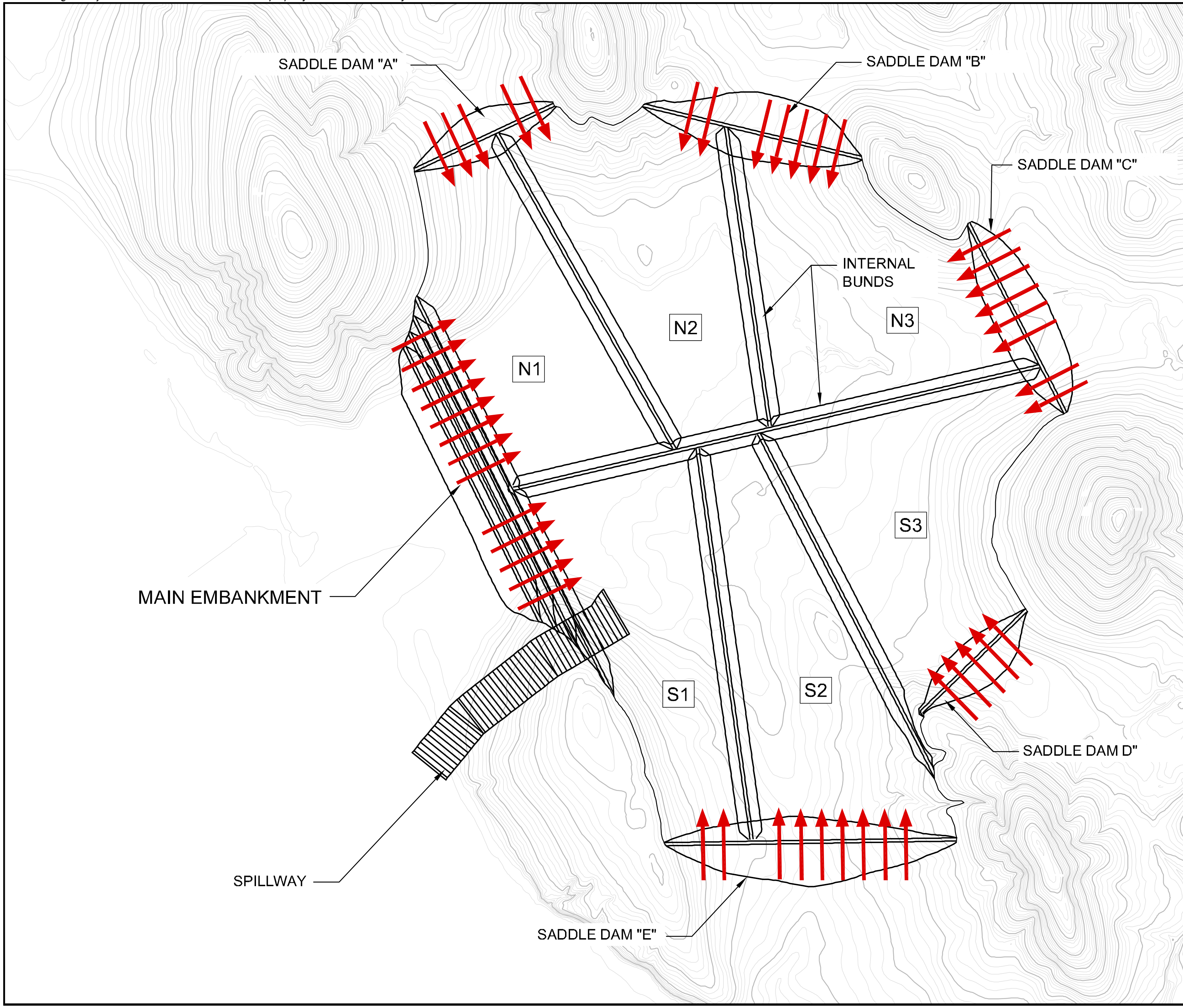
Due to the existence of natural topographical and landform constraints, such as low land area, site and access boundary, saddle dams are proposed in order to achieve the required surface area, storage volume, and surface water management requirements.

Six saddle dams are proposed to be constructed with either locally sourced and/or imported earthfill materials. Details of conceptual saddle dam design are presented in Attachment G6.

6 Conceptual Layout

6.5.3 Internal Bunds

Two types of internal bunds are proposed: Type 1 constructed using engineered earthfill and built on original ground areas, and Type 2 constructed using coarse grained dredged materials on areas overlying the mudflats. Proposed details of Type 1 and Type 2 bunds are discussed in Attachment G6. The bund types are illustrated in Figure 6.5 and the proposed staging of internal bund construction are presented in Figures 6-6a and 6-6b.



N W E S

LEGEND

INDICATIVE DISCHARGE LOCATION

N3 CELL

100 0 100

1 : 10 000 (A4)

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DISCHARGE PLAN

Figure: **6-4**

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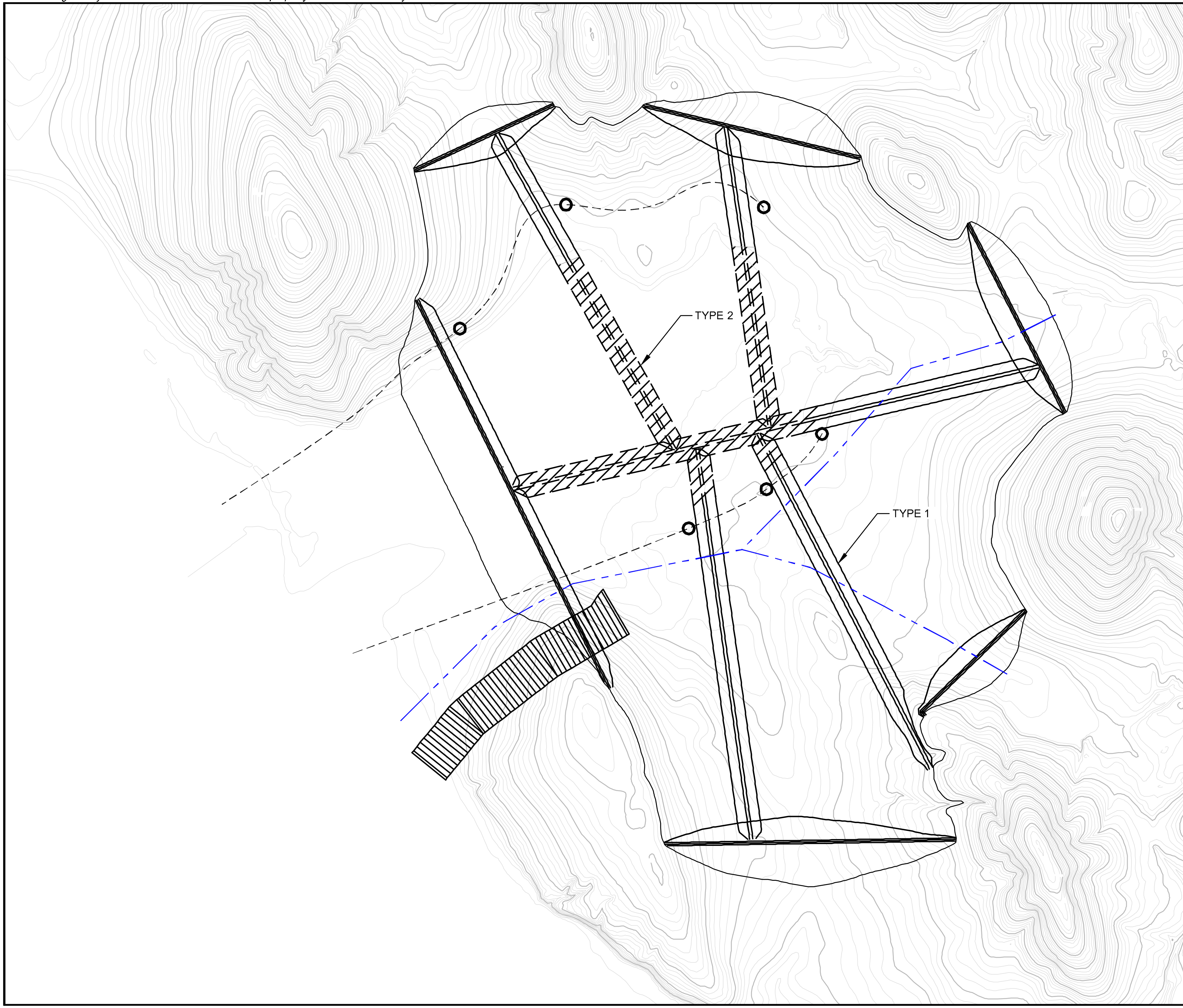

LEGEND

- INTERNAL BUND TYPE 1
- INTERNAL BUND TYPE 2
- SLUICE INTAKE
- DISCHARGE PIPELINE
- STORMWATER DRAIN

100 0 100

1 : 10 000 (A4)

Source: 42626450

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INTERNAL BUNDS CONCEPT LAYOUT

Figure: **6-5**

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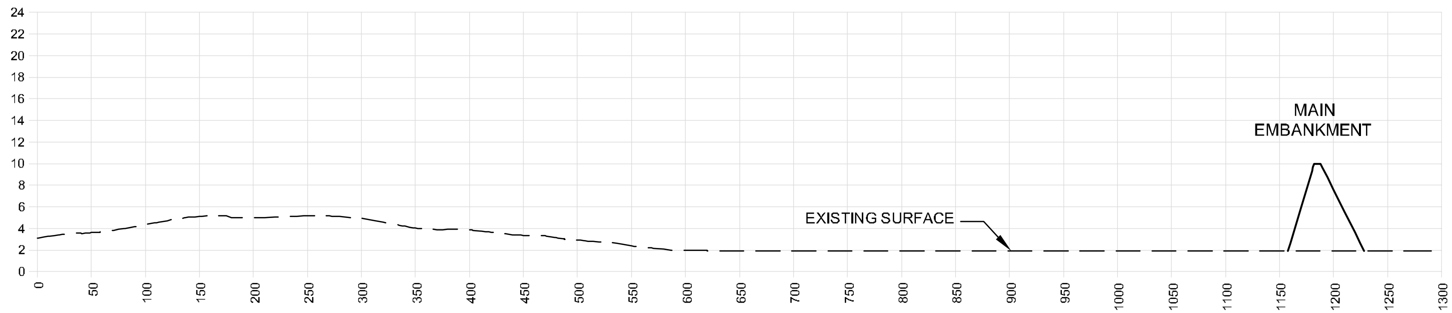
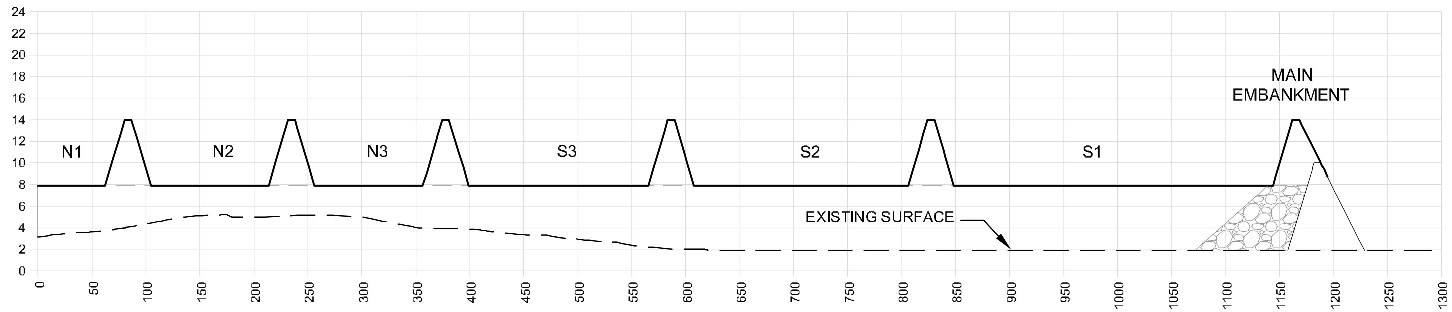


STAGE 01



STAGE 02

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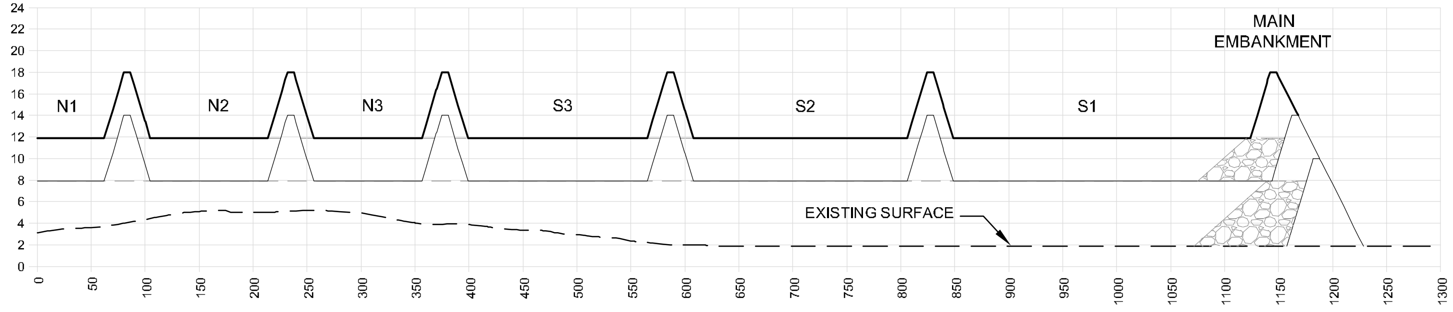
Title
CREATION OF INTERNAL BUNDS SHEET 1

Figure: **6-6a** Rev. A A4



STAGE 03

STAGE 04

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CREATION OF INTERNAL BUNDS SHEET 2

Figure: **6-6b**

Rev. A

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7

Mass and Water Balance Model

As stated in section 1.2, the main objectives of the DMPF are to provide adequate storage capacity during hydraulic placement of dredged materials and to ensure that discharges from the facility meet the required discharge criteria.

Mass and water balance modelling was conducted using Goldsim to evaluate the performance of the proposed preliminary design to retain the dredged materials and to achieve the effluent water quality standard taking into account the detention time, rainfall, runoff and evaporation. The mass and water balance model input data and assumptions are presented in Appendix B. A design and terrain model was used to verify that the proposed area has sufficient capacity for the anticipated dredge material volumes.

7.1 Model Assumptions and Accuracy

In addition to the assumptions listed in Appendix B, several other assumptions were made in the construction of the model, including:

- No allowance was made in the model for seepage through the base of the storages. This is a conservative assumption and will generally overestimate the overflow volumes and frequency;
- No allowance was made for lag time for catchments upstream of the facility. For the scale of the catchments represented by the modelling, lag would typically be less than a day, and as such this assumption is not significant;
- No allowance was made for tidal effects;
- Discharge concentration limit of 50 mg/L for TSS;
- The model also contains several sources of potential inaccuracy, including:
- Hydrologic information of the site was unavailable, and as such synthetic data for the 100 year simulation was used as a substitute;
- Relatively poor correlation of natural runoff parameters was achieved, and no data was available to calibrate hardstand runoff parameters;
- Lack of data regarding model layout, surface gradient and contaminated areas; and
- Model verification and calibration of the model has not been undertaken given the lack of available local gauged data.

However, the accuracy of the assessment is considered adequate for preliminary design of the DMPF and EIS purposes. Further model refinement would be required for detailed design of the facility.

7.2 Model Parameters

7.2.1 'Capacity to Contain' Assessment

A conservative approach has been adopted for the 'capacity to contain' assessment by assuming that all material for embankment construction will be sourced from external local sources or imported materials. In practice it is likely that some embankment raising and internal bund construction would be undertaken using dredged materials.

Modelling work has been carried out to determine the amount of dredged materials to be contained in the facility. Applying a bulking factor of 1.4 to the dredge spoil, a total volume of 9.52 million m^3 of dredged material will need to be contained in the facility. This will be discharged into the facility combined with approximately 41.8 million m^3 of transport water which will be discharged back into the ocean following sufficient detention for the suspended solids to settle out. To account for the reduction in effective volume and surface area due to mounding of coarse grained materials and dead spots, 20 % of hydraulically inactive zone has been assumed in the capacity to contain assessment.

Allowing for the minimum ponding depth required for settling of suspended solids, freeboard and capacity required for stormwater management, and the volume of dredge spoil, the modelling result demonstrates that approximately 113 ha of storage area and dredged material storage depth of 17.4 m with ultimate embankment height of 22 m AHD is sufficient to contain the dredge spoil. The following table shows the volume of materials contain in each cell and final solid level for each stage of development.

Table 7-1 Volume of Dredged Material Contained at each Stage in Each Cell

Stage	Cell	Final Solid Level (m)	Volume of Dredged Materials (million m^3)
1	-	7.9	2.14
2	S1	11.90	0.36
	S2	11.92	0.37
	S3	11.91	0.28
	N1	11.91	0.41
	N2	11.92	0.43
	N3	11.92	0.40
Total:			2.25
3	S1	15.90	0.42
	S2	15.93	0.46
	S3	15.93	0.42
	N1	15.94	0.43
	N2	15.93	0.47
	N3	15.94	0.48
Total:			2.68
4	S1	19.34	0.38
	S2	19.33	0.43
	S3	19.32	0.42
	N1	19.14	0.35
	N2	19.33	0.43
	N3	19.33	0.44
Total:			2.45

Details on the DMPF performance for each stage of the proposed operations are summarised in Appendix C.

7.2.2 Effluent Discharge Quality

The assessment on the effluent discharge quality encompasses the discharge criteria and constraints as outlined in Section 5. The effluent discharge quality has been assessed based on suspended solids concentrations. URS has adopted a conservative approach by assuming that the settling properties of particles exhibit Class I sedimentation where the particles settle at constant velocity and they settle as individual particles and do not flocculate during settling. The assessment was conducted by comparing the surface overflow rate to settling velocity whereby any particle with a settling velocity equal or larger than the surface overflow rate will completely settle out.

7.2.3 Treatment of Resuspension

Direct rainfall and short wind-waves may play an important role in shallow water sediment resuspension processes (Wright *et al*., 1992). USACE recommended that an appropriate adjustment should be made for dredged material exhibiting zone settling. At this stage however the potential impact of wind on sedimentation processes has not been considered in the modelling. These aspects will be considered during detailed design and are likely to have limited environmental impacts.

7.3 Modelling Results

The modelling results indicate that approximately 59.3 ha of ponded surface area must be provided within the DMPF for appropriate settling based on a dredge spoil pumping rate of approximately 7,100 m^3/hour. This surface area requires five cells to be operational during Stage 2 to Stage 4 of the development to achieve the required settling. In reality however, it is likely that less operational cells would be required as a conservative approach was adopted for the modelling which assume that no flocculation of suspended particles occurs. Once dredged material is in suspension, its settlement characteristics are a function of water salinity, turbulence and soils concentration which cause clay particles to form flocculants (Herbich, 1992). Consequently, representative settling velocities are likely to be higher thus reducing the surface area required to achieve the required effluent discharge quality.

8 Model Findings

Based on the results of the dredged material characterisation analysis and the water balance modelling, the following is concluded:

- Approximately 57 % of the dredged materials are coarse grained and 43 % are fine grained;
- The Port Curtis sediment exhibits zone settling with minimum settling rate of $3.32*10^{-6}$ m/s;
- The concentrations of solids within the effluent discharge from the DMPF are highly dependent on the finest fraction of materials being discharged into the facility and how the material is handled through the facility (i.e. discharge location, outlets height and locations etc);
- The effluent discharge dredge plume is expected to have minimal impact on the receiving water quality;
- The modelling result indicates the storage of 6.8 million m^3 of dredged material requires approximately 113 ha of storage area and dredged material storage depth of 17.4 m with ultimate embankment height of 22 m AHD. However, if the dredged materials are being used to construct the internal bunds, the surface area and depth of dredged material will be reduced. Additionally, as a conservative bulking factor of 1.4 has been utilised in this analysis, it should be noted that the actual volume will be smaller depending on dredging methodology; and
- The modelling results indicates that in order to achieve concentrations of 50 mg/L for effluent discharge, approximately 59.3 ha of ponded surface area must be provided within the DMPF for appropriate settling based on a dredge spoil pumping rate of approximately 7,100 m^3/hour. In reality however, it is likely that less operational cells would be required as a conservative approach was adopted for the modelling which assume that no flocculation of suspended particles occurs. Consequently; representative settling velocities are likely to be higher thus reducing the surface area required to achieve the required effluent discharge quality.

9

Surface Water Assessment

9.1 Site Surface Water Existing Conditions

9.1.1 Natural Catchments

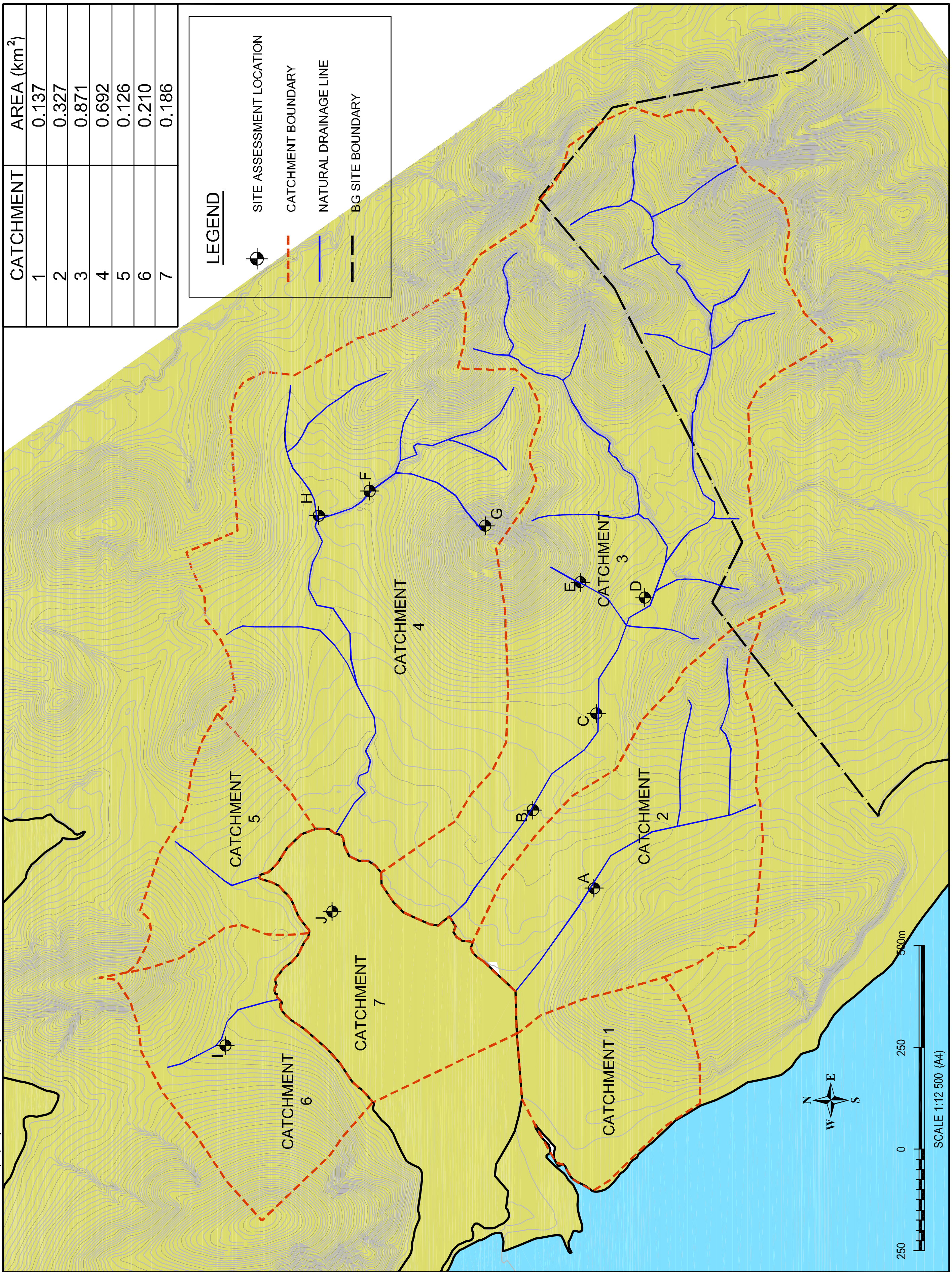
The study area has a plan area of 2.28 km^2 and is located some 1.5 km south east of Laird Point on Curtis Island. The site is bounded on the west by Port Curtis at sea level and rises to the east with various small hill crests around the north, east and south of the site area, the highest of which is 71 m AHD. The site area consists of an estuarine/marine mudflat and tidal mangrove flats surrounded by low to moderately sloped foothills and undulating valleys. The estuarine flat is not vegetated; however the foothills are covered in medium to high density woodland.

Within and surrounding the DMPF five significant drainage paths/watercourses have been identified. These are shown in Figure 9-1. The features are all ephemeral in nature, with small catchments (less than 1 km^2) and generally quite undefined flow paths (except for the larger catchments 3 and 4). Additionally one area in catchment 2 was found to be a low lying basin holding surface water, which appears to have formed due to the naturally occurring flat topography.

The site investigation indicated that defined drainage paths have evolved from erosive runoff in the upper catchment during high intensity storm events. The small feature drains are hard to distinguish with the channel width varying between 0.3 – 3 m, and in some flat areas multiple small channels were observed. The channels are generally extremely shallow with depths of 0.1 – 1.5 m, however heavily eroded bends in steeper parts of the catchment have gully features up to 3 m in depth.

The site assessment notes are summarised in Appendix F with an existing catchment plan shown in Figure 9-1.

CATCHMENT	AREA (km^2)
1	0.137
2	0.327
3	0.871
4	0.692
5	0.126
6	0.210
7	0.186



Client: LNG / URS	Project: GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT SUPPLEMENT DREDGE MATERIAL PLACEMENT FACILITY DEWATERING AND PRELIMINARY DESIGN	Title: **EXISTING CATCHMENT PLAN**
	Drawn: BKH · Approved: TR · Date: 15-10-2009	Figure: **9.1** · Rev. A
	Job No.: 42626440/6220 · File No.: 42626440-g-2121.dwg	A4

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Soil and Geology

The soils on the estuarine/coastal flats areas comprise deep soft saline clay, silt and muddy sand soils, with deep uniform (non-cracking) clay soils with a silty clay surface and some thin silt loamy surface duplex soils. On the alluvial flats and drainage-ways a moderately saline medium to heavy clay subsoils is encountered. The lower slopes and valley plains are characterised by medium to deep gravelly loamy surface duplex soils and locally some gradational clay soils occur. In the low rounded hilly areas shallow to medium deep gravelly red-brown duplex soils were encountered, and on the steeper hilly land and saddles shallow to medium deep stony loams and shallow gravelly uniform structured clay soils occur.

In most of the observed eroded watercourses no rock was encountered, indicating the ephemeral nature of the streams and the ongoing nature of the erosion process. In some cases, particularly near the flatter downstream areas of watercourses 3 and 4, the eroded watercourses in clayey substrate widen out into alluvial soils leaving no signs of a defined channel. This is a sign of surface-groundwater connection and occurs most notably at point C and also downstream of location H (refer Appendix F).

Most of the site is not underlain with rock, except in some areas to the south where rock was encountered at significant depths of greater than 20 m. Additionally, weathered conglomerate was observed in the eroded bed of some upstream areas of watercourses 3 and 4. Geological and geotechnical investigations were undertaken and are discussed in more detail in the site geotechnical investigation report.

9.1.2 Flood Hydrology

A hydrological assessment was undertaken for the DMPF site based on AR&R (IEAust, 1987). This analysis considered the catchment characteristics and local hydrological patterns to determine the time of concentration and runoff coefficient, and was confirmed by the Rational Method based on the Queensland MRD Bridge-Branch method (AR&R, 1987) for runoff coefficients as discussed in the previous reports on site surface water for the DMPF.

Details of the hydrological assessment undertaken for the seven drainage features identified are provided in Appendix F. Results of the assessment are summarised below in Table 9-1. As the facility has a proposed life of 20 years peak flows were calculated for annual recurrence intervals (ARI's) of 2, 20 and 100 years.

Table 9-1 Predicted peak design flow for drainage features at the edge of the estuarine flat

Catchment/Drainage Feature	Catchment Area (km^2)	2 Year ARI Peak Flow (m^3/s)	20 Year ARI Peak Flow (m^3/s)	100 Year ARI Peak Flow (m^3/s)
Catchment 1	0.137	1.3	4.0	7.0
Catchment 2	0.327	2.8	8.8	15.6
Catchment 3	0.871	4.2	13.2	23.1
Catchment 4	0.692	4.4	13.8	24.3
Catchment 5	0.126	1.5	4.7	8.5
Catchment 6	0.210	2.4	7.6	13.5

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Catchment/Drainage Feature	Catchment Area (km^2)	2 Year ARI Peak Flow (m^3/s)	20 Year ARI Peak Flow (m^3/s)	100 Year ARI Peak Flow (m^3/s)
Catchment 7 –estuarine mudflat (to proposed main embankment location)	0.186	0.7	2.3	4.1

Further details of each drainage feature are provided in Appendices F and H.

9.1.3 Flood Assessment

To approximate the flood depths at significant natural drainage features, a basic hydraulic assessment has been undertaken using industry accepted software (HEC-RAS v3). The predicated water depths are summarized below in Table 9-2 (further details of the assessment are provided in Appendix F). In all three simulated flood events 2, 20 and 100 year ARI, some out of channel bank flooding is predicated to occur.

Table 9-2 Predicted flood depths for main drainage features at the edge of the estuarine mudflat, Curtis Island

Drainage Feature	2yr ARI Depth (m)	20yr ARI Depth (m)	100yr ARI Depth (m)
Unnamed Drainage Feature No. 3	0.30	0.42	0.51
Unnamed Drainage Feature No. 4	0.41	0.52	0.59
Unnamed Drainage Feature No. 6	0.19	0.31	0.41

Further details of each drainage feature crossing are provided in Appendix F and G.

9.1.4 Tidal Flooding

Although the marine environment has been explored in further detail in EIS Section 8, it is expected the naturally occurring semi-diurnal tidal range will have an impact on flood levels on the site. During the regular high tide range (between MHWS and MHWN) the entire mudflat area will be inundated, including any drainage infrastructure and sea outfalls below the tide level. The tidal range at Gladstone is displayed in Table 9-3. This has implications for the construction of the site, particularly the main embankment, outfall and any other drainage infrastructure.

Table 9-3 Tidal Range at Gladstone (Standard Port)

Tidal Plane	Tide Levels (m AHD)
Highest Astronomical Tide (HAT)	2.42
Mean High Water Spring (MHWS)	1.64
Mean High Water Neap (MHWN)	0.79
Mean Low Water Neap (MLWN)	-0.75
Mean Low Water Spring (MLWS)	-1.60
Lowest Astronomical Tide (LAT)	-2.27

Storm Surge

The following storm surge levels show that during large storms a significant portion of the site is inundated. This inundation will influence flood levels in the lower areas of the site and the main embankment stability during a combined tidal surge and hydrologic event. Table below provides extreme tidal level predictions for Gladstone (Queensland Government, 2008).

Table 9-4 Predicted Extreme Tidal Surge Levels at Gladstone

Probability	Predicted Level
100 yr ARI	2.82 m AHD
500 yr ARI	3.51 m AHD
1000 yr ARI	3.80 m AHD

The above flow and water depth results have been calculated with limited data of the site and have not calibrated to real data. Due to the simplistic nature of this investigation and the lack of verification, the level of accuracy is low. Hence any results provided in this appendix should only be used to obtain an indicative understanding of the flooding behaviour they are not suitable for design purposes but are sufficient for impact assessment.

All of these events are significantly below the proposed first stage of the main embankment facility and it would be expected that inundation of the site from storm surge in an extreme event will not occur once the main embankment is constructed. Storm surge and tidal flooding will be able to be managed through one way flow devices on the outfall pipes of the facility and appropriate embankment erosion protection on the downstream side of the main embankment.

9.2 Existing Water Quality

The Australian and New Zealand Environment and Conservation Council (ANZECC) Guidelines 2000 provide guideline values or descriptive statements for different indicators to protect aquatic ecosystems and human uses of waters (e.g. primary recreation, human drinking water, agriculture, stock watering). The ANZECC (2000) Guidelines are a broad scale assessment and it is recommended that, where applicable, locally relevant guidelines are adopted.

The Queensland EPAs Queensland Water Quality Guidelines 2006 (QWQG, 2006) are intended to address the need identified in the ANZECC Guidelines by:

- Providing guideline values that are specific to Queensland regions and water types; and
- Provide a process/framework for deriving and applying local guidelines for waters in Queensland (i.e. more specific guidelines than those in the ANZECC).

Relevant water quality objectives for the study area were identified from QWQG (2006) to support and protect different environmental values for waters in the Curtis Island Basin (refer to Table 5-1). Salinity guidelines were obtained from Appendix G of the QWQG (2006). These water quality objectives should be used as a guide to what the ambient water quality should be. The receiving environment is Port Curtis. Detailed assessment of the water quality of Port Curtis is contained in the LNG facility EIS.

Table 9-5 Water Quality Objectives for the Waters of Curtis Island

Parameters	Enclosed Coastal	Upper Estuarine	Lowland Streams
Ammonia N (µg/l)	8	30	20
Oxidised Nitrogen (Nitrate and Nitrite) (µg/l)	3	15	60
Organic N (µg/l)	180	400	420
Total N (µg/l)	200	450	500
Filterable Reactive Phosphorus (µg/l)	6	10	20
Total Phosphorous (µg/l)	20	40	50
Chlorophyll-*a* (µg/l)	2	10	5
Dissolved Oxygen (%saturation)	90 – 100	70 - 100	85 - 110
Turbidity (NTU)	6	25	50
Suspended Solids (mg/l)	15	25	10
pH	8.0 - 8.4	7.0 – 8.4	6.5 – 8.0
Conductivity (µS/cm)	970	970	970

9.2.1 Water Quality Assessment

No existing surface water quality data was available for watercourses and drainage features within the DMPF area on Curtis Island. There are no DERM recognized watercourses that will potentially be affected by the project. The water features within the study area would generally be classified as drainage feature lines carrying water only during immediately and after storm events. Observations during the URS site visual assessment, undertaken in August 2009, indicated drainage features at the site were ephemeral and dry outside of rain events. The visual assessment also suggested that both minor and major flows would carry sediment and organic matter such as leaf litter. Appendix F presents details of the drainage features as noted by the URS site assessment. These characterizations will be used to establish baseline physical conditions of the watercourses and be used to determine changes over time and from potential impacts as a result of the development.

9.3 Modification to Site Surface Water

9.3.1 Proposed Catchment Modifications

As part of the development of the facility several modifications will be required to the natural hydrology and drainage. This is primarily due to the installation of embankments, which intersect natural drainage paths and create a need for drainage diversion.

DMPF Catchment

The DMPF will be constructed to have no external catchment flows entering it, so that it collects runoff only from rainfall directly on its footprint. The footprint of the dredge placement area alone will be approximately 1.3 km^2 and will also have some minor hillside catchments draining into it to make the facility catchment 1.4 km^2. All direct rainfall will be collected in the facility which will dilute the saline

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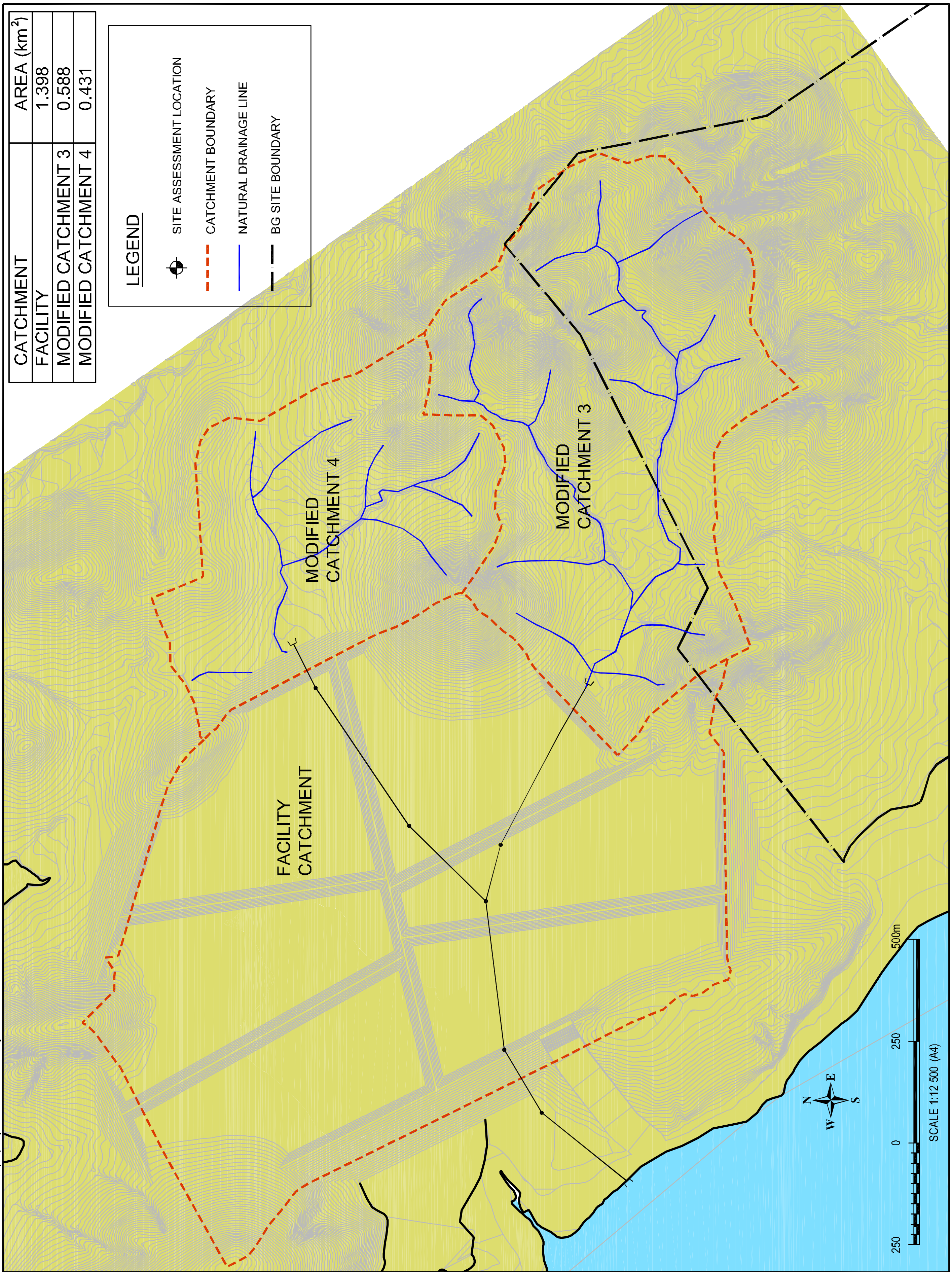
dredge water. This will be discharge from the facility and managed in the same way as the effluent from the dredge slurry. Figure 9-2 shows the extent of the proposed catchment modifications.

CATCHMENT	AREA (km^2)
FACILITY	1.398
MODIFIED CATCHMENT 3	0.588
MODIFIED CATCHMENT 4	0.431

LEGEND

- SITE ASSESSMENT LOCATION
- CATCHMENT BOUNDARY
- NATURAL DRAINAGE LINE
- BG SITE BOUNDARY



Client: LNG / URS	Project: GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT SUPPLEMENT DREDGE MATERIAL PLACEMENT FACILITY DEWATERING AND PRELIMINARY DESIGN	Title: **MODIFIED CATCHMENT PLAN**	
	Drawn: BKH · Approved: TR · Date: 15-10-2009	Figure: 9.2	Rev. A
	Job No.: 42626440/6220 · File No.: 42626440-g-2122.dwg		A4

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External Catchment Diversion

The key catchment modification on site will occur in catchments 3 and 4. This modification will encompass the construction of catchment storages and diversion high flows and overflows of the upper reaches of these catchments by large diameter pipe through the site to discharge directly into Port Curtis.

Confirmation will be required on the proposals for any alteration of catchment 3 within the QGC site. At this stage of the project it is assumed that the development of the QGC site will not cause any increase in runoff volume or significant change in water quality entering the DMPF site.

Additionally as the proposed QGC site boundary intersects catchment 3, diversion pipes and storage upstream of the embankment across catchment 3 will be provided to pass and store the volumes up to the 1 in 100 ARI event to prevent flooding back into the QGC site.

The proposed facility design requires saddle dams to be installed across the existing drainage lines in catchments 3 and 4. This will create water storages in these catchments which will need to be drained to prevent un-necessary retention of water in these catchments and risk of water backing up and flooding the QGC site for catchment 3 or the adjoining Grahams Creek catchment for catchment 4.

It is proposed to drain these areas of potential water retention by installation of both small and large diameter pipes sized for up to the peak 20 year ARI design flow. This will mean the upstream storages in catchments 3 and 4 will act essentially as retarding basins, which have low flow outlets and higher level outlets to control outflows and improve water quality. Additionally it is proposed that the storages will have some permanent retention of water. This is to provide a water source for site construction and operation and also for sediment control and to improve water quality discharges from the upstream catchments.

The proposed diversion pipes have not been sized, but it is expected that sizing for no greater than the 20 year ARI peak flow would be a sufficient level of protection for the facility. As there is significant storage available upstream of the embankment this can be utilised to prevent the 1:100 year ARI flood inundating the adjacent QGC site.

Storage available

Using survey data an estimate of storage upstream of the proposed bunds in catchment 3 and 4 was made. These storage volumes are displayed in Table 9-6.

Table 9-6 Natural Storage available in Catchment Valleys

Catchment	Level Range for Storage (m AHD)	Volume (ML)
3	10.0 -16.0	123
4	12.0 - 17.0	222

In catchment 4, storage is only available between RL 10 and RL 16, as any additional storage above this will cause overspilling to the North into the catchments flowing to the Grahams creek area. Similarly storage in catchment 3 is only available between RL12 and RL17 as any storage above RL 17 will cause inundation of the adjoining QGC site. This will be managed by provision of low flow and overflow pipes to transmit the peak 1 in 100 ARI flow.

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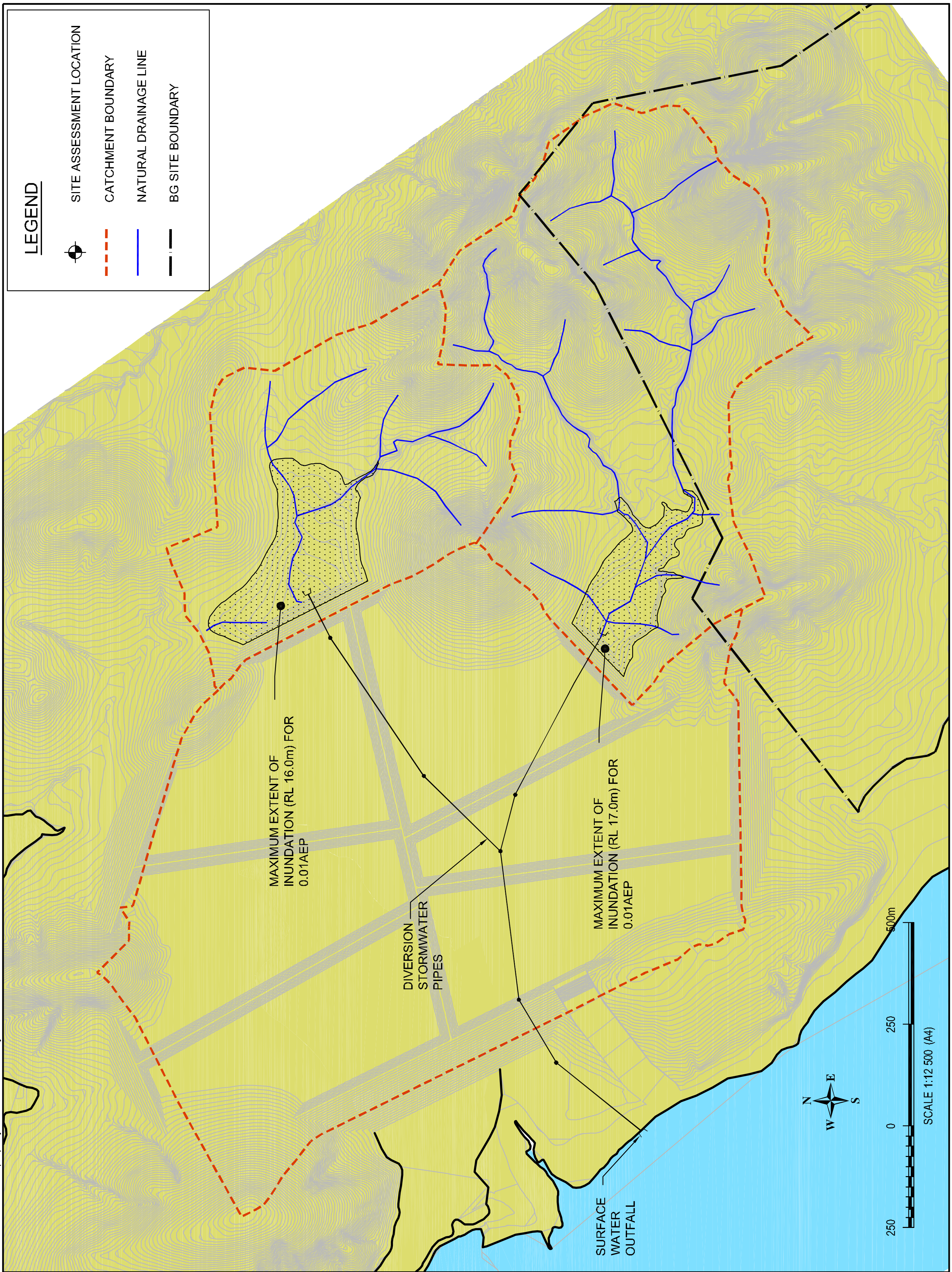
Area envelopes of the maximum inundation possible are shown in Figure 9-3; however it is expected the actual day to day inundation will be significantly less than this. These are worst case areas, which will be significantly reduced by diligent design of the dam outlets and pipes. The inundation upstream of the new embankments will cause changes to vegetation in the proposed storage area and likely loss of some vegetation in areas regularly wet/inundated.

Water quality from the natural catchments is expected to be reasonably good. The storages at catchment 3 and 4 will remove sediment and to some extent attenuate peak flows from the natural catchments prior to discharge into the site drainage system and ultimately Port Curtis.

It is proposed that the outfall of these diversion pipes will be into the tidal zone of Port Curtis between the dredge water outfall and the proposed spillway. It is not anticipated that there will be significant quality issues with this water as it will be water from the natural catchment, with naturally occurring sediment loads and water quality that will be buffered by storage. The rate of outflow of the stormwater diversion outfall will be managed so as to not have a higher rate of discharge than currently occurs as storage and attenuation of flows will be achieved by careful design of the upstream storage areas. The storages will provide a buffer for reducing flow rate and improving water quality from the diversion pipes, prior to discharge to the ocean.

Blockage

Blockage prevention of the drainage system is a key issue which needs to be regularly monitored and managed. Over sizing of pipes may be considered to mitigate likely blockage from siltation. Through the installation of inlet screens and a high level bypass inlet some protection and redundancy will be provided to prevent blockage. Regular maintenance of the diversion drainage system will be required to be undertaken by the facility operator, particularly during the wet season.



Client	Project	Title
LNG URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT SUPPLEMENT DREDGE MATERIAL PLACEMENT FACILITY DEWATERING AND PRELIMINARY DESIGN	**SURFACE WATER INFRASTRUCTURE PLAN**

Drawn: BKH	Approved: TR	Date: 15-10-2009	Figure: **9.3**	Rev. A
Job No.: 42626440/6220	File No.: 42626440-g-2123.dwg			A4

9.3.2 Site Water Supply

The upstream storages created in catchments 3 or 4 will be used for surface water storage and harvesting for construction water. As the natural storage areas are generally flat and shallow some modification of the existing topography may be required to improve the storage characteristics of these areas. This will require clearance and earthworks to achieve the required surface profile.

An approximate yield assessment was undertaken to evaluate the potential yield of the two catchments and is attached in Appendix H. The average annual catchment yield for both catchments is displayed in Table 9-7. This shows there is a significant volume of water available for harvesting from the catchments for construction water and any water requirements for the operation of the facility. It is expected only a fraction of this potential yield would be retained and stored and sufficient bypassing and overflows will be provided to ensure outflows from the catchments do not change significantly.

Table 9-7 Potential Average Annual Stormwater yields

Location	Potential Runoff available for harvesting (ML)
Catchment 3	204
Catchment 4	104

Water quality of the water supply is as discussed in section 9.2.1 and it is not expected treatment will be required for construction water or other site uses.

9.3.3 Spillway

A design life of 20 years has been adopted for the DMPF as the facility will hold and retain water beyond its expected operational life of 50 weeks. This requires that the spillway shall be sized for the 1 in 20,000 ARI event (Manual for Assessing Hazard Categories and Hydraulic Performance of Dams v1.0 EPA) with a design storage allowance (DSA) for the 1 in 100 ARI, 72 hour event.

It is expected that beyond the 20 year design life, re-profiling and rehabilitation of the site will be undertaken to remove the water retaining embankments and make the site and associated catchment free-draining. The rehabilitation will eliminate the risk posed from the high hazard main embankment during operations, and allow the facility to be reclassified with a lower hazard category.

Due to the expected similarity of the geotechnical conditions on both abutments the preferred location for the spillway is the southern abutment of the main embankment. This has more favourable topography and will result in fewer earthworks. The spillway will require significant excavation (approx. 210,000 m^3) but it is anticipated that the material won from these earthworks will be used in the construction of the main embankment.

Design Storage Allowance (DSA)

The design storage allowance and mandatory reporting level for the DMP facility were calculated using a hydrological model to estimate rainfall and runoff across the facility and upstream catchments. This was calculated for the 1 in 100 ARI event.

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RORB

A hydrological model was built using RORB (version 6) software to assess the runoff from the site catchments and the estuarine flat where the DMPF is located. This software output the peak catchment flows and volumes, which were then used for the preliminary design of the spillway and assessment of the DSA.

The RORB model was used to identify the peak runoff volume likely in both the 1 in 100 ARI, 72 hour duration event to calculate the Design Storage Allowance required in the placement area. Additionally runoff volumes and flows from the upper reaches of catchments 3 and 4 were calculated to identify the requirements for draining these areas when the perimeter bunds are constructed.

Peak volumes are displayed in Table 9-8 and a summary of the RORB output is displayed in Appendix H.

Table 9-8 RORB output of peak flood volumes and natural flows to DMPF Facility

Catchment	Area (km^2)	100yr ARI, 72 hr Flood Volume (ML)	Peak 100 year flow (m^3/s)
Modified Catchment 3	0.588	357	10.2
Modified Catchment 4	0.431	254	14.0
Facility Catchment	1.398	821	23.2
TOTAL AREA (Facility plus outlying areas)	**2.477**	**1432**	**41.9**

Given the DMPF facility area is 1.3 km^2, 0.6 m of freeboard is required between the finished level of dredge material and the spillway sill to accommodate the DSA requirement of 821 ML. This ensures that the DSA is provided prior to the spillway being engaged.

A sluice offtake will be used to decant clean water from the dredge material within the facility. This will occur throughout the predicted life of the facility, beyond the operation phase. The sluice offtake will discharge a significant volume of runoff during the critical 72 hour event. It is estimated that the sluice offtake will discharge up to 7,100 m^3/hr, which equates to approximately 511 ML over the 72 hour event. This means that the 1 in 10 ARI event and approximately 60 % of the 1 in 100 ARI event (821 ML) can be passed by the sluice offtake at only small head requirements (0.1 - 0.2 m). If this is taken into account a DSA of only 381 ML or 0.29 m is required for the 1 in 100 ARI event.

Spillway Staging

The spillway will be raised three times in parallel with the embankment raises. The ultimate outlet chute profile and initial spillway excavation will be constructed as part of the first stage of works. The spillway will then be upgraded (raised) three times in conjunction with the associated embankment raise. The three embankment raises are envisaged to be required during the ~50 week filling period specified for the facility. This may mean that the embankment raise and spillway upgrade works will be ongoing during the operation of the facility.

Each raise will be approximately 4 m in height and is proposed to be undertaken through a combination of sheet piling and filling with select site clay material and/or concrete works. The approximate geometry for the proposed spillway raises are shown in Figure 9-4 to Figure 9-6.

The initial, stage 2 and Stage 3 spillway upgrades have been designed for the 1:20,000 AEP event. It is anticipated that during these stages and with the current embankment raising regime, that a composite free overflow and fuseplug type spillway may be required to safely pass the design event due to the low head available. This is due to the limited driving head above the DSA allowance in these stages due to the high proposed water level during operations.

A fuseplug spillway typically consists of erodible earth panels that washout at predetermined supply levels. For example, the composite spillway could operate as follows:

- DSA provided below the free overflow spillway sill level;
- 100 yr ARI event discharge provided through the free overflow spillway;
- Fuseplugs overtopped for events exceeding the 100 yr ARI event; and
- Composite spillway to pass the 20,000 yr ARI event.

This composite arrangement requires that the sill of the fuseplug spillway be below that of the free overflow spillway. This level has not yet been determined. This arrangement is considered a reasonable compromise considering the operational life specified for the facility.

Further optimisation of the main embankment and the spillway staging will be undertaken in the future design stages.

Ultimate Spillway Sizing

Concept sizing of the spillway has been undertaken and the design flow estimated using the rational method in accordance with previous reports. The rational method parameters are displayed in Table 9-9.

Table 9-9 Rational Method Parameters

Parameter	Value
Flood Event (ARI)	20,000
Runoff Coefficient	1.0
Rainfall Intensity (mm/hr)	250

The key design parameters, flow and characteristics for the spillway are displayed in Table 9-10. This corresponds to a facility design life of 20 years which requires that the spillway must pass the 20,000 year ARL event peak flow.

Table 9-10 Spillway Design Parameters

Spillway Parameter	Value
Design Flow (20,000 year ARI)	177m^3/s
Depth of flow over sill	1.4m
Design Storage Allowance (0.01 AEP)	0.29m
Spillway Width	80m

An arrangement for the proposed final spillway is provided as Figure 9-5.

Geotechnical conditions

Geotechnical investigations were not carried out in either of the abutments due to environmental access restrictions (significant felling of trees required). Boreholes drilled in saddle areas encountered deep deposits of clayey residual soil and some bedrock (below 25 m). However, the topography at the

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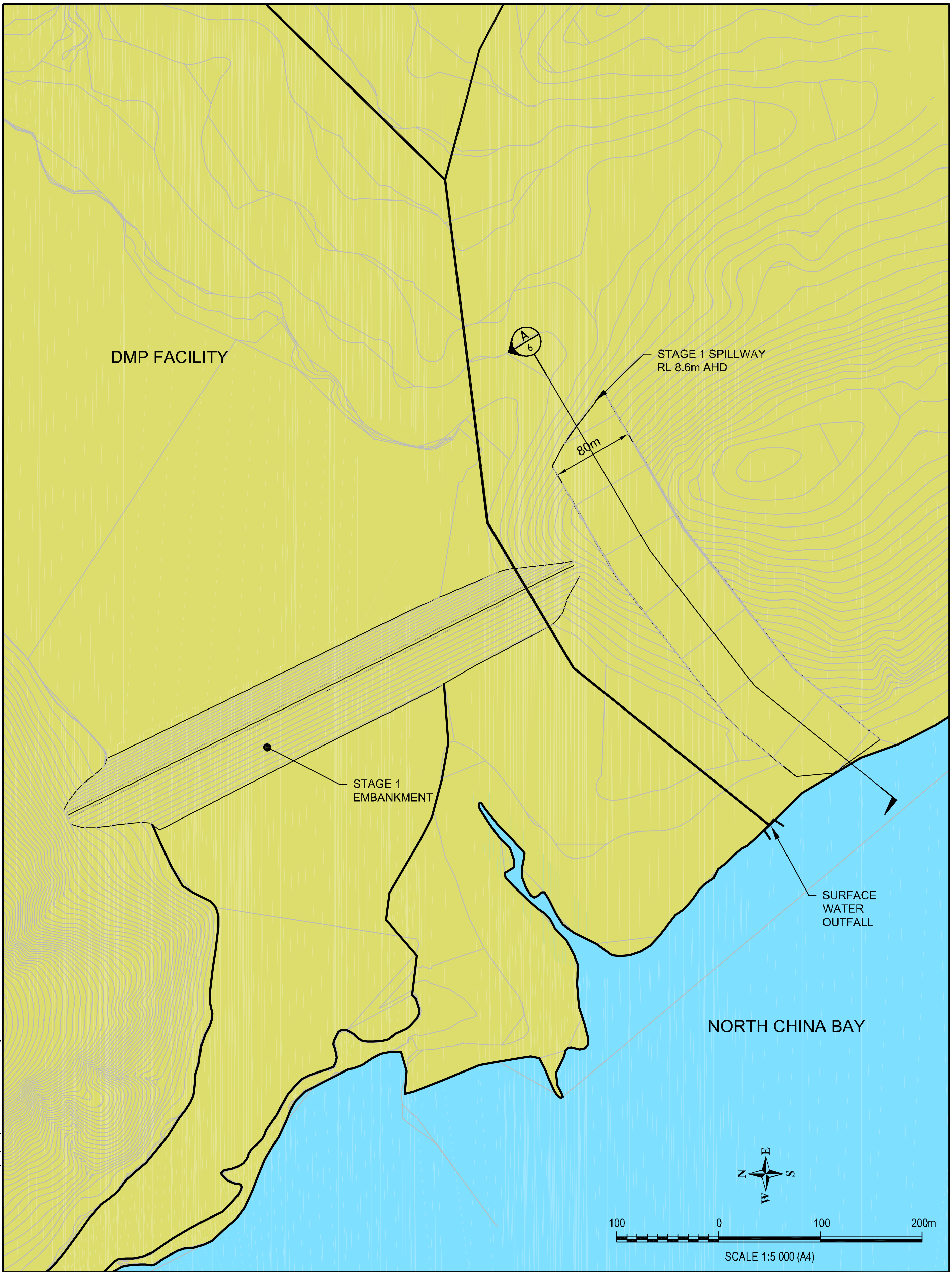
southern abutment is relatively steep (40 % grade), which implies harder and more resistant natural materials may be present. It should be anticipated that hard residual soils and bedrock are present.

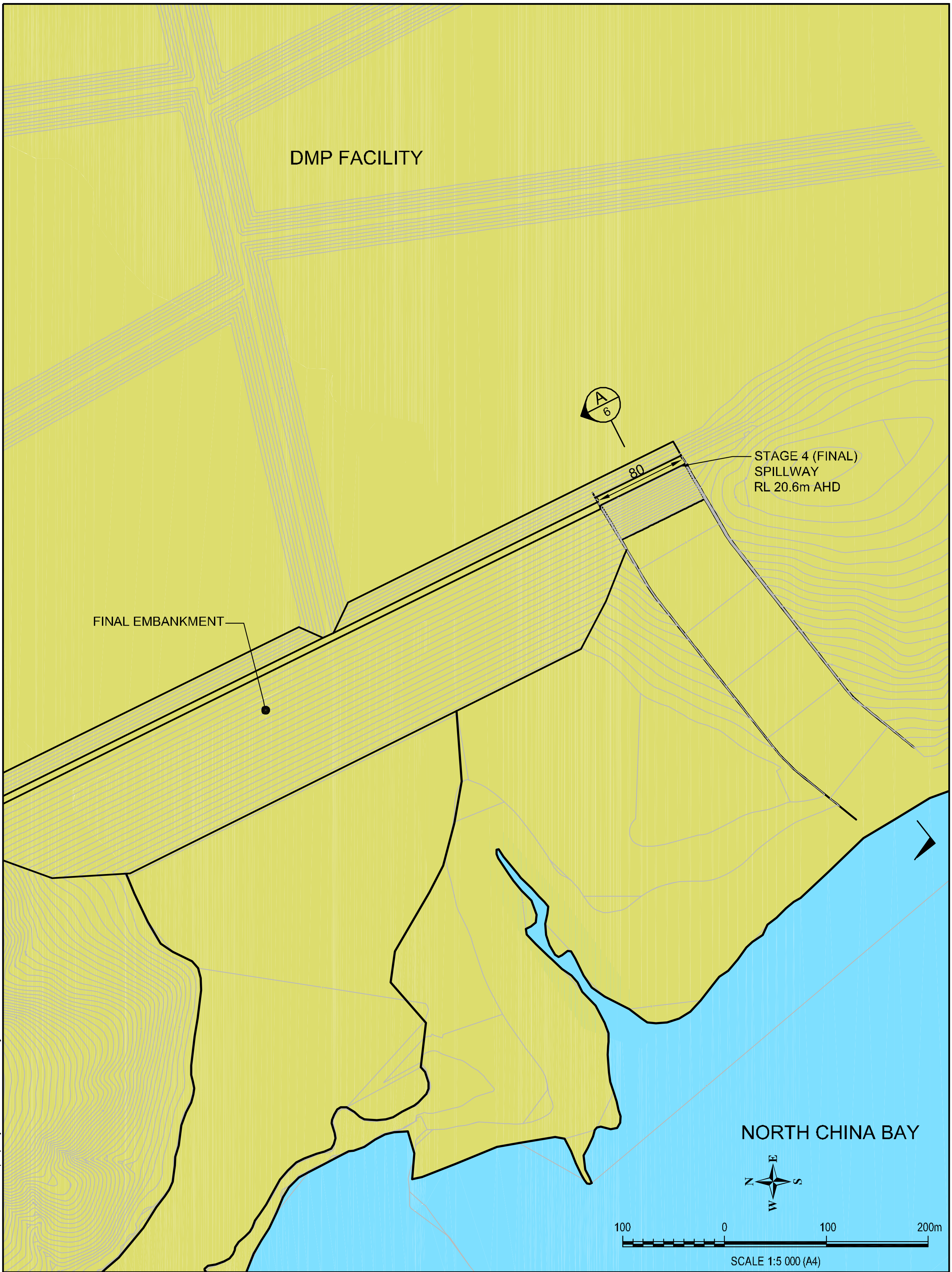
A key consideration is the possible need to provide energy dissipation for the design flows downstream of the spillway crest if softer, less resistant materials are encountered. Concrete or rip rap armouring would be suitable for this purpose.

The progressive spillway raising will be done by adding a 4 m section at each stage of the spillway. The Stage 2 through Stage 4 spillway raises would pass over a portion of the embankment, which also would require armouring for erosion protection.



Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT SUPPLEMENT DREDGE MATERIAL PLACEMENT FACILITY DEWATERING AND PRELIMINARY DESIGN	**INITIAL SPILLWAY PLAN**

Drawn: BKH	Approved: TR	Date: 15-10-2009	Figure: 9.4	Rev. A
Job No.: 42626440/6220	File No.: 42626440-g-2124.dwg			A4



Client	Project GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT SUPPLEMENT DREDGE MATERIAL PLACEMENT FACILITY DEWATERING AND PRELIMINARY DESIGN		Title **FINAL SPILLWAY PLAN**
	Drawn: BKH	Approved: TR	Date: 15-10-2009
	Job No.: 42626440/6220	File No.: 42626440-g-2125.dwg	Figure: **9.5**
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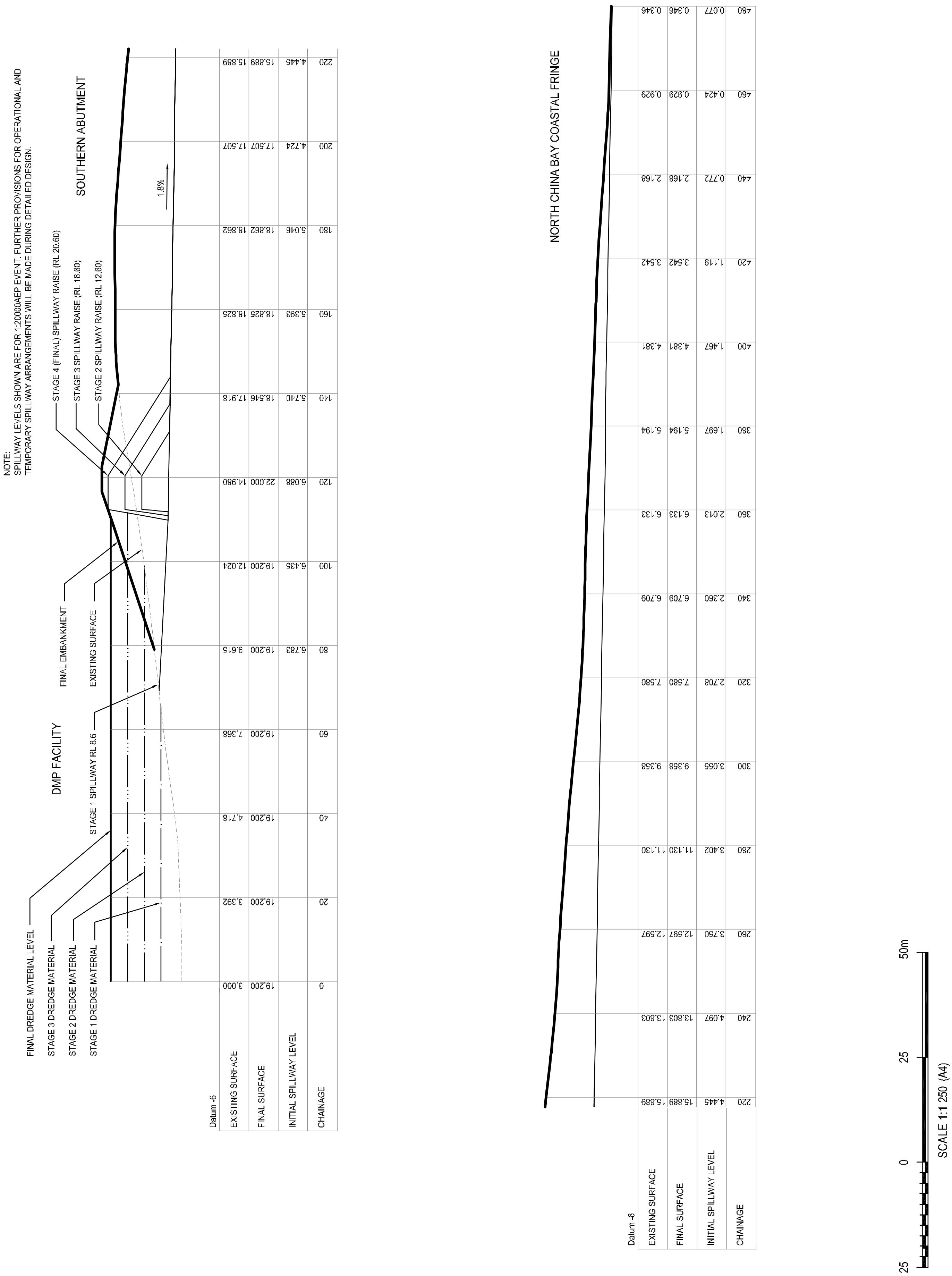

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Project
GLADSTONE LNG PROJECT
ENVIRONMENTAL IMPACT STATEMENT SUPPLEMENT
DREDGE MATERIAL PLACEMENT FACILITY
DEWATERING AND PRELIMINARY DESIGN

Title
SPILLWAY SECTION

Drawn: BKH	Approved: TR	Date: 15-10-2009
Job No.: 42626440/6220	File No.: 42626440-g-2126.dwg	

Figure: 9.6

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A4

9.4 Dam Hazard Classification – All Embankments

As discussed in previous reporting the Dam Hazard classification for the main embankment is high based on the dam break criteria. Hence the criterion for design of the embankment offers the highest level of protection required by the current guidelines (Manual for Assessing Hazard Categories and Hydraulic Performance of Dams v1.0 EPA).

The main embankment and saddle dams will be constructed to 22 m AHD. The actual height of the main embankment will be 20 m whilst saddle dams (A-E) will be 9.1 m, 14.1m, 12.6 m, 10.2 m and 15.0 m respectively. The main embankment is considered to represent the highest hazard and will therefore used to determine the design requirements for the entire facility. As the highest level of protection is required on the main embankment and hence the facility as a whole, it is not necessary to assess the surrounding perimeter embankments for dam hazard classification. This is because the design considerations and criteria being used for the spillway and DSA of the main embankment will either match or exceed any guideline requirements for the perimeter embankments, which generally are expected to have significantly lesser consequences of failure.

Dams in Catchments 3 and 4

The proposed storages in catchments 3 and 4 will ultimately be landlocked by the accumulation of dredge material downstream of the embankments, and hence the hazard risk of these embankments will be Low for catastrophic failure.

If the storage in catchment 3 fails to contain flood volume within the DMPF site, there is a risk of overspilling into the QGC site adjacent to it. The 1 in 100 year flow volume will be designed for both the storage and dam bypass flow of catchment 3, however if a larger event occurs there is the potential for significant harm based on general economic loss of the neighbouring site. This will need to be confirmed with the proposals for the development of this site. Currently any overspilling into the adjoining site would cause low harm under all categories.

Similarly if the storage in catchment 4 does not contain the flood volume of catchment 4 below RL 16, there is the potential for flows to spill into the adjoining Grahams Creek catchment. As the flows are expected to be natural with no significant contaminants the hazard category of this occurring would be low under all categories, or as an extreme worst case significant under the general environmental criteria.

10

Proposed Impact Management

10.1 Operation of Facility

The following information details the major planned activities for the proposed DMPF site through the different stages of construction, commissioning, operation (both initial capital works dredging and ongoing maintenance dredging) and decommissioning. The potential impacts are discussed and management measures to minimise those impacts are outlined. This was undertaken using a qualitative risk assessment approach (refer to Appendix I). The detailed risk matrix for the proposed DMPF site activities is provided in Appendix J and the impacts and mitigation measures identified are outlined as follows.

10.2 Construction Phase

It is anticipated that the DMPF construction will generally involve the following steps:

- Site survey;
- Mobilisation of earthmoving equipment;
- Construction of the Haul Road to the site;
- Transport and storage of bulk fuels, including the construction of bunded areas to avoid spillage;
- Clearance of vegetation on and around the site;
- Removal of topsoil and stockpiling in an approved area. This will be used for landscaping following construction of the facility;
- Excavation, backfilling and compaction of material in accordance with detailed design specifications;
- Construction of appropriate foundations;
- Construction of barge landing and/or causeway (if required);
- Construction of outfall and facility drainage works and foundations;
- Construction of main bund and spillway; and
- Construction of saddle dams.

10.2.1 Erosion and Sediment Mobilisation

Activities

Earth moving activities are expected to include:

- Removal of vegetation;
- Top soil removal and stockpiling;
- Cut and fill activities; and
- Construction of storage and lay down areas as required for equipment storage.

Potential Impacts

Sediment mobilised during construction activities may enter surface water runoff during rainfall events and discharge to drainage lines leading to deleterious effects on water quality and aquatic habitats. Sediment exposed or generated during construction may also be blown by wind into surface water bodies.

Mitigation and Management Measures

Areas of disturbed or exposed soil may be managed to reduce sediment mobilisation and erosion by:

- Concentrating work to as small an area as possible and progressively expanded to reduce the area potentially at risk;
- Minimising the number of passes by heavy earth moving equipment;
- Stripping and stockpiled usable topsoil away from drainage lines to protect it from erosion;
- Implementing sediment limitation devices (e.g. settlement/evaporation ponds, drainage ditches);
- Constructing temporary and permanent bunds to restrict flow velocities across the project site;
- Limiting vegetation clearing work during heavy rainfall;
- Requesting the earthworks contractor to prepare a Sediment and Erosion Control Plan prior to the commencement of construction;
- Adopting stormwater controls and upstream treatment, such as infiltration devices, sediment ponds and vegetation filters;
- Locating vehicle wash bays away from watercourses;
- Revegetating and/or using of other stabilisation techniques, considering seasonal influences, upon completion of works;
- Minimising vegetation disturbance, especially riparian vegetation;
- Implementing dust suppression measures including irrigation and/or covering of stockpiles;
- Adopting erosion control, energy dissipation and scour protection, such as matting, riprap and gabions;
- Preparing a Stormwater Management Plan (SWMP) for the construction of the DMPF; and
- The application of the above proposed management measures will reduce both the likelihood and the consequences of the above impacts.

10.2.2 Works Adjacent to/within Drainage Lines

Activities

Works adjacent to or within drainage lines are expected to include:

- Perimeter embankment construction;
- Surface water diversion pipe work; and
- Vehicle crossings of watercourses and drainage lines.

Potential Impacts

Construction activities at or near drainage features can mobilise sediment and alter flow and quality characteristics.

Mitigation and Management Measures

These potential impacts may be mitigated by:

- Construction during seasonal times of low rainfall;
- Installing suitable stormwater management infrastructure prior to commencing construction activities;
- Using low flow diversions or coffer dams with pumping, to divert flows;
- Minimising disturbance by heavy earth moving equipment, especially in riparian areas; and
- Riverine Protection Permit Under Section 266 of the *Water Act 2000*, a Riverine Protection Permit is required from DERM where development will:
  - Destroy vegetation in a watercourse;

— Excavate in a watercourse; or
— Place fill in a watercourse.

Watercourse surveys have yet to be undertaken by DERM to determine whether watercourses as defined in the Water Act 2000 are present in the vicinity of the DMPF. Should designated watercourses not be identified in the vicinity of the DMPF, then a Riverine Protection Permit may not be required for works within the drainage features.

If a Riverine Protection Permit is required, then a range of specific management measures and conditions relating to each watercourse will be established by DERM. As a minimum, this is likely to include the following:

- The area of disturbance must be no greater than the minimum area necessary for the purpose;
- The area of bed and banks disturbed by the activities must be stabilised regardless of previous stability;
- The extent and duration of bare surface exposure must be minimised, and protected from weathering, rain drop impact, and water runoff;
- Clean water run-off must be diverted around areas of disturbance where practicable;
- Bed and bank stability must be managed to minimise erosion and reduce sedimentation;
- Where practicable, sediment must be captured and retained on-site;
- Machinery to be used in carrying out the activities must be selected on the basis of a type and size necessary and capable of safe operation to achieve minimal disturbance of the site; and
- Constructed drainage and discharge structures must not alter the natural bed and bank profile.

10.2.3 Pollution

Activities

Potential sources of onsite pollution during the construction phase predominantly comprise diesel and other petroleum-based fuels and lubricants used by excavation and construction machinery. Litter and sewage will also detrimentally impact the surface water environment.

Potential Impacts

Without proper mitigation measures, runoff from potentially contaminated drainage from fuel oil storage areas and general washdown water could enter into drainage features and receiving waters, altering the physical and chemical quality of the water and receiving environment. Additionally, site excavation works may expose groundwater which have been found to have high background levels of dissolved metals in both near-surface and deeper aquifers.

Mitigation and Management Measures

These potential impacts may be mitigated by:

- The construction of bunded storage areas for contaminants are recommended with spill cleanup kits in accordance with Australian Standards (AS1940 and AS3780) to prevent the contamination of surrounding surface runoff;
- The transfers of fuels and chemicals controlled and managed to prevent spillage outside bunded areas;

- Implement controls so that leaks/spills are immediately reported and appropriate emergency clean-up operations implemented to prevent possible mobilisation of contaminants;
- Chemically contaminated areas are to be protected from rainfall by roofing to reduce the likelihood of overtopping;
- Bunds and sumps are frequently drained, and effluent is treated appropriately;
- Contaminants or major spillages of stored material in the bunded areas are collected by licensed waste collection and transport contractors for disposal off site at a licensed facility;
- Any site groundwater extraction activities may require treatment or other appropriate management controls before discharges;
- The application of the above proposed management measures may reduce the likelihood and consequence of the potential impacts; and
- Pollution from sewage can be managed with a Waste Management/Disposal Plan.

10.2.4 Flooding

Potential Impacts

In the existing environment, flooding on the proposed DMPF study area and along the valleys entering the area is predicted to occur at least every 2 years (Appendix G). Fluvial flooding may therefore present a significant risk to plant, equipment and workers' health and safety, especially given the likely 'flashy' response of the catchment to short, intense rainfall events. Furthermore, out-of-bank flooding could cause damage to erosion and sediment control infrastructure leading to detrimental impacts on the environment. Flooding within the valleys around the site is however likely to subside relatively quickly following cessation of rainfall.

As much of the site lies on the tidal flat area, construction of the main embankment and spillway will be subject to tidal inundation regularly during high tides. This poses a risk to workers, plant and equipment. Tidal flooding also poses a risk of mobilising sediment and causing erosion damage to construction works on the mudflat area.

Mitigation and Management Measures

Stormwater management measures such as permanent or temporary drainage diversions and flood defence bunds (designed to provide an appropriate level of protection – recommended at AEP 0.01 (100 yr ARI)) will be implemented before construction commences to mitigate impacts. Furthermore these will be inspected on a regular basis throughout the construction period, especially following significant storm events, and maintained as necessary.

Emergency response procedures (including evacuation procedures) and a flood warning system will be established and incorporated into the site's Health, Safety and Environment Plan to protect on-site personnel. Vulnerable infrastructure will be designed with floor levels above a given AEP flood level (this is recommended to be set at the 0.01 AEP (100 yr ARI) level) or specific defences should be provided.

Additionally the tidal regime will be assessed regularly and flood prevention measures taken to protect works from tidal inundation. The main embankment and other works exposed to tidal variance will have sufficient erosion and protection measures to minimise impacts from tidal inundation.

The application of the above proposed management measures will reduce the likelihood of the above impacts.

10.2.5 Water Supply

Potential Impacts

A lack of water supply may result in inadequate dust suppression, soil compaction and washdown, allowing sediment movement into nearby watercourses, with a resultant deterioration in water quality.

Mitigation and Management Strategies

It is proposed to develop at least one water supply dam on site. This will be managed to provide water for the site throughout the year where possible. Alternative supplies shall be investigated for backup to the main supply through the development, implementation and maintenance of a Water Supply Strategy.

Sediment and erosion control, dust suppression and vehicle/facility washdown techniques will also be developed along with the water supply strategy and emergency plan (as detailed in Section 10.2.1).

10.2.6 Seawater Discharge

Activities

The operation of the DMPF will involve the discharge of seawater from the facility at a rate of approximately 7,100 m^3/hr. The quality of the discharge will be dependent on sufficient detention time within the DMPF for settlement of suspended solids to an appropriate concentration prior to discharge. The design concept for the DMPF is based on achieving a discharge quality of 50 mg/L.

Impacts

Modelling of the proposed discharge predicts that only localised turbidity and depositional impacts would arise from the discharge and there would be a negligible effect on sensitive receptors in the area. This was based on a discharge quality of 50 mg/L for TSS. However should concentrations exceed 50 mg/L the potential impacts in terms of turbidity and deposition would increase and may have a negative impact on sensitive receptors in close proximity to the discharge location.

Mitigation and Management Measures

The design assumptions will be verified through more detailed investigations to:

- Better characterise of the effective PSD of suspended sediment that will be conveyed to the DMPF. This will include an assessment of the proportion of fine material that will be in suspension as opposed to being present in clay balls that will readily settle out;
- Improve understanding of the flocculation behaviour of suspended material within the DMPF; and
- Improve understanding of the sediment solids to water ratios that will be generated during dredging operations.

The findings of these additional investigations will be used to inform the detailed facility design.

10 Proposed Impact Management

When dredging operations commence, frequent sampling should be taken at the dredge pipeline discharge into the facility to verify the design assumptions.

Water quality will be regularly monitored in the polishing ponds to ensure that discharges from the facility comply with licence conditions. The frequency of sampling will increase in the period prior to and during embankment raises and towards the end of the dredging process as the remaining capacity within the DMPF reduces and the detention time available for settling decreases.

During the operation of the facility, periodic site inspections will be conducted. Management effort will be focused on maximising the storage capacity gained from drying and consolidation of dredged material.

To avoid ponding of water due to precipitation, the sluice intake levels will be kept at a level that allows efficient release of runoff water.

Silt curtains and baffles may be employed to increase the effectiveness of the DMPF.

10.2.7 Erosion and Sediment Mobilisation

Activities

During operation the main sources of erosion and sediment mobilisation are likely to arise from vehicle usage of construction roads and earthworks for embankment raises.

Potential Impacts

The above activities can result in localised erosion and sediment mobilisation leading to deleterious effects on water quality and aquatic habitats.

Mitigation and Management Measures

- Concentrating work to as small an area as possible and progressively expanded to reduce the area potentially at risk;
- Minimising the number of passes by heavy earth moving equipment;
- Stripping and stockpiled usable topsoil away from drainage lines to protect it from erosion;
- Implementing sediment limitation devices (e.g. settlement/evaporation ponds, drainage ditches);
- Constructing temporary and permanent bunds to restrict flow velocities across the project site;
- Limiting vegetation clearing work during heavy rainfall;
- Requesting the earthworks contractor to prepare a Sediment and Erosion Control Plan prior to the commencement of construction;
- Adopting stormwater controls and upstream treatment, such as infiltration devices, sediment ponds and vegetation filters;
- Locating vehicle wash bays away from watercourses;
- Minimising vegetation disturbance, especially riparian vegetation;
- Implementing dust suppression measures including irrigation and/or covering of stockpiles; and
- Adopting erosion control, energy dissipation and scour protection, such as matting, riprap and gabions.

10.2.8 Improper Disposal of Effluent and Operational Waste Water

Activities

It is expected a small amount of human sewage waste may result from site construction and operation. This will be generated by civil and dredging contractors working on site. It is expected that the construction phase will create the bulk of the human activity on site, with this reducing significantly during the operation phase of the site for maintenance dredging.

Impacts

Sewage and operational waste water can enter into drainage features and receiving waters altering the physical and chemical quality of the water and waterway. Effluent from any site ablutions facilities requires appropriate treatment and discharge or removal from site to avoid scour, sediment mobilisation or adverse impact on receiving surface water quality.

Mitigation and Management Measures

The effective level and rate of treatment will be evaluated to mitigate the likelihood of uncontrolled and/or non compliant discharge to receiving waters. This may be undertaken using a water balance or water quality model.

Telemetry monitoring systems will be installed (to measure, EC, pH and water level) in all containment facilities with off-site discharges to the receiving environment. This will provide accurate information regarding both quantity and quality of discharged effluent and calibration data for future water balance, water quality and flood assessment modelling.

Any other site effluent and/or any operational waste water will be removed and disposed of as per the Waste Management Strategy (refer to EIS Section 7).

10.2.9 Flooding

Impacts

Out-of-bank/flash flood events during the operational phase of the project could result in non-compliant off-site discharges due to inadequate containment capacity of the proposed stormwater management system. If fluvial flooding is frequent and uncontrolled, it may present a significant risk to workers' health and safety, as well as to vulnerable infrastructure, especially given the likely 'flashy' response of the catchment to short, intense rainfall events.

Additionally siltation or blockage of stormwater diversion infrastructure may pose a potential risk of inundation to adjoining properties and catchments.

Flooding or fast surface flows within the DMPF has the potential to cause re-suspension of dredge material and cause a non-compliant discharge.

Mitigation and Management Measures

Assessments described in Appendix F and H, consider indicative designs for stormwater management measures at the DMPF study area. In areas where high velocities are predicted erosion protection will be provided in the form of baffles, bunds or rock protection.

Drainage diversions and sedimentation dams/evaporation basins will be inspected on a bi-annual basis, and after significant storm events, to check for erosion, cracking, visible seepage and any other unsuitable conditions. Timely action will be taken to prevent or minimise any actual or potential environmental harm through preventative works.

A guideline for the operation of the DMPF discharges during rainfall events will be developed to prevent discharges after a certain amount of rainfall when the risk of re-suspension of sediment is high.

Emergency response procedures (including evacuation procedures) and a flood warning system will be established and incorporated into the site's Health, Safety and Environment Plan to protect on-site personnel. Vulnerable infrastructure will be designed with floor levels above the 0.01 AEP (100 yr ARI) level.

10.3 Decommissioning Phase

Decommissioning of the DMPF will involve the reshaping of the surface into a stable free-draining landform by promoting controlled runoff and preventing ponding of water. Runoff from higher elevations around the periphery would be directed in a controlled manner along a network of surface drains toward the centre of the landform then to the spillway. The spillway would serve as a chute directing surface waters to the sea.

The surface drains would be designed to meet suitable ARI flood events and to resist erosion. Sediment traps and/or silt dams will be constructed to capture suspended sediment while vegetation is established. A range of options is available to provide erosion protection including a number of proprietary surface mat products, straw mulching or hydro-mulching.

Vegetation would be established across the surface of the final landform to promote natural regrowth and control erosion. Limited topsoil is available from the existing soil profile so additional treatment would be required, such as the addition of fertiliser and mulch, to promote vegetative growth across the rehabilitated surfaces.

Consolidation settlement of the dredged material and foundation is likely to occur for several years. However the rate of settlement will decrease over time. Several metres of settlement are estimated to occur primarily in areas above the mudflat, and lesser so toward the periphery. However a significant portion of this settlement would likely occur during placement of the dredge spoil. Surface drainage would be designed to allow for changes in grade to maintain positive drainage.

The stormwater drains built to transfer under the facility stormwater captured from upstream catchments would also be used to drain vadose water percolating through the dredge material. The drains are envisaged as maintenance-free, comprised of rockfill encased in engineered filter materials

The range of potential impacts and proposed mitigation and management measures during the decommissioning phase are broadly similar to those which are likely to be encountered during the construction phase of the Project.

The following impacts will be managed during the decommissioning phase of the project.

10 Proposed Impact Management

10.3.1 Erosion and Sediment Mobilisation

Activities

Earth moving activities are expected to include:

- Reshaping of the surface of the dredged material to provide a stable free-draining landform;
- Creation of surface drains;
- Filling and re-contouring of sedimentation/evaporation basins to match the surrounding topography; and
- Rehabilitation of storage and lay down areas.

Potential Impacts

Sediment mobilised during earth moving activities associated with the rehabilitation of storage and lay down areas and decommissioning of sedimentation/evaporation ponds may enter surface water runoff during rainfall events and discharge to drainage lines leading to deleterious effects on water quality and aquatic habitats. Sediment exposed or generated during earth moving works may also be blown by wind into surface water bodies.

Mitigation and Management Measures

Areas of disturbed or exposed soil will be managed to reduce sediment mobilisation and erosion by:

- Concentrating work to as small an area as possible and progressively expanded to reduce the area potentially at risk;
- Minimising the number of passes by heavy earth moving equipment;
- Requesting the earthworks contractor to prepare a Sediment and Erosion Control Plan covering the decommissioning works;
- Locating vehicle wash bays away from watercourses;
- Revegetating and/or using of other stabilisation techniques, considering seasonal influences, upon completion of works;
- Implementing dust suppression measures including irrigation and/or covering of stockpiles; and
- Adopting erosion control, energy dissipation and scour protection, such as matting, riprap and gabions.

The application of the above proposed management measures will reduce both the likelihood and the consequences of the above impacts.

10.3.2 Contaminant Mobilisation

Activities

The use of fuels onsite may involve the refuelling of vehicles during decommissioning of the site facility and associated infrastructure. Potential aqueous waste streams may include oily waste water (from equipment wash water), contaminated drainage from fuel oil storage areas, and general washdown water.

Potential Impacts

Without proper mitigation measures, runoff from potentially contaminated drainage from fuel oil storage areas and general washdown water could enter into drainage features and receiving waters, altering the physical and chemical quality of the water and receiving environment. Additionally, site excavation works may expose groundwater which have been found to have high background levels of dissolved metals in both near-surface and deeper aquifers.

Mitigation and Management Measures

These potential impacts will be mitigated by:

- Storage of fuels and chemicals in bunded areas with spill cleanup kits in accordance with Australian Standards (AS1940 and AS3780) to prevent the contamination of surrounding surface runoff;
- The transfers of fuels and chemicals controlled and managed to prevent spillage outside bunded areas;
- Implement controls so that leaks/spills are immediately reported and appropriate emergency clean-up operations implemented to prevent possible mobilisation of contaminants;
- Chemically contaminated areas are to be protected from rainfall by roofing to reduce the likelihood of overtopping;
- Bunds and sumps are frequently drained, and effluent is treated appropriately; and
- Contaminants or major spillages of stored material in the bunded areas are collected by licensed waste collection and transport contractors for disposal off site at a licensed facility;

The application of the above proposed management measures may reduce the likelihood and consequence of the potential impacts.

10.3.3 Pollution

Activities & Potential Impacts

Decommissioning activities associated with potential pollution sources will involve the removal of chemical storage areas and other pollutant storage areas. Testing of these areas will be undertaken and decontamination work undertaken where necessary. These areas will then be rehabilitated and revegetated.

Mitigation and Management Measures

Mitigation measures for the decommissioning of potential pollution sources:

- Testing and decontamination works will be undertaken by appropriately qualified personnel;
- Earthworks will be undertaken in accordance with the sediment and erosion control plan; and
- Waste materials from the decommissioning works areas will be collected by licensed waste collection and transport contractors for disposal off site at a licensed facility

The application of the above proposed management measures will reduce the likelihood of the potential pollution impacts.

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Limitations

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 15 July 2009.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between 6 July to 23 October 2009 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

Appendix A Sediment Characterisation

A.1 Summary dredge sample descriptions

Table A-1 Laboratory Analysis - Dredge Sample Descriptions

Location	Depth (m)	Description
BH01A	0.0 - 1.0	SILTY SAND: grey, fine to coarse sand, some gravel (shells), some clay of low plasticity (Alluvial).
	1.0 - 2.1	SANDY CLAY: grey, medium plasticity, fine to coarse sand, some fine gravel (shells) (Alluvial).
	2.1 - 2.8	SANDY CLAY: grey, medium plasticity, fine to coarse sand, some fine gravel (Residual).
BH02A	0.0 - 1.0	SAND: brown, fine to coarse sand, trace of silt, trace of fine gravel (shells)
	1.0 - 2.75	SANDY CLAY/CLAYEY SAND: dark grey, medium plasticity, fine to coarse sand, some fine to medium gravel (Shells) (Alluvial).
	2.75 - 3.1	SANDY CLAY: brown & grey, medium plasticity, fine to medium sand (Residual).
BH04A	0.0 - 0.2	GRAVELLY (shells) SAND: grey, fine to coarse sand, some clay of low plasticity (Alluvial soil)
	0.2 - 0.5	SANDY CLAY: mottled yellow-brown and grey, medium plasticity, some fine to medium gravel (Residual soil)
	0.5 - 1.0	SILTY CLAY: mottled yellow-brown and grey. High plasticity, some fine to coarse sand (Residual soil)
BH07A	0.0 - 1.0	SANDY CLAY/CLAYEY SAND: grey, fine to coarse sand, low plasticity, some fine gravel shells present (Alluvium).
	2.0 - 2.8	SANDY GRAVEL: fine to coarse gravel, fine to coarse sand, some silt and clay of low plasticity (Alluvial).
	3.0 - 4.0	GRAVELLY SAND: brown, fine to coarse sand, fine to medium gravel, some silt (Alluvial).
BH08C	0.0 - 1.0	GRAVELLY SAND: grey, fine to coarse sand, fine to medium gravel, some silt (Alluvial).
	3.0 - 4.0	SILTY SAND: grey, fine to coarse sand, some gravel (shells) some clay of low plasticity (Alluvial)
	4.75 - 5.6	SANDY CLAY: grey, medium plasticity, fine to coarse sand, with fine to medium gravel as shells (Alluvial).
BH13A	0.0 - 1.0	SAND: grey, fine to coarse, some clay of low plasticity, some gravel (shells) (Alluvial).
	6.0 - 7.0	SILTY SAND: grey, fine to coarse sand, some low plastic clay, some fine gravel (shells) (Alluvial).
	11.5 - 12	SANDY CLAY: grey, medium plasticity, fine to coarse sand, some gravel (shells) (Alluvial)
BH14A	0.0 - 1.0	CLAYEY SILT: grey, fine to coarse, low plasticity with shells (Alluvial).
	2.5 - 3.5	SANDY CLAY: dark grey, high plasticity, fine to coarse sand, some of fine gravel (Alluvial).
	6.0 - 7.0	GRAVELLY SANDY CLAY/SANDY GRAVEL: brown, fine to medium gravel, fine to coarse sand, some silt (Alluvial).
BH17A	0.0 – 0.3	SANDY CLAY/CLAYEY SAND: dark grey, medium plasticity, fine to coarse sand, some fine to medium gravel,(shells and rock)
	0.3 – 1.2	SILTY CLAY: brown, medium plasticity, some fine to coarse sand.
BH18A	2.0 - 3.0	SANDY CLAY/CLAYEY SAND: dark grey, medium plasticity, fine to coarse sand, some fine to medium gravel (shells and rock) (Alluvial).
	10.0 - 11.0	SILTY CLAY: brown, medium plasticity, some fine to coarse sand (Residual).

Appendix A

Location	Depth (m)	Description
	11.1 - 11.5	SAND: grey, fine to coarse, some fine to medium gravel (shells), some low plastic clay (Alluvial).

A.2 Average Particle Size Distribution

Table A-2 Laboratory Analysis - Average PSD

Sieve Size (mm)	% Passing
<0.002	21
0.002 - 0.005	26
0.005 - 0.01	29
0.01 - 0.02	33
0.02 - 0.05	38
0.05 - 0.075	43
0.075 - 0.15	47
0.15 - 0.3	59
0.3 - 0.425	66
0.425 - 0.6	72
0.6 - 1.18	81
1.18 - 2.36	87
2.36 - 4.75	91
4.75 - 6.7	93
6.7 - 9.5	96
9.5 - 13.2	97
13.2 – 19	98
19 - 26.5	98
26.5 - 37.5	99
37.5 – 53	100

A.3 Zone Settling Summary

Table A-3 Laboratory Analysis - Zone Settling

Borehole Sample	Depth (m)	Time for 100% settlement (mins)	Sample Settling Velocity (m/s)
BH01A	0.0 - 1.0	500	9.528E-06
	1.0 - 2.1	500	1.014E-05
	2.1 - 2.8	500	9.528E-06
BH02A	0.0 - 1.0	20	2.870E-04
	1.0 - 2.75	600	1.086E-05
	2.75 - 3.1	600	1.098E-05
BH04A	0.0 - 0.2	60	8.964E-05

Appendix B Mass and Water Balance Model Input Data

The mass and water balance model has been developed on the basis of the following information and data:

- URS project proposal (9 February 2009);
- Site inspection and geotechnical investigation;
- Climate data (rainfall and evaporation) obtained by URS from Queensland Department of Natural Resources and Water SILO Data Drill (17 July 2009);
- Feasibility of Disposal of Dredged Material on Curtis Island (GLNG Ref: 1603-HRW-2-3.3-9006-PDF);
- Laird Point Placement Facility Concept Description report by HR Wallingford (GLNG Ref: 1603-HRW-2-3.3-9038-PDF);
- Source Terms for Plume Dispersion Modelling (GLNG Ref: 3301-HRW-3-3.3-9101-PDF); and
- The water sources represented in the water management system include:
  - — Runoff from varying catchment types,
  - — Evaporation from storage areas, and
  - — Direct rainfall onto the inundation surface of storages.

B.1 Rainfall

Long-term rainfall data for the LPDSPF was obtained from the Department of Natural Resources and Water (NRW) Data Drill system. The Data Drill rainfall is determined through accessing grids of data derived from interpolation of regional Bureau of Meteorology (BoM) station records. This provides a synthetic data set for a defined set of co-ordinates, derived from actual recorded data.

The long-term rainfall statistics for the proposed site are listed in following table.

Table B-4 Long Term Rainfall Statistics (107 years, commencing 1900) (mm)

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average	122	117	83	43	45	39	32	26	26	47	67	102	749
Std. Dev	108	119	81	54	55	43	38	28	28	42	44	81	255

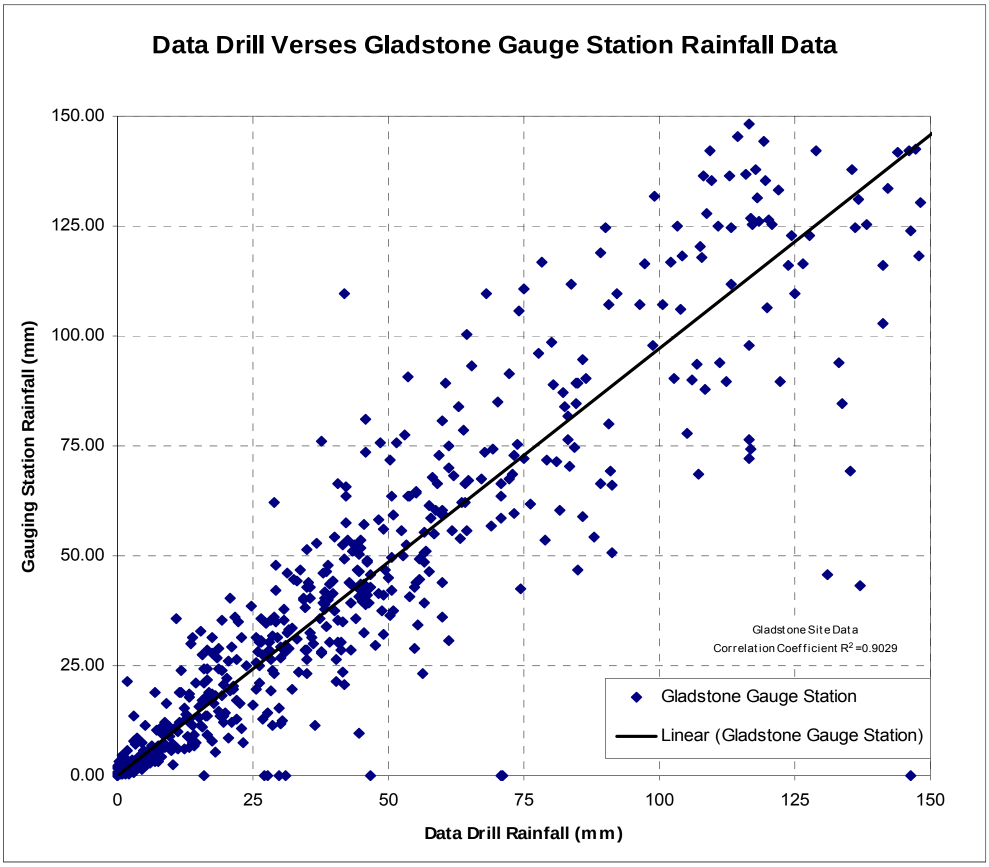
Daily site records from the Gladstone Radar gauge (station number 039326) for the period January 1958 to December 2007 was used to analyse against the corresponding Data Drill averages for the period. Monthly averages are detailed in Table B-5, along with the corresponding Data Drill averages for that period.

Table B-5 Monthly Site & Data Drill Rainfalls (Jan 1958 - Dec 2007) (mm)

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Data Drill Average	146	143	96	52	63	40	33	32	26	53	72	125	881
Stn No. 039326 Average	141	133	82	45	60	39	32	32	26	62	72	130	853

Comparison of monthly totals is also represented in Figure B-1.

Figure B-1 Comparison of Data Drill with Site Recorded Data, Monthly Totals (1958 - 2007)



Review of Figure B-1 shows good correlation between the Gladstone gauge station recorded data and data drill rainfall values, for the concurrent period, with a R^2 value of 0.9029. Given this, current investigations have adopted the Data Drill rainfall values for long-term water management simulation.

The WBM was run using the highest wet year daily rainfall data in 100 years commencing 1900 to 2000. Using the Log-Persons III method it has been identified that this event occurred from 1 September 1955 to 31 October 1956 with 1666.5 mm of rainfall falls within that period.

B.2 Evaporation

Long-term evaporation data for the Laird Point dredge spoil placement facility was obtained from the Department of Natural Resources and Water (NRW) Data Drill system. The Data Drill evaporation is determined through accessing grids of data derived from interpolation of regional Bureau of Meteorology (BoM) station records. This provides a synthetic data set for a defined set of co-ordinates, derived from actual recorded data.

Average total evaporation rates from the Gladstone Radar gauge station (039123) and Data Drill evaporation data, provided by DERM are listed in Table B-6.

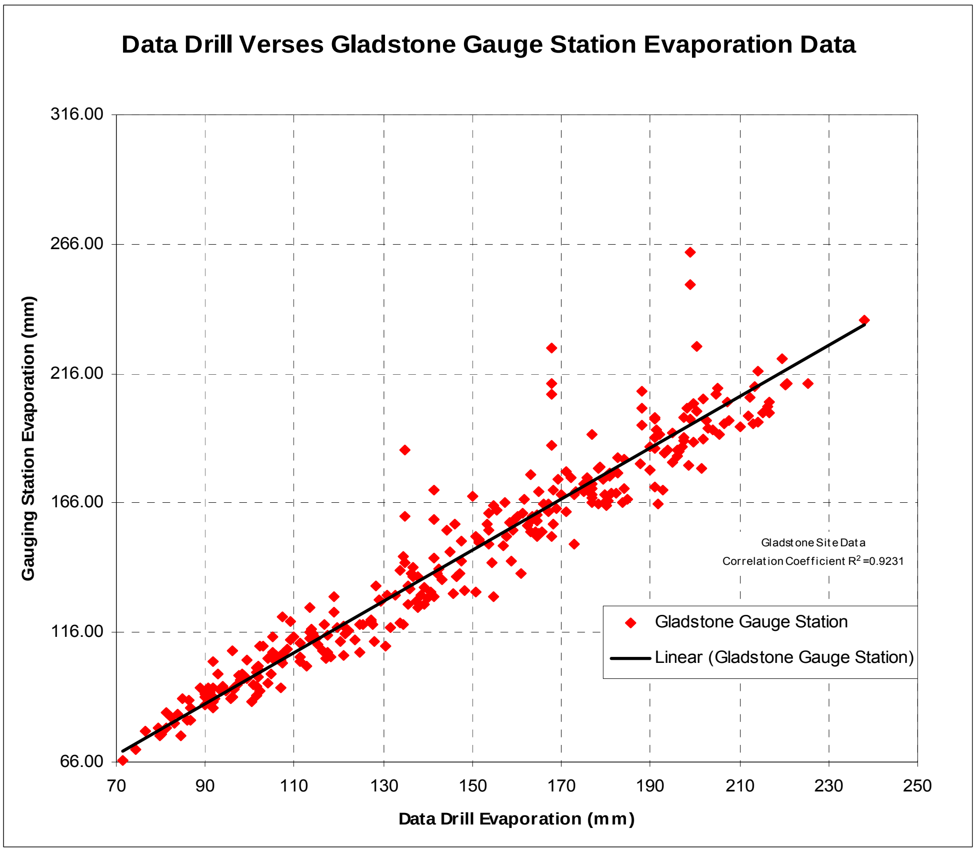
Appendix B

Table B-6 Mean Monthly Pan Evaporation (mm/day)

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Data Drill Average	6	5	5	4	3	3	3	4	5	6	6	6	147
Stn No. 039326 Average	6	5	5	4	3	3	3	3	4	5	6	6	145

Comparison of monthly totals is also compared in Figure B-2.

Figure B-2 Correlation of evaporation Data Drill values with site recorded data, monthly totals (January 1967 – December 1992)



Review of Figure B-2 shows good correlation between the Gladstone gauge station recorded data and data drill evaporation values, for the concurrent period, with a R^2 value of 0.9231. As for rainfall data, given its good correlation current investigations have adopted the Data Drill evaporation values for long-term water management simulation.

B.3 Survey

Contour and feature survey information for the site were provided by Santos. This information was current as at June 2009 and for the purposes of this investigation, this data has been assumed to define current conditions (e.g. land disturbance, catchment areas, etc). Survey data is presented in Figure B-3.

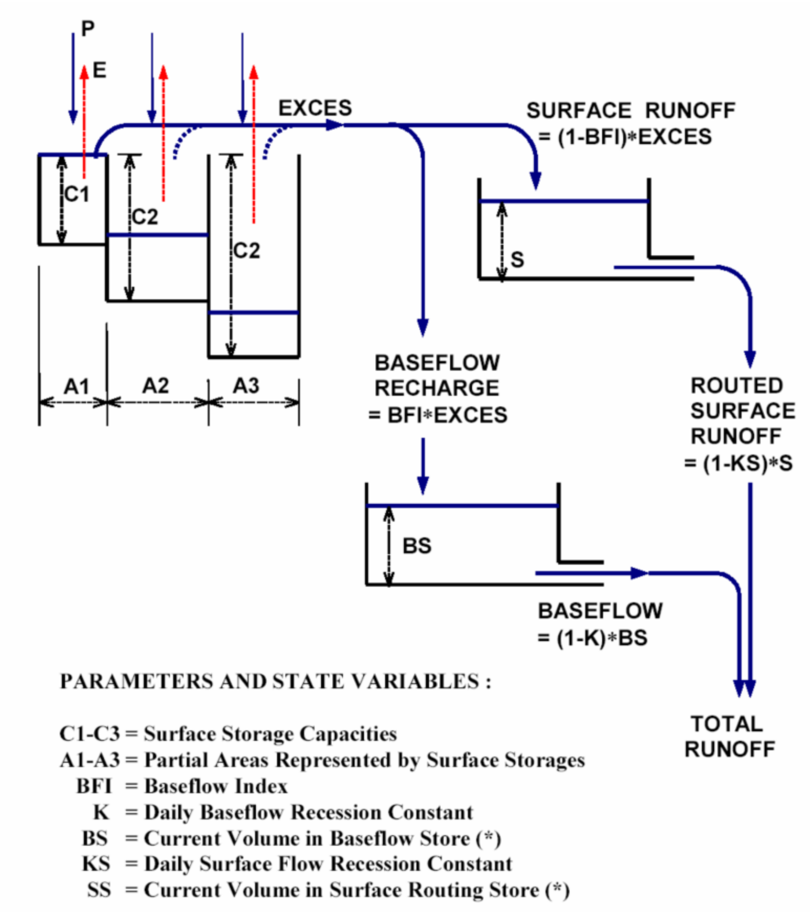
Source: This map may be sourced and Copyright. See Section 18.2 of the EIS for Ownership and Copyright.

Client	Project	Title	
LNG	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT SUPPLEMENT DREDGE MATERIAL PLACEMENT FACILITY DEWATERING ASSESSMENT AND PRELIMINARY DESIGN	**SITE LAYOUT**	
URS	Drawn: RG Approved: JB Date: 27-10-2009	Figure: **B3**	Rev. B
	Job No.: **4262 6440** /6220 File No. 42626440-g-2150.cdr		A4

B.4 Catchment Runoff

Catchment runoff was modelled using the AWBM runoff model, further description of the may be obtained from the CRC Catchment Hydrology Rainfall Runoff Library software documentation (www.toolkit.net.au). The AWBM model is considered a more superior method of estimating runoff from rainfall than simpler methods using runoff coefficients. The AWBM model takes account of observe variability of runoff rate in response to preceding rainfall conditions and corresponding effect on catchments “wetness”. For example a moderate to intense rainfall event on a relatively dry catchment could produce little or no runoff, whereas a relatively small rainfall event on saturated catchment can produce substantial runoff (see Figure B-4).

Figure B-4 AWBM Process



B.4.1 Adopted AWBM Parameters

The natural land type parameters were calibrated using the Rainfall Runoff Library (RRL). The RRL uses daily time series rainfall and evapotranspiration data to generate daily catchment runoff. The generator provides several commonly used lumped rainfall-runoff models, calibration optimisers and display tools to facilitate model calibration. Once the runoff is estimated, it is then compared, using statistical correlation methods, to real flow data.

Appendix B

The calibration of AWBM runoff parameters for natural land type was presented in EIS Appendix O using recorded flow data. A variety of different optimisation methods were used to assess numerous AWBM parameter sets, resulting in the highest correlation being adopted. For this assessment a correlation R^2 value of 0.676 was achieved, which is considered adequate for this level of assessment.

There was no data available to calibrate runoff parameters for hardstand catchment land types. The adopted AWBM runoff parameters were therefore estimated by adjustment of the natural land type runoff model parameters based on the inferred physical differences between hardstand areas relative to characteristics of natural (relatively undisturbed) catchment surfaces.

The general approach was to reduce the catchment store depth (C1, C2 and C3), generally to produce higher runoff. This alteration takes into account the relatively heavily compacted areas and the assumption that hardstand areas will be well drained. However, hardstand areas are often relatively flat and include many minor small surface depressions, which produce some losses as water is retained on the surface and evaporates away after rainfall events.

Additionally, hardstand catchments are assumed to have minimal or no significant baseflow recession. Therefore the Base Flow Index parameter was set to zero. Table B-7 below provides the adopted AWBM parameters for the proposed site.

Table B-7 Adopted Natural Land Type AWBM Parameters

AWM Parameters	Natural	Hardstand
A1	0.134	0.134
A2	0.433	0.433
A3	0.433	0.433
BFI	0.673	0
C1	19.292	5
C2	154.526	20
C3	914.447	40
K Base	0.269	0.269
K Surf	0.917	0.917

A1-A3 = Partial areas represented by surface storages

C1-C3 = Surface storage capacities

BFI = Baseflow index

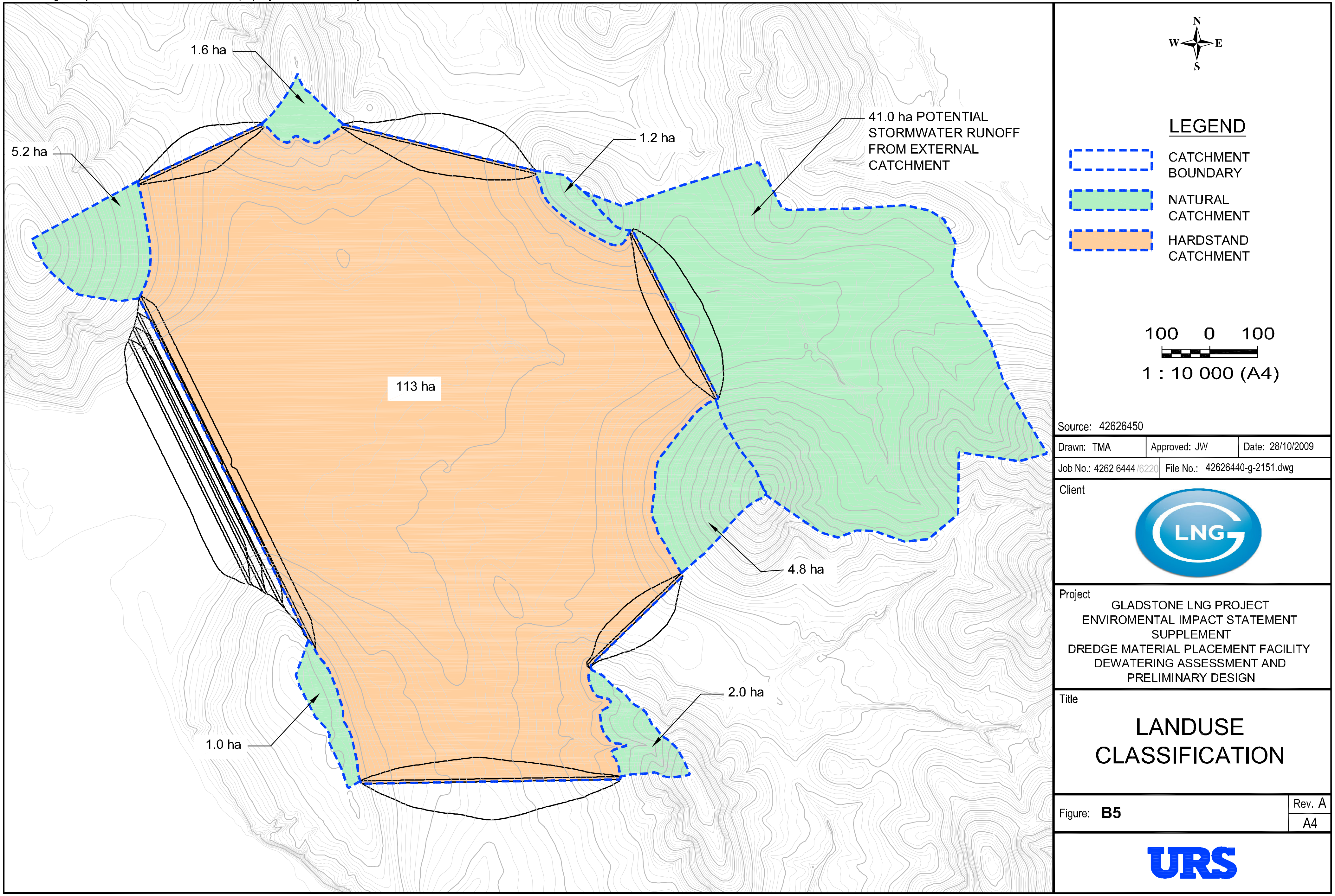
Kbase = Daily baseflow recession constant

Ksurf = Daily surface flow recession constant

B.5 Catchment Areas and Land Use Classifications

The dredge spoil placement facility and upstream catchments were divided into different catchment that can be considered as having relatively similar runoff quantity characteristics. Stormwater runoff is anticipated to be attributed by two key sources, disturbed and natural catchments. These areas will also be referred to as natural and hardstand.

Maximum stormwater runoff is anticipated to occur once the dredge spoil placement area has been cleared. This cleared area within the footprint of the proposed facility is classified as hardstand while the external area which contributes to stormwater runoff flowing into the facility is classified as natural land type. The following figure shows the catchment area and land use classification of the propose facility. Runoff from the external catchment has been included in the WBM to evaluate the capacity of the facility to handle stormwater runoff from the upstream catchment. However, it has been proposed that the runoff from the external catchment will be diverted by large diameter pipe through the site to discharge directly into North China Bay. For detailed information please refer to the Gladstone LNG Dredge Material Placement Facility Phase II Surface Water Assessment report.



Source: 42626450

Drawn: TMA	Approved: JW	Date: 28/10/2009
Job No.: 4262 6444 /6220	File No.: 42626440-g-2151.dwg	

Client

LNG

Project
GLADSTONE LNG PROJECT
ENVIROMENTAL IMPACT STATEMENT
SUPPLEMENT
DREDGE MATERIAL PLACEMENT FACILITY
DEWATERING ASSESSMENT AND
PRELIMINARY DESIGN

Title

LANDUSE CLASSIFICATION

Figure: **B5** Rev. A A4

URS

Appendix B

B.5.1 Catchment Runoff Suspended Solids Concentrations

The catchment runoff suspended solids concentrations adopted in the WBM were sourced from MUSIC where 100 mg/L and 200 mg/L has been adopted for natural and hardstand land type respectively.

B.6 Particle Size Distribution

The PSD used in the modelling was based on the average PSD taken from the laboratory analysis as presented in the following table.

Table B-8 Average Particle Size Distribution

Sieve Size (mm)	% Passing
<0.002	21
0.002 - 0.005	26
0.005 - 0.01	29
0.01 - 0.02	33
0.02 - 0.05	38
0.05 - 0.075	43
0.075 - 0.15	47
0.15 - 0.3	59
0.3 - 0.425	66
0.425 - 0.6	72
0.6 - 1.18	81
1.18 - 2.36	87
2.36 - 4.75	91
4.75 - 6.7	93
6.7 - 9.5	96
9.5 - 13.2	97
13.2 – 19	98
19 - 26.5	98
26.5 - 37.5	99
37.5 – 53	100

Appendix C Sediment Basin Design Calculations

Table C-9 Stage 1 DMPF Performance Assessment Summary

Laird Point Dredge Material Placement Facility Performance Assessment Summary Scenario: Stage 1 with external embankments being constructed to 10 m RL and no internal bunds.		
1.	Material Description	Parameters
	Total dredge material to be removed (m^3)	6.8 million m^3
	Solid to water ratio (%)	14:86
	Total combined volume (m^3)	48.57 million m^3
	Bulking factor	1.4
	Grading:	
	• Silt and Clay (<0.075 mm)	43%
	• Sand (0.075 mm to 4.75 mm)	48%
	• Gravel (>4.75 mm)	9%
	Concentration (mg/L)	293023
	Assumed average dry bulk density (kg/m^3)	1800
	Assumed density of particle (kg/m^3)	2600
	Density of fluid (kg/m^3)	1030
	Dynamic viscosity (Pa.s)	0.00108
2.	Extraction Rate	
	Solid volume (m^3/hr)	995.3
	Total inflow (solid+water) (m^3/hr)	7109.4
3.	Project Duration	
	Production hours per day	20
	Total extraction time (weeks)	48.8
4.	Performance	
	Height of embankment (m RL)	10
	Total surface area at 10m RL (m^2)	821801
	Total capacity (m^3)	4256101
	Height of sluice (m RL)	8.7
	Assumed dead zone (%)	20
	Surface Area at 8.7m RL (m^2)	741202
	Effective surface area at 8.7m RL (m^2)	592962
	Freeboard allowance (m)	1-1.5
	Maximum operating volume (m^3)	2479049
	Days of operation	77.7
	Average detention time (hrs)	214.4
	Pond rating (m^2 per m^3/s)	300259
	Minimum ponding/operating depth (m)	0.6
	Maximum ponding/operating depth (m)	4.7

Laird Point Dredge Material Placement Facility Performance Assessment Summary Scenario: Stage 1 with external embankments being constructed to 10 m RL and no internal bunds.		
1.	Material Description	Parameters
	Final solid level (m RL)	7.9
	Final water depth (m)	0.8
	Minimum flow velocity (m/s)	$3.329*10^{-6}$
	Maximum flow velocity (m/s)	$3.331*10^{-6}$
	Smallest particle removed based on Stokes Law (mm)	0.002
	Estimated concentration in discharge effluent (mg/l)	<50

Table C-10 Stage 2 DMPF Performance Assessment Summary

Laird Point Dredge Material Placement Facility performance Assessment Summary Scenario: Stage 2 with external and internal embankments being constructed to 14 m RL.		
1.	Material Description	Parameters
	Total dredge material to be removed (m^3)	6.8 million m^3
	Solid to water ratio (%)	14:86
	Total combined volume (m^3)	48.57 million m^3
	Bulking factor	1.4
	Grading:	
	• Silt and Clay (<0.075 mm)	43%
	• Sand (0.075 mm to 4.75 mm)	48%
	• Gravel (>4.75 mm)	9%
	Concentration (mg/L)	293023
	Assumed average dry bulk density (kg/m^3)	1800
	Assumed density of particle (kg/m^3)	2600
	Density of fluid (kg/m^3)	1030
	Dynamic viscosity (Pa.s)	0.00108
2.	Extraction Rate	
	Solid volume (m^3/hr)	995.3
	Total inflow (solid+water) (m^3/hr)	7109.4
3.	Project Duration	
	Production hours per day	20
	Total extraction time (weeks)	48.8
4.	Performance	
	Combined Pond S1, S2, S3, N3 and N2 Performance	
	Height of embankment (m RL)	14
	Total surface area at 14m RL (m^2)	782289
	Total capacity (m^3)	3813164

Appendix C

Laird Point Dredge Material Placement Facility performance Assessment Summary Scenario: Stage 2 with external and internal embankments being constructed to 14 m RL.		
1.	Material Description	Parameters
	Height of sluice (m RL)	13.2
	Assumed dead zone (%)	20
	Surface Area at 13.2m RL (m^2)	747481
	Effective surface area at 13.2m RL (m^2)	597985
	Freeboard allowance (m)	1-1.5
	Maximum operating volume (m^3)	2562365
	Days of operation	13.7
	Average detention time (hrs)	161.9
	Pond rating (m^2 per m^3/s)	289649
	Minimum ponding/operating depth (m)	0.6
	Maximum ponding/operating depth (m)	3.7
	Final solid level (m RL)	11.9
	Final water depth (m)	0.7
	Minimum flow velocity (m/s)	$3.302*10^{-6}$
	Maximum flow velocity (m/s)	$3.304*10^{-6}$
	Smallest particle removed based on Stokes Law (mm)	0.002
	Estimated concentration in discharge effluent (mg/l)	<50
	Combined Pond S2, S3, N3, N2 and N1 Performance	
	Height of embankment (m RL)	14
	Total surface area at 14m RL (m^2)	784778
	Total capacity (m^3)	3890181
	Height of sluice (m RL)	13.2
	Assumed dead zone (%)	20
	Surface Area at 13.2m RL (m^2)	752243
	Effective surface area at 13.2m RL (m^2)	601794
	Freeboard allowance (m)	1-1.5
	Maximum operating volume (m^3)	2621560
	Days of operation	13
	Average detention time (hrs)	212
	Pond rating (m^2 per m^3/s)	304726
	Minimum ponding/operating depth (m)	0.6
	Maximum ponding/operating depth (m)	4.0
	Final solid level (m RL)	11.9
	Final water depth (m)	1.33
	Minimum flow velocity (m/s)	$3.282*10^{-6}$
	Maximum flow velocity (m/s)	$3.290*10^{-6}$
	Smallest particle removed based on Stokes Law (mm)	0.002
	Estimated concentration in discharge effluent (mg/l)	<50

Laird Point Dredge Material Placement Facility performance Assessment Summary Scenario: Stage 2 with external and internal embankments being constructed to 14 m RL.		
1.	Material Description	Parameters
	Combined Pond S3, N3, N2, N1 and S1 Performance	
	Height of embankment (m RL)	14
	Total surface area at 14m RL (m^2)	780219
	Total capacity (m^3)	3869778
	Height of sluice (m RL)	13.2
	Assumed dead zone (%)	20
	Surface Area at 13.2m RL (m^2)	746725
	Effective surface area at 13.2m RL (m^2)	597380
	Freeboard allowance (m)	1-1.5
	Maximum operating volume (m^3)	2608551
	Days of operation	9.9
	Average detention time (hrs)	201
	Pond rating (m^2 per m^3/s)	302496
	Minimum ponding/operating depth (m)	0.6
	Maximum ponding/operating depth (m)	3.8
	Final solid level (m RL)	11.9
	Final water depth (m)	1.3
	Minimum flow velocity (m/s)	$3.305*10^{-6}$
	Maximum flow velocity (m/s)	$3.306*10^{-6}$
	Smallest particle removed based on Stokes Law (mm)	0.002
	Estimated concentration in discharge effluent (mg/l)	<50
	Combined Pond N3, N2, N1, S1 and S2 Performance	
	Height of embankment (m RL)	14
	Total surface area at 14m RL (m^2)	795538
	Total capacity (m^3)	4011573
	Height of sluice (m RL)	13.2
	Assumed dead zone (%)	20
	Surface Area at 13.2m RL (m^2)	762981
	Effective surface area at 13.2m RL (m^2)	610385
	Freeboard allowance (m)	1-1.5
	Maximum operating volume (m^3)	2711791
	Days of operation	14.2
	Average detention time (hrs)	222.5
	Pond rating (m^2 per m^3/s)	309082
	Minimum ponding/operating depth (m)	0.6
	Maximum ponding/operating depth (m)	4.1
	Final solid level (m RL)	11.9
	Final water depth (m)	1.3
	Minimum flow velocity (m/s)	$3.235*10^{-6}$

Appendix C

Laird Point Dredge Material Placement Facility performance Assessment Summary Scenario: Stage 2 with external and internal embankments being constructed to 14 m RL.		
1.	Material Description	Parameters
	Maximum flow velocity (m/s)	$3.255*10^{-6}$
	Smallest particle removed based on Stokes Law (mm)	0.002
	Estimated concentration in discharge effluent (mg/l)	<50
	Combined Pond N2, N1, S1, S2 and S3 Performance	
	Height of embankment (m RL)	14
	Total surface area at 14m RL (m^2)	779445
	Total capacity (m^3)	3823198
	Height of sluice (m RL)	13.2
	Assumed dead zone (%)	20
	Surface Area at 13.2m RL (m^2)	745167
	Effective surface area at 13.2m RL (m^2)	596134
	Freeboard allowance (m)	1-1.5
	Maximum operating volume (m^3)	2572005
	Days of operation	15.2
	Average detention time (hrs)	225.3
	Pond rating (m^2 per m^3/s)	301865
	Minimum ponding/operating depth (m)	0.6
	Maximum ponding/operating depth (m)	4.2
	Final solid level (m RL)	11.9
	Final water depth (m)	1.3
	Minimum flow velocity (m/s)	$3.312*10^{-6}$
	Maximum flow velocity (m/s)	$3.322*10^{-6}$
	Smallest particle removed based on Stokes Law (mm)	0.002
	Estimated concentration in discharge effluent (mg/l)	<50
	Combined Pond N1, S1, S2, S3 and N3 Performance	
	Height of embankment (m RL)	14
	Total surface area at 14m RL (m^2)	775913
	Total capacity (m^3)	3780233
	Height of sluice (m RL)	13.2
	Assumed dead zone (%)	20
	Surface Area at 13.2m RL (m^2)	740149
	Effective surface area at 13.2m RL (m^2)	592119
	Freeboard allowance (m)	1-1.5
	Maximum operating volume (m^3)	2540075
	Days of operation	14.6
	Average detention time (hrs)	220.6
	Pond rating (m^2 per m^3/s)	299832
	Minimum ponding/operating depth (m)	0.6

Laird Point Dredge Material Placement Facility performance Assessment Summary Scenario: Stage 2 with external and internal embankments being constructed to 14 m RL.		
1.	Material Description	Parameters
	Maximum ponding/operating depth (m)	4.3
	Final solid level (m RL)	11.9
	Final water depth (m)	1.3
	Minimum flow velocity (m/s)	$3.330*10^{-6}$
	Maximum flow velocity (m/s)	$3.338*10^{-6}$
	Smallest particle removed based on Stokes Law (mm)	0.002
	Estimated concentration in discharge effluent (mg/l)	<50

Table C-11 Stage 3 DMPF Performance Assessment Summary

Laird Point Dredge Material Placement Facility Performance Assessment Summary Scenario: Stage 3 with external and internal embankments being constructed to 18 m RL.		
5.	Material Description	Parameters
	Total dredge material to be removed (m^3)	6.8 million m^3
	Solid to water ratio (%)	14:86
	Total combined volume (m^3)	48.57 million m^3
	Bulking factor	1.4
	Grading:	
	• Silt and Clay (<0.075 mm)	43%
	• Sand (0.075 mm to 4.75 mm)	48%
	• Gravel (>4.75 mm)	9%
	Concentration (mg/L)	293023
	Assumed average dry bulk density (kg/m^3)	1800
	Assumed density of particle (kg/m^3)	2600
	Density of fluid (kg/m^3)	1030
	Dynamic viscosity (Pa.s)	0.00108
6.	Extraction Rate	
	Solid volume (m^3/hr)	995.3
	Total inflow (solid+water) (m^3/hr)	7109.4
7.	Project Duration	
	Production hours per day	20
	Total extraction time (weeks)	48.8
8.	Performance	
	Combined Pond S1, S2, S3, N3 and N2 Performance	
	Height of embankment (m RL)	18
	Total surface area at 18m RL (m^2)	861424

Appendix C

Laird Point Dredge Material Placement Facility Performance Assessment Summary Scenario: Stage 3 with external and internal embankments being constructed to 18 m RL.		
5.	Material Description	Parameters
	Total capacity (m^3)	4522181
	Height of sluice (m RL)	16.5
	Assumed dead zone (%)	20
	Surface Area at 16.5m RL (m^2)	805811
	Effective surface area at 16.5m RL (m^2)	644649
	Freeboard allowance (m)	1-1.5
	Maximum operating volume (m^3)	2617736
	Days of operation	16.1
	Average detention time (hrs)	186.8
	Pond rating (m^2 per m^3/s)	326432
	Minimum ponding/operating depth (m)	0.6
	Maximum ponding/operating depth (m)	3.8
	Final solid level (m RL)	15.9
	Final water depth (m)	0.6
	Minimum flow velocity (m/s)	$3.063*10^{-6}$
	Maximum flow velocity (m/s)	$3.082*10^{-6}$
	Smallest particle removed based on Stokes Law (mm)	0.002
	Estimated concentration in discharge effluent (mg/l)	<50
	Combined Pond S2, S3, N3, N2 and N1 Performance	
	Height of embankment (m RL)	18
	Total surface area at 18m RL (m^2)	858682
	Total capacity (m^3)	4526966
	Height of sluice (m RL)	16.5
	Assumed dead zone (%)	20
	Surface Area at 16.5m RL (m^2)	803848
	Effective surface area at 16.5m RL (m^2)	643079
	Freeboard allowance (m)	1-1.5
	Maximum operating volume (m^3)	2624391
	Days of operation	16.4
	Average detention time (hrs)	186.8
	Pond rating (m^2 per m^3/s)	325637
	Minimum ponding/operating depth (m)	0.6
	Maximum ponding/operating depth (m)	3.7
	Final solid level (m RL)	15.9
	Final water depth (m)	0.6
	Minimum flow velocity (m/s)	$3.070*10^{-6}$
	Maximum flow velocity (m/s)	$3.087*10^{-6}$
	Smallest particle removed based on Stokes Law (mm)	0.002
	Estimated concentration in discharge effluent (mg/l)	<50

Laird Point Dredge Material Placement Facility Performance Assessment Summary Scenario: Stage 3 with external and internal embankments being constructed to 18 m RL.		
5.	Material Description	Parameters
	Combined Pond S3, N3, N2, N1 and S1 Performance	
	Height of embankment (m RL)	18
	Total surface area at 18m RL (m^2)	847649
	Total capacity (m^3)	4463832
	Height of sluice (m RL)	16.5
	Assumed dead zone (%)	20
	Surface Area at 16.5m RL (m^2)	793825
	Effective surface area at 16.5m RL (m^2)	635060
	Freeboard allowance (m)	1-1.5
	Maximum operating volume (m^3)	2586516.75
	Days of operation	15
	Average detention time (hrs)	184.4
	Pond rating (m^2 per m^3/s)	321577
	Minimum ponding/operating depth (m)	0.6
	Maximum ponding/operating depth (m)	3.8
	Final solid level (m RL)	15.9
	Final water depth (m)	0.6
	Minimum flow velocity (m/s)	$3.109*10^{-6}$
	Maximum flow velocity (m/s)	$3.115*10^{-6}$
	Smallest particle removed based on Stokes Law (mm)	0.002
	Estimated concentration in discharge effluent (mg/l)	<50
	Combined Pond N3, N2, N1, S1 and S2 Performance	
	Height of embankment (m RL)	18
	Total surface area at 18m RL (m^2)	856603
	Total capacity (m^3)	4532308
	Height of sluice (m RL)	16.5
	Assumed dead zone (%)	20
	Surface Area at 16.5m RL (m^2)	803641
	Effective surface area at 16.5m RL (m^2)	642913
	Freeboard allowance (m)	1-1.5
	Maximum operating volume (m^3)	2629976
	Days of operation	17
	Average detention time (hrs)	195.1
	Pond rating (m^2 per m^3/s)	325553
	Minimum ponding/operating depth (m)	0.6
	Maximum ponding/operating depth (m)	4.0
	Final solid level (m RL)	15.9
	Final water depth (m)	0.6

Appendix C

Laird Point Dredge Material Placement Facility Performance Assessment Summary Scenario: Stage 3 with external and internal embankments being constructed to 18 m RL.		
5.	Material Description	Parameters
	Minimum flow velocity (m/s)	$3.071*10^{-6}$
	Maximum flow velocity (m/s)	$3.084*10^{-6}$
	Smallest particle removed based on Stokes Law (mm)	0.002
	Estimated concentration in discharge effluent (mg/l)	<50
	Combined Pond N2, N1, S1, S2 and S3 Performance	
	Height of embankment (m RL)	18
	Total surface area at 18m RL (m^2)	848293
	Total capacity (m^3)	4442735
	Height of sluice (m RL)	16.5
	Assumed dead zone (%)	20
	Surface Area at 16.5m RL (m^2)	792012
	Effective surface area at 16.5m RL (m^2)	633609
	Freeboard allowance (m)	1-1.5
	Maximum operating volume (m^3)	2570351
	Days of operation	16.9
	Average detention time (hrs)	186.2
	Pond rating (m^2 per m^3/s)	320842
	Minimum ponding/operating depth (m)	0.6
	Maximum ponding/operating depth (m)	3.8
	Final solid level (m RL)	15.9
	Final water depth (m)	0.6
	Minimum flow velocity (m/s)	$3.116*10^{-6}$
	Maximum flow velocity (m/s)	$3.132*10^{-6}$
	Smallest particle removed based on Stokes Law (mm)	0.002
	Estimated concentration in discharge effluent (mg/l)	<50
	Combined Pond N1, S1, S2, S3 and N3 Performance	
	Height of embankment (m RL)	18
	Total surface area at 18m RL (m^2)	849133
	Total capacity (m^3)	4446909
	Height of sluice (m RL)	16.5
	Assumed dead zone (%)	20
	Surface Area at 16.5m RL (m^2)	793302
	Effective surface area at 16.5m RL (m^2)	634641
	Freeboard allowance (m)	1-1.5
	Maximum operating volume (m^3)	2572447
	Days of operation	15.5
	Average detention time (hrs)	183.2
	Pond rating (m^2 per m^3/s)	321365

Laird Point Dredge Material Placement Facility Performance Assessment Summary Scenario: Stage 3 with external and internal embankments being constructed to 18 m RL.		
5.	Material Description	Parameters
	Minimum ponding/operating depth (m)	0.6
	Maximum ponding/operating depth (m)	3.8
	Final solid level (m RL)	15.9
	Final water depth (m)	0.6
	Minimum flow velocity (m/s)	$3.111*10^{-6}$
	Maximum flow velocity (m/s)	$3.115*10^{-6}$
	Smallest particle removed based on Stokes Law (mm)	0.002
	Estimated concentration in discharge effluent (mg/l)	<50

Table C-12 Stage 4 DMPF Performance Assessment Summary

Laird Point Dredge Material Placement Facility Performance Assessment Summary Scenario: Stage 4 with external and internal embankments being constructed to 22 m RL.		
9.	Material Description	Parameters
	Total dredge material to be removed (m^3)	6.8 million m^3
	Solid to water ratio (%)	14:86
	Total combined volume (m^3)	48.57 million m^3
	Bulking factor	1.4
	Grading:	
	• Silt and Clay (<0.075 mm)	43%
	• Sand (0.075 mm to 4.75 mm)	48%
	• Gravel (>4.75 mm)	9%
	Concentration (mg/L)	293023
	Assumed average dry bulk density (kg/m^3)	1800
	Assumed density of particle (kg/m^3)	2600
	Density of fluid (kg/m^3)	1030
	Dynamic viscosity (Pa.s)	0.00108
10.	Extraction Rate	
	Solid volume (m^3/hr)	995.3
	Total inflow (solid+water) (m^3/hr)	7109.4
11.	Project Duration	
	Production hours per day	20
	Total extraction time (weeks)	48.8
12.	Combined Pond S1, S2, S3, N3 and N2 Performance	
	Height of embankment (m RL)	22
	Total surface area at 22m RL (m^2)	920938

Appendix C

Laird Point Dredge Material Placement Facility Performance Assessment Summary Scenario: Stage 4 with external and internal embankments being constructed to 22 m RL.		
9.	Material Description	Parameters
	Total capacity (m^3)	4955033
	Height of sluice (m RL)	19.9
	Assumed dead zone (%)	20
	Surface Area at 19.9m RL (m^2)	846559
	Effective surface area at 19.9m RL (m^2)	677247
	Freeboard allowance (m)	1-1.5
	Maximum operating volume (m^3)	2480946
	Days of operation	14.7
	Average detention time (hrs)	177.7
	Pond rating (m^2 per m^3/s)	342939
	Minimum ponding/operating depth (m)	0.6
	Maximum ponding/operating depth (m)	3.3
	Final solid level (m RL)	19.3
	Final water depth (m)	0.6
	Minimum flow velocity (m/s)	$2.916*10^{-6}$
	Maximum flow velocity (m/s)	$2.922*10^{-6}$
	Smallest particle removed based on Stokes Law (mm)	0.0019
	Estimated concentration in discharge effluent (mg/l)	<50
13.	Combined Pond S2, S3, N3, N2 and N1 Performance	
	Height of embankment (m RL)	22
	Total surface area at 22m RL (m^2)	917625
	Total capacity (m^3)	4939385
	Height of sluice (m RL)	19.9
	Assumed dead zone (%)	20
	Surface Area at 19.9m RL (m^2)	843618
	Effective surface area at 19.9m RL (m^2)	674894
	Freeboard allowance (m)	1-1.5
	Maximum operating volume (m^3)	2473556
	Days of operation	15.3
	Average detention time (hrs)	178.1
	Pond rating (m^2 per m^3/s)	341747
	Minimum ponding/operating depth (m)	0.6
	Maximum ponding/operating depth (m)	3.2
	Final solid level (m RL)	19.3
	Final water depth (m)	0.6
	Minimum flow velocity (m/s)	$2.926*10^{-6}$
	Maximum flow velocity (m/s)	$2.932*10^{-6}$
	Smallest particle removed based on Stokes Law (mm)	0.0019
	Estimated concentration in discharge effluent (mg/l)	<50

Laird Point Dredge Material Placement Facility Performance Assessment Summary Scenario: Stage 4 with external and internal embankments being constructed to 22 m RL.		
9.	Material Description	Parameters
14.	Combined Pond S3, N3, N2, N1 and S1 Performance	
	Height of embankment (m RL)	22
	Total surface area at 22m RL (m^2)	898130
	Total capacity (m^3)	4831856
	Height of sluice (m RL)	19.9
	Assumed dead zone (%)	20
	Surface Area at 19.9m RL (m^2)	825714
	Effective surface area at 19.9m RL (m^2)	660571
	Freeboard allowance (m)	1-1.5
	Maximum operating volume (m^3)	2419087
	Days of operation	14.8
	Average detention time (hrs)	171.2
	Pond rating (m^2 per m^3/s)	334495
	Minimum ponding/operating depth (m)	0.6
	Maximum ponding/operating depth (m)	3.2
	Final solid level (m RL)	19.3
	Final water depth (m)	0.6
	Minimum flow velocity (m/s)	$2.990*10^{-6}$
	Maximum flow velocity (m/s)	$2.993*10^{-6}$
	Smallest particle removed based on Stokes Law (mm)	0.0019
	Estimated concentration in discharge effluent (mg/l)	<50
15.	Combined Pond N3, N2, N1, S1 and S2 Performance	
	Height of embankment (m RL)	22
	Total surface area at 22m RL (m^2)	896201
	Total capacity (m^3)	4849969
	Height of sluice (m RL)	19.9
	Assumed dead zone (%)	20
	Surface Area at 19.9m RL (m^2)	827369
	Effective surface area at 19.9m RL (m^2)	661896
	Freeboard allowance (m)	1-1.5
	Maximum operating volume (m^3)	2433321
	Days of operation	15.8
	Average detention time (hrs)	168.1
	Pond rating (m^2 per m^3/s)	335165
	Minimum ponding/operating depth (m)	0.6
	Maximum ponding/operating depth (m)	3.2
	Final solid level (m RL)	19.3
	Final water depth (m)	0.6
	Minimum flow velocity (m/s)	$2.984*10^{-6}$

Appendix C

Laird Point Dredge Material Placement Facility Performance Assessment Summary Scenario: Stage 4 with external and internal embankments being constructed to 22 m RL.		
9.	Material Description	Parameters
	Maximum flow velocity (m/s)	$2.996*10^{-6}$
	Smallest particle removed based on Stokes Law (mm)	0.0019
	Estimated concentration in discharge effluent (mg/l)	<50
16.	Combined Pond N2, N1, S1, S2 and S3 Performance	
	Height of embankment (m RL)	22
	Total surface area at 22m RL (m^2)	898712
	Total capacity (m^3)	4811977
	Height of sluice (m RL)	19.9
	Assumed dead zone (%)	20
	Surface Area at 19.9 m RL (m^2)	823328
	Effective surface area at 19.9m RL (m^2)	658662
	Freeboard allowance (m)	1-1.5
	Maximum operating volume (m^3)	2404636
	Days of operation	15.3
	Average detention time (hrs)	167.3
	Pond rating (m^2 per m^3/s)	333528
	Minimum ponding/operating depth (m)	0.6
	Maximum ponding/operating depth (m)	3.2
	Final solid level (m RL)	19.3
	Final water depth (m)	0.6
	Minimum flow velocity (m/s)	$2.998*10^{-6}$
	Maximum flow velocity (m/s)	$2.999*10^{-6}$
	Smallest particle removed based on Stokes Law (mm)	0.0019
	Estimated concentration in discharge effluent (mg/l)	<50
17.	Combined Pond N1, S1, S2, S3 and N3 Performance	
	Height of embankment (m RL)	22
	Total surface area at 22m RL (m^2)	903729
	Total capacity (m^3)	4842454
	Height of sluice (m RL)	19.9
	Assumed dead zone (%)	20
	Surface Area at 19.9m RL (m^2)	828275
	Effective surface area at 19.9m RL (m^2)	662620
	Freeboard allowance (m)	1-1.5
	Maximum operating volume (m^3)	2420777
	Days of operation	12.6
	Average detention time (hrs)	176.3
	Pond rating (m^2 per m^3/s)	335532
	Minimum ponding/operating depth (m)	0.6
	Maximum ponding/operating depth (m)	3.2

Laird Point Dredge Material Placement Facility Performance Assessment Summary Scenario: Stage 4 with external and internal embankments being constructed to 22 m RL.		
9.	Material Description	Parameters
	Final solid level (m RL)	19.1
	Final water depth (m)	0.8
	Minimum flow velocity (m/s)	$2.980*10^{-6}$
	Maximum flow velocity (m/s)	$2.996*10^{-6}$
	Smallest particle removed based on Stokes Law (mm)	0.0019
	Estimated concentration in discharge effluent (mg/l)	<50

Appendix D Leach Elutriate Results

Location	Sample ID	Units	Aluminium	Arsenic	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Nickel	Zinc
	LOR	mg/kg	50	5	1	2	5	50	5	5	2	5
	QEPA EILs	mg/kg	ne	20	3	50	60	ne	300	500	60	200
	NEPM HBILs 'F'	mg/kg	ne	500	100	500	5000	ne	1500	7500	0	35000
	NADG 2009	mg/kg	ne	ne	1.5	80	65	ne	50	ne	21	200
	Guideline Values Derived from Local Ambient Monitoring and ANZECC/QLD Water Quality Objectives	µg/L	ne	ne	5.5	27.4	1.3	ne	4.4	ne	70	15
Location	**Sample ID**											
BH01A	Total Metals GC/GLNG #1_0.5-1.0	mg/kg	**7290**	**15**	<1	**18**	**11**	**38200**	**9**	**546**	**15**	**33**
BH01A	DI Water Leach 0-1.0	µg/L	5820	24	<1	9	9	6910	4	57	6	57
BH01A	DI Water Leach 1.0-2.1	µg/L	3470	27	<1	6	13	3800	4	39	4	59
BH01A	DI Water Leach 2.1-2.8	µg/L	17800	15	<1	29	40	25700	20	91	13	126
BH01A	Elutriate 0-1.0	µg/L	<10	7.8	<0.2	<0.5	<1	<5	<0.2	359	0.5	<5
BH01A	Elutriate 1.0-2.1	µg/L	<10	7	<0.2	<0.5	<1	<5	<0.2	240	<0.5	<5
BH01A	Elutriate 2.1-2.8	µg/L	<10	4.7	<0.2	<0.5	<1	<5	<0.2	282	3.6	<5
BH01A	Elutriate SEA WATER	µg/L	<10	0.8	<0.2	<0.5	<1	<5	<0.2	0.6	1.1	<5

240
359

Notes:

Exceeds the Queensland Environmental Protection Agency 1998 Environmental Investigation Levels

Exceeds the National Environment Protection Council 1999 Healthnabased Investigation Levels na Commercial/Industrial

Exceeds the National Assessment Guidelines for dredging 2009

Exceeds the Guideline Values Derived from Local Ambient Monitoring and ANZECC/QLD Water Quality Objectives

ne: not established

Location	Sample ID	Units	Aluminium	Arsenic	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Nickel	Zinc
	LOR	mg/kg	50	5	1	2	5	50	5	5	2	5
	QEPA EILs	mg/kg	ne	20	3	50	60	ne	300	500	60	200
	NEPM HBILs 'F'	mg/kg	ne	500	100	500	5000	ne	1500	7500	0	35000
	NADG 2009	mg/kg	ne	ne	1.5	80	65	ne	50	ne	21	200
	Guideline Values Derived from Local Ambient Monitoring and ANZECC/QLD Water Quality	µg/L	ne	ne	5.5	27.4	1.3	ne	4.4	ne	70	15
BH02	Total Metals BH02 1.9-2.3	µg/L	**5210**	**10**	<1	**11**	**11**	**14600**	**5**	**1110**	**7**	**22**
BH02	Total Metals BH02 4.2-4.6	µg/L	**6190**	<5	<1	**13**	**26**	20700	<5	**1340**	**12**	**31**
BH 2A	DI Water Leach 0-1.0	µg/L	800	3	<0.1	1	2	1650	<1	15	<1	120
BH 2A	DI Water Leach 2.0-2.75	µg/L	2150	17	0.3	4	5	3720	3	68	3	25
BH 2A	DI Water Leach 2.75-3.1	µg/L	6250	2	0.1	7	13	10900	2	169	5	72
BH 2A	Elutriate 0-1.0	µg/L	170	2.4	<0.2	<0.5	<1	<5	<0.2	208	4.8	<5
BH 2A	Elutriate 2.0-2.75	µg/L	50	5.1	<0.2	<0.5	<1	<5	<0.2	1330	4.9	<5
BH 2A	Elutriate 2.75-3.1	µg/L	<10	<0.5	<0.2	<0.5	<1	<5	<0.2	2520	2.3	<5
BH 2A	Elutriate SEA WATER	µg/L	20	<0.5	<0.2	<0.5	<1	<5	<0.2	<0.5	<0.5	<0.5

Notes:

Exceeds the Queensland Environmental Protection Agency 1998 Environmental Investigation Levels

Exceeds the National Environment Protection Council 1999 Healthnabased Investigation Levels na Commercial/Industrial

Exceeds the National Assessment Guidelines for dredging 2009

Exceeds the Guideline Values Derived from Local Ambient Monitoring and ANZECC/QLD Water Quality Objectives

ne: not established

Location	Sample ID	Units	Aluminium	Arsenic	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Nickel	Zinc
	LOR	mg/kg	50	5	1	2	5	50	5	5	2	5
	QEPA EILs	mg/kg	ne	20	3	50	60	ne	300	500	60	200
	NEPM HBILs 'F'	mg/kg	ne	500	100	500	5000	ne	1500	7500	0	35000
	NADG 2009	mg/kg	ne	ne	1.5	80	65	ne	50	ne	21	200
	Guideline Values Derived from Local Ambient Monitoring and ANZECC/QLD Water Quality Objectives	µg/L	ne	ne	5.5	27.4	1.3	ne	4.4	ne	70	15
Location	**Sample ID**											
BH04A	DI Water Leach 0-0.2	µg/L	4990	8	0.4	8	6	6850	3	60	4	87
BH04A	DI Water Leach 0.2-0.5	µg/L	13200	11	<0.1	12	15	16000	6	63	5	526
BH04A	DI Water Leach 0.5-1.0	µg/L	6060	4	<0.1	4	3	5520	3	18	<1	198
BH04A	Elutriate 0-0.2	µg/L	<10	6.8	<0.2	<0.5	2	<5	<0.2	515	0.9	<5
BH04A	Elutriate 0.2-0.5	µg/L	<10	4.8	<0.2	<0.5	<1	<5	<0.2	63.3	0.6	<5
BH04A	Elutriate 0.5-1.0	µg/L	<10	0.8	<0.2	<0.5	<1	<5	<0.2	152	1.1	22
BH04A	Elutriate SEA WATER	µg/L	<10	1.4	<0.2	<0.5	<1	<5	<0.2	<0.5	<0.5	<5

Notes:

Exceeds the Queensland Environmental Protection Agency 1998 Environmental Investigation Levels

Exceeds the National Environment Protection Council 1999 Healthnabased Investigation Levels na Commercial/Industrial

Exceeds the National Assessment Guidelines for dredging 2009

Exceeds the Guideline Values Derived from Local Ambient Monitoring and ANZECC/QLD Water Quality Objectives

ne: not established

Location	Sample ID	Units	Aluminium	Arsenic	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Nickel	Zinc
	LOR	mg/kg	50	5	1	2	5	50	5	5	2	5
	QEPA EILs	mg/kg	ne	20	3	50	60	ne	300	500	60	200
	NEPM HBILs 'F'	mg/kg	ne	500	100	500	5000	ne	1500	7500	0	35000
	NADG 2009	mg/kg	ne	ne	1.5	80	65	ne	50	ne	21	200
	Guideline Values Derived from Local Ambient Monitoring and ANZECC/QLD Water Quality Objectives	µg/L	ne	ne	5.5	27.4	1.3	ne	4.4	ne	70	15
Location	**Sample ID**											
BH07	Total Metals BH07 2.7-3.2	µg/L	na	13	<1	15	**96**	na	6	na	**9**	**43**
BH07	Total Metals BH07 3.2-3.5	µg/L	8330	10	<1	16	**117**	18400	7	274	**8**	**47**
BH7A	DI Water Leach 0-1.0	µg/L	2790	19	<0.1	5	5	3730	2	51	4	145
BH7A	DI Water Leach 2.0-2.8	µg/L	740	10	0.3	1	2	870	<1	23	1	149
BH7A	DI Water Leach 3.0-4.0	µg/L	270	<1	0.1	<1	<1	440	<1	10	<1	146
BH7A	Elutriate 0-1.0	µg/L	<10	5.4	<0.2	<0.5	<1	136	<0.2	814	0.8	<5
BH7A	Elutriate 2.0-2.8	µg/L	140	3.3	<0.2	<0.5	<1	111	<0.2	1470	0.7	<5
BH7A	Elutriate 3.0-4.0	µg/L	<1	1.4	<0.2	0.6	<1	14	<0.2	1070	2.1	<5
BH 7A	Elutriate SEA WATER	µg/L	30	1.2	<0.2	<0.5	<1	<5	1.2	<0.5	0.6	<5

Notes:

Exceeds the Queensland Environmental Protection Agency 1998 Environmental Investigation Levels

Exceeds the National Environment Protection Council 1999 Healthnabased Investigation Levels na Commercial/Industrial

Exceeds the National Assessment Guidelines for dredging 2009

Exceeds the Guideline Values Derived from Local Ambient Monitoring and ANZECC/QLD Water Quality Objectives

ne: not established

na: not analysed

Location	Sample ID	Units	Aluminium	Arsenic	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Nickel	Zinc
	LOR	mg/kg	50	5	1	2	5	50	5	5	2	5
	QEPA EILs	mg/kg	ne	20	3	50	60	ne	300	500	60	200
	NEPM HBILs 'F'	mg/kg	ne	500	100	500	5000	ne	1500	7500	0	35000
	NADG 2009	mg/kg	ne	ne	1.5	80	65	ne	50	ne	21	200
	Guideline Values Derived from Local Ambient Monitoring and ANZECC/QLD Water Quality Objectives	µg/L	ne	ne	5.5	27.4	1.3	ne	4.4	ne	70	15
Location	Sample ID											
BH08C	DI Water Leach 0-1.0	µg/L	280	1	0.5	<1	<1	440	<1	8	<1	20
BH08C	DI Water Leach 3.0-4.0	µg/L	16700	24	<.1	30	22	2100	12	238	15	204
BH08C	DI Water Leach 4.75-5.6	µg/L	3000	9	<.1	5	4	3890	2	54	2	58
BH08C	Elutriate 0-1.0	µg/L	10	2.1	<0.2	<0.5	<1	<5	<0.2	1180	2.3	<5
BH08C	Elutriate 3.0-4.0	µg/L	10	11.2	<0.2	<0.5	<1	105	<0.2	766	2.1	6
BH08C	Elutriate 4.75-5.6	µg/L	90	4.2	<0.2	<0.5	<1	317	<0.2	1440	0.6	<5
BH08C	Elutriate SEA WATER	µg/L	<10	1.4	<0.2	<0.5	<1	<5	<0.2	<0.5	<0.5	<5

Notes:

Exceeds the Queensland Environmental Protection Agency 1998 Environmental Investigation Levels

Exceeds the National Environment Protection Council 1999 Healthnabased Investigation Levels na Commercial/Industrial

Exceeds the National Assessment Guidelines for dredging 2009

Exceeds the Guideline Values Derived from Local Ambient Monitoring and ANZECC/QLD Water Quality Objectives

ne: not established

		Units	Aluminium	Arsenic	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Nickel	Zinc
	LOR	mg/kg	50	5	1	2	5	50	5	5	2	5
	QEPA EILs	mg/kg	ne	20	3	50	60	ne	300	500	60	200
	NEPM HBILs 'F'	mg/kg	ne	500	100	500	5000	ne	1500	7500	0	35000
	NADG 2009	mg/kg	ne	ne	1.5	80	65	ne	50	ne	21	200
	Guideline Values Derived from Local Ambient Monitoring and ANZECC/QLD Water Quality Objectives	µg/L	ne	ne	5.5	27.4	1.3	ne	4.4	ne	70	15
Location	**Sample ID**											
BH13	Total Metals BH13 1.0-1.6	µg/L	2580	18	<1	8	<5	16500	<5	**1730**	6	10
BH13	Total Metals BH13 1.6-2.3	µg/L	2840	**26**	<1	7	<5	15800	<5	**808**	5	6
BH13	Total Metals QC 42	µg/L	4600	14	<1	11	7	16800	<5	**624**	7	14
BH13	Total Metals QC 43	µg/L	2660	**22**	<1	6	<5	12900	<5	**934**	5	6
BH13	Total Metals BH13 4.9-5.3	µg/L	2490	11	<1	7	<5	10200	<5	**934**	5	<5
BH13	Total Metals BH13 7.3-7.4	µg/L	4660	10	<1	10	11	14100	<5	**840**	6	12
BH13	Total Metals BH13 9.0-9.15	µg/L	3300	7	<1	9	16	15500	5	**2490**	9	14
BH13	Total Metals BH13 11.3-11.4	µg/L	na	**28**	<1	10	10	na	6	na	11	28
BH13	Total Metals BH13 11.9-12.07	µg/L	3030	**23**	<1	7	12	32400	<5	170	11	24
BH13A	DI Water Leach 0-1.0	µg/L	4300	15	0.1	8	6	6200	200	59	4	207
BH13A	DI Water Leach 6.0-7.0	µg/L	960	7	<0.1	2	2	1360	<1	42	1	42
BH13A	DI Water Leach 11.5-12.0	µg/L	240	<1	<0.1	<1	<0.001	110	<1	40	<1	46
BH13A	DI Water Leach COMP	µg/L	320	<1	<0.1	<1	<0.001	300	<1	36	<1	133
BH13A	Elutriate 0-1.0	µg/L	40	6.8	<0.2	<0.5	<1	10	<0.2	738	<0.5	<5
BH13A	Elutriate 6.0-7.0	µg/L	<10	2.7	<0.2	<0.5	<1	688	<0.2	2340	<0.5	<5
BH13A	Elutriate 11.5-12.0	µg/L	<10	1.1	<0.2	<0.5	<1	<5	<0.2	1530	3.9	<5
BH 13A	Elutriate SEA WATER	µg/L	<10	2	<0.2	<0.5	<1	<5	<0.2	<0.5	<0.5	<5

Notes:

Exceeds the Queensland Environmental Protection Agency 1998 Environmental Investigation Levels
Exceeds the National Environment Protection Council 1999 Healthnabased Investigation Levels na Commercial/Industrial
Exceeds the National Assessment Guidelines for dredging 2009
Exceeds the Guideline Values Derived from Local Ambient Monitoring and ANZECC/QLD Water Quality Objectives
ne: not established
na: not analysed

Location	Sample ID	Units	Aluminium	Arsenic	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Nickel	Zinc
	LOR	mg/kg	50	5	1	2	5	50	5	5	2	5
	QEPA EILs	mg/kg	ne	20	3	50	60	ne	300	500	60	200
	NEPM HBILs 'F'	mg/kg	ne	500	100	500	5000	ne	1500	7500	0	35000
	NADG 2009	mg/kg	ne	ne	1.5	80	65	ne	50	ne	21	200
	Guideline Values Derived from Local Ambient Monitoring and ANZECC/QLD Water Quality Objectives	µg/L	ne	ne	5.5	27.4	1.3	ne	4.4	ne	70	15
Location	**Sample ID**											
BH 14	Total Metals BH14 7.1-7.4	µg/L	1300	<5	<1	**66**	6	12400	<5	122	6	17
BH 14	Total Metals BH14 7.8-8	µg/L	na	11	<1	12	23	na	8	na	68	156
BH 14	Total Metals BH14 8.2-8.5	µg/L	9030	<5	<1	24	21	22000	14	99	23	47
BH 14	Total Metals BH14 8.6-8.85	µg/L	na	5	<1	16	21	na	11	na	22	54
BH 14A	DI Water Leach 0-1.0	µg/L	3080	12	1.1	5	5	4390	2	36	3	37
BH 14A	DI Water Leach 2.5-3.5	µg/L	1000	9	<0.1	2	2	1240	<1	37	1	88
BH 14A	DI Water Leach 6.0-7.0	µg/L	460	<1	2.4	<1	<1	460	<1	18	<1	166
BH 14A	Elutriate 0-1.0	µg/L	<10	3.5	<0.2	<0.5	<1	329	<0.2	2050	1.2	<5
BH 14A	Elutriate 2.5-3.5	µg/L	40	2.2	<0.2	<0.5	<1	443	<0.2	2130	<0.5	10
BH 14A	Elutriate 6.0-7.0	µg/L	70	1	<0.2	<0.5	4	<5	<0.2	913	1.7	<5
BH 13A	Elutriate SEA WATER	µg/L	<10	1.2	<0.2	<0.5	1.2	<5	1.2	<0.5	0.6	<5

Notes:

Exceeds the Queensland Environmental Protection Agency 1998 Environmental Investigation Levels

Exceeds the National Environment Protection Council 1999 Healthnabased Investigation Levels na Commercial/Industrial

Exceeds the National Assessment Guidelines for dredging 2009

Exceeds the Guideline Values Derived from Local Ambient Monitoring and ANZECC/QLD Water Quality Objectives

ne: not established

na: not analysed

Location	Sample ID	Units	Aluminium	Arsenic	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Nickel	Zinc
	LOR	mg/kg	50	5	1	2	5	50	5	5	2	5
	QEPA EILs	mg/kg	ne	20	3	50	60	ne	300	500	60	200
	NEPM HBILs 'F'	mg/kg	ne	500	100	500	5000	ne	1500	7500	0	35000
	NADG 2009	mg/kg	ne	ne	1.5	80	65	ne	50	ne	21	200
	Guideline Values Derived from Local Ambient Monitoring and ANZECC/QLD Water Quality Objectives	µg/L	ne	ne	5.5	27.4	1.3	ne	4.4	ne	70	15
Location	**Sample ID**											
BH 18	BH18 0.7-0.85	µg/L	3260	10	<1	9	<5	14400	<5	**623**	5	15
BH 18	BH18 0.9-1.2	µg/L	2170	**12**	<1	7	<5	12200	<5	**812**	4	7
BH 18	BH18 1.3-1.7	µg/L	3480	11	<1	8	5	12900	<5	**999**	5	10
BH 18	QC 34	µg/L	3200	**11**	<1	8	<5	13700	<5	**817**	5	11
BH 18	BH18 3.0-3.2	µg/L	2880	37	<1	11	7	21900	<5	**607**	7	12
BH 18	BH18 4.6-4.9	µg/L	3720	12	<1	11	6	14200	<5	**1400**	6	11
BH 18	BH18 5.7-6.0	µg/L	3270	20	<1	10	5	13300	<5	**733**	6	9
BH 18	BH18 11.3-11.5	µg/L	10700	**<5**	<1	17	63	26500	9	3750	20	58
BH 18	BH18 13.0-13.25	µg/L	11800	**5**	<1	16	52	35900	10	1670	14	56
BH 18	BH18 15.6-16.0	µg/L	4780	**16**	<1	8	42	19000	7	275	25	44
BH18A	DI Water Leach 2.0-3.0	µg/L	1170	14	<0.1	2	2	1630	1	26	1	15
BH18A	DI Water Leach 10.0-11.0	µg/L	5480	21	<0.1	9	21	7560	7	182	6	164
BH18A	DI Water Leach 11.1-11.5	µg/L	17100	4	<0.1	23	50	36800	6	296	15	134
BH18A	DI Water Leach COMP	µg/L	8270	4	<0.1	11	21	12700	2	185	7	201
BH18A	Elutriate 2.0-3.0	µg/L	60	14.4	<0.2	<0.5	<1	7	<0.2	351	0.7	<5
BH18A	Elutriate 10.0-11.0	µg/L	60	4.9	<0.2	<0.5	<1	18	<0.2	2060	0.7	<5
BH18A	Elutriate 11.1-11.5	µg/L	260	0.9	0.8	<0.5	2	6	<0.2	2290	1.1	<5
BH 18A	Elutriate SEA WATER	µg/L	90	1.1	<0.2	<0.5	<1	6	<0.2	0.7	0.7	<5

Notes:

Exceeds the Queensland Environmental Protection Agency 1998 Environmental Investigation Levels

Exceeds the National Environment Protection Council 1999 Healthnabased Investigation Levels na Commercial/Industrial

Exceeds the National Assessment Guidelines for dredging 2009

Exceeds the Guideline Values Derived from Local Ambient Monitoring and ANZECC/QLD Water Quality Objectives

ne: not established

Appendix E GLNG Marine Water Quality Report

Report

GLNG Marine Water Quality Report

NOVEMBER 2009

Prepared for

Santos

Brisbane, Australia

42626234

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Abbreviations

Abbreviation	Description
Al	aluminium
ALS	Australian Laboratory Services
ANZECC	Australian and New Zealand Environment Conservation Council
APHA	American Public Health Association
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AAS	atomic-absorption spectroscopy
AS	Australian Standards
As	arsenic
AWQG	Australian Water Quality Guidelines
ºC	degrees celsius
Cd	cadmium
Cr	chromium
Cu	copper
DO	dissolved oxygen
EIS	Environmental Impact Statement
Fe	iron
FIMS	field ionization mass spectrometry
Hg	mercury
ICP-MS	inductively coupled plasma mass spectroscopy
L	litre
LD	less than detection
mg	milligram
Mn	manganese
N	nitrogen
NEPM	National Environment Protection Measures
NH_3	ammonia
Ni	nickel
nm	nanometer
NO_2	nitrite
NO_3	nitrate
N_{org}	organic nitrogen
NTU	nephelometric turbidity units
P	phosphorus
Pb	lead
PCIMP	Port Curtis Integrated Monitoring Program
QWQG	Queensland Water Quality Guidelines
$SnCl_2$	stannous chloride
TKN	total Kjeldahl nitrogen
TN	total nitrogen
TON	total organic nitrogen
TP	total phosphorus
TSS	total suspended solids
USEPA	United States Environmental Protection Agency

Abbreviation	Description
WQO	Water Quality Objectives
Zn	zinc
μg	microgram

Executive Summary

Santos Ltd. proposes to develop a Dredge Material Placement Facility (DMPF) as a component of its proposed Gladstone Liquefied Natural Gas (LNG) project. This report provides a water quality assessment of the immediate coastal vicinity of the proposed DMPF.

URS conducted a one-time marine water quality survey from 22 to 23 July 2009 to supplement marine water quality data previously gathered from other areas around Port Curtis. Various physico-chemical parameters were analysed to characterise the baseline marine water quality. Nutrients, total and dissolved metals levels were among the parameters examined.

Analytical results were compared to a draft Water Quality Objectives based on the Queensland Water Quality Guidelines (EPA, 2006) and the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000).

The key findings based on the results of the marine water quality survey of the immediate coastal vicinity of the DMPF are as follows:

Physical Parameters

- pH, temperature, turbidity and TSS did not show significant difference between high water and low water.
- pH, DO, temperature, conductivity and salinity did not show significant variation with depth.
- Turbidity and TSS levels exceed the QWQG.

Nutrients

- Nutrient levels are elevated with respect to QWQG.
  - Total nitrogen, total phosphorus and total organic nitrogen levels exceed prescribed QWQG concentrations.
  - The presence of high total organic nitrogen levels suggests that likely sources of nutrients are resuspended organic detrital sediments.
  - Oxidisable nitrogen and ammonia as N levels also exhibited readings greater than the prescribed criteria.
- Chlorophyll a levels exceed the QWQG prescribed level.

Metals

- Aluminium, iron, manganese, and arsenic levels are comparable to other areas of Port Curtis based on results of previous surveys. There are no prescribed limits for these metals but concentrations are mostly sediment bound as shown by the ratio of total to dissolved levels.
- Cadmium, chromium, lead, mercury and nickel exhibited concentrations that are within their respective ANZECC (2000) 95% trigger values. Levels of these metals were also generally less than analytical detection limits for both total and dissolved concentrations.
- Both total and dissolved levels of zinc and copper indicated exceedance to prescribed ANZECC (2000) 95% trigger limits. Insufficient data exists to conclude the source of elevated levels.

1 Introduction

2.1 Project Background

Santos Ltd. proposes to develop a Dredge Material Placement Facility (DMPF) as a component of its proposed Gladstone Liquefied Natural Gas (LNG) project. The proposed DMPF is to be located in Laird Point, Curtis Island. This report provides a water quality assessment of the immediate coastal vicinity of the proposed DMPF. URS conducted a one-time marine water quality survey from 22 to 23 July 2009 to supplement marine water quality data previously gathered from other areas around Port Curtis.

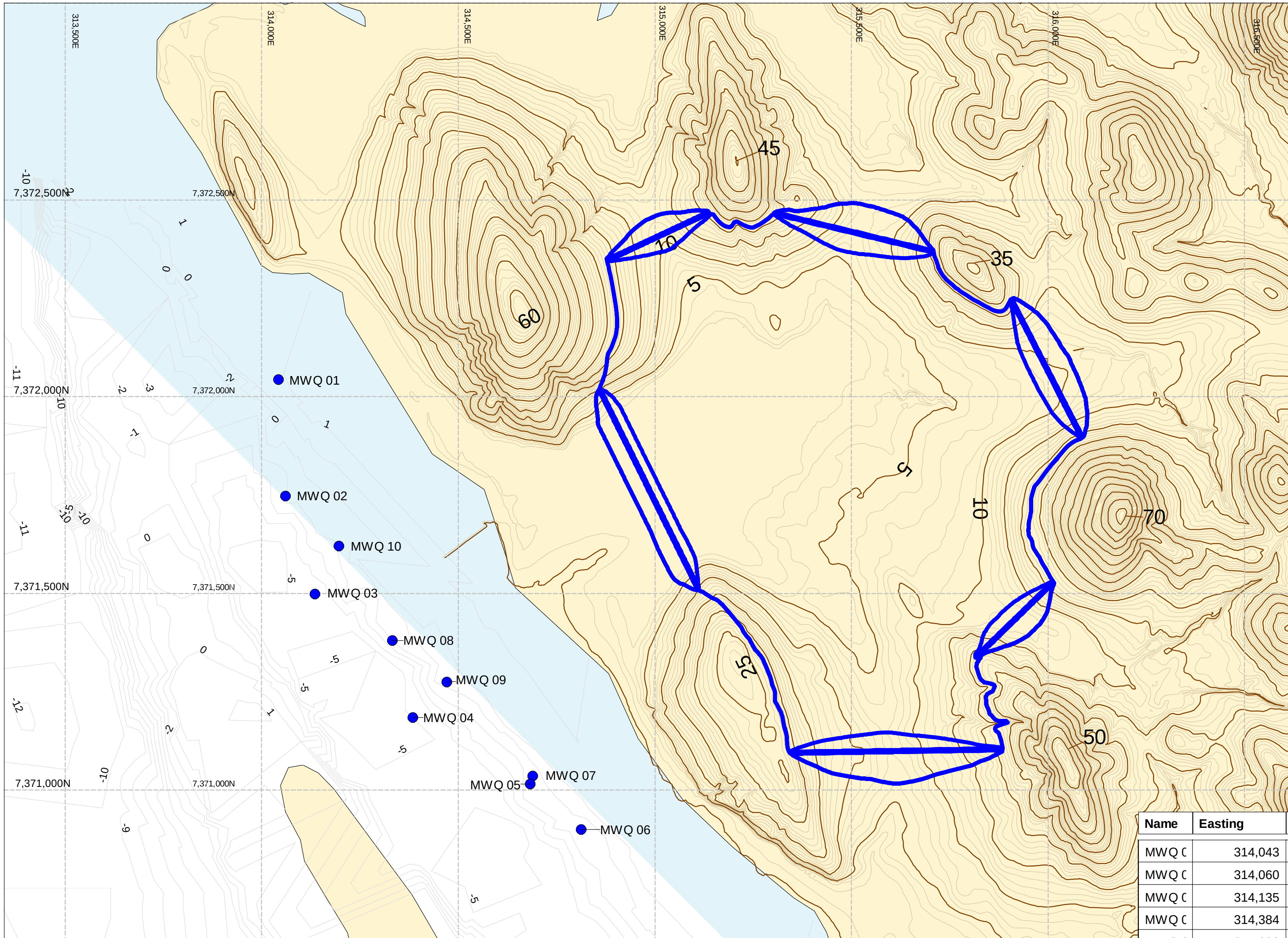
Methodology

3.1 Sampling Locations

Ten locations were surveyed to assess the water quality of the immediate coastal vicinity of the proposed DMPF, (**Figure 1**, **Table 1**).

Table 2-1 Marine Water Quality Sampling Locations

Sampling Locations	Easting	Northing
MW1	314,043	7,372,043
MW2	314,060	7,371,748
MW3	314,135	7,371,499
MW4	314,384	7,371,185
MW5	314,683	7,371,016
MW6	314,813	7,370,900
MW7	314,690	7,371,036
MW8	314,332	7,371,380
MW9	314,471	7,371,275
MW10	314,196	7,371,620



Name	Easting	Northing
MWQ (	314,043	7,372,043
MWQ (	314,060	7,371,748
MWQ (	314,135	7,371,499
MWQ (	314,384	7,371,185
MWQ (	314,683	7,371,016
MWQ (	314,813	7,370,900
MWQ (	314,690	7,371,036
MWQ (	314,471	7,371,275
MWQ (	314,332	7,371,380
MWQ 1	314,196	7,371,620

N S E W

0 250m 500m

Scale 1:15 000 (A4)
Datum: GDA94

Marine Water Quality
Elevation relative to LAT

Client

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URS

LNG

Project

GLADSTONE LNG PROJECT
ENVIRONMENTAL IMPACT STATEMENT
SUPPLEMENT
DREDGE MATERIAL PLACEMENT FACILITY
DEWATERING ASSESSMNET AND PRELIMINARY DESIGN

Drawn: LL | Approved: JB | Date: 04-11-2009

Job No: 4262 6440 /6220 | File No: 42626440-g-2175.wor

Title

LAIRD POINT DREDGED
MATERIAL PLACEMENT FACILITY
MARINE WATER QUALITY
SAMPLING LOCATIONS

Figure: 2.3

Rev:A

A4

3.2 Sampling Techniques

Two separate surveys were undertaken: one at low water (afternoon, 22 July 09) and one at high water (morning, 23 July 09), all conducted under a spring tide regime.

In-situ measurements of pH, dissolved oxygen (DO), temperature, conductivity and salinity were taken for each location using a TPS 90SL model Water Quality Multimeter. Measurements were taken at three depths by submerging the multi-parameter probes at near surface, mid, and near bottom depths.

Grab samples from the near surface, mid and near bottom depths of the water column were collected using Van Dorn horizontal water sampler . These were then composited to form a representative sample for each site at each tidal condition. This equated to 20 sets of samples in total. In addition, two sets of site replicates were also collected for each tidal condition. The samples were sent to Australian Laboratory Services (ALS) laboratory within 24 hours of sampling for analysis of the parameters outlined in **Table 2**.

Table 2-2 Parameters and Sample Handling and Preservation

Parameter	Container Type (*Preservation*)
Turbidity, Total Suspended Solids (TSS)	Plastic container *(no preservative, cool stored)*
Chlorophyll- a	Opaque Plastic container *(no preservative, dark cool storage)*
Dissolved Metals (Al, As, Cd, Cr, Cu, Pb, Mn, Ni, Zn, Fe, Hg)	Plastic container *(field filtered, no preservative, cool stored), lab acidified (nitric acid)*
Total Metals (Al, As, Cd, Cr, Cu, Pb, Mn, Ni, Zn, Fe, Hg)	Plastic container *(no preservative, cool stored), lab acidified (nitric acid)*
Nutrients (Ammonia as N, Nitrite as N, Nitrate as N, Nitrite+Nitrate as N, Total Kjeldahl Nitrogen as N, Total Nitrogen as N, Total Phosphorus)	Plastic container *(sulphuric acid, cool stored)*
Reactive Phosphorus as P	Plastic container *(no preservative, cool stored)*

3.3 Analytical Techniques

The analytical procedures used by the laboratory to analyse the water samples are in accordance with established internationally recognized procedures such as those published by the United States Environmental Protection Agency (USEPA), American Public Health Association (APHA), Australian Standards (AS) and NEPM.

Table 2-3 Laboratory Analytical Methods

Parameter	Analytical Method Description
Dissolved Metals	Inductively coupled plasma mass spectroscopy (ICP-MS) (APHA 21st ed., 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020): The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.
Total Metals	ICP-MS (APHA 21st ed., 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020)

2 Methodology

Parameter	Analytical Method Description
Dissolved Mercury	Field ionization mass spectrometry **(**FIMS) AS 3550, APHA 21st ed. 3112 Hg - B (Flow-injection (SnCl2)(Cold Vapour generation) AAS) FIM-AAS is an automated flameless atomic absorption technique. A bromate/bromide reagent is used to oxidise any organic mercury compounds in the filtered sample. The ionic mercury is reduced online to atomic mercury vapour by $SnCl_2$ which is then purged into a heated quartz cell. Quantification is by comparing absorbance against a calibration curve. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Total Mercury	FIMS AS 3550, APHA 21st ed. 3112 Hg - B (Flow-injection (SnCl2)(Cold Vapour generation) AAS)
Ammonia as N	Discrete Analyser APHA 21st ed., 4500-NH_3 G Ammonia is determined by direct colorimetry by Discrete Analyser. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Nitrite as N	Discrete Analyser APHA 21st ed., 4500-NO_2- B. Nitrite is determined by direct colourimetry by Discrete Analyser. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Nitrate as N	Discrete Analyser APHA 21st ed., 4500-NO_3- F. Nitrate is reduced to nitrite by way of a cadmium reduction column followed by quantification by Discrete Analyser. Nitrite is determined seperately by direct colourimetry and result for Nitrate calculated as the difference between the two results. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Nitrite and Nitrate as N (NOx)	Discrete Analyser APHA 21st ed., 4500-NO_3- F. Combined oxidised Nitrogen (NO2+NO3) is determined by Cadmium Reduction and direct colourimetry by Discrete Analyser. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Total Kjeldahl Nitrogen as N	Discrete Analyser APHA 21st ed., 4500-N_{org} D. 25mL water samples are digested using a traditional Kjeldahl digestion followed by determination by Discrete Analyser. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Total Nitrogen as N (TKN + Nox)	Discrete Analyser APHA 21st ed., 4500-N_{org} / 4500-NO_3-. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Total Phosphorus as P	Discrete Analyser APHA 21st ed., 4500-P B&F This procedure involves sulphuric acid digestion of a 100mL sample to break phosphorus down to orthophosphate. The orthophosphate reacts with ammonium molybdate and antimony potassium tartrate to form a complex which is then reduced and its concentration measured at 880nm using Discrete Analyser. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)
Reactive Phosphorus as P	Discrete Analyser APHA 21st ed., 4500-P F Ammonium molybdate and potassium antimonyl tartrate reacts in acid medium with othophosphate to form a heteropoly acid -phosphomolybdic acid - which is reduced to intensely coloured molybdenum blue by ascorbic acid. Quantification is by Discrete Analyser. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)

2 Methodology

Parameter	Analytical Method Description
Chlorophyll a	ALS In-house (APHA 21st ed., 10200 H mod.) The pigments are extracted into aqueous acetone. The optical density of the extract before and after acidification at both 664 nm and 665 nm is determined spectrometrically.
Turbidity	APHA 21st ed., 2130 B. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)

Results and Discussion

4.1 Water Quality Objectives

Table 3-1 shows the water quality parameters analysed and a draft list of the corresponding water quality objectives (WQO's). The WQO's for nutrients and physical parameters were based on the Queensland Water Quality Guidelines (QWQG 2006) Table 2.5.2.1, for slightly to moderately disturbed enclosed coastal systems in the Central Coast Queensland region. The guidelines for enclosed coastal systems were selected over those of the open coastal systems as the study area lies within the inner reaches of Port Curtis. Open Coastal guidelines are more appropriate for the coastal waters on the pacific side of Curtis Island. There are no metal WQO's prescribed under QWQG 2006, as such, these were sourced from the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000) Table 3.4.1 – guidelines for slightly to moderately disturbed marine environments in South East Australia at the 95% level of protection of species.

The draft WQO's are provided for initial comparative purposes and are subject to review. WQO's are typically based on annual statistics and require a comprehensive monitoring data set. It should be noted that current results are a result of a one-time sampling activity and are being informally compared to the draft WQO's. ANZECC guidelines also encourage the use of locally specific data, where available, for defining WQO's. Such locally specific data does exist for Port Curtis, however ownership of this data is unclear and as such has not been presented or used in detail in this report (WBM, 2008).

Table 4-1 Water Quality Parameters and Draft WQO's

Physical and Nutrient Parameters	WQO	
	Enclosed Coastal	Open Coastal
Turbidity	6 NTU	1 NTU
TSS	15 mg/L	10.0 mg/L
Total Nitrogen	200 µg/L	140 µg/L
Total Phosphorus P	20 µg/L	20 µg/L
Ammonia	8 µg/L	6 µg/L
Organic Nitrogen	180 µg/L	130 µg/L
Oxidised Nitrogen (Nitrate + Nitrite)	3 µg/L	3 µg/L
Filterable Reactive Phosphorus	6 µg/L	6 µg/L
Dissolved Oxygen	lower limit-90%, upper limit-100%	lower limit-95%, upper limit-105%
pH	lower limit- 8, upper limit-8.4	lower limit-8, upper limit-8.4
Chlorophyll a	2 µg/L	1 µg/L

Notes:
WQO's are from Queensland Water Quality Guidelines (QWQG 2006) Table 2.5.2.1, for slightly to moderately disturbed enclosed and open coastal systems in the Central Coast Queensland region.
The enclosed coastal objectives have been given preference as the survey location is within inner Port Curtis. Open Coastal objectives were presented fur purposes of comparison.

Metal Parameters	**WQO**
Aluminium	ID
Arsenic	ID
Cadmium	5.5 µg/L

Metal Parameters	WQO
Copper	1.3 µg/L
Chromium (Cr III)	27.4 µg/L
Chromium (Cr VI)	4.4 µg/L
Iron	ID
Lead	4.4 µg/L
Manganese	ID
Mercury (inorganic)	0.4 µg/L
Nickel	70 µg/L
Zinc	15 µg/L

Notes:
WQO's are from the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, ARMCANZ, 2000) Table 3.4.1 – guidelines for slightly to moderately disturbed marine environments in South East Australia at the 95% level of protection of species
ID= Insufficient data to derive a reliable trigger value.

4.2 Results

Tables 3-2 to **3-5** provide the high and low water survey results for the various physico-chemical parameters analysed for each of the 10 sampling locations. Water quality objectives are included for reference. H and L refer to high water and low water samples, respectively. Potential exceedance to the draft WQO's are indicated in bold.

Table 4-2 Physico-chemical Water Quality Results(*In-situ*)

	Location	MW1		MW2		MW3		MW4		MW5		MW6		MW7		MW8		MW9		MW10		
	Tide State	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	
Parameter	Date, Time	22 July 1230h	23 July 0740h	22 July 1245h	23 July 0755h	22 July 1310h	23 July 0810h	22 July 1335h	23 July 0850h	22 July 1355h	23 July 1025h	22 July 1415h	23 July 1040h	22 July 1500h	23 July 1055h	22 July 1545h	23 July 0930h	22 July 1515h	23 July 0950h	22 July 1610h	23 July 0910h	WQO
Depth (m)		1	1	6	6.1	6.9	8.5	6.8	9.3	2.5	8	2	5	2.5	4.4	3.8	6.5	1	4.9	2	5.1	
pH	Near Surface	8.40	**7.77**	8.06	8.01	8.18	8.18	8.21	8.23	8.27	8.28	8.26	8.29	8.26	8.24	8.24	8.27	8.25	8.27	8.27	8.26	Lower: 8.0
	Mid Depth	8.40	**7.88**	8.17	8.03	8.19	8.21	8.23	8.24	-	8.29		8.30	-	8.24	8.24	8.27	-	8.28	-	8.26	Upper: 8.4
	Near Bottom	8.00	**7.93**	8.20	8.12	8.21	8.22	8.23	8.25	8.20	8.31	8.19	8.29	8.26	8.25	8.23	8.28	8.22	8.28	8.26	8.27	
DO (% sat)	Near Surface	**84**	98	**84**	**106**	**88**	**105**	**88**	**104**	**84**	100	**75**	**102**	**82**	**101**	**86**	**103**	90	**102**	90	**103**	Lower: 90%
	Mid Depth	**84**	97	**82**	**102**	**86**	**102**	**86**	**101**	-	100	-	99		100	**84**	**101**	-	100		**102**	Upper: 100%
	Near Bottom	**83**	94	**79**	100	**86**	100	**85**	**100**	**80**	96	-	**101**	**77**	**101**	**82**	100	**82**	99	**87**	**101**	
Conductivity (mS/cm)	Near Surface	46.1	38.9	47.5	43.0	47.0	43.5	46.5	43.8	46.5	43.5	46.4	43.5	46.1	43.8	45.5	43.5	45.9	43.6	45.2	43.6	
	Mid Depth	46.1	40.4	47.9	43.3	47.2	43.9	46.6	43.8	-	43.4	-	43.5	-	43.3	45.3	43.4	-	43.6	-	43.7	NGV
	Near Bottom	47.2	41.3	47.8	43.5	47.2	43.9	46.6	43.9	46.4	43.6	46.3	43.5	46.1	43.5	45.3	43.6	45.9	43.6	45.1	43.8	

	Location	MW1		MW2		MW3		MW4		MW5		MW6		MW7		MW8		MW9		MW10		
	Tide State	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	
Parameter	Date, Time	22 July 1230h	23 July 0740h	22 July 1245h	23 July 0755h	22 July 1310h	23 July 0810h	22 July 1335h	23 July 0850h	22 July 1355h	23 July 1025h	22 July 1415h	23 July 1040h	22 July 1500h	23 July 1055h	22 July 1545h	23 July 0930h	22 July 1515h	23 July 0950h	22 July 1610h	23 July 0910h	WQO
Salinity (ppt)	Near Surface	33.3	28.1	34.8	31.4	34.3	31.8	33.8	31.8	33.5	30.8	33.2	31	32.9	31.6	32.7	31.4	32.9	31.3	32.7	31.6	
	Mid Depth	33.3	29.2	35.2	31.5	34.7	32	34.0	31.7	-	31.0	-	31.3	-	31	32.9	31.6	-	31.4	-	31.6	NGV
	Near Bottom	34.5	29.9	35.2	31.7	34.7	32	34.1	31.8	33.8	31.3	33.3	31.3	32.8	31.3	33.0	31.6	32.9	31.4	32.7	31.8	
Temperature (ºC)	Near Surface	20.1	19.5	19.8	19.5	20.0	19.5	20.0	19.8	20.4	20.8	20.7	20.5	20.8	21	20.4	20.1	20.6	20.2	20.1	19.8	
	Mid Depth	20.1	19.6	19.7	19.6	19.7	19.6	19.8	19.9		20.4		20.2		20.4	20.0	20.0		20.1		19.9	NGV
	Near Bottom	19.9	19.6	19.6	19.6	19.6	19.6	19.8	19.9	20.0	20.2	20.5	20.1	20.9	20.2	19.8	20.0	20.6	20.1	20.0	19.8	

Notes (Table 3-2):

WQO's are from Queensland Water Quality Guidelines (QWQG 2006) Table 2.5.2.1, for slightly to moderately disturbed enclosed coastal systems in the Central Coast Queensland region.
NGV- stands for No Guideline Value available under QWQG 2006 and ANZECC 2000
WQO for temperature: QWQG 2006 recommends that local guidelines be developed. A full seasonal cycle of measurements is required to develop guideline values.
L, H – stand for low water survey and high water survey, respectively
Values in bold indicate exceedance to WQO

Table 4-3 Physico-chemical Water Quality Indicators- Suspended Solids, Turbidity, and Nutrients

	MW1		MW2		MW3		MW3-Replicate		MW4		MW5		MW6		MW7		MW8		MW9		MW9-Replicate		MW10		
	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	
Parameter	22 July 1230 h	23 July 0740 h	22 July 1245 h	23 July 0755 h	22 July 1310 h	23 July 0810 h	22 July 1310 h	23 July 0810 h	22 July 1335 h	23 July 0850 h	22 July 1355 h	23 July 1025 h	22 July 1415 h	23 July 1040 h	22 July 1500 h	23 July 1055 h	22 July 1545 h	23 July 0930 h	22 July 1515 h	23 July 0950 h	22 July 1515 h	23 July 0950 h	22 July 1610 h	23 July 0910 h	WQO
Suspended Solids (mg/L)	**71**	**71**	**68**	**80**	**63**	**27**	**69**	**79**	**67**	**17**	**64**	**64**	**83**	**65**	**79**	**65**	**65**	**59**	**69**	**88**	**88**	**63**	**61**	**83**	15 mg/L
Turbidity (NTU)	**4.5**	**9.0**	**7.1**	**8.1**	**7.0**	**11.0**	5.0	3.1	**6.0**	**10.0**	5.3	**7.1**	**13.0**	5.6	**14.0**	**6.8**	**7.2**	**7.8**	**12.0**	**8.0**	**13.0**	**9.0**	**8.4**	**8.8**	6 NTU
Chlorophyll a (µg/L)	**6**	**5**	**6**	**5**	**8**	**4**	LD	**5**	**2**	LD	**6**	LD	**5**	LD	LD	**3**	**7**	**1**	**8**	LD	**10**	**5**	**7**	**2**	2 µg/L
Total Nitrogen (µg/L)	**300**	**200**	**300**	**200**	**300**	**200**	**200**	**300**	**300**	**200**	**200**	**300**	**300**	**200**	**200**	**200**	**300**	**200**	**300**	**200**	**200**	**200**	**200**	**300**	200 µg/L
Ammonia as N (µg/L)	**40**	LD	**20**	LD	**20**	LD	**120**	LD	**120**	LD	**40**	LD	**200**	LD	LD	LD	LD	LD	**140**	LD	**20**	LD	LD	LD	8 µg/L
Nitrite + Nitrate as N (µg/L)	**60**	**10**	LD	**30**	LD	LD	LD	**10**	LD	**20**	LD	**20**	LD	**20**	LD	**10**	LD	LD	**10**	**20**	**20**	**10**	LD	**10**	3 µg/L
Total Kjeldahl Nitrogen (µg/L)	200	200	300	200	300	200	200	300	300	200	200	300	300	200	200	200	300	200	300	200	200	200	200	300	NGV

	MW1		MW2		MW3		MW3-Replicate		MW4		MW5		MW6		MW7		MW8		MW9		MW9-Replicate		MW10		
	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	
Parameter	22 July 1230 h	23 July 0740 h	22 July 1245 h	23 July 0755 h	22 July 1310 h	23 July 0810 h	22 July 1310 h	23 July 0810 h	22 July 1335 h	23 July 0850 h	22 July 1355 h	23 July 1025 h	22 July 1415 h	23 July 1040 h	22 July 1500 h	23 July 1055 h	22 July 1545 h	23 July 0930 h	22 July 1515 h	23 July 0950 h	22 July 1515 h	23 July 0950 h	22 July 1610 h	23 July 0910 h	WQO
Organic Nitrogen (Total Kjeldahl Nitrogen – Ammonia as N) (µg/L)	**160**	**190**	**280**	**190**	**280**	**190**	80	**290**	**290**	**190**	**190**	**290**	100	**190**	**190**	**190**	**190**	**190**	**160**	**190**	**180**	**190**	**190**	**290**	180 µg/L
Total Phosphorus as P (µg/L)	**180**	**220**	**160**	**100**	**330**	**90**	**170**	**90**	**80**	**90**	**100**	**140**	**120**	**80**	**120**	**110**	**120**	**160**	**110**	**130**	**120**	**200**	**600**	**90**	20 µg/L
Reactive Phosphorus as P (µg/L)	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	6 µg/L

Notes (Table 3-3):

WQO's are from Queensland Water Quality Guidelines (QWQG 2006) Table 2.5.2.1, for slightly to moderately disturbed enclosed coastal systems in the Central Coast Queensland region.
NGV- stands for No Guideline Value available under QWQG 2006 and ANZECC 2000
L, H – stand for low water survey and high water survey, respectively
LD- stands for less than analytical detection limit
Values in bold indicate exceedance to WQO
Organic nitrogen was calculated as the difference between TKN and Ammonia as N.

Detection Limits:

Chlorophyll a: 1 µg/L
Nitrite + Nitrate as N : 10 µg/L
Ammonia as N: 10 µg/L
Reactive Phosphorus as P: 10 µg/L

Table 4-4 Total Metal Concentrations

	MW1		MW2		MW3		MW3-Rep		MW4		MW5		MW6		MW7		MW8		MW9		MW9-Rep		MW10		
	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	
Parameter	22 July 1230 h	23 July 0740 h	22 July 1245 h	23 July 0755 h	22 July 1310 h	23 July 0810 h	22 July 1310 h	23 July 0810 h	22 July 1335 h	23 July 0850 h	22 July 1355 h	23 July 1025 h	22 July 1415 h	23 July 1040 h	22 July 1500 h	23 July 1055 h	22 July 1545 h	23 July 0930 h	22 July 1515 h	23 July 0950 h	22 July 1515 h	23 July 0950 h	22 July 1610 h	23 July 0910 h	WQO
Aluminium (µg/L)	500	940	770	980	550	1210	560	1020	700	940	170	1020	1500	680	950	510	620	1000	990	700	1060	900	840	710	ID
Arsenic (µg/L)	LD	13	LD	18	LD	10	7	9	LD	17	17	17	12	18	14	15	7	16	15	17	18	14	15	16	ID
Cadmium (µg/L)	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	2.7	LD	LD	LD	LD	LD	LD	LD	LD	LD	5.5 µg/L
Chromium (µg/L)	8	LD	7	LD	LD	LD	9	LD	9	LD	LD	LD	LD	LD	10	LD	LD	LD	LD	LD	LD	LD	LD	LD	27.4 µg/L
Copper (µg/L)	28	6	21	10	20	8	21	8	20	9	6	6	11	7	12	LD	15	8	9	9	9	19	9	6	1.3 µg/L
Lead (µg/L)	8	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	8	LD	LD	LD	LD	4.4 µg/L
Manganese (µg/L)	19	18	21	20	18	24	18	23	18	23	5	16	31	13	28	11	18	24	26	17	26	22	20	18	ID
Mercury (µg/L)	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.4 µg/L
Nickel (µg/L)	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	7	LD	LD	LD	LD	LD	LD	LD	LD	LD	70 µg/L
Zinc (µg/L)	**39**	9	**23**	6	**23**	13	**25**	LD	**20**	5	11	LD	**30**	LD	**17**	LD	**19**	LD	**15**	6	**24**	14	**15**	LD	15 µg/L
Iron (µg/L)	1410	1350	1830	1620	1400	1860	1480	1640	1580	1660	460	1310	2030	1060	1500	1100	1190	1700	1590	1360	1670	1510	1450	1270	ID

Notes (Table 3-4):

WQO's are from the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, ARMCANZ, 2000)
NGV- stands for No Guideline Value available under QWQG 2006 and ANZECC 2000
L, H – stand for low water survey and high water survey, respectively
LD- stands for less than analytical detection limit
Values in bold indicate exceedance to WQO

Detection Limits:

Arsenic: 5 μg/L	Cadmium: 0.5 μg/L
Chromium: 5 μg/L	Copper: 5 μg/L
Lead: 5 μg/L	Manganese: 5 μg/L
Mercury: 0.1 μg/L	Nickel: 5 μg/L
Zinc: 5 μg/L	Iron: 250 μg/L

Table 4-5 Dissolved Metal Concentrations

	MW1		MW2		MW3		MW3-Rep		MW4		MW5		MW6		MW7		MW8		MW9		MW9-Rep		MW10		
	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	
Parameter	22 July 1230 h	23 July 0740 h	22 July 1245 h	23 July 0755 h	22 July 1310 h	23 July 0810 h	22 July 1310 h	23 July 0810 h	22 July 1335 h	23 July 0850 h	22 July 1355 h	23 July 1025 h	22 July 1415 h	23 July 1040 h	22 July 1500 h	23 July 1055 h	22 July 1545 h	23 July 0930 h	22 July 1515 h	23 July 0950 h	22 July 1515 h	23 July 0950 h	22 July 1610 h	23 July 0910 h	WQO
Aluminium (µg/L)	300	170	150	170	160	250	160	200	170	180	210	180	170	250	180	170	160	190	170	210	200	180	170	180	ID
Arsenic (µg/L)	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	ID
Cadmium (µg/L)	LD	LD	LD	LD	0.6	LD	LD	LD	0.5	LD	LD	LD	LD	LD	2.4	LD	LD	LD	LD	LD	LD	LD	LD	LD	5.5 µg/L
Chromium (µg/L)	12	LD	10	LD	LD	LD	8	LD	8	LD	LD	LD	LD	LD	12	LD	LD	LD	LD	LD	LD	LD	LD	LD	27.4 µg/L
Copper (mg/L)	**15**	**6**	**13**	**10**	**11**	**10**	**10**	LD	**11**	**12**	**7**	LD	**12**	LD	**11**	LD	**12**	**6**	**12**	**11**	**11**	**12**	**10**	**6**	1.3 µg/L
Lead (µg/L)	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	4.4 µg/L
Manganese (µg/L)	8	9	5	7	6	5	6	5	6	LD	LD	LD	8	6	8	LD	7	LD	9	LD	9	LD	7	LD	ID
Mercury (µg/L)	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.4 µg/L
Nickel (µg/L)	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	70 µg/L
Zinc (µg/L)	**29**	6	**16**	7	14	14	12	LD	13	LD	11	LD	**15**	LD	**17**	LD	14	LD	**17**	LD	**24**	**15**	**15**	LD	15 µg/L
Iron (µg/L)	LD	690	LD	770	330	760	410	810	510	780	610	740	540	830	570	830	610	LD	610	440	690	380	730	420	ID

Notes (Table 3-5):

WQO's are from the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, ARMCANZ, 2000)
NGV- stands for No Guideline Value available under QWQG 2006 and ANZECC 2000
L, H – stand for low water survey and high water survey, respectively
LD- stands for less than analytical detection limit
Values in bold indicate exceedance to WQO

Detection Limits:

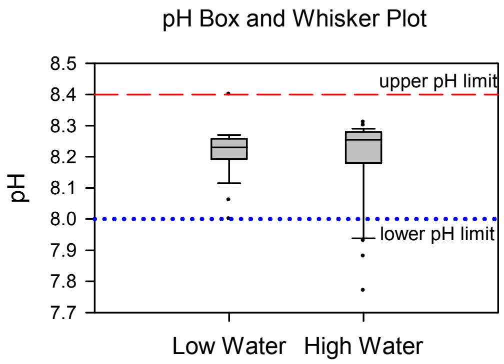
Arsenic: 5 μg/L
Chromium: 5 μg/L
Lead: 5 μg/L
Mercury: 0.1 μg/L
Zinc: 5 μg/L
Cadmium: 0.5 μg/L
Copper: 5 μg/L
Manganese: 5 μg/L
Nickel: 5 μg/L
Iron: 250 μg/L

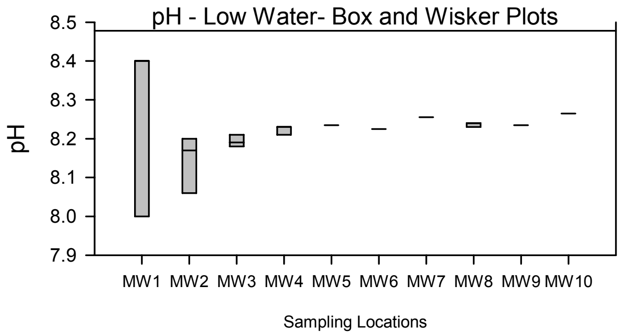
4.2.1 Physico-chemical Water Quality Results(*In-situ*)

In-situ physicochemical characteristics were recorded on two occasions – low water and high water sampling. Results for temperature, conductivity, salinity, dissolved oxygen, and pH measurements at surface, middle, and near-bottom depths are in Table 3-2.

pH

The pH levels are generally within the QWQG 2006 limits and exhibit pH characteristic of seawater pH. There is no significant difference between pH levels in low water and in high water surveys. There is also limited spatial variation among the locations, with most sampling points having pH levels that vary from 8.0 to 8.4. Only MW1 exhibited levels that are less than the recommended lower pH limit and also showed significant pH variability.





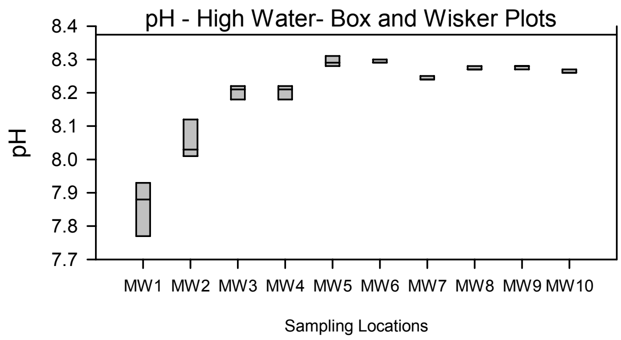


Figure 4-1 pH measurements- low water (22 July 09) and high water (23 July 09) surveys

DO

A significant difference was noted between the low water and the high water DO levels. High water DO levels are generally within the upper and lower limits of the QWQG 2006 (90% - 100% saturation). Low water DO levels, which ranged from 75% to 90% saturation, however, were less than the lower limit of the guideline. Spatial difference among the various locations was also noted to be significant during the low water regime.

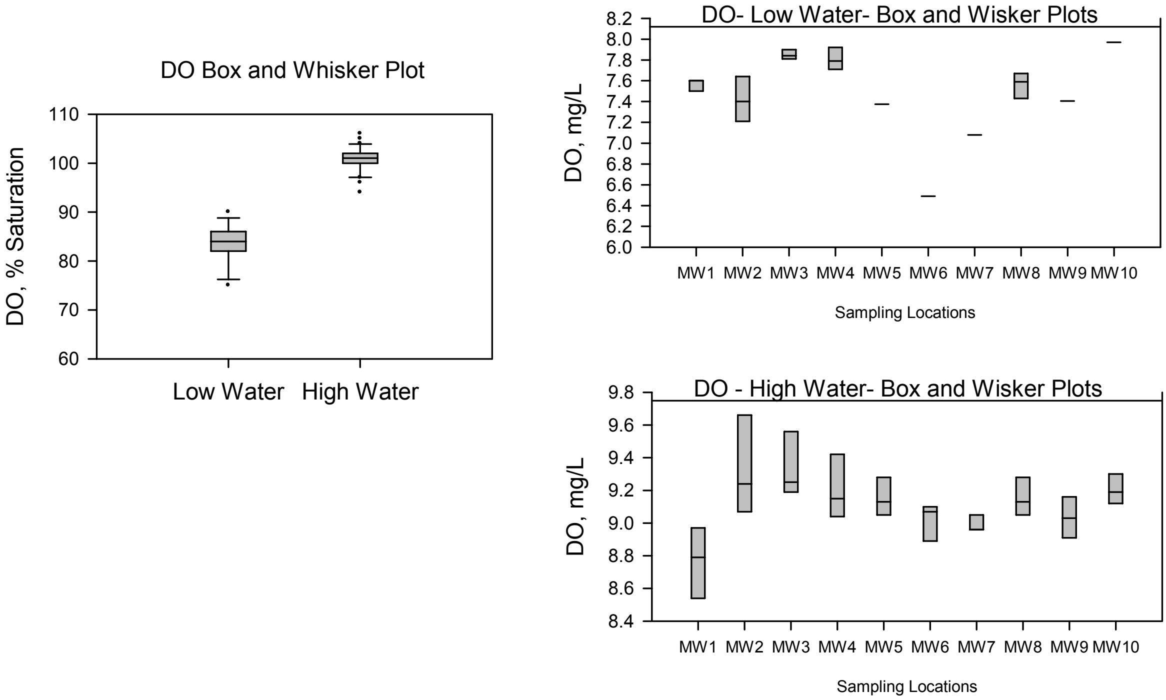


Figure 4-2 dissolved oxygen measurements, low water (22 July 09) and high water (23 July 09) surveys

Conductivity and Salinity

Conductivity and salinity levels were noted to vary significantly between low water and high water sampling surveys. Salinity levels in low water ranged from approximately 32.5 ppt to 35 ppt, more saline than the levels observed during high water, which generally ranged from 30 to 32 ppt. Salinity and conductivity levels also appear to be more variable across the sampling locations during the low water survey.

Typically, salinity levels may be expected to increase during high tide events with more saline water flooding in from the open ocean. The above observation can be further verified in future monitoring events.

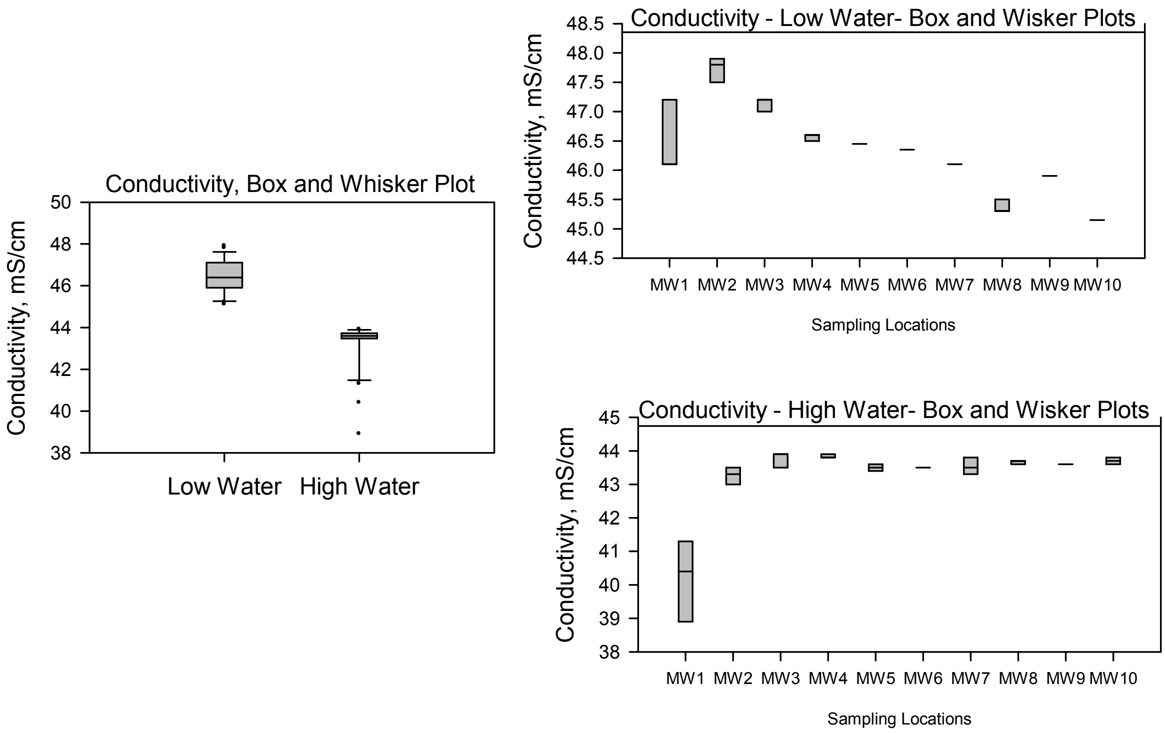


Figure 4-3 Conductivity measurements- low water (22 July 09) and high water (23 July 09) surveys

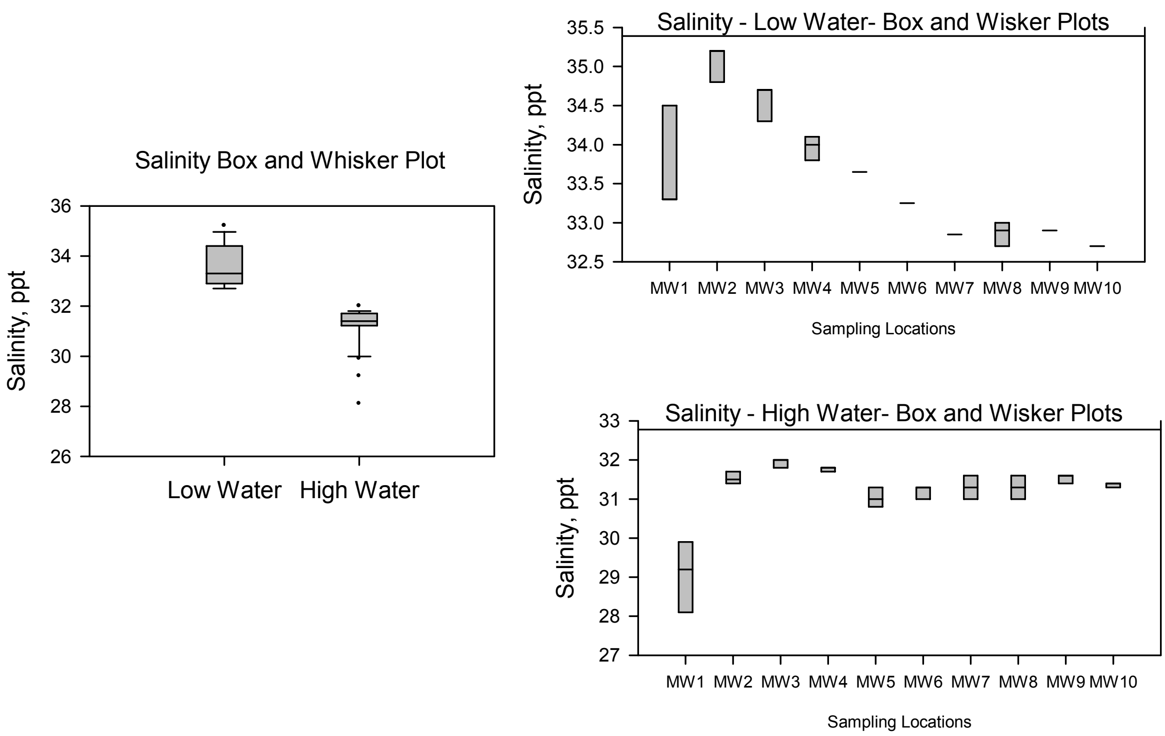


Figure 4-4 Salinity - low water (22 July 09) and high water (23 July 09) surveys

Temperature

No significant difference in temperature was noted between low and high water sampling. Temperature readings ranged between 19.4ºC to 21ºC. In addition, thermal stratification was not noted to occur based on the readings. The are no temperature guidelines prescribed in QWQG 2006 and it was recommended that local temperature guidelines be developed for a specific locale. A full seasonal cycle of measurements is required to develop temperature guideline values.

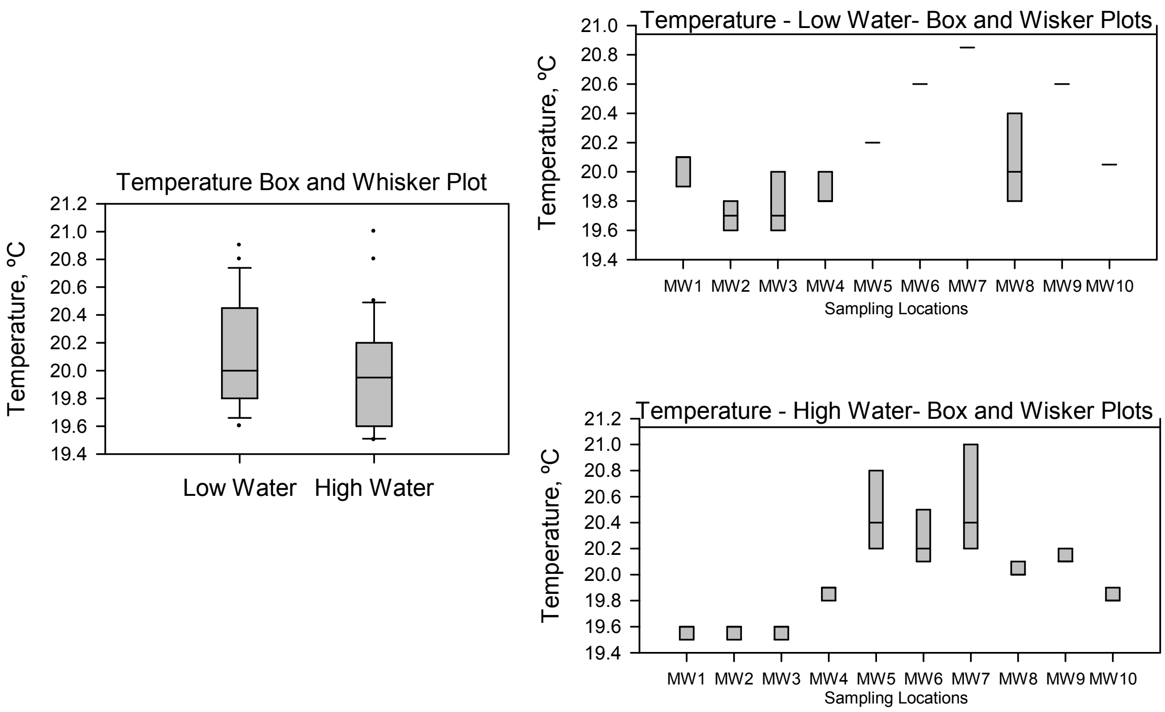


Figure 4-5 Temperature- low water (22 July 09) and high water (23 July 09) surveys

4.2.2 Turbidity and Nutrient Levels

Table 3-3 provides the high and low water results for suspended solids, turbidity, chlorophyll-a, and nutrient parameters for each of the 10 collection locations. Water quality objectives are included for reference.

Turbidity and Suspended Solids

The levels of turbidity and suspended solids are greater than the prescribed values under QWQG 2006 which are 6 NTU and 15 mg/L, respectively. Turbidity levels ranged from 3.1 NTU to 13.0 NTU while suspended solids varied from 17 mg/L to 88 mg/L. The elevated levels were consistent with the results of the previous WBM (2008) survey. Such elevated levels were described to be consistent for high energy environments where current-driven sediment resuspension contributes to water column sediment load (WBM, 2008). However, unlike the previous survey results, there was no significant difference found between turbidity and suspended solids levels for high water and low water.

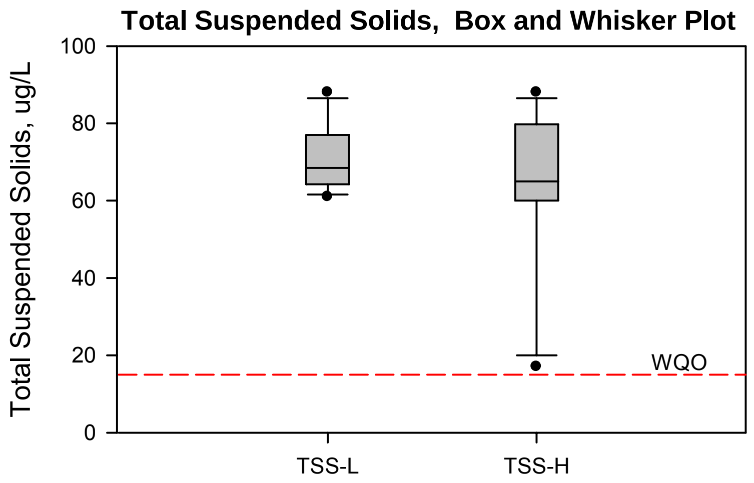


Figure 4-6 Total Suspended Solids- low water (22 July 09) and high water (23 July 09) surveys

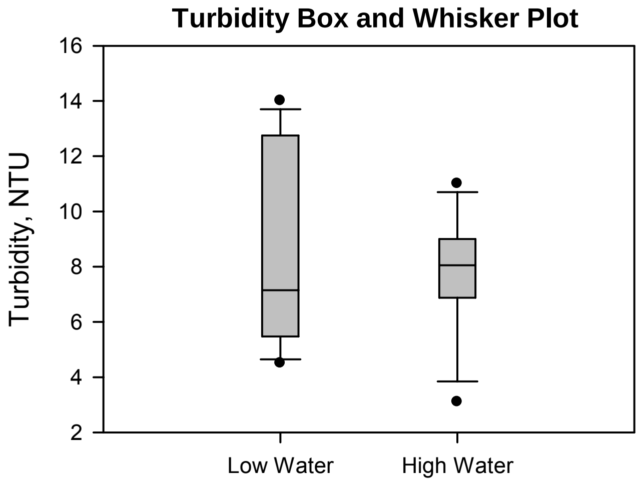


Figure 4-7 Turbidity- low water (22 July 09) and high water (23 July 09) surveys

Nutrients

Total nitrogen levels were elevated (200-300 µg/L) compared to the QWQG limit of 200 µg/L. Most of the nitrogen present appears to be of the organic form. This is apparent from the levels of Kjeldahl nitrogen, which is the total of organic and ammonium nitrogen, being similar to those of the total nitrogen levels. Ammonium nitrogen levels are comparatively lower with most of the reported concentrations being less than the analytical detection limit. However, detectable concentrations are elevated (20-140 µg/L) compared to the limit of 8 µg/L. Oxidisable nitrogen levels registered values that are mostly greater than the QWQG limit of 3 µg/L.

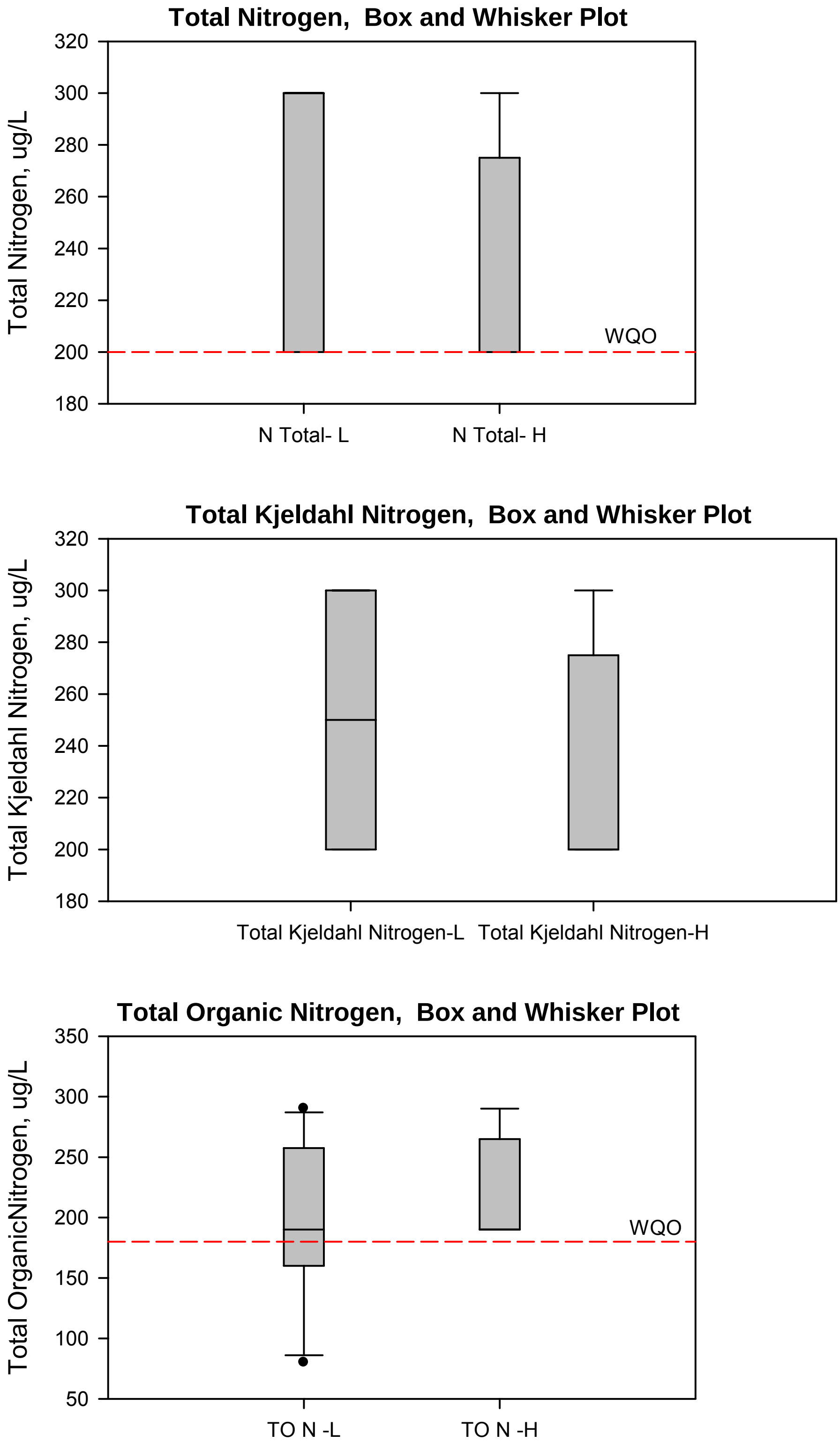


Figure 4-8 Nitrogen Levels- low water (22 July 09) and high water (23 July 09) surveys

Total phosphorus levels were also found to be significantly elevated (80-600 µg/L) compared to the QWQG limit of 20 µg/L. Reactive phosphorus levels were less than the detection limit of 10 µg/L; levels, but could still be greater than the 6 µg/L limit.

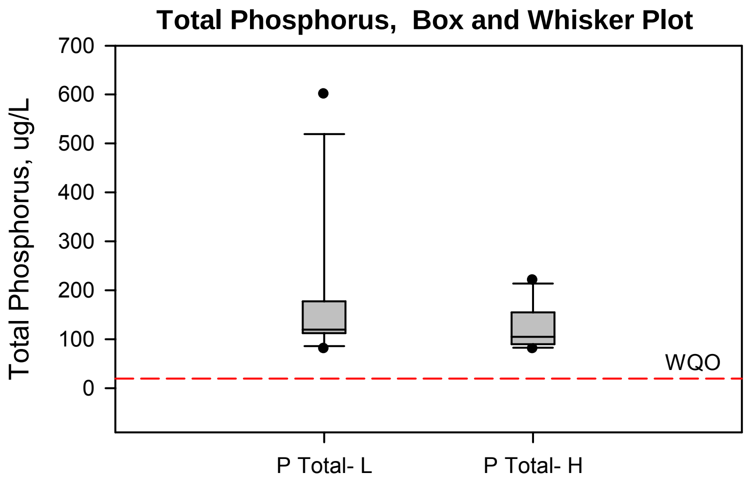


Figure 4-9 Total Phosphorus- low water (22 July 09) and high water (23 July 09) surveys

Elevated total nutrient levels may be associated with suspended solids in the water column with the bedload being the most likely source of the observed nutrient levels. The study area is surrounded by intertidal flats with fringes of mangrove communities. These are potential sources of organic detritus that can significantly contribute to elevated nutrient levels. The elevated nutrient levels are also confirmed by the presence of elevated chlorophyll-a levels (2-10 µg/L); the QWQG limit being 2 µg/L.

Previous studies have also reported the occurrence of elevated total nutrient levels around Port Curtis. The PCIMP Report (2007) reported elevated total nitrogen levels ranging from 200 µg/L to 260 µg/L. Total phosphorus levels were also elevated ranging from 40 µg/L to 60 µg/L. Results of the WBM (2008) survey however, indicated total nitrogen levels (110-160 µg/L) and total phosphorus levels (9-24 µg/L) that may be classified as generally within the limits the QWQG limits.

With respect to variability of nutrient concentrations in high water and lower water, There was no significant difference noted between tidal events.

A review of nutrient water quality objectives may be required considering the elevated levels.

4.2.3 Metals with no prescribed guideline values- Aluminum, Iron, Manganese and Arsenic

The QWQG 2006 has no prescribed guidelines with respect to metal levels. For this reason, the ANZECC (2000) guidelines were used for purposes of comparison. ANZECC (2000) however, notes that there is insufficient data to derive a reliable trigger value for aluminium, iron, manganese and arsenic.

Aluminium, iron, and manganese have appreciable levels compared to other metals analysed which generally have levels less than the detection limits. These metals are mostly particulate-bound based on comparative levels of total and dissolved fractions (Figure 3-10 to Figure 3-12). Dissolved levels in individual samples can vary from 14% to 100% of the total levels, averaging about 33%. These results are similar with those of WBM (2008), which found that dissolved levels vary from 10% to 100% of the total fraction. The range of aluminium, iron and manganese levels in this latest survey also did not vary significantly from the findings of WBM (2008).

Previous findings (WBM, 2008) have found trends indicating a higher level of metals during low tide than high tide, this being a factor of sediment dynamics (with metals largely in the particulate fraction). Such a trend was not observed in the survey as there was no significant difference in the metal levels between high and low tide. About 90% of the locations surveyed had depths, at the time of sampling, of less than seven meters and it is possible that the effects of sediment dynamics at this depth would not be as pronounced so as to cause a significant variation on metals levels between tides. In addition, turbidity levels between low tide and high tide surveys did not show a significant difference.

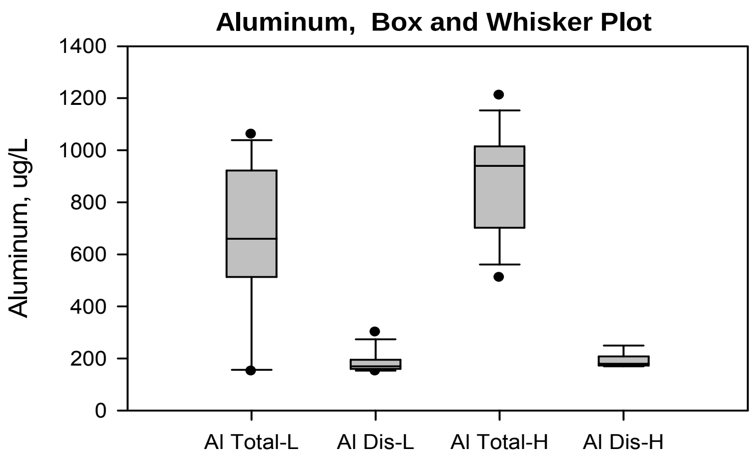


Figure 4-10 Aluminium- Comparative levels of total and dissolved concentrations for low and high water

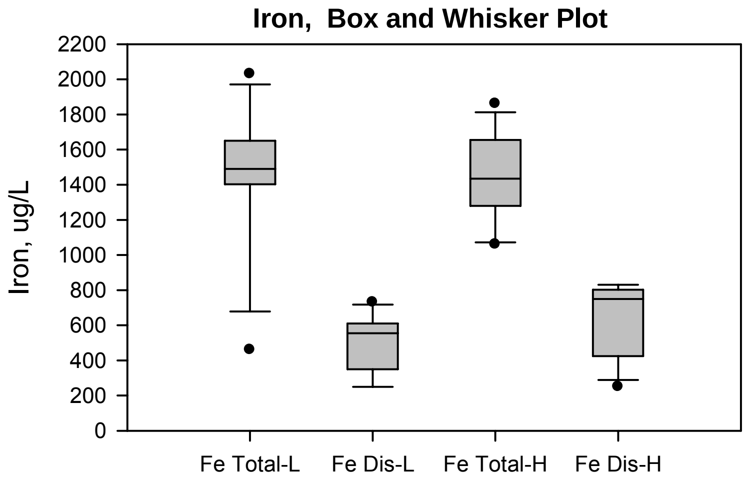


Figure 4-11 Iron- Comparative levels of total and dissolved concentrations for low and high water

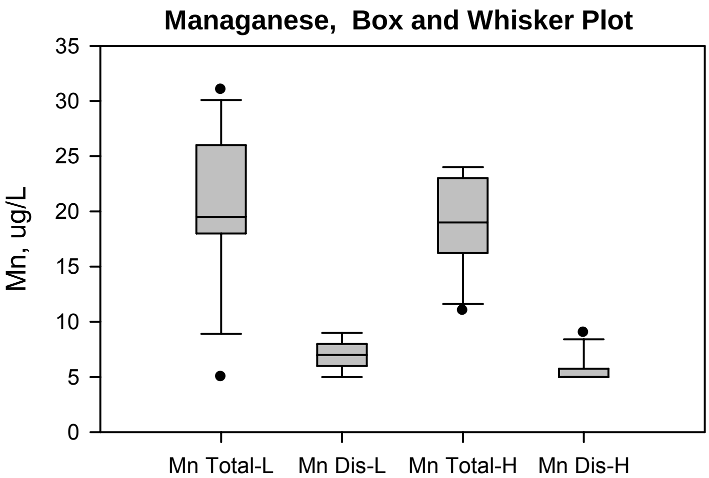


Figure 4-12 Manganese-Comparative levels of total and dissolved concentrations for low and high water

Total arsenic levels ranged from <5 µg/L to approximately 18 µg/L. Dissolved levels were less than detection limits, which suggest that the arsenic levels are mostly sediment bound. Previous findings found similar levels of arsenic within Port Curtis. The PCIMP Report (2007), through biomonitoring of oysters, have found arsenic levels, that ranged from 13 ppb to 18 ppb. The report also noted that estuarine impact zones tended to have lowest concentrations, whereas the reference and oceanic zones (*which are outside Port Curtis*) were among the highest (*arsenic*) concentrations. WBM (2008) reported total and dissolved arsenic levels that are generally less than 20 µg/L.

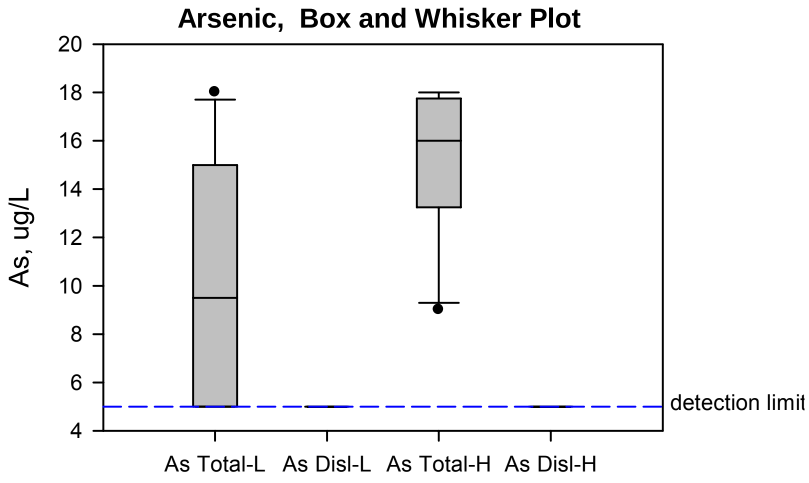


Figure 4-13 Arsenic-Comparative levels of total and dissolved concentrations for low and high water

4.2.4 Metals with prescribed guideline values- Cadmium, Chromium, Copper, Lead, Mercury, Nickel and Zinc

Cadmium

Cadmium levels were mostly less than detection for both the total and dissolved concentrations, with values ranging from <0.5 µg/L to 2.7 µg/L. Readings are within the ANZECC (2000) trigger level of 5.5 µg/L. WBM (2008) reported total and dissolved cadmium levels of <2 µg/L. The PCIMP Report (2007) concluded that cadmium levels were also within the ANZECC (2000) guideline.

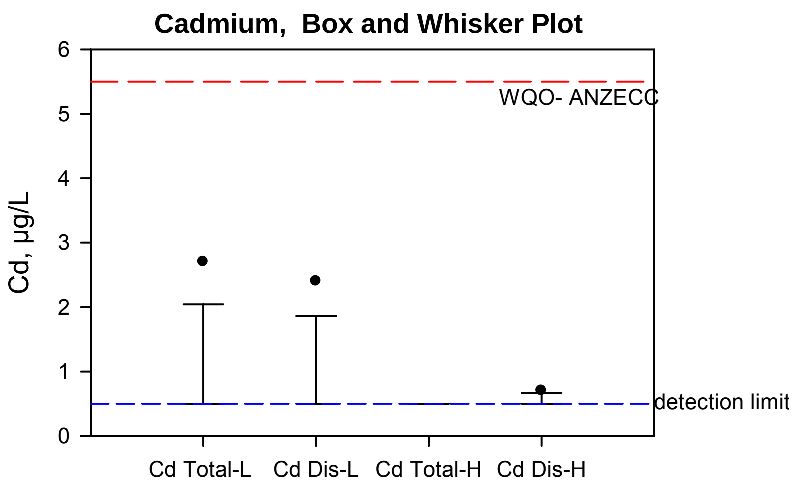


Figure 4-14 Cadmium- Comparative levels of total and dissolved concentrations for low and high water

Chromium

Chromium levels were mostly less than detection limits for both the total and dissolved concentrations. Readings ranged from <5 µg/L to 13 µg/L. These values are less than the ANZECC (2000) trigger level of 27.4 µg/L for chromium (III). Chromium was also reported by WBM (2008) to be within the guidelines, with total and dissolved chromium levels mostly at <3 µg/L. The PCIMP Report (2007) also concluded that chromium (III) levels were well within the ANZECC (2000) trigger value.

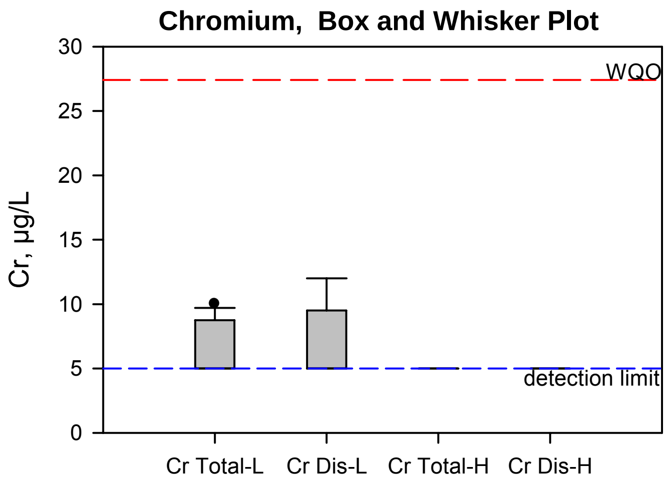


Figure 4-15 Chromium- Comparative levels of total and dissolved concentrations for low and high water

Copper

Total copper levels ranged from <5 µg/L to 28 µg/L. Dissolved levels ranged from <5 µg/L to 15 µg/L and comprised 50% to 100% of the total levels. Results indicate that copper levels generally exceed the 1.3 µg/L ANZECC (2000) limit. WBM (2008) previously reported copper levels that were generally less than an analytical detection limit of 5 µg/L for both total and dissolved copper levels, but also showed sporadic detectable readings ranging from 5 µg/L to 11 µg/L.

The PCIMP Report (2007) however, found that copper concentrations around Port Curtis are within the ANZECC (2000) 95% trigger value based on the results of its diffusive gradients in thin films (DGT) labile metals monitoring. Labile copper levels were found to range between 0.06 µg/L and 0.36 µg/L in various locations around Port Curtis. In the same report, reference sites located in the open coastal waters at the Pacific Ocean side, indicated copper levels ranging from 0.06 µg/L to 0.08 µg/L.

As the locations surveyed have not been studied in the PCIMP Report (2007), the elevated copper concentrations may represent a localised concentration. Insufficient data exists to conclude the source of elevated levels.

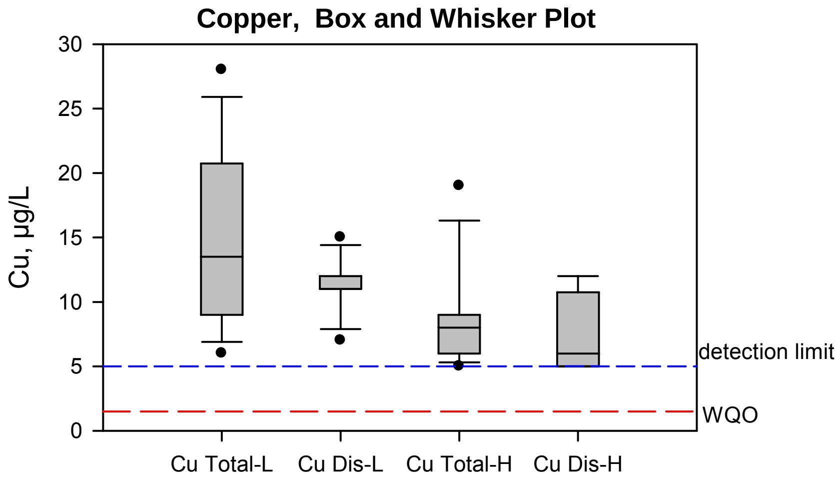


Figure 4-16 Copper - Comparative levels of total and dissolved concentrations for low and high water

Lead

Both total and dissolved concentrations of lead were mostly less than the analytical detection limit of 5 µg/L. However, sporadic detectable readings (<10% of data) of 7 µg/L to 8 µg/L were also reported. The ANZECC (2000) trigger value for lead is 4.4 µg/L, thus, the possibility exists that reported lead levels could still be greater than the trigger value but less than 5 µg/L. WBM (2008) reported total and dissolved lead levels that were mostly less than or equal to an analytical detection limit of 40 µg/L. Lead concentrations were shown to be within the ANZECC (2000) 95% trigger value as reported by PCIMP Report (2007). DGT labile lead concentrations in various locations around Port Curtis were also found to have lower concentrations which ranged from 0.007 µg/L to 0.008 µg/L. Oceanic reference points were reported to have a concentration of 0.002 µg/L.

Mercury

Total and dissolved concentrations of mercury are less than the analytical detection limit of 0.1 µg/L. The levels are within the AWQG 95% trigger value for inorganic mercury, 0.4 µg/L.

Nickel

Nickel levels are well within the 70 µg/L ANZECC (2000) trigger value. Total and dissolved concentrations are generally less than the analytical detection limit of 5 µg/L. WBM (2008) also reported total and dissolved nickel concentrations that are within the guidelines.

Zinc

Exceedance to the 15 µg/L ANZECC (2000) trigger value was noted for the total and dissolved zinc levels. Dissolved levels can comprise 50% to 100% of dissolved levels. Elevated values were mostly observed for the low water survey with elevated concentrations ranging from 15 µg/L to 39 µg/L. WBM (2008) previously reported concentrations that are less than an analytical detection limit of 20 µg/L for both total and dissolved zinc levels.

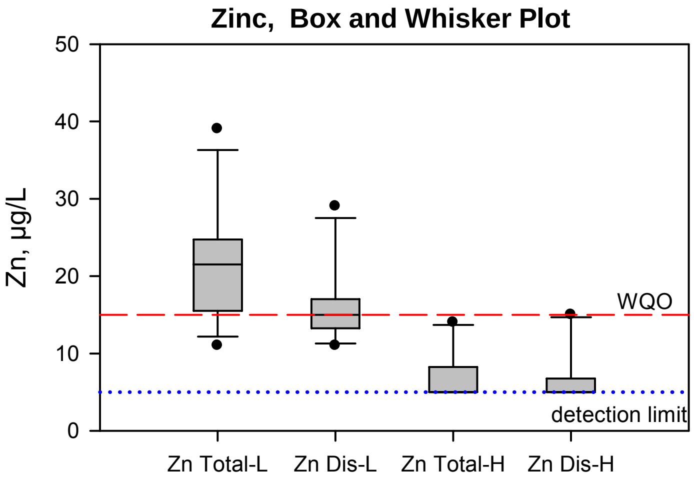


Figure 4-17 Zinc- Comparative levels of total and dissolved concentrations for low and high water

Conclusion

The following are key findings based on the results of the marine water quality survey of the immediate coastal vicinity of the DMPF:

Physical Parameters

Physical parameters which include pH, temperature, turbidity and TSS did not show significant difference between high water and low water. In addition, pH, DO, temperature, conductivity and salinity did not show significant variation with depth. Turbidity and TSS levels exceed the QWQG.

Nutrients

Nutrient levels are elevated with respect to QWQG. Total nitrogen, total phosphorus and total organic nitrogen levels exceed prescribed concentrations. The presence of high total organic nitrogen levels suggests that likely sources of nutrients are resuspended organic detrital sediments. Oxidisable nitrogen and ammonia as N levels also exhibited readings greater than the prescribed criteria.

Chlorophyll a levels exceed the QWQG prescribed level.

Metals

The levels of aluminium, iron, manganese, and arsenic are comparable to other areas of Port Curtis based on results of previous surveys. There are no prescribed limits for these metals. Detectable concentrations however, are mostly sediment bound as shown by the ratio of total to dissolved levels.

Cadmium, chromium, lead, mercury and nickel exhibited concentrations that are within their respective ANZECC (2000) 95% trigger values. Levels were also generally less than analytical detection limits for both total and dissolved concentrations.

Both total and dissolved levels of zinc and copper indicated exceedance to prescribed ANZECC (2000) 95% trigger limits. Insufficient data exists to conclude the source of elevated levels.

References

Anderson, L. E., Melville, F., Teasdale, P.R., and Story, A.W. (2006) 2005 Port Curtis integrated Monitoring Program (PCIMP): Centre for Environmental Management, Central Queensland University.

Anderson, L.E., Melville, F., Steinberg, A. N., Teasdale, P.R., Storey, A. W., and Fabbro, L.D. (2007) PCIMP Biomonitoring 2006: Port Curtis Integrated Monitoring Program, Centre for Environmental Management, Central Queensland University.

Anderson, L.E., Melville, F., Steinberg, A. N., Teasdale, A. W., and Fabbro, L.D. (2008) PCIMP Biomonitoring 2007: Port Curtis Integrated Monitoring Program, Centre for Environmental Management, Central Queensland University.

ANZECC, ARMCAZZ (2000) National Water Quality Management Strategy. Paper number 4: Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Volume 1. The Guidelines. Chapter 3.

Queensland EPA (2006) Queensland Water Quality Guidelines (Minor Updates March 2007).

WBM (2008) Proposed Santos LNG Facility- Marine Water Quality Assessments. Prepared for URS.

Limitations

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession. It is based on generally accepted practices and standards at the time it was prepared. No cover warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 15th July 2009.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between 22 July and 22 August 2009 and is based on the conditions encountered in the field, laboratory results and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report would be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

Appendix A Certificate of Analysis

Appendix A

The table shows the locations and the corresponding samples collected to aid in the reading of the certificate of analysis.

Location ID	Description	Sample ID
MW1	MW1-Low Water	1
	MW1-High Water	11
MW2	MW2-Low Water	2
	MW2-High Water	12
MW3	MW3-Low Water	3
	MW3- High Water	13
	MW3-Low Water-Replicate	4A
	MW3- High Water-Replicate	14A
MW4	MW4-Low Water	4B
	MW4- High Water	14
MW5	MW5-Low Water	5
	MW5- High Water	15
MW6	MW6-Low Water	6
	MW6- High Water	16
MW7	MW7-Low Water	7
	MW7- High Water	17
MW8	MW8-Low Water	8
	MW8- High Water	18
MW9	MW9-Low Water	9
	MW9- High Water	19
	MW9-Low Water-Replicate	10A
	MW9- High Water-Replicate	20A
MW10	MW10-Low Water	10
	MW10-High Water	20

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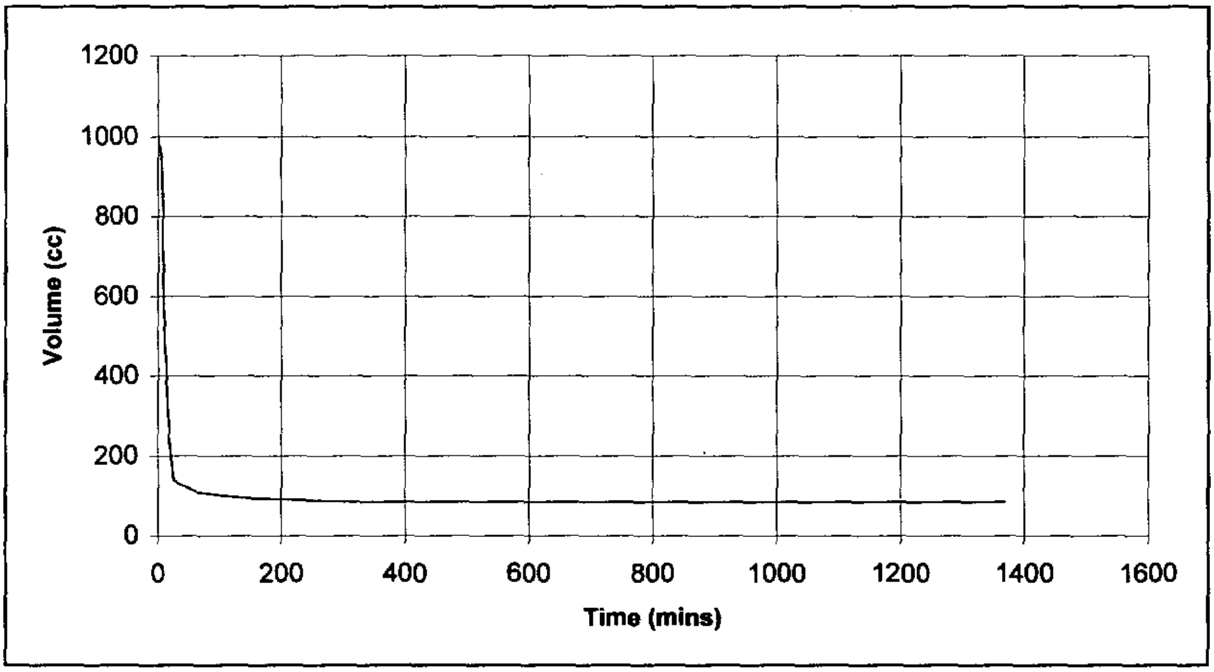
ZONE SETTLEMENT TEST REPORT

US Army engineers - Guidelines for dredging operating and managing dredged materials in containment areas.

CLIENT: **Santos Ltd**
60 Edward St, Brisbane Qld 4000

PROJECT: **GLNG Project : Dredge facility Design**

Job Number:	119-229	**Date Tested:**	03.08.09
Laboratory Number:	53729	**Sampled By:**	Geo Coastal
Sample Source:	BH13A 0 to 1.0m		
Sample Description:	SAND:grey,fine to coarse, some clay of low plasticity,some gravel (shells)		



Initial Dry Concentration	50	(grams/ litre)
Time for Initial Zone	1	(mins)
Time for 100% Settlement	330	(mins)
Water Temperature:	19	°C
Water Type:	Sea Water	

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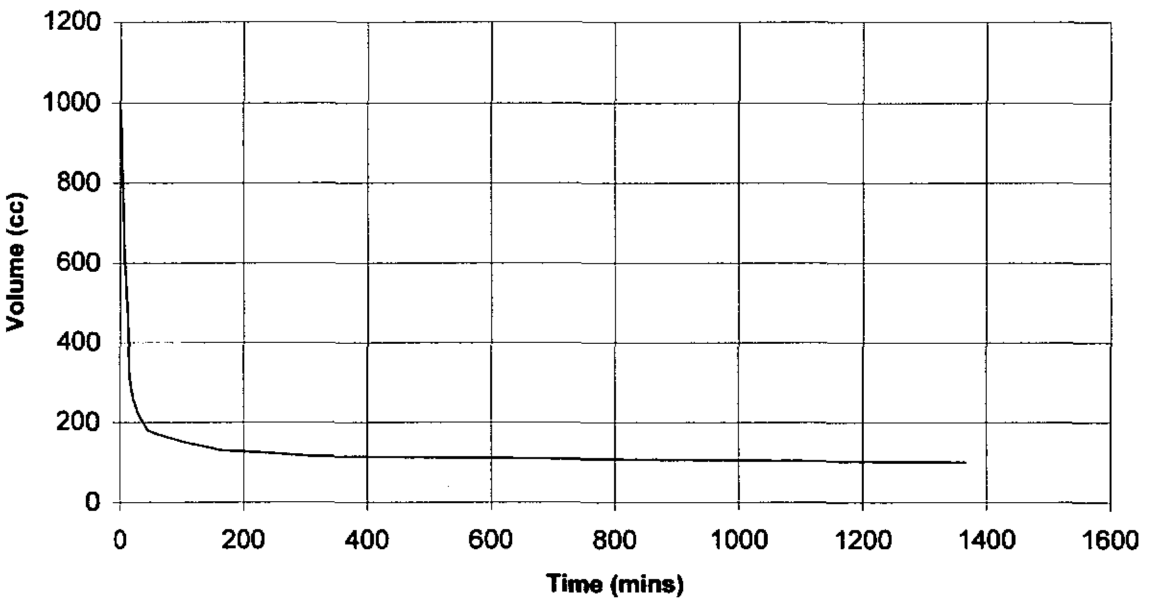
ZONE SETTLEMENT TEST REPORT

US Army engineers - Guidelines for dredging operating and managing dredged materials in containment areas.

CLIENT: **Santos Ltd**
60 Edward St, Brisbane Qld 4000

PROJECT: **GLNG Project : Dredge facility Design**

Job Number:	119-229	**Date Tested:**	03.08.09
Laboratory Number:	53730	**Sampled By:**	Geo Coastal
Sample Source:	BH 13A 6.0 to 7.0m		
Sample Description:	SILTY SAND:grey,fine to coarse sand,some low plastic clay, some fine gravel(shells)		



Initial Dry Concentration	50	(grams/ litre)
Time for Initial Zone	1	(mins)
Time for 100% Settlement	1440	(mins)
Water Temperature:	19	°C
Water Type:	Sea Water	

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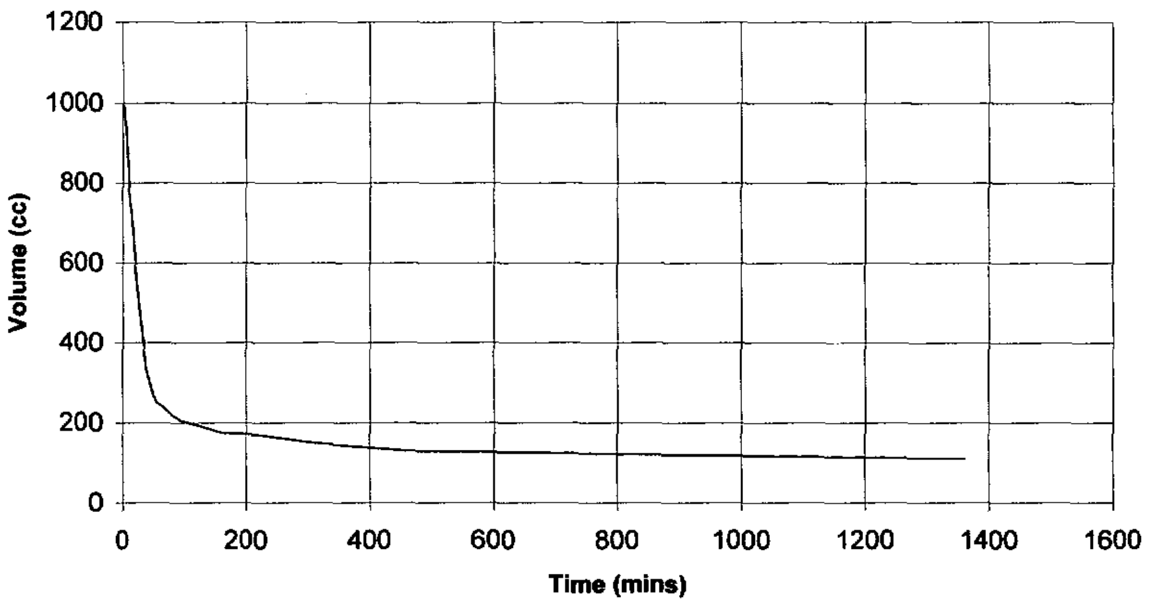
ZONE SETTLEMENT TEST REPORT

US Army engineers - Guidelines for dredging operating and managing dredged materials in containment areas.

CLIENT: **Santos Ltd**
60 Edward St, Brisbane Qld 4000

PROJECT: **GLNG Project : Dredge facility Design**

Job Number:	119-229	**Date Tested:**	03.08.09
Laboratory Number:	53731	**Sampled By:**	Geo Coastal
Sample Source:	BH 13A 11.5 to 12.0m		
Sample Description:	SANDY CLAY:grey, medium plasticity,fine to coarse sand,some gravel (shells)		



Initial Dry Concentration	50	(grams/ litre)
Time for Initial Zone	1	(mins)
Time for 100% Settlement	1440	(mins)
Water Temperature:	19	°C
Water Type:	Sea Water	

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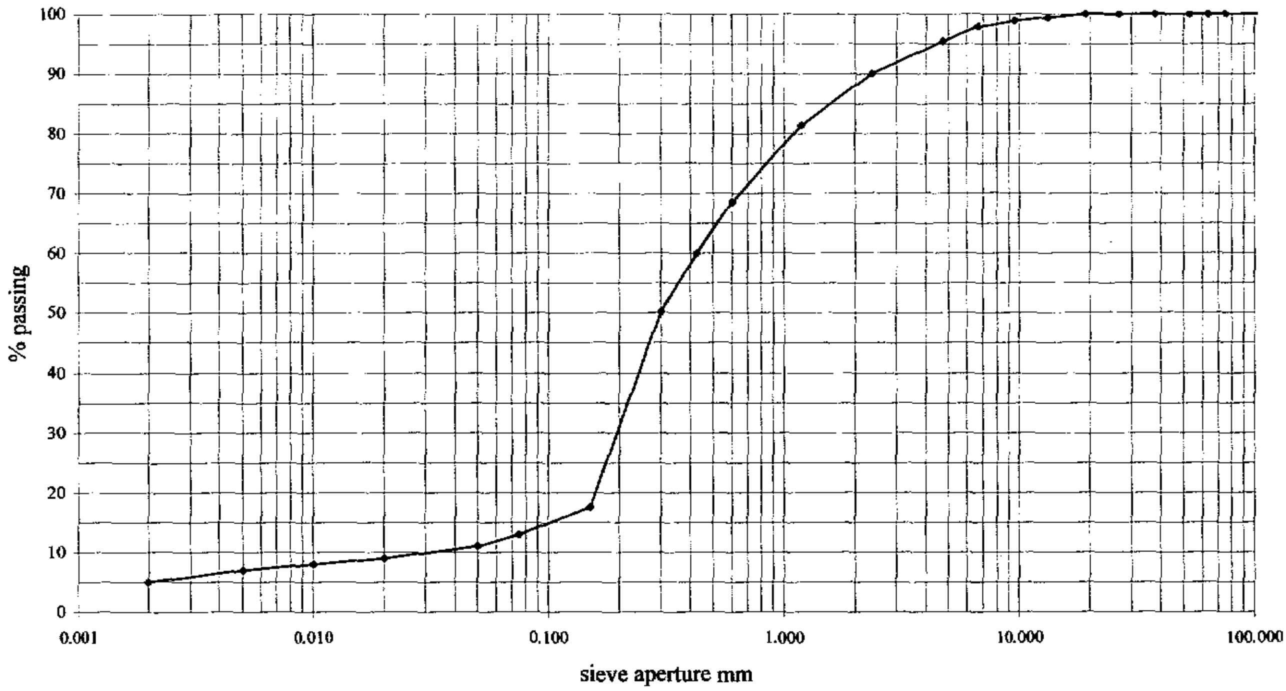
PARTICLE SIZE DISTRIBUTION TEST REPORT

Client:	**SANTOS Ltd**		
Address:	**60 Edward St, Brisbane QLD 4000**		
Project:	**GLNG PROJECT: DREDGE FACILITY DESIGN**		
Test Method:	**AS1289 3.6.1/3**		
Job Number:	**119-229**	Lab Number:	**53729**
Sample Source:	**BH13A 0 to 1.0m**	Date Tested:	**31/07/09**
Sampled by:	**Geo Coastal**	Checked By:	**CWS**



Clay	Silt	Sand	Gravel

Sample Description: **SAND:grey, fine to coarse , some silt and clay of low plasticity, some gravel (shells) (Alluvial soil)**

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	**100**	1.18	**81**
75.0	**100**	0.600	**69**
63.0	**100**	0.425	**60**
53.0	**100**	0.300	**50**
37.5	**100**	0.150	**18**
26.5	**100**	0.075	**13**
19.0	**100**	0.050	**11**
13.2	**99**	0.020	**9**
9.5	**99**	0.010	**8**
6.7	**98**	0.005	**7**
4.75	**95**	0.002	**5**
2.36	**90**		

Hydrometer Type: **ASTM 152H**
Dispersant Type: **Sodium Hexametaphosphate /**
Pretreatment: **None**
Loss on Pretreatment: **None**
Remarks:

File C06 File C:\Excel Reports\C06 Particle Size Distribution +19mm No Riffle Issue 2 June 2008 CL

Signed: .... Name: C. Lloyd
Title: LM Date: 22/8/09

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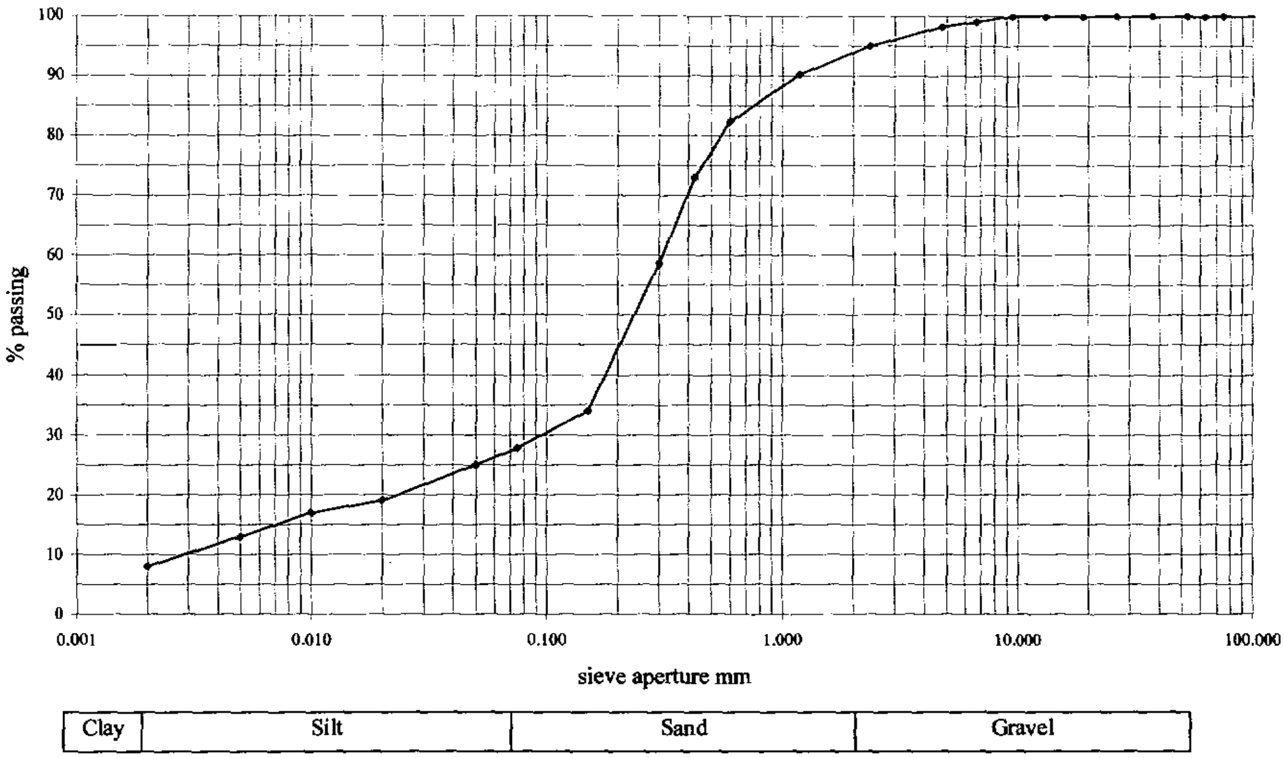
PARTICLE SIZE DISTRIBUTION TEST REPORT

Client:	**SANTOS Ltd**		
Address:	**60 Edward St, Brisbane QLD 4000**		
Project:	**GLNG PROJECT: DREDGE FACILITY DESIGN**		
Test Method:	**AS1289 3.6.1/3**		
Job Number:	**119-229**	Lab Number:	**53730**
Sample Source:	**BH13A 6.0 to 7.0m**	Date Tested:	**31.08.09**
Sampled by:	**Geo Coastal**	Checked By:	**CWS**



Sample Description: **SILTY SAND: grey, fine to coarse sand,some low plastic clay, some fine gravel (shells) (Alluvial)**

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	**100**	1.18	**90**
75.0	**100**	0.600	**82**
63.0	**100**	0.425	**73**
53.0	**100**	0.300	**59**
37.5	**100**	0.150	**34**
26.5	**100**	0.075	**28**
19.0	**100**	0.050	**25**
13.2	**100**	0.020	**19**
9.5	**100**	0.010	**17**
6.7	**99**	0.005	**13**
4.75	**98**	0.002	**8**
2.36	**95**		

Hydrometer Type: **ASTM 152H**
Dispersant Type: **Sodium Hexametaphosphate**
Pretreatment: **None**
Loss on Pretreatment: **None**
Remarks:

Signed: .... Name: C. Lloyd
Title: LM Date: 22/8/09

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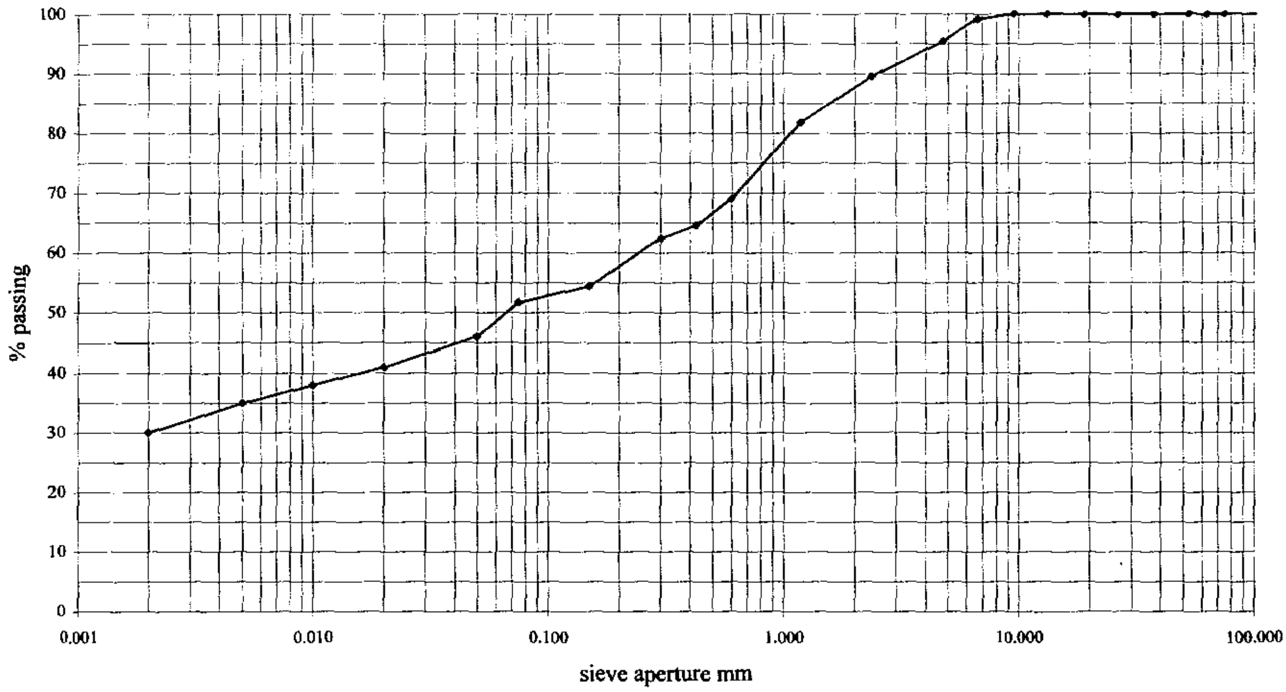
PARTICLE SIZE DISTRIBUTION TEST REPORT

Client: SANTOS Ltd
Address: 60 Edward St, Brisbane QLD 4000
Project: GLNG PROJECT: DREDGE FACILITY DESIGN

Test Method:	AS1289 3.6.1/3		
Job Number:	119-229	Lab Number:	53731
Sample Source:	BH13A 11.5 to 12.0m	Date Tested:	06.08.09
Sampled by:	Geo Coastal	Checked By:	CWS



Clay	Silt	Sand	Gravel

Sample Description: **SANDY CLAY:grey,medium plasticity,fine to coarse sand,some gravel as shells (Alluvial)**

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	100	1.18	82
75.0	100	0.600	69
63.0	100	0.425	65
53.0	100	0.300	62
37.5	100	0.150	54
26.5	100	0.075	52
19.0	100	0.050	46
13.2	100	0.020	41
9.5	100	0.010	38
6.7	99	0.005	35
4.75	95	0.002	30
2.36	90		

Hydrometer Type: ASTM 152H
Dispersant Type: Sodium Hexametaphosphate
Pretreatment: None
Loss on Pretreatment: None
Remarks:

File C06 File C:\Excel Reports\C06 Particle Size Distribution +19mm No Riffle Issue 2 June 2008 CL

Signed: .... Name: C. Lloyd
Title: LM Date: 22/8/09

AUSTRALIAN SOIL TESTING PTY LTD. A.B.N. 79 003 493 623
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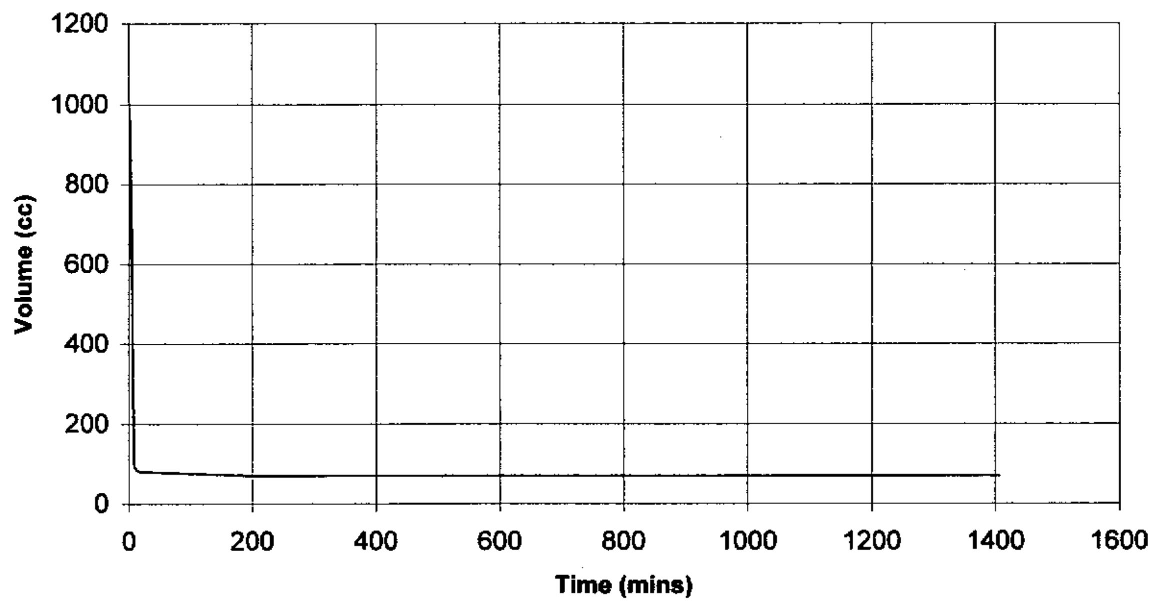
ZONE SETTLEMENT TEST REPORT

US Army engineers - Guidelines for dredging operating and managing dredged materials in containment areas.

CLIENT: **Santos Ltd**
60 Edward St, Brisbane Qld 4000

PROJECT: **GLNG Project : Dredge facility Design**

Job Number:	119-229	**Date Tested:**	04.08.08
Laboratory Number:	53717	**Sampled By:**	Geo Coastal
Sample Source:	BH 08C 0 to 1.0m		
Sample Description:	GRAVELLY SAND:grey,fine to coarse sand,fine to medium gravel, some silt		



Initial Dry Concentration	50	(grams/ litre)
Time for Initial Zone	1	(mins)
Time for 100% Settlement	200	(mins)
Water Temperature:	19	°C
Water Type:	Sea Water	

File C:\Zone Settlement issue 1 March 2008 CL

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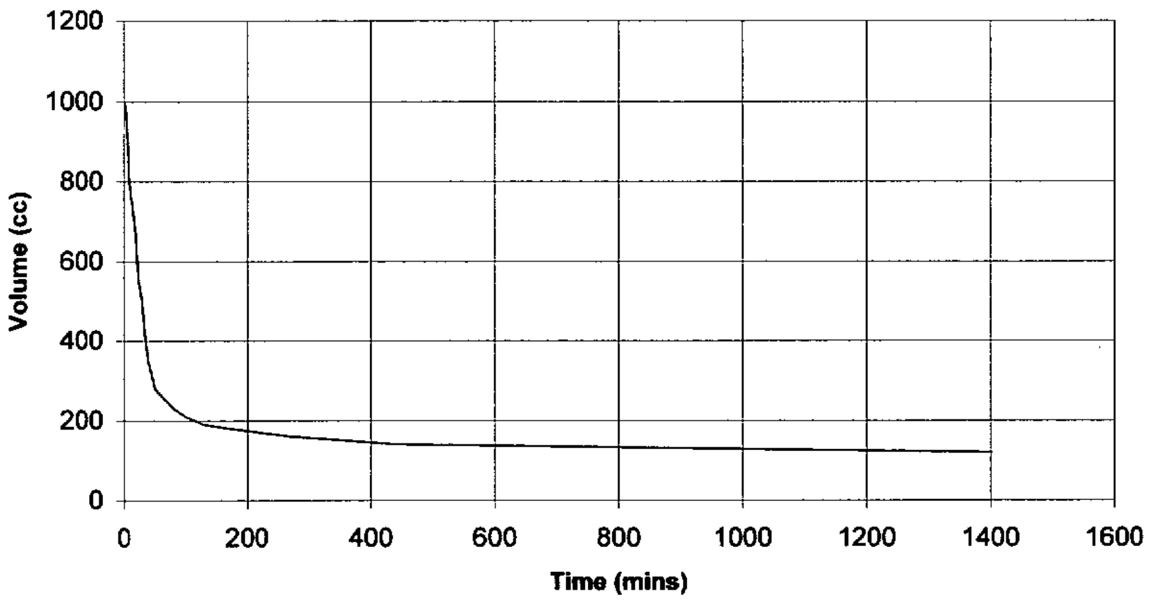
ZONE SETTLEMENT TEST REPORT

US Army engineers - Guidelines for dredging operating and managing dredged materials in containment areas.

CLIENT: **Santos Ltd**
60 Edward St, Brisbane Qld 4000

PROJECT: **GLNG Project : Dredge facility Design**

Job Number:	119-229	**Date Tested:**	04.08.08
Laboratory Number:	53718	**Sampled By:**	Geo Coastal
Sample Source:	BH 08C 3.0 to 4.0m		
Sample Description:	SILTY SAND: grey, fine to coarse sand,some gravel (shells) some clay of low plasticity		



Initial Dry Concentration	50	(grams/ litre)
Time for Initial Zone	1	(mins)
Time for 100% Settlement	600	(mins)
Water Temperature:	19deg C	°C
Water Type:	Sea Water	

File C:\Zone Settlement issue 1 March 2008 CL

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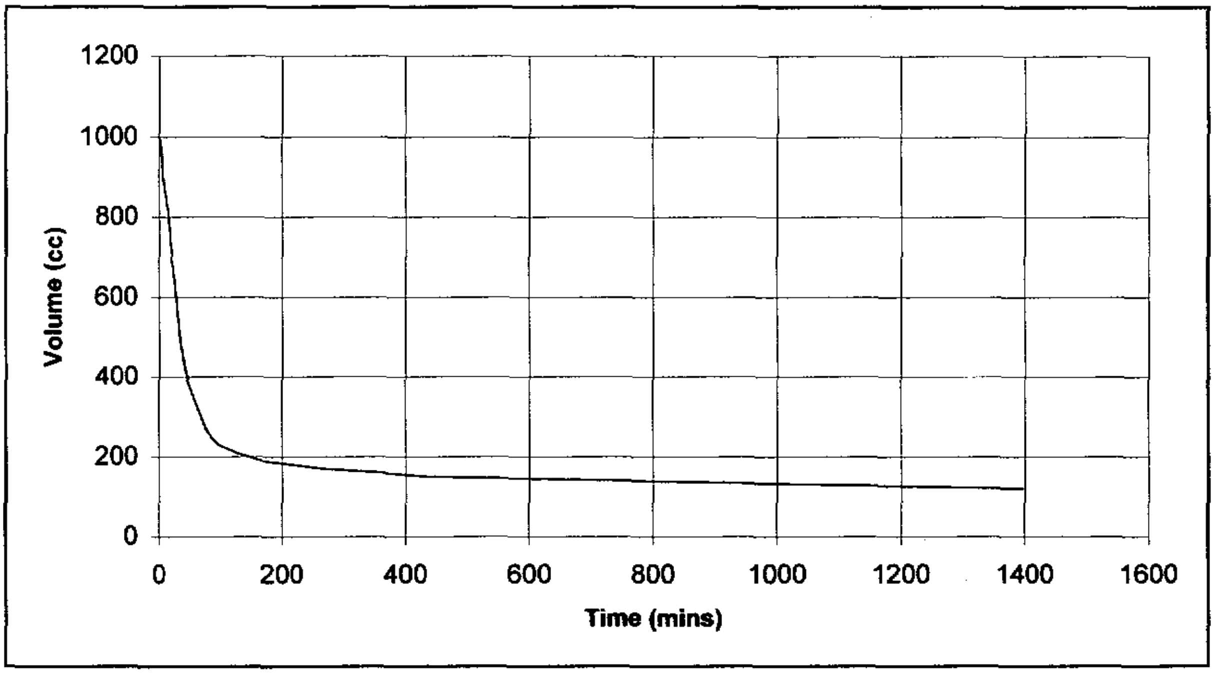
ZONE SETTLEMENT TEST REPORT

US Army engineers - Guidelines for dredging operating and managing dredged materials in containment areas.

CLIENT: **Santos Ltd**
60 Edward St, Brisbane Qld 4000

PROJECT: **GLNG Project : Dredge facility Design**

Job Number:	119-229	**Date Tested:**	06.08.08
Laboratory Number:	53719	**Sampled By:**	Geo Coastal
Sample Source:	BH 08C 4.75 to 5.6m		
Sample Description:	SANDY CLAY:grey,medium plasticity,fine to coarse sand,with fine to medium gravel.		



Initial Dry Concentration	50	(grams/ litre)
Time for Initial Zone	1	(mins)
Time for 100% Settlement	420	(mins)
Water Temperature:	19	°C
Water Type:	Sea Water	

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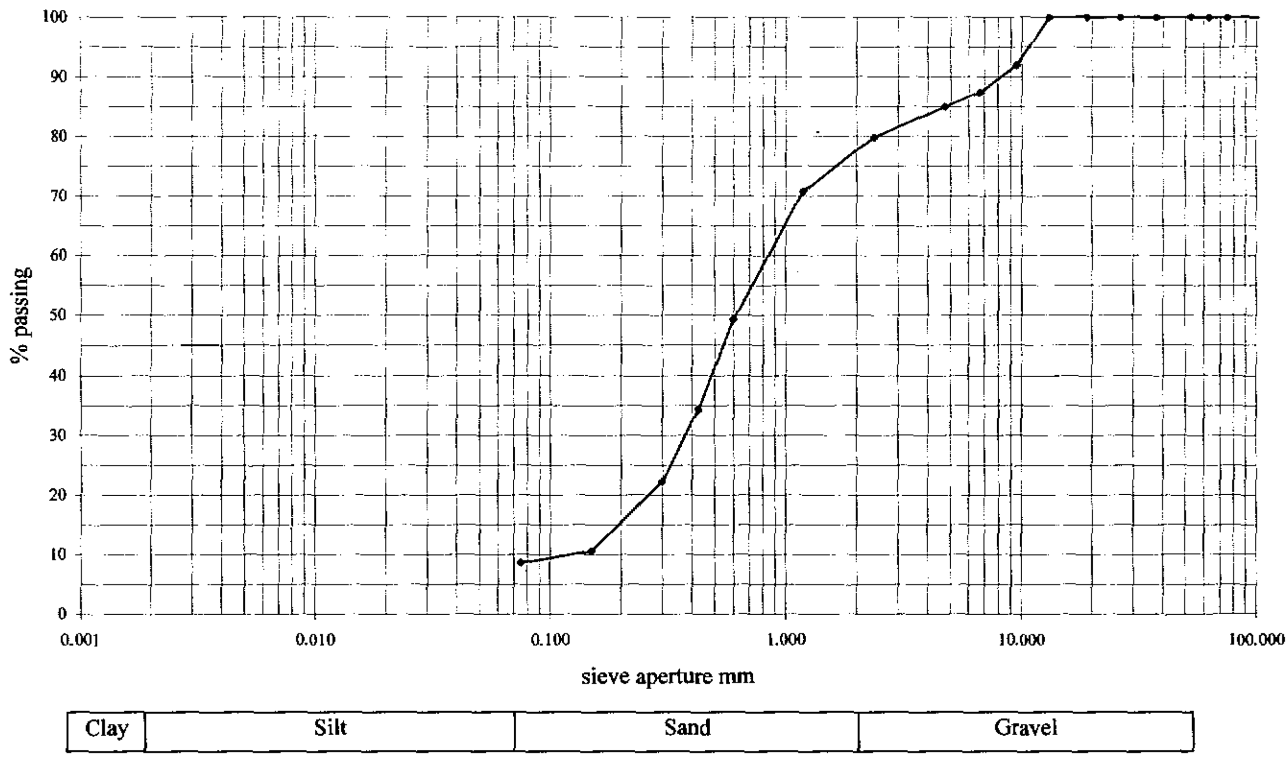
PARTICLE SIZE DISTRIBUTION TEST REPORT

Client:	**SANTOS Ltd**		
Address:	**60 Edward St, Brisbane QLD 4000**		
Project:	**GLNG PROJECT: DREDGE FACILITY DESIGN**		
Test Method:	**AS1289 3.6.1/3**		
Job Number:	**119-229**	Lab Number:	**53717**
Sample Source:	**BH08C 0 to 1.0m**	Date Tested:	**14/08/09**
Sampled by:	**Geo Coastal**	Checked By:	**CWS**



Sample Description: **GRAVELLY SAND: grey,fine to coarse sand, fine to medium gravel, some silt (Alluvial)**

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	**100**	1.18	**71**
75.0	**100**	0.600	**49**
63.0	**100**	0.425	**34**
53.0	**100**	0.300	**22**
37.5	**100**	0.150	**11**
26.5	**100**	0.075	**9**
19.0	**100**	0.050	
13.2	**100**	0.020	
9.5	**92**	0.010	
6.7	**87**	0.005	
4.75	**85**	0.002	
2.36	**80**		

Hydrometer Type: **ASTM 152H**
Dispersant Type: **Sodium Hexametaphosphate**
Pretreatment: **None**
Loss on Pretreatment: **None**
Remarks:

File C06 File C:\Excel Reports\C06 Particle Size Distribution +19mm No Riffle Issue 2 June 2008 CL

Signed: .... Name: C. Lloyd
Title: LM Date: 22/8/09

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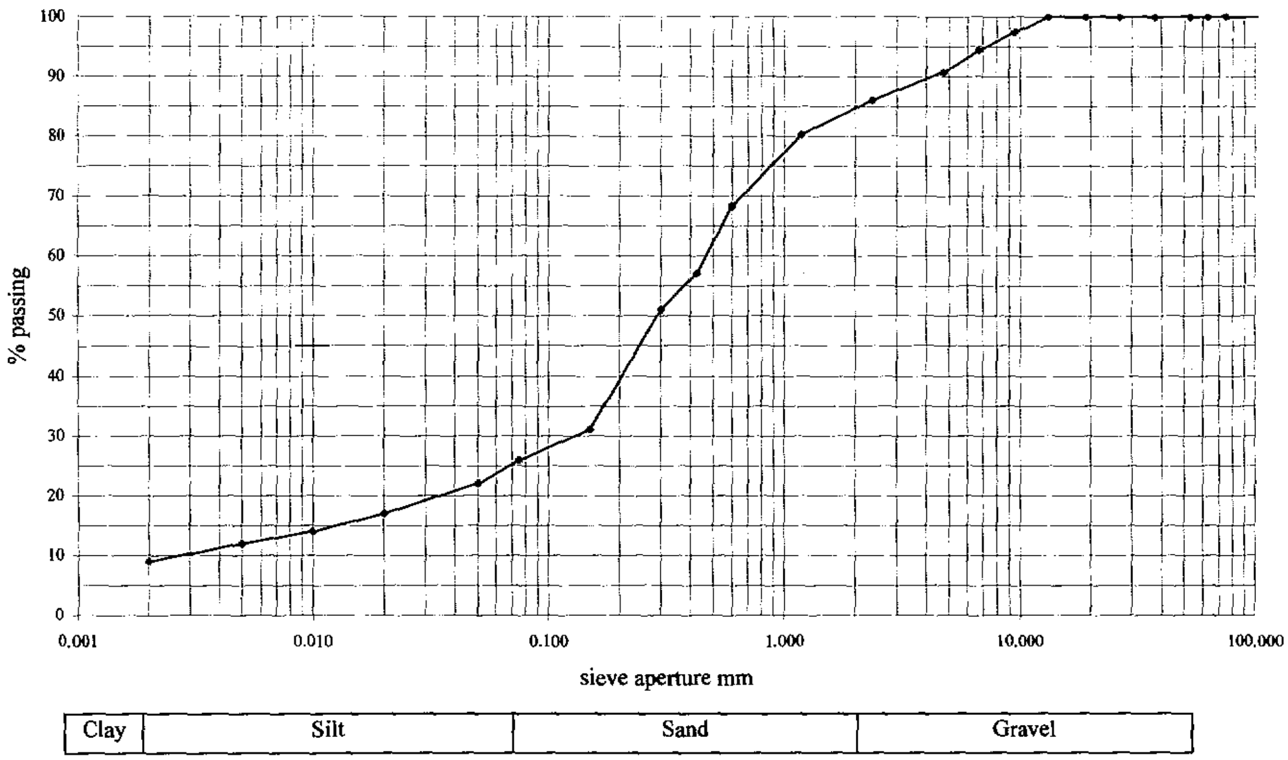
PARTICLE SIZE DISTRIBUTION TEST REPORT

Client: SANTOS Ltd
Address: 60 Edward St, Brisbane QLD 4000
Project: GLNG PROJECT: DREDGE FACILITY DESIGN
Test Method: **AS1289 3.6.1/3**
Job Number: **119-229** Lab Number: **53718**
Sample Source: **BH08C 3.0 to 4.0m** Date Tested: **14/08/09**
Sampled by: **Geo Coastal** Checked By: **CWS**



Sample Description: **SILTY SAND: grey, fine to coarse, some gravel (shells) some clay of low plasticity, (Alluvial)**

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	**100**	1.18	**80**
75.0	**100**	0.600	**68**
63.0	**100**	0.425	**57**
53.0	**100**	0.300	**51**
37.5	**100**	0.150	**31**
26.5	**100**	0.075	**26**
19.0	**100**	0.050	**22**
13.2	**100**	0.020	**17**
9.5	**97**	0.010	**14**
6.7	**94**	0.005	**12**
4.75	**91**	0.002	**9**
2.36	**86**		

Hydrometer Type: **ASTM 152H**
Dispersant Type: **Sodium Hexametaphosphate**
Pretreatment: **None**
Loss on Pretreatment: **None**
Remarks:

Signed: .... Name: C Lloyd
Title: LM Date: 22/8/09

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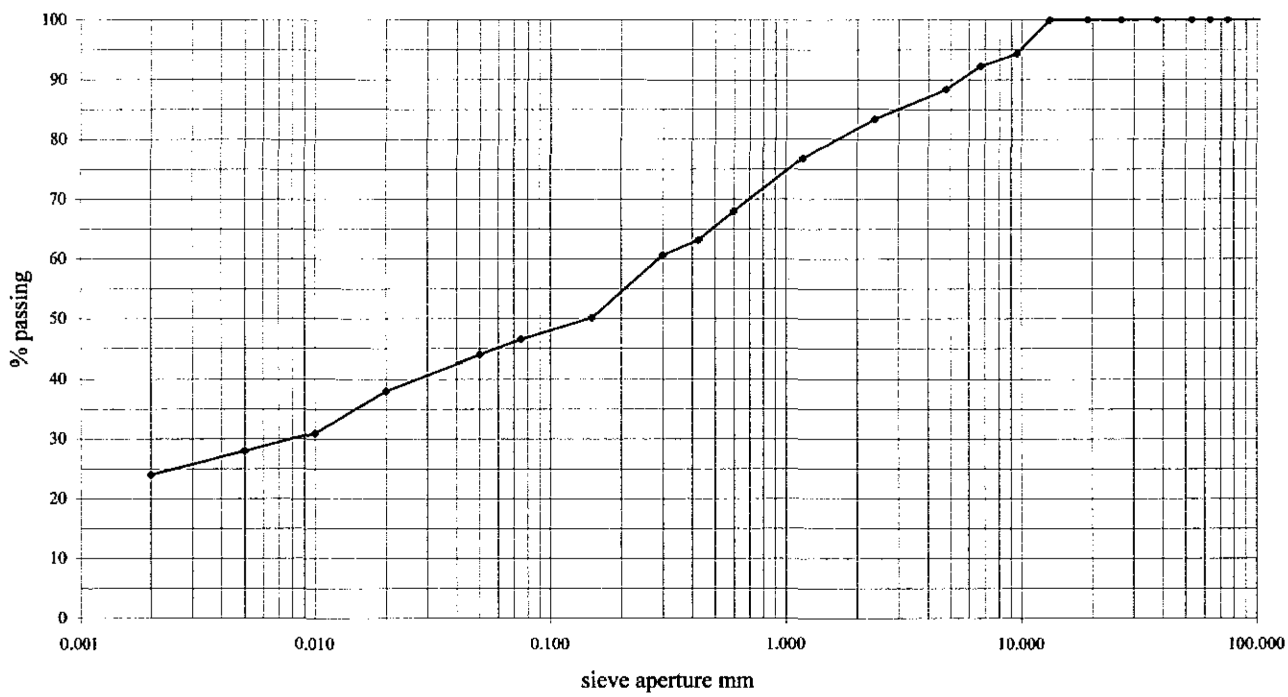
PARTICLE SIZE DISTRIBUTION TEST REPORT

Client: SANTOS Ltd
Address: 60 Edward St, Brisbane QLD 4000
Project: GLNG PROJECT: DREDGE FACILITY DESIGN

Test Method:	**AS1289 3.6.1/3**		
Job Number:	**119-229**	Lab Number:	**53719**
Sample Source:	**BH08C 4.75 to 5.6m**	Date Tested:	**14/08/09**
Sampled by:	**Geo Coastal**	Checked By:	**CWS**



Clay	Silt	Sand	Gravel

Sample Description: **SANDY CLAY:grey,medium plasticity,fine to coarse sand, with fine to medium gravel as shells (Alluvial)**

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	100	1.18	77
75.0	100	0.600	68
63.0	100	0.425	63
53.0	100	0.300	61
37.5	100	0.150	50
26.5	100	0.075	47
19.0	100	0.050	44
13.2	100	0.020	38
9.5	94	0.010	31
6.7	92	0.005	28
4.75	88	0.002	24
2.36	83		

Hydrometer Type: ASTM 152H
Dispersant Type: Sodium Hexametaphosphate
Pretreatment: None
Loss on Pretreatment: None
Remarks:

File C06 File C:\Excel Reports\C06 Particle Size Distribution +19mm No Riffle Issue 2 June 2008 CL

Signed: .... Name: C. Lloyd
Title: LM Date: 22/8/09

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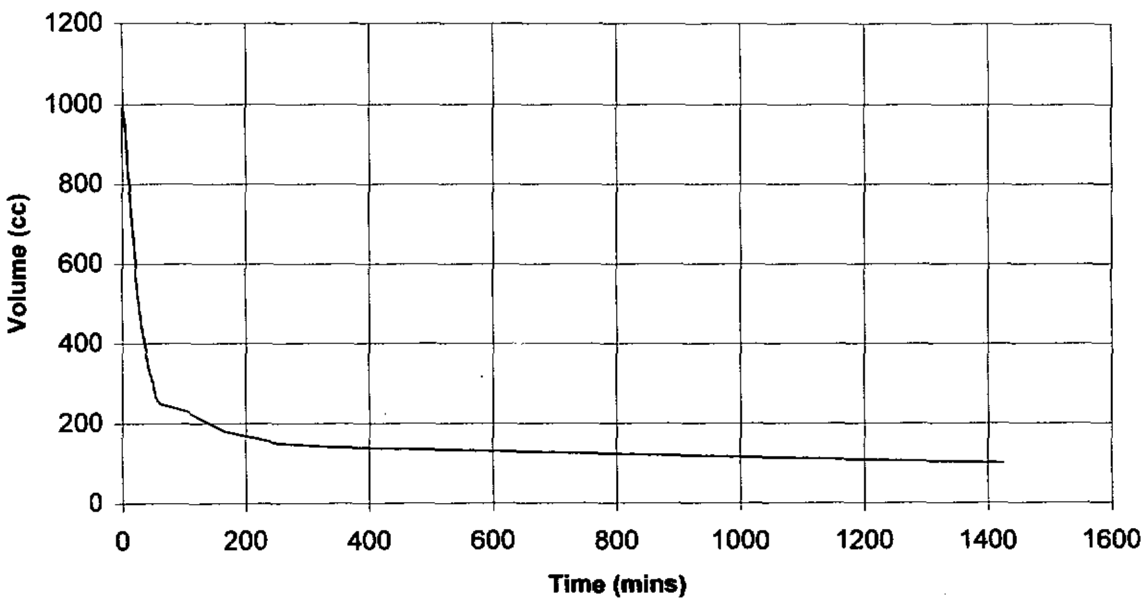
ZONE SETTLEMENT TEST REPORT

US Army engineers - Guidelines for dredging operating and managing dredged materials in containment areas.

CLIENT: **Santos Ltd**
60 Edward St, Brisbane Qld 4000

PROJECT: **GLNG Project : Dredge facility Design**

Job Number:	119-229	**Date Tested:**	03.08.08
Laboratory Number:	53726	**Sampled By:**	Geo Coastal
Sample Source:	BH 07A 0 to 1.0m		
Sample Description:	SANDY CLAY/CLAYEY SAND: grey, fine to coarse sand,low plasticity, some fine gravel (shells)		



Initial Dry Concentration	50	(grams/ litre)
Time for Initial Zone	1	(mins)
Time for 100% Settlement	1440	(mins)
Water Temperature:	19	°C
Water Type:	Sea Water	

File C:\Zone Settlement issue 1 March 2008 CL

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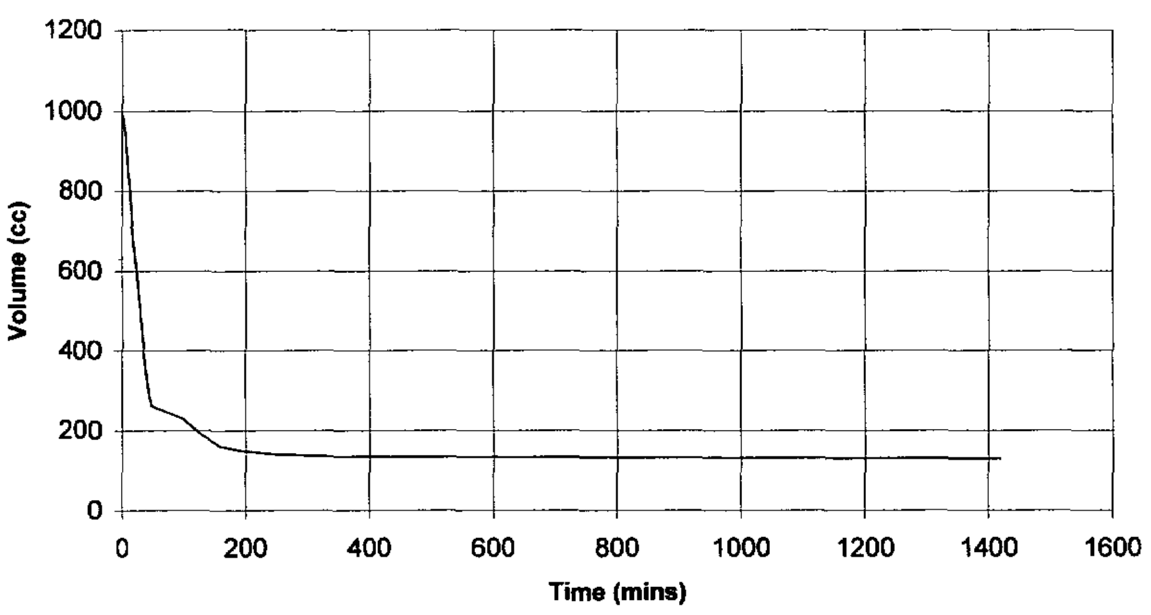
ZONE SETTLEMENT TEST REPORT

US Army engineers - Guidelines for dredging operating and managing dredged materials in containment areas.

CLIENT: **Santos Ltd**
60 Edward St, Brisbane Qld 4000

PROJECT: **GLNG Project : Dredge facility Design**

Job Number:	119-229	**Date Tested:**	04.08.08
Laboratory Number:	53727	**Sampled By:**	Geo Coastal
Sample Source:	BH 07A 2.0 to 2.8m		
Sample Description:	SANDY GRAVEL:grey,fine to coarse gravel,fine to coarse sand some silt and clay of low plasticity		



Initial Dry Concentration	50	(grams/ litre)
Time for Initial Zone	1	(mins)
Time for 100% Settlement	400	(mins)
Water Temperature:	19	°C
Water Type:	Sea Water	

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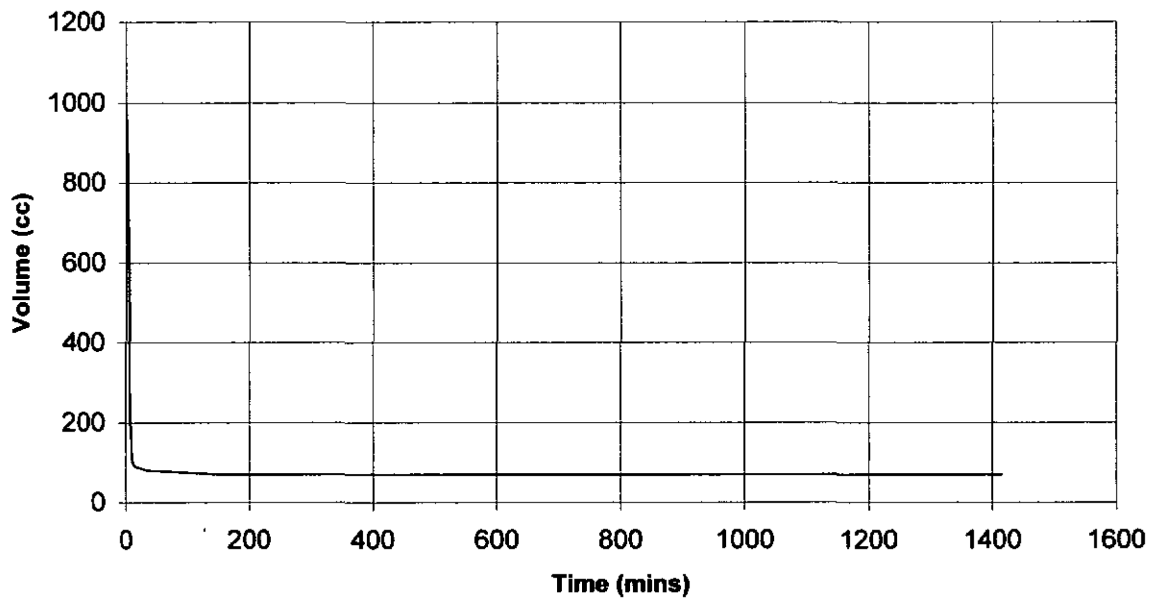
ZONE SETTLEMENT TEST REPORT

US Army engineers - Guidelines for dredging operating and managing dredged materials in containment areas.

CLIENT: **Santos Ltd**
60 Edward St, Brisbane Qld 4000

PROJECT: **GLNG Project : Dredge facility Design**

Job Number:	119-229	**Date Tested:**	04.08.08
Laboratory Number:	53728	**Sampled By:**	Geo Coastal
Sample Source:	BH 07A 3.0 to 4.0m		
Sample Description:	GRAVELLY SAND:brown,fine to coarse sand,fine to medium gravel, some silt		



Initial Dry Concentration	50	(grams/ litre)
Time for Initial Zone	1	(mins)
Time for 100% Settlement	15	(mins)
Water Temperature:	19	°C
Water Type:	Sea Water	

File C:\Zone Settlement issue 1 March 2008 CL

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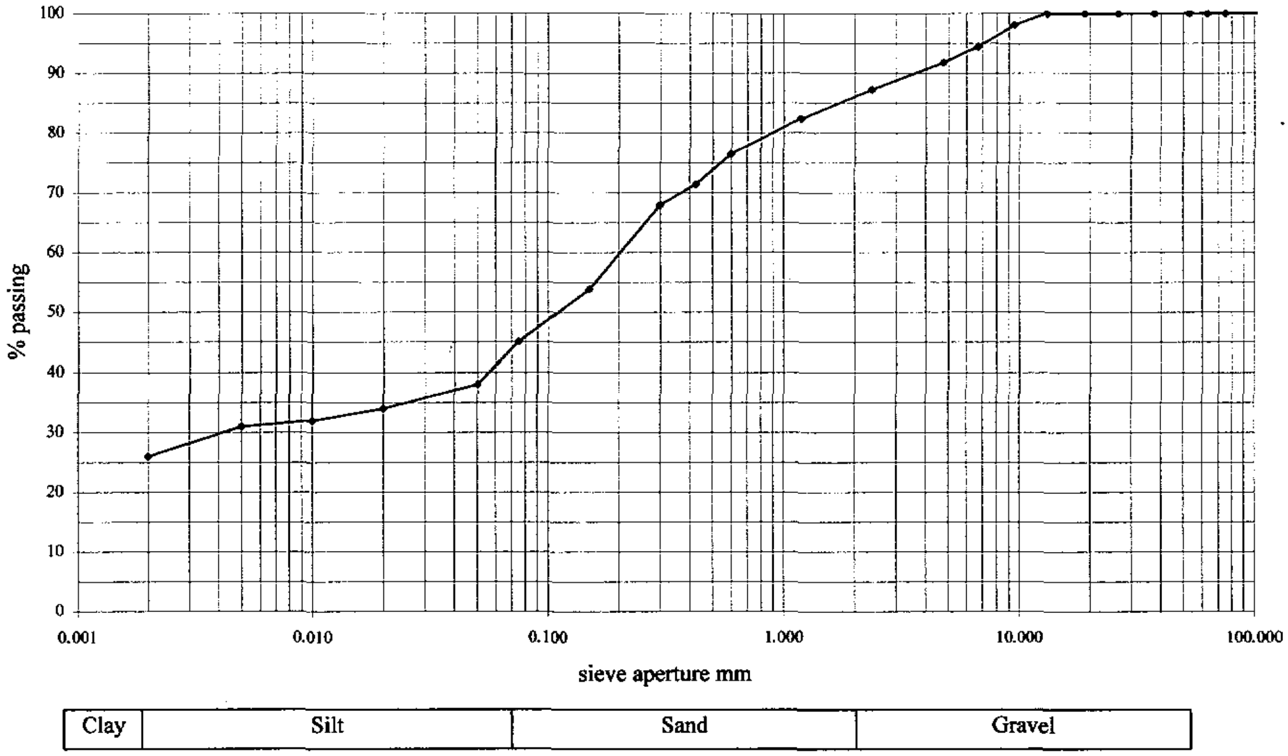
Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

PARTICLE SIZE DISTRIBUTION TEST REPORT

Client:	**SANTOS Ltd**		
Address:	**60 Edward St, Brisbane QLD 4000**		
Project:	**GLNG PROJECT: DREDGE FACILITY DESIGN**		
Test Method:	**AS1289 3.6.1/3**		
Job Number:	**119-229**	Lab Number:	**53726**
Sample Source:	**BH07A 0 to 1.0m**	Date Tested:	**06.08.09**
Sampled by:	**Geo Coastal**	Checked By:	**CWS**



Sample Description: **SANDY CLAY/CLAYEY SAND:grey,fine to coarse sand,low plasticity,some fine gravel,shells present (Alluvium)**

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	**100**	1.18	**82**
75.0	**100**	0.600	**77**
63.0	**100**	0.425	**71**
53.0	**100**	0.300	**68**
37.5	**100**	0.150	**54**
26.5	**100**	0.075	**45**
19.0	**100**	0.050	**38**
13.2	**100**	0.020	**34**
9.5	**98**	0.010	**32**
6.7	**94**	0.005	**31**
4.75	**92**	0.002	**26**
2.36	**87**		

Hydrometer Type: **ASTM 152H**
Dispersant Type: **Sodium Hexametaphosphate**
Pretreatment: **None**
Loss on Pretreatment: **None**
Remarks:

File C06 File C:\Excel Reports\C06 Particle Size Distribution +19mm No Riffle Issue 2 June 2008 CL

Signed: .... Name: C. Lloyd
Title: LM Date: 22/8/09

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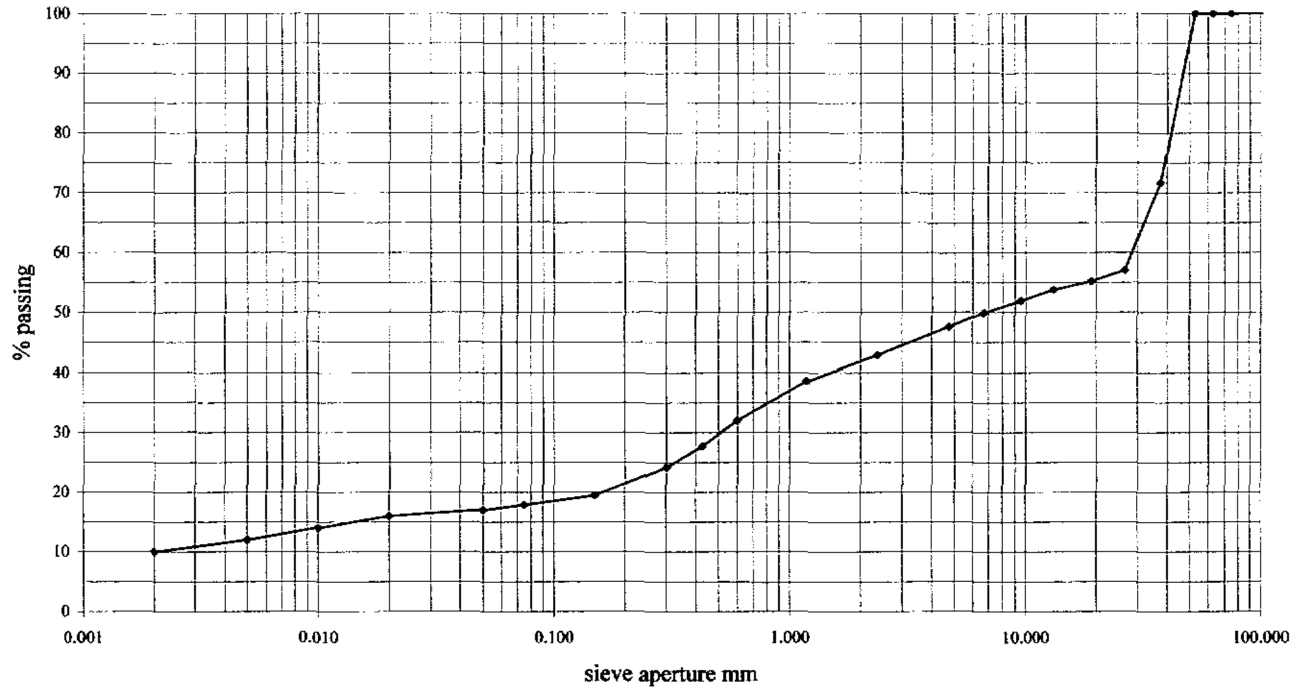
PARTICLE SIZE DISTRIBUTION TEST REPORT

Client:	**SANTOS Ltd**		
Address:	**60 Edward St, Brisbane QLD 4000**		
Project:	**GLNG PROJECT: DREDGE FACILITY DESIGN**		
Test Method:	**AS1289 3.6.1/3**		
Job Number:	**119-229**	Lab Number:	**53727**
Sample Source:	**BH07A 2.0 to 2.8m**	Date Tested:	**06.08.09**
Sampled by:	**Geo Coastal**	Checked By:	**CWS**



Clay	Silt	Sand	Gravel

Sample Description: **SANDY GRAVEL:grey,fine to coarse gravel,fine to coarse sand,some silt and clay of low plasticity. (Alluvial)**

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	**100**	1.18	**39**
75.0	**100**	0.600	**32**
63.0	**100**	0.425	**28**
53.0	**100**	0.300	**24**
37.5	**72**	0.150	**19**
26.5	**57**	0.075	**18**
19.0	**55**	0.050	**17**
13.2	**54**	0.020	**16**
9.5	**52**	0.010	**14**
6.7	**50**	0.005	**12**
4.75	**48**	0.002	**10**
2.36	**43**		

Hydrometer Type: **ASTM 152H**
Dispersant Type: **Sodium Hexametaphosphate**
Pretreatment: **None**
Loss on Pretreatment: **None**
Remarks:

Signed: .... Name: C-Lloyd
Title: LM Date: 22/8/09

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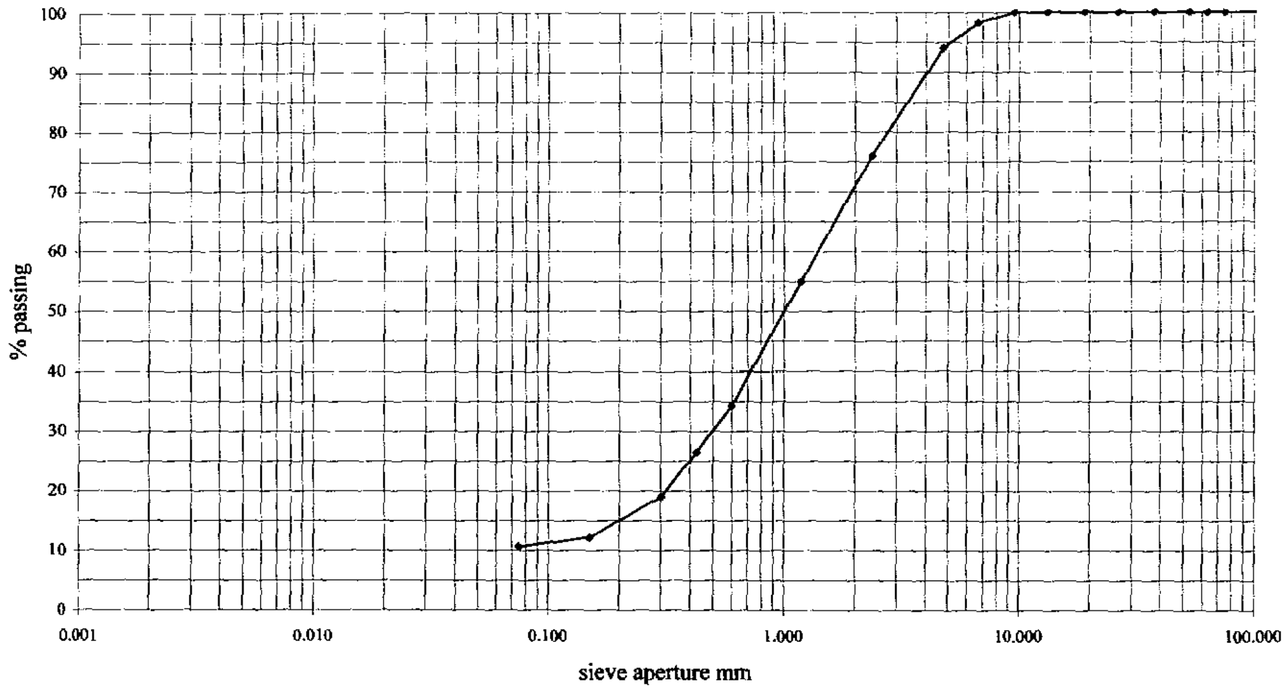
PARTICLE SIZE DISTRIBUTION TEST REPORT

Client:	**SANTOS Ltd**		
Address:	**60 Edward St, Brisbane QLD 4000**		
Project:	**GLNG PROJECT: DREDGE FACILITY DESIGN**		
Test Method:	**AS1289 3.6.1/~~3~~**		
Job Number:	**119-229**	Lab Number:	**53728**
Sample Source:	**BH07A 3.0 to 4.0m**	Date Tested:	**06.08.09**
Sampled by:	**Geo Coastal**	Checked By:	**CWS**



Clay	Silt	Sand	Gravel

Sample Description: **GRAVELLY SAND:brown,fine to medium gravel, fine to coarse sand some silt. (Alluvial)**

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	**100**	1.18	**55**
75.0	**100**	0.600	**34**
63.0	**100**	0.425	**26**
53.0	**100**	0.300	**19**
37.5	**100**	0.150	**12**
26.5	**100**	0.075	**11**
19.0	**100**	0.050	
13.2	**100**	0.020	
9.5	**100**	0.010	
6.7	**98**	0.005	
4.75	**94**	0.002	
2.36	**76**		

Hydrometer Type: **ASTM 152H**
Dispersant Type: **Sodium Hexametaphosphate**
Pretreatment: **None**
Loss on Pretreatment: **None**
Remarks:

File C06 File C:\Excel Reports\C06 Particle Size Distribution +19mm No Riffle Issue 2 June 2008 CL

Signed: .... Name: C. Lloyd
Title: LM Date: 22/1/09

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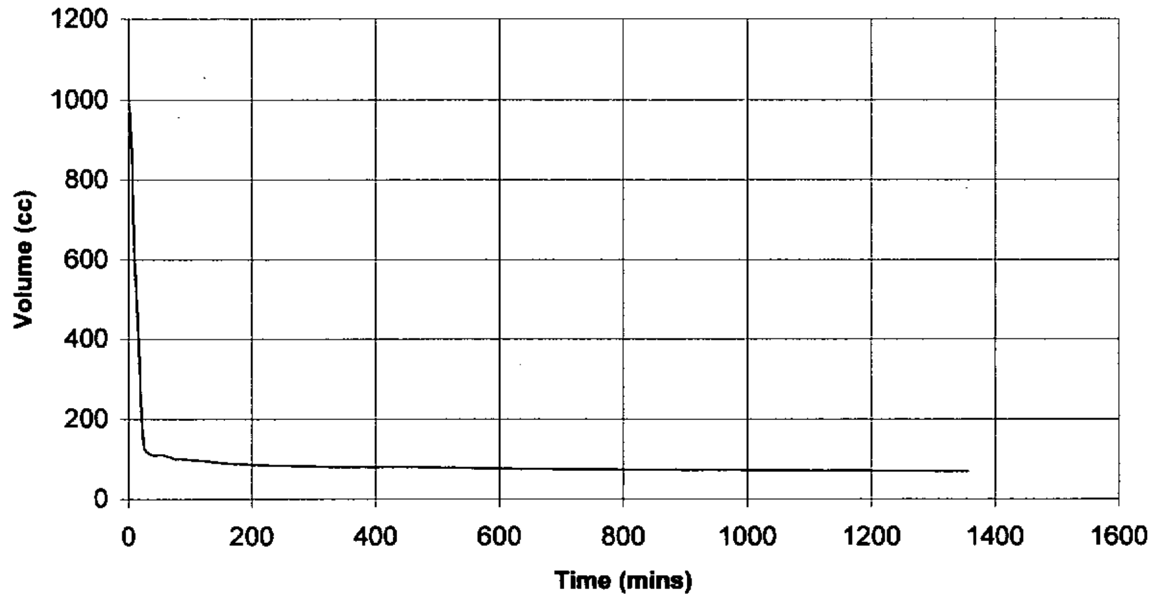
ZONE SETTLEMENT TEST REPORT

US Army engineers - Guidelines for dredging operating and managing dredged materials in containment areas.

CLIENT: **Santos Ltd**
60 Edward St, Brisbane Qld 4000

PROJECT: **GLNG Project : Dredge facility Design**

Job Number:	119-229	**Date Tested:**	06.08.09
Laboratory Number:	53720	**Sampled By:**	Geo Coastal
Sample Source:	BH 04A 0 to 0.2m		
Sample Description:	GRAVELLY(Shells) SAND:grey,fine to coarse sand, some clay of low plasticity		



Initial Dry Concentration	50	(grams/ litre)
Time for Initial Zone	1	(mins)
Time for 100% Settlement	60	(mins)
Water Temperature:	19	°C
Water Type:	Sea Water	

File C:\Zone Settlement issue 1 March 2008 CL

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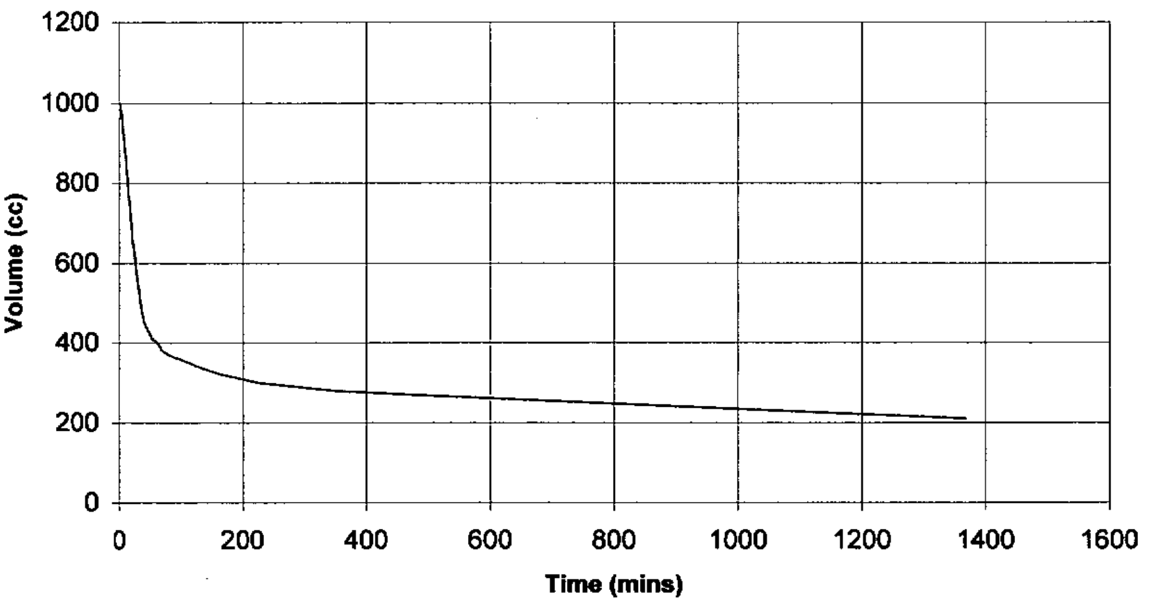
ZONE SETTLEMENT TEST REPORT

US Army engineers - Guidelines for dredging operating and managing dredged materials in containment areas.

CLIENT: **Santos Ltd**
60 Edward St, Brisbane Qld 4000

PROJECT: **GLNG Project : Dredge facility Design**

Job Number:	119-229	**Date Tested:**	06.08.09
Laboratory Number:	53721	**Sampled By:**	Geo Coastal
Sample Source:	BH 04A 0.2 to 0.5m		
Sample Description:	SANDY CLAY:mottled yellow-brown and grey,medium plasticity,fine to coarse sand,some fine to medium gravel.		



Initial Dry Concentration	50	(grams/ litre)
Time for Initial Zone	1	(mins)
Time for 100% Settlement	1440	(mins)
Water Temperature:	19	°C
Water Type:	Sea Water	

File C:\Zone Settlement issue 1 March 2008 CL

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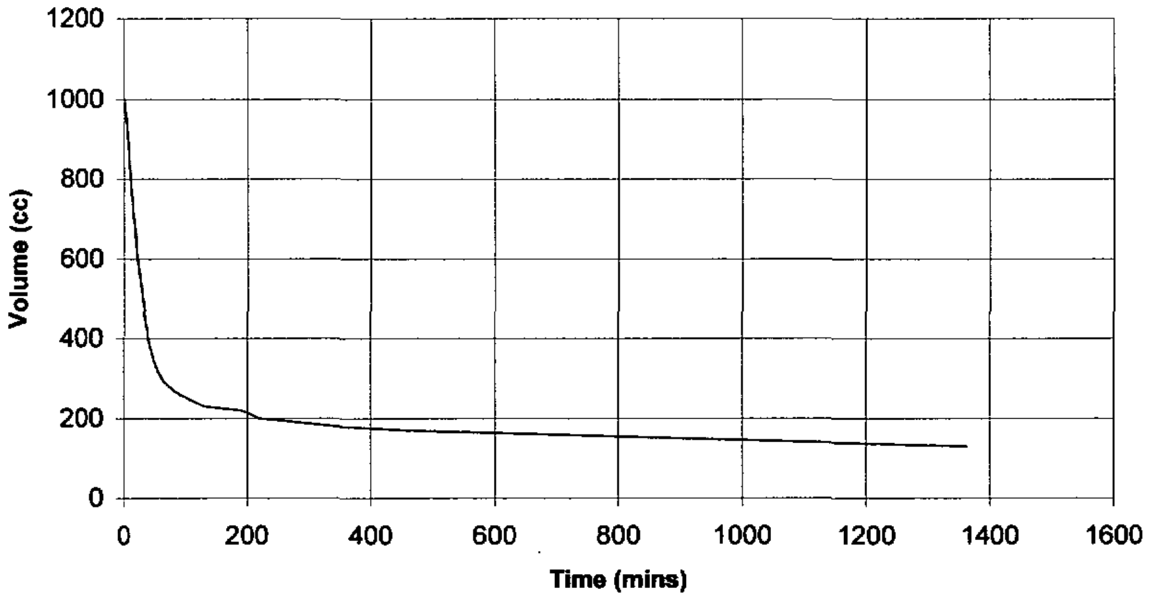
ZONE SETTLEMENT TEST REPORT

US Army engineers - Guidelines for dredging operating and managing dredged materials in containment areas.

CLIENT: **Santos Ltd**
60 Edward St, Brisbane Qld 4000

PROJECT: **GLNG Project : Dredge facility Design**

Job Number:	119-229	**Date Tested:**	06.08.09
Laboratory Number:	53722	**Sampled By:**	Geo Coastal
Sample Source:	BH 04A 0.5 to 1.0m		
Sample Description:	SILTY CLAY:mottled yellow-brown & grey,high plasticity, some fine to coarse sand.		



Initial Dry Concentration	50	(grams/ litre)
Time for Initial Zone	1	(mins)
Time for 100% Settlement	1440	(mins)
Water Temperature:	19	°C
Water Type:	Sea Water	

File C:\Zone Settlement issue 1 March 2008 CL

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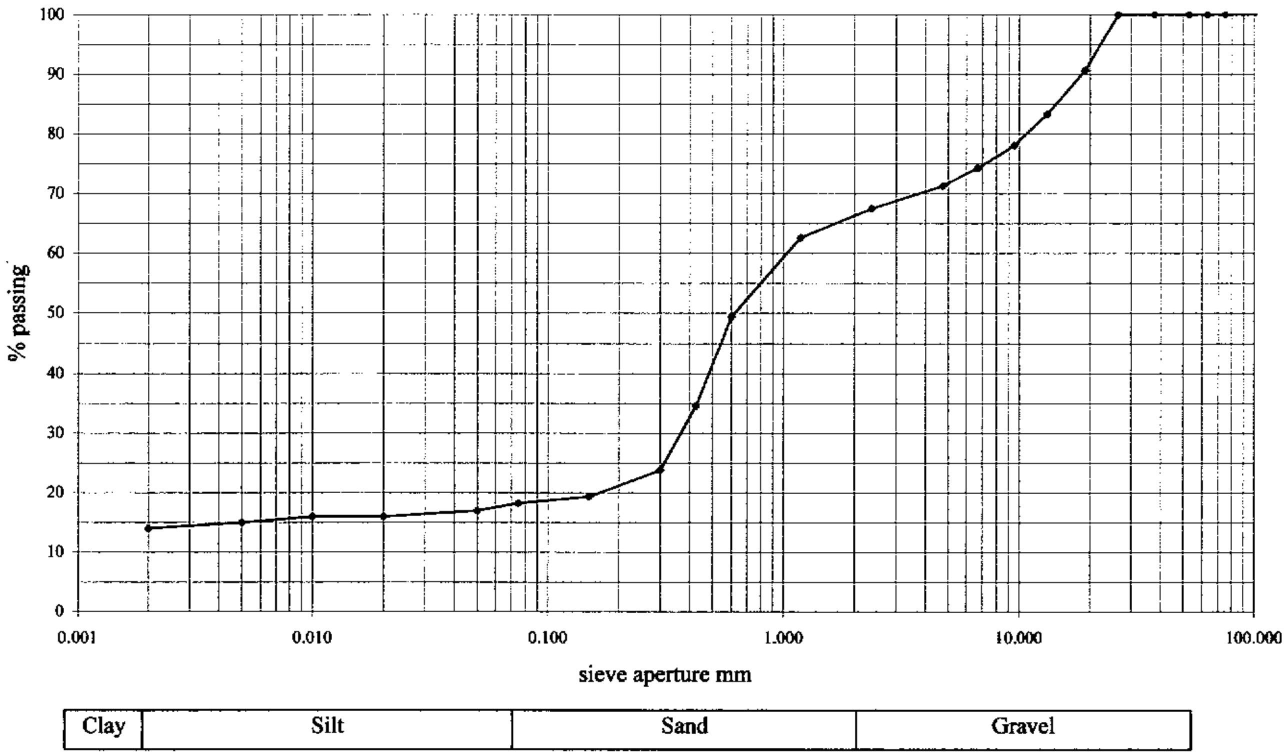
Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

PARTICLE SIZE DISTRIBUTION TEST REPORT

Client:	**SANTOS Ltd**		
Address:	**60 Edward St, Brisbane QLD 4000**		
Project:	**GLNG PROJECT: DREDGE FACILITY DESIGN**		
Test Method:	**AS1289 3.6.1/3**		
Job Number:	**119-229**	Lab Number:	**53720**
Sample Source:	**BH04A 0 to 0.2m**	Date Tested:	**07.08.09**
Sampled by:	**Geo Coastal**	Checked By:	**CWS**



Sample Description: **GRAVELLY (Shells) SAND: grey, fine to coarse sand,some clay of low plasticity (Alluvial soil)**

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	100	1.18	63
75.0	100	0.600	49
63.0	100	0.425	35
53.0	100	0.300	24
37.5	100	0.150	19
26.5	100	0.075	18
19.0	91	0.050	17
13.2	83	0.020	16
9.5	78	0.010	16
6.7	74	0.005	15
4.75	71	0.002	14
2.36	67		

Hydrometer Type: **ASTM 152H**
Dispersant Type: **Sodium Hexametaphosphate /**
Pretreatment: **None**
Loss on Pretreatment: **None**
Remarks:

File C06 File C:\Excel Reports\C06 Particle Size Distribution +19mm No Riffle Issue 2 June 2008 CL

Signed: .... Name: C. Lloyd
Title: .... Date: 22/ 8 /09

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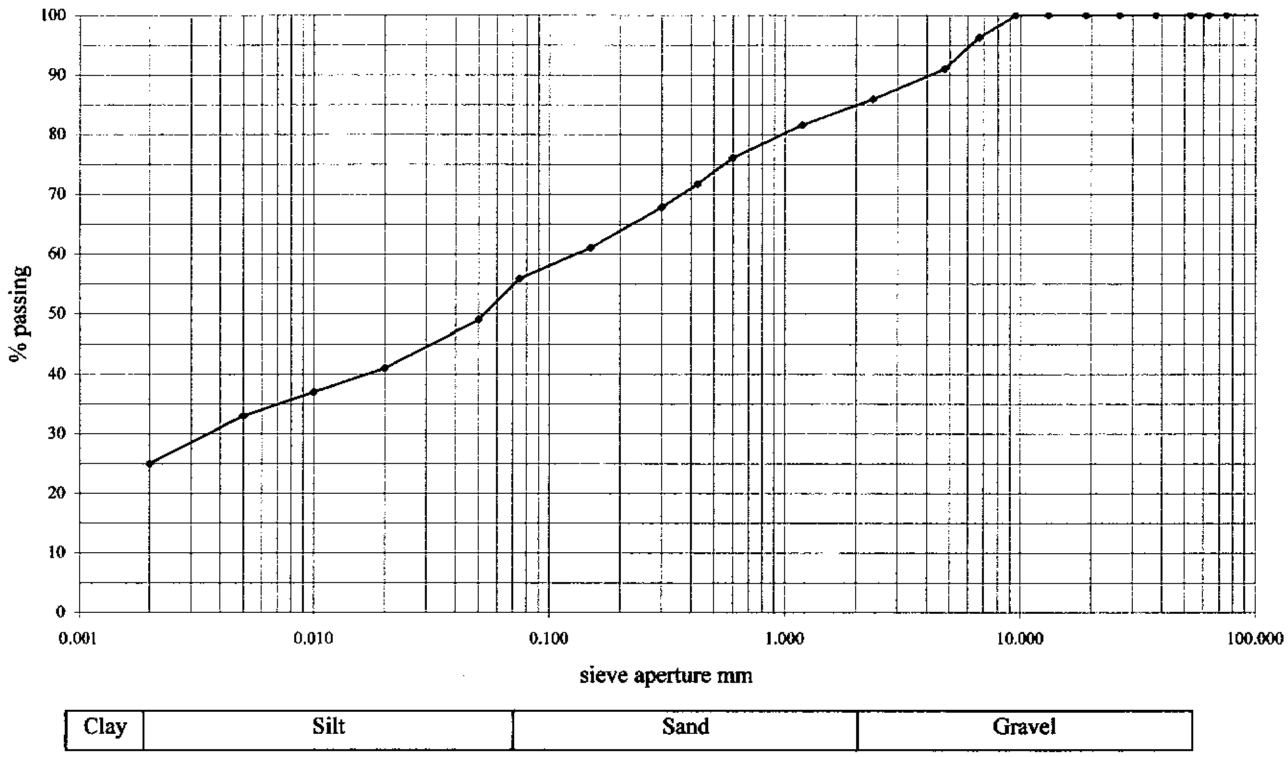
Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

PARTICLE SIZE DISTRIBUTION TEST REPORT

Client:	**SANTOS Ltd**		
Address:	**60 Edward St, Brisbane QLD 4000**		
Project:	**GLNG PROJECT: DREDGE FACILITY DESIGN**		
Test Method:	**AS1289 3.6.1/3**		
Job Number:	**119-229**	Lab Number:	**53721**
Sample Source:	**BH04A 0.2 to 0.5m**	Date Tested:	**07.08.09**
Sampled by:	**Geo Coastal**	Checked By:	**CWS**



Sample Description: **SANDY CLAY: grey,mottled yellow-brown & grey,medium plasticity,fine to coarse sand,some fine to medium gravel. (Residual soil)**

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	**100**	1.18	**82**
75.0	**100**	0.600	**76**
63.0	**100**	0.425	**72**
53.0	**100**	0.300	**68**
37.5	**100**	0.150	**61**
26.5	**100**	0.075	**56**
19.0	**100**	0.050	**49**
13.2	**100**	0.020	**41**
9.5	**100**	0.010	**37**
6.7	**96**	0.005	**33**
4.75	**91**	0.002	**25**
2.36	**86**		

Hydrometer Type: **ASTM 152H**
Dispersant Type: **Sodium Hexametaphosphate /**
Pretreatment: **None**
Loss on Pretreatment: **None**
Remarks:

File C06 File C:\Excel Reports\C06 Particle Size Distribution +19mm No Riffle Issue 2 June 2008 CL

Signed: .... Name: C Lloyd
Title: LM Date: 22 / 8 / 09

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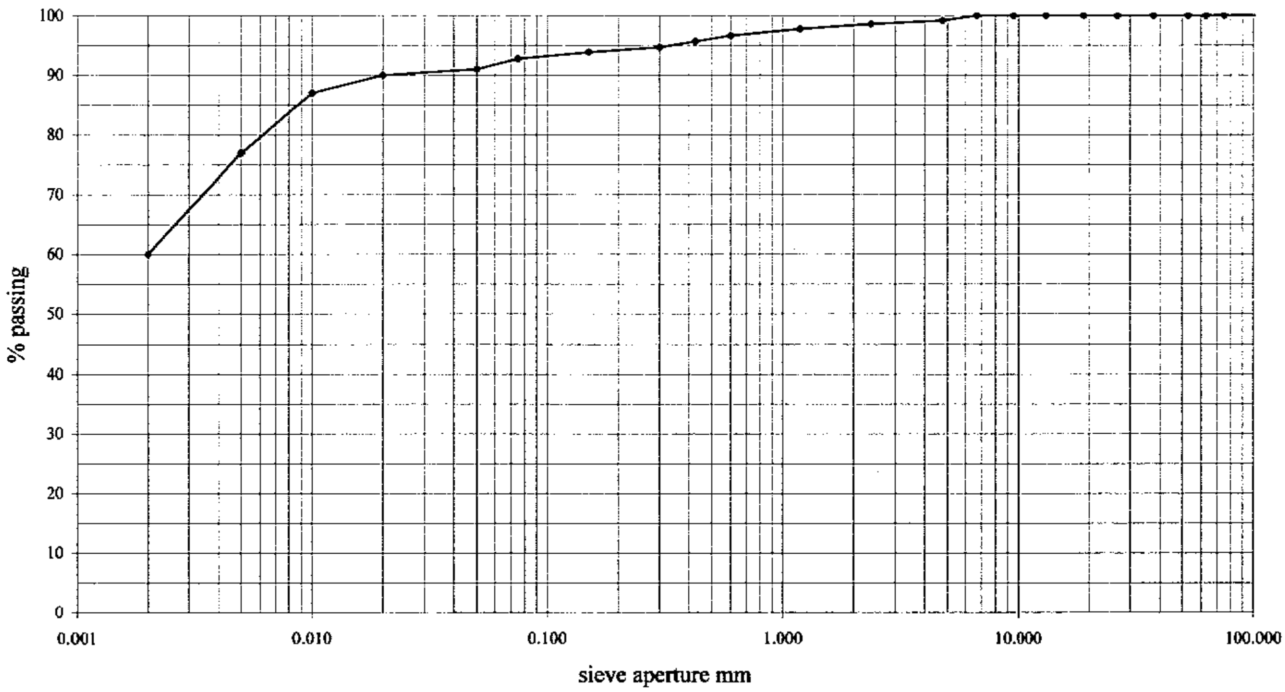
Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

PARTICLE SIZE DISTRIBUTION TEST REPORT

Client: SANTOS Ltd
Address: 60 Edward St, Brisbane QLD 4000
Project: GLNG PROJECT: DREDGE FACILITY DESIGN

Test Method:	AS1289 3.6.1/3		
Job Number:	119-229	Lab Number:	53722
Sample Source:	BH04A 0.5 to 1.0m	Date Tested:	07.08.09
Sampled by:	Geo Coastal	Checked By:	CWS



Clay	Silt	Sand	Gravel

Sample Description: **SILTY CLAY:mottled yellow-brown & grey, high plasticity,some fine to coarse sand (Residual soil)**

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	100	1.18	98
75.0	100	0.600	97
63.0	100	0.425	96
53.0	100	0.300	95
37.5	100	0.150	94
26.5	100	0.075	93
19.0	100	0.050	91
13.2	100	0.020	90
9.5	100	0.010	87
6.7	100	0.005	77
4.75	99	0.002	60
2.36	99		

Hydrometer Type: ASTM 152H
Dispersant Type: Sodium Hexametaphosphate /
Pretreatment: None
Loss on Pretreatment: None
Remarks:

File C06 File C:\Excel Reports\C06 Particle Size Distribution +19mm No Riffle Issue 2 June 2008 CL

Signed: ...... Name: C Lloyd
Title: LM Date: 22/8/09

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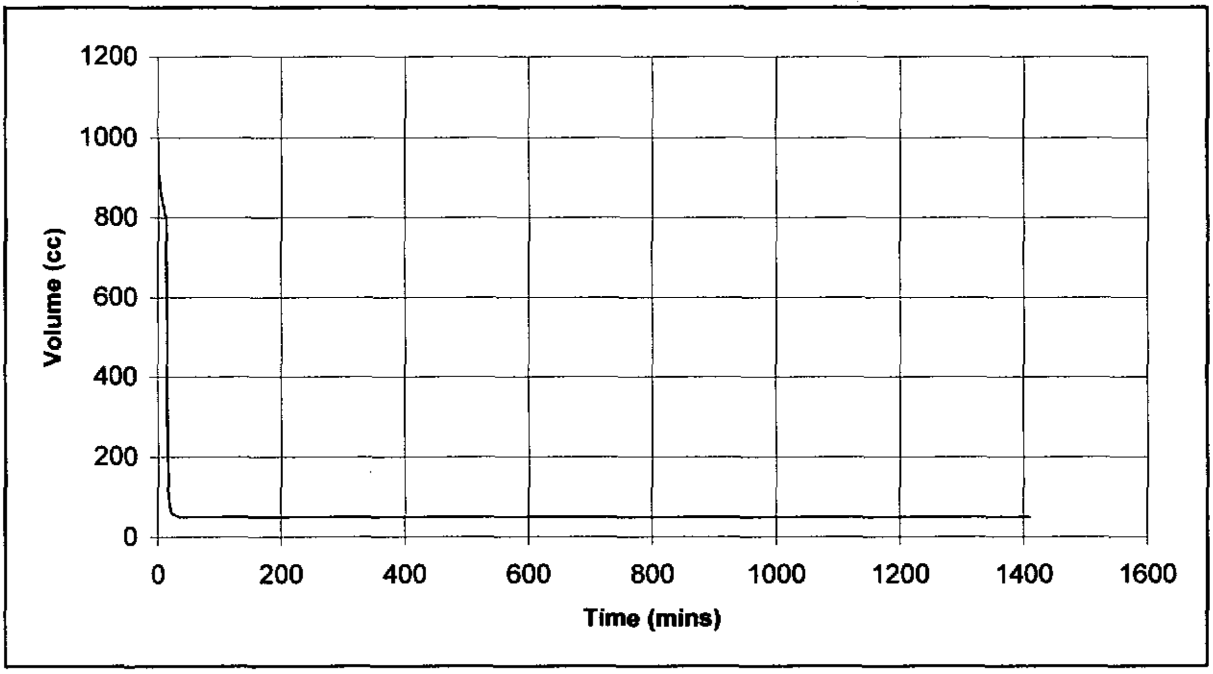
ZONE SETTLEMENT TEST REPORT

US Army engineers - Guidelines for dredging operating and managing dredged materials in containment areas.

CLIENT: **Santos Ltd**
60 Edward St, Brisbane Qld 4000

PROJECT: **GLNG Project : Dredge facility Design**

Job Number:	119-229	**Date Tested:**	12.08.08
Laboratory Number:	53735	**Sampled By:**	Geo Coastal
Sample Source:	BH 02A 0 to 1.0m		
Sample Description:	SAND: brown,fine to coarse sand, trace of silt, trace of fine gravel (shells)		



Initial Dry Concentration	50	(grams/ litre)
Time for Initial Zone	1	(mins)
Time for 100% Settlement	20	(mins)
Water Temperature:	19	°C
Water Type:	Sea Water	

File C:\Zone Settlement issue 1 March 2008 CL

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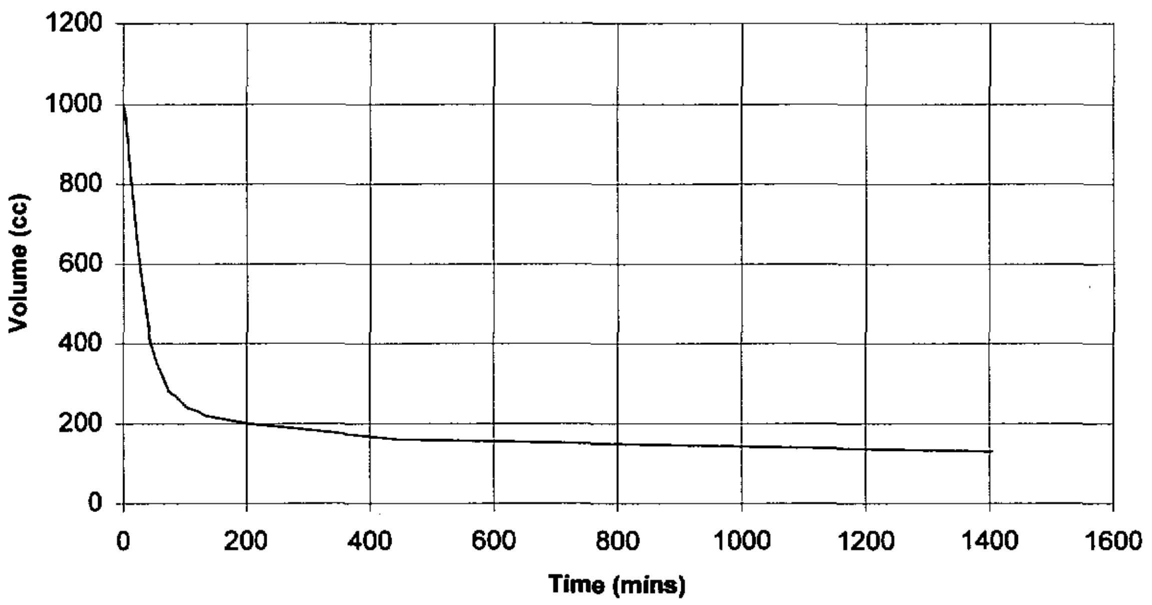
ZONE SETTLEMENT TEST REPORT

US Army engineers - Guidelines for dredging operating and managing dredged materials in containment areas.

CLIENT: **Santos Ltd**
60 Edward St, Brisbane Qld 4000

PROJECT: **GLNG Project : Dredge facility Design**

Job Number:	119-229	**Date Tested:**	12.08.08
Laboratory Number:	53736	**Sampled By:**	Geo Coastal
Sample Source:	BH 02A 2.0 to 2.75m		
Sample Description:	SANDY CLAY/CLAYEY SAND: dark grey,medium plasticity,fine to coarse sand,some fine to medium gravel (shells)		



Initial Dry Concentration	50	(grams/ litre)
Time for Initial Zone	1	(mins)
Time for 100% Settlement	600	(mins)
Water Temperature:	19	°C
Water Type:	Sea Water	

File C:\Zone Settlement issue 1 March 2008 CL

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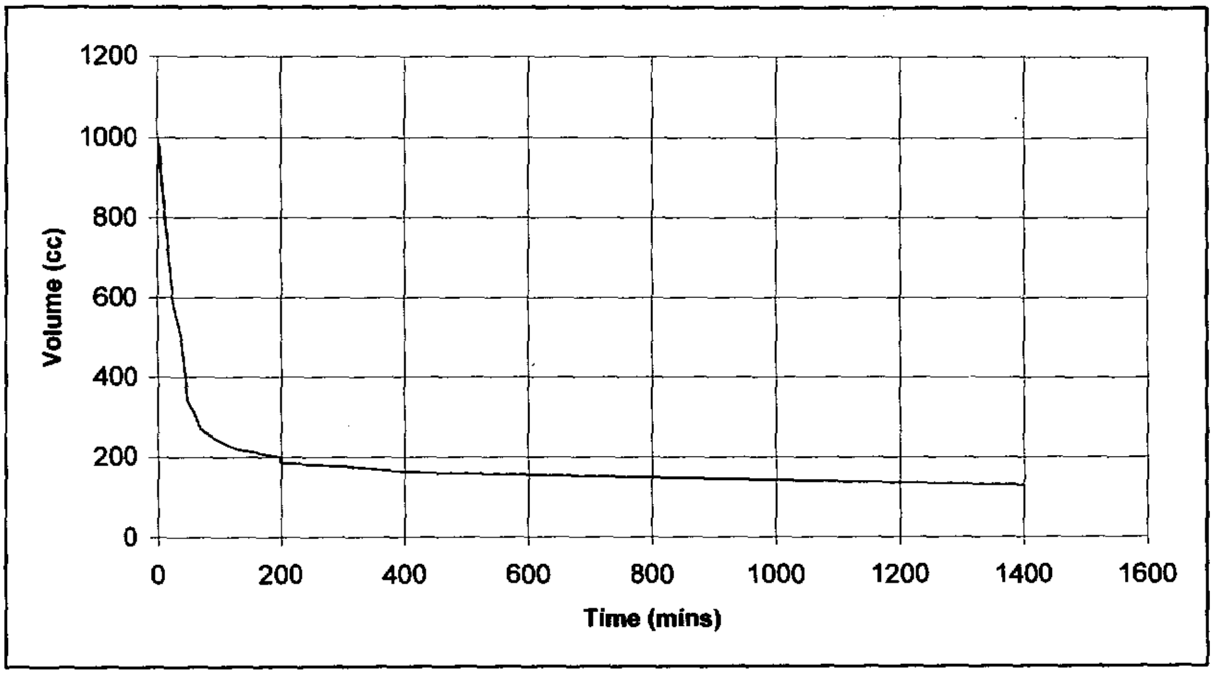
Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

ZONE SETTLEMENT TEST REPORT

US Army engineers - Guidelines for dredging operating and managing dredged materials in containment areas.

CLIENT:	**Santos Ltd** 60 Edward St, Brisbane Qld 4000
PROJECT:	**GLNG Project : Dredge facility Design**

Job Number:	119-229	**Date Tested:**	12.08.08
Laboratory Number:	53737	**Sampled By:**	Geo Coastal
Sample Source:	BH 02A 2.75 to 3.1m		
Sample Description:	SANDY CLAY:brown & grey,medium plasticity, fine to medium sand,		



Initial Dry Concentration	50	(grams/ litre)
Time for Initial Zone	1	(mins)
Time for 100% Settlement	600	(mins)
Water Temperature:	19	°C
Water Type:	Sea Water	

File C:\Zone Settlement issue 1 March 2008 CL

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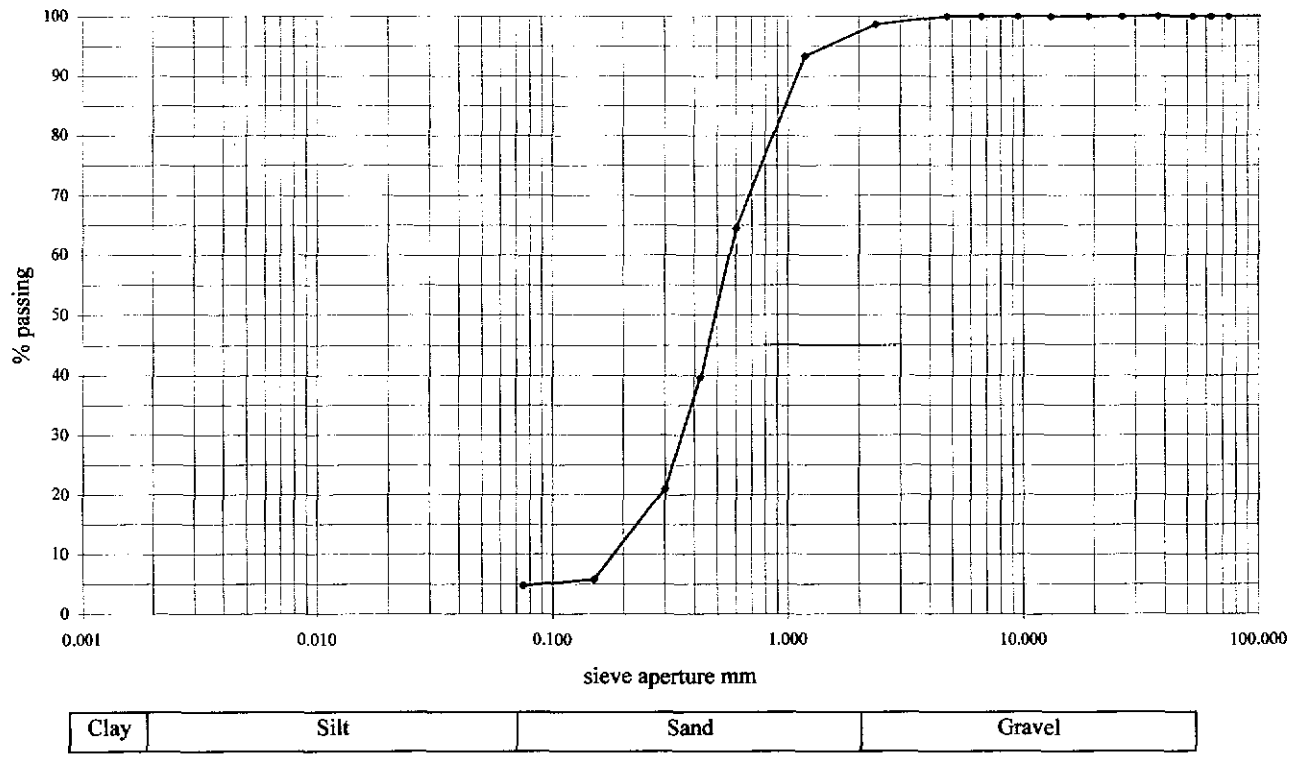
PARTICLE SIZE DISTRIBUTION TEST REPORT

Client:	**SANTOS Ltd**		
Address:	**60 Edward St, Brisbane QLD 4000**		
Project:	**GLNG PROJECT: DREDGE FACILITY DESIGN**		
Test Method:	**AS1289 3.6.1/~~5~~**		
Job Number:	**119-229**	Lab Number:	**53735**
Sample Source:	**BH 02A 0 to 1.0m**	Date Tested:	**14.08.09**
Sampled by:	**Geo Coastal**	Checked By:	**CWS**



Sample Description: **SAND:brown, fine to coarse,trace of silt and trace of gravel (shells)**

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	100	1.18	93
75.0	100	0.600	64
63.0	100	0.425	40
53.0	100	0.300	21
37.5	100	0.150	6
26.5	100	0.075	5
19.0	100	0.050	
13.2	100	0.020	
9.5	100	0.010	
6.7	100	0.005	
4.75	100	0.002	
2.36	99		

Hydrometer Type: **ASTM 152H**
Dispersant Type: **Sodium Hexametaphosphate**
Pretreatment: **None**
Loss on Pretreatment: **None**
Remarks:

File C06 File C:\Excel Reports\C06 Particle Size Distribution +19mm No Riffle Issue 2 June 2008 CL

Signed: .... Name: C. Lloyd

Title: LM Date: 22/8/09

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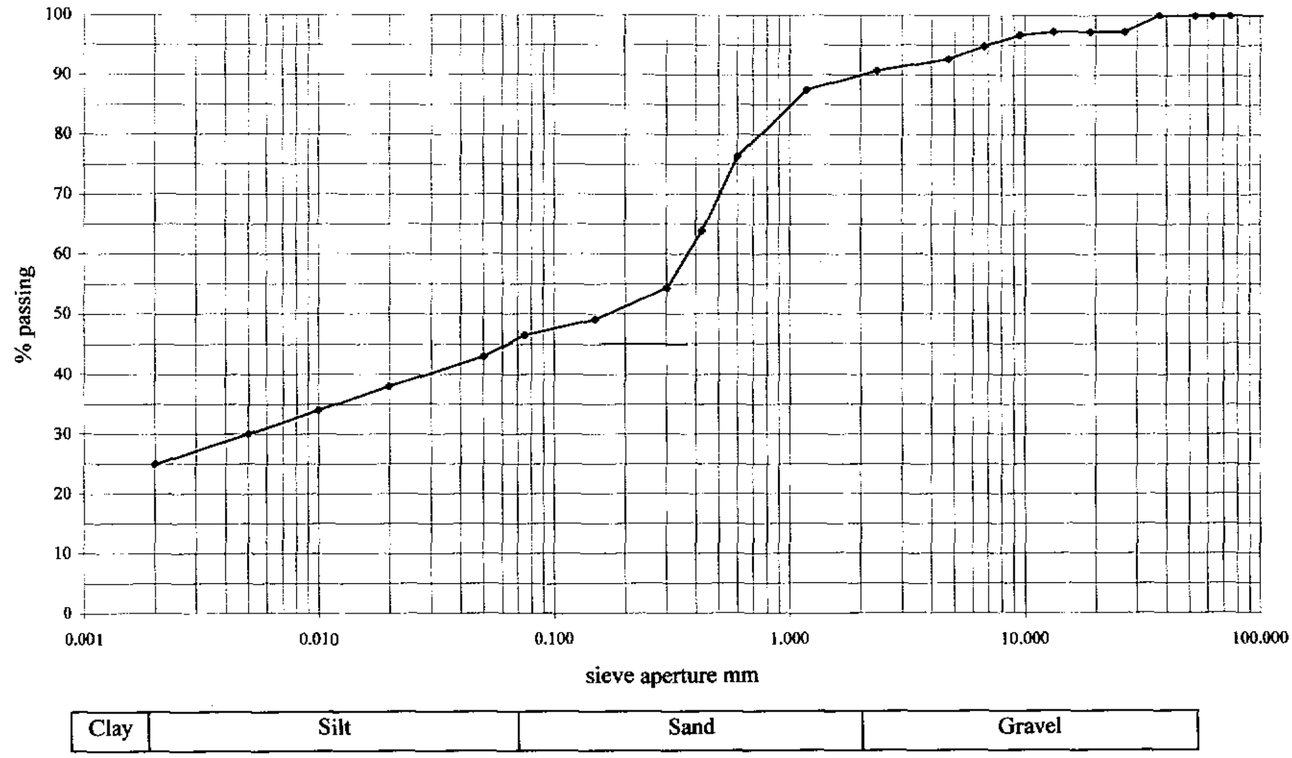
PARTICLE SIZE DISTRIBUTION TEST REPORT

Client:	**SANTOS Ltd**		
Address:	**60 Edward St, Brisbane QLD 4000**		
Project:	**GLNG PROJECT: DREDGE FACILITY DESIGN**		
Test Method:	**AS1289 3.6.1/3**		
Job Number:	**119-229**	Lab Number:	**53736**
Sample Source:	**BH 02A 2.0 to 2.75m**	Date Tested:	**14.08.09**
Sampled by:	**Geo Coastal**	Checked By:	**CWS**



Sample Description: **SANDY CLAY/CLAYEY SAND:dark grey,medium plasticity,fine to coarse sand, some fine to medium gravel (shells)(Alluvial)**

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	**100**	1.18	**87**
75.0	**100**	0.600	**76**
63.0	**100**	0.425	**64**
53.0	**100**	0.300	**54**
37.5	**100**	0.150	**49**
26.5	**97**	0.075	**46**
19.0	**97**	0.050	**43**
13.2	**97**	0.020	**38**
9.5	**97**	0.010	**34**
6.7	**95**	0.005	**30**
4.75	**93**	0.002	**25**
2.36	**91**		

Hydrometer Type: **ASTM 152H**
Dispersant Type: **Sodium Hexametaphosphate**
Pretreatment: **None**
Loss on Pretreatment: **None**
Remarks:

File C06 File C:\Excel Reports\C06 Particle Size Distribution +19mm No Riffle Issue 2 June 2008 CL

Signed: .... Name: C. Lloyd
Title: LM Date: 22/8/09

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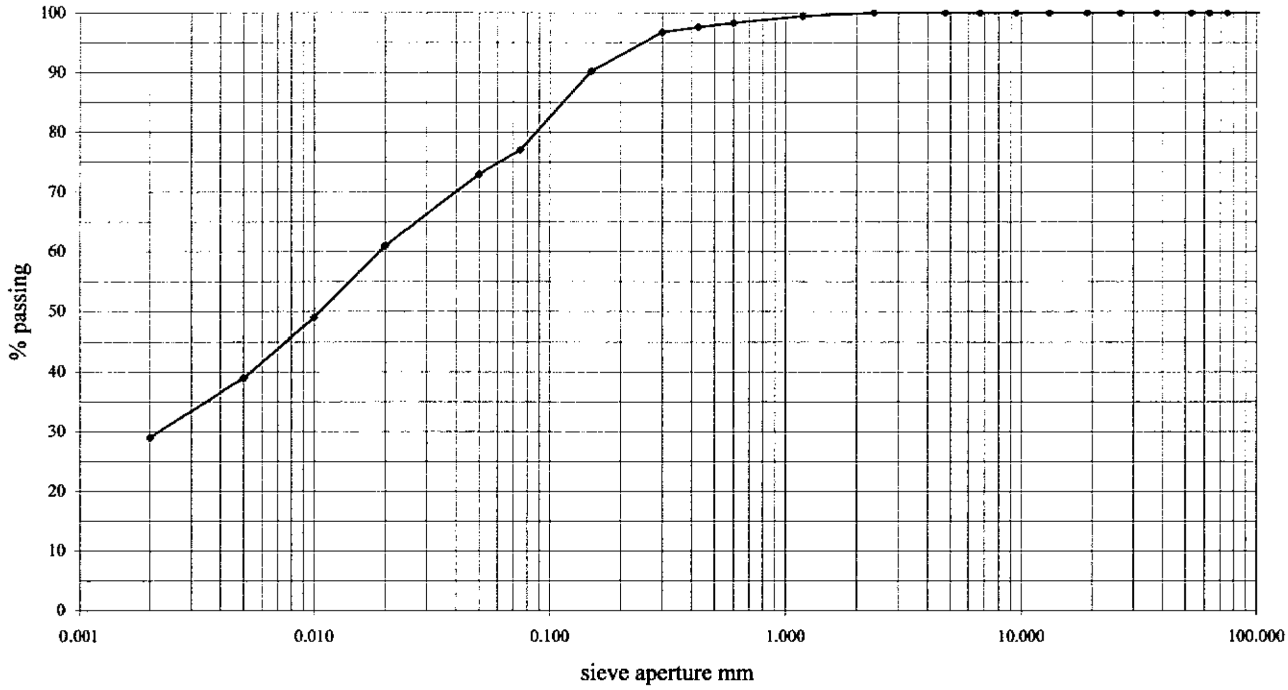
PARTICLE SIZE DISTRIBUTION TEST REPORT

Client: SANTOS Ltd
Address: 60 Edward St, Brisbane QLD 4000
Project: GLNG PROJECT: DREDGE FACILITY DESIGN

Test Method:	**AS1289 3.6.1/3**		
Job Number:	**119-229**	Lab Number:	**53737**
Sample Source:	**BH 02A 2.75 to 3.1m**	Date Tested:	**14.08.09**
Sampled by:	**Geo Coastal**	Checked By:	**CWS**



Clay	Silt	Sand	Gravel

Sample Description: **SANDY CLAY:brown & grey, medium plasticity,fine to medium sand. (Residual)**

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	**100**	1.18	**99**
75.0	**100**	0.600	**98**
63.0	**100**	0.425	**98**
53.0	**100**	0.300	**97**
37.5	**100**	0.150	**90**
26.5	**100**	0.075	**77**
19.0	**100**	0.050	**73**
13.2	**100**	0.020	**61**
9.5	**100**	0.010	**49**
6.7	**100**	0.005	**39**
4.75	**100**	0.002	**29**
2.36	**100**		

Hydrometer Type: **ASTM 152H**
Dispersant Type: **Sodium Hexametaphosphate**
Pretreatment: **None**
Loss on Pretreatment: **None**
Remarks:

File C06 File C:\Excel Reports\C06 Particle Size Distribution +19mm No Riffle Issue 2 June 2008 CL

Signed: ...... Name: C-Lloyd
Title: LM Date: 22/8/09

Appendix B Quality Control

Appendix B

Site Replicates- Relative Percent Difference

Site replicates were collected for two sampling locations, MW3 and MW9, for both high and low water surveys. Replicate samples are environmental samples collected twice in rapid succession from the same location and analyzed to determine the variability of the system, the sampling method, and the analytical methods. This comprised about 20% of the samples collected. The samples were analysed for the entire parameter suite which included turbidity, suspended solids, nutrients, total and dissolve metals.

Relative Percent Difference- Total Metals

Total Metals	MW3-L		RPD	MW3-H		RPD	MW9-L		RPD	MW9-H		RPD	Median RPD
	1	*2*		*1*	*2*		*1*	*2*		*1*	*2*		
Aluminium (µg/L)	550	560	1.8	1210	1020	17.0	990	1060	6.8	700	900	25.0	11.9
Arsenic (µg/L)	5	7	33.3	10	9	10.5	15	18	18.2	17	14	19.4	18.8
Cadmium (µg/L)	0.5	0.5	0.0	0.5	0.5	0.0	0.5	0.5	0.0	0.5	0.5	0.0	0.0
Chromium (µg/L)	5	9	57.1	5	5	0.0	5	5	0.0	5	5	0.0	0.0
Copper (µg/L)	20	21	4.9	8	8	0.0	9	9	0.0	9	19	71.4	2.4
Lead (µg/L)	5	5	0.0	5	5	0.0	5	5	0.0	8	5	46.2	0.0
Manganese (µg/L)	18	18	0.0	24	23	4.3	26	26	0.0	17	22	25.6	2.1
Mercury (µg/L)	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.0
Nickel (µg/L)	5	5	0.0	5	5	0.0	5	5	0.0	5	5	0.0	0.0
Zinc (µg/L)	23	25	8.3	13	5	88.9	15	24	46.2	6	14	80.0	63.1
Iron (µg/L)	1400	1480	5.6	1860	1640	12.6	1590	1670	4.9	1360	1510	10.5	8.0

Relative Percent Difference- Dissolved Metals

Dissolved Metals	MW3-L		RPD	MW3-H		RPD	MW9-L		RPD	MW9-H		RPD	Median RPD
	1	*2*		*1*	*2*		*1*	*2*		*1*	*2*		
Aluminium (µg/L)	160	160	0.0	250	200	22.2	200	170	16.2	180	180	0.0	8.1
Arsenic (µg/L)	5	5	0.0	5	5	0.0	5	5	0.0	5	5	0.0	0.0
Cadmium (µg/L)	0.6	0.5	18.2	0.5	0.5	0.0	0.5	0.5	0.0	0.5	0.5	0.0	0.0
Chromium (µg/L)	5	13	88.9	5	5	0.0	5	5	0.0	5	5	0.0	0.0
Copper (µg/L)	11	10	9.5	10	5	66.7	12	11	8.7	11	12	8.7	9.1
Lead (µg/L)	5	5	0.0	5	5	0.0	5	5	0.0	5	5	0.0	0.0
Manganese (µg/L)	6	6	0.0	5	5	0.0	9	7	25.0	5	5	0.0	0.0
Mercury (µg/L)	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.0
Nickel (µg/L)	5	5	0.0	5	5	0.0	5	5	0.0	5	5	0.0	0.0
Zinc (µg/L)	14	12	15.4	14	5	94.7	17	15	12.5	5	15	100.0	55.1
Iron (µg/L)	330	410	21.6	760	810	6.4	690	730	5.6	380	420	10.0	8.2

Relative Percent Difference- Nutrients and Other Parameters

Nutrients and Others	MW3-L		RPD	MW3-H		RPD	MW9-L		RPD	MW9-H		RPD	Median RPD
	1	*2*		*1*	*2*		*1*	*2*		*1*	*2*		
Suspended Solids (mg/L)	63	69	9.1	27	79	98.1	69	88	24.2	88	63	33.1	28.7
Turbidity (NTU)	7	5	33.3	11	3.1	112.1	12	13	8.0	8	9	11.8	22.5
Chlorophyll a (µg/L)	8	1	155.6	4	5	22.2	8	10	22.2	1	5	133.3	77.8
Total Nitrogen (µg/L)	300	200	40.0	200	300	40.0	300	200	40.0	200	200	0.0	40.0
Ammonia as N (µg/L)	20	120	142.9	10	10	0.0	140	20	150.0	10	10	0.0	71.4
Nitrite + Nitrate as N (µg/L)	10	10	0.0	10	10	0.0	10	20	66.7	20	10	66.7	33.3
Total Kjeldahl Nitrogen (µg/L)	300	200	40.0	200	300	40.0	300	200	40.0	200	200	0.0	40.0
Organic Nitrogen (Total Kjeldahl Nitrogen – Ammonia as N) (µg/L)	280	80	111.1	190	290	41.7	160	180	11.8	190	190	0.0	26.7
Total Phosphorus as P (µg/L)	330	170	64.0	90	90	0.0	110	120	8.7	130	200	42.4	25.6
Reactive Phosphorus as P (µg/L)	10	10	0.0	10	10	0.0	10	10	0.0	10	10	0.0	0.0

URS

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Appendix F Site Assessment Notes

Catchment 1

Table F-13 Catchment 1 Site Assessment

Catchment Size:	*0.137 km²*		
Average Channel Slope:	*37 m/km*		
Catchment Storage:	Considerable Surface Depressions, Overland Flow is significant		
Catchment relief:	Rolling With Slopes 1-4%		
	Q2	**Q20**	**Q100**
Duration (mins)	16.1		
Intensity (mm)	91.0	154.0	206.0
Flow (m^3/s)	1.3	4.0	7.0

No site Assessment was undertaken in Catchment 1 as it is out with the facility footprint.

Appendix F

Catchment 2

Table F-14 Catchment 2 Site Assessment

Catchment Size:	0.327 *km²*		
Average Channel Slope:	44 *m/km*		
Catchment Storage:	Considerable Surface Depressions, Overland Flow is significant		
Catchment relief:	Hilly with average slopes 4-8%		
	Q2	**Q20**	**Q100**
Duration (mins)	21.9		
Intensity (mm)	80.0	135.0	181.0
Flow (m^3/s)	2.8	8.8	15.6
Depth (m)	0.24	0.41	0.55

Figure F-6 Hec-Ras Result for Catchment 2

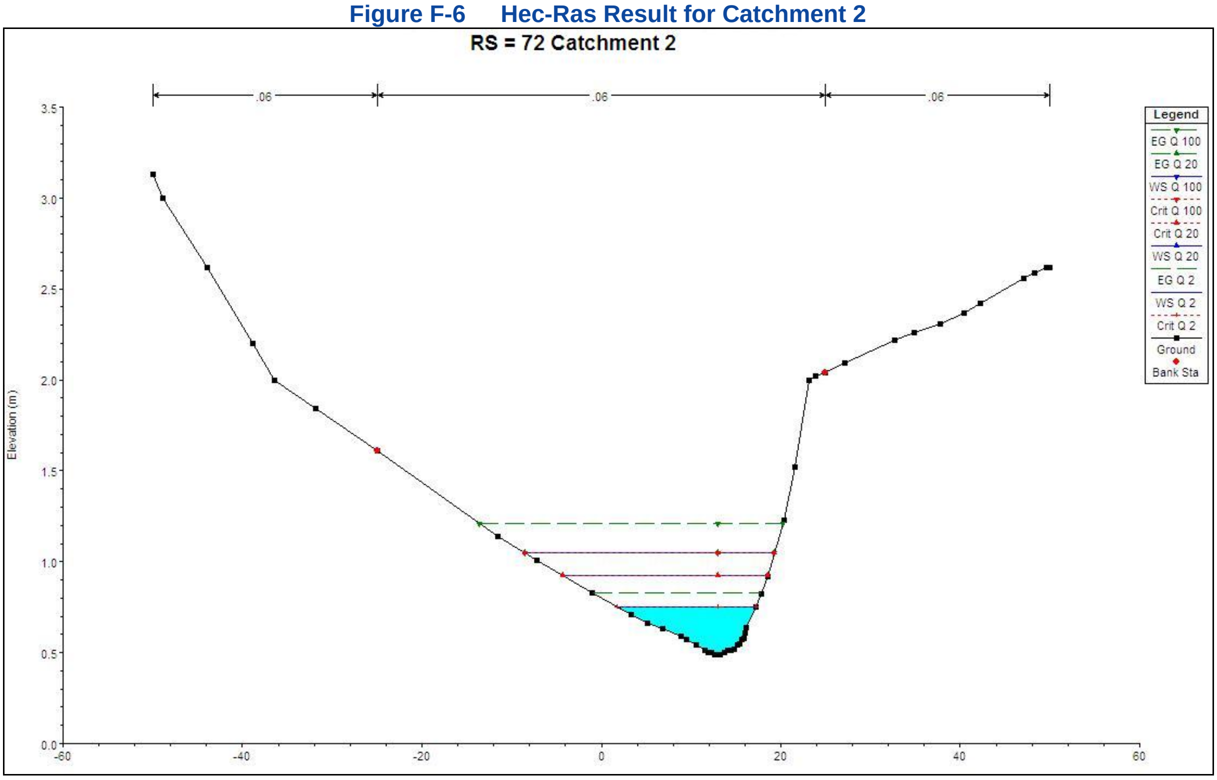
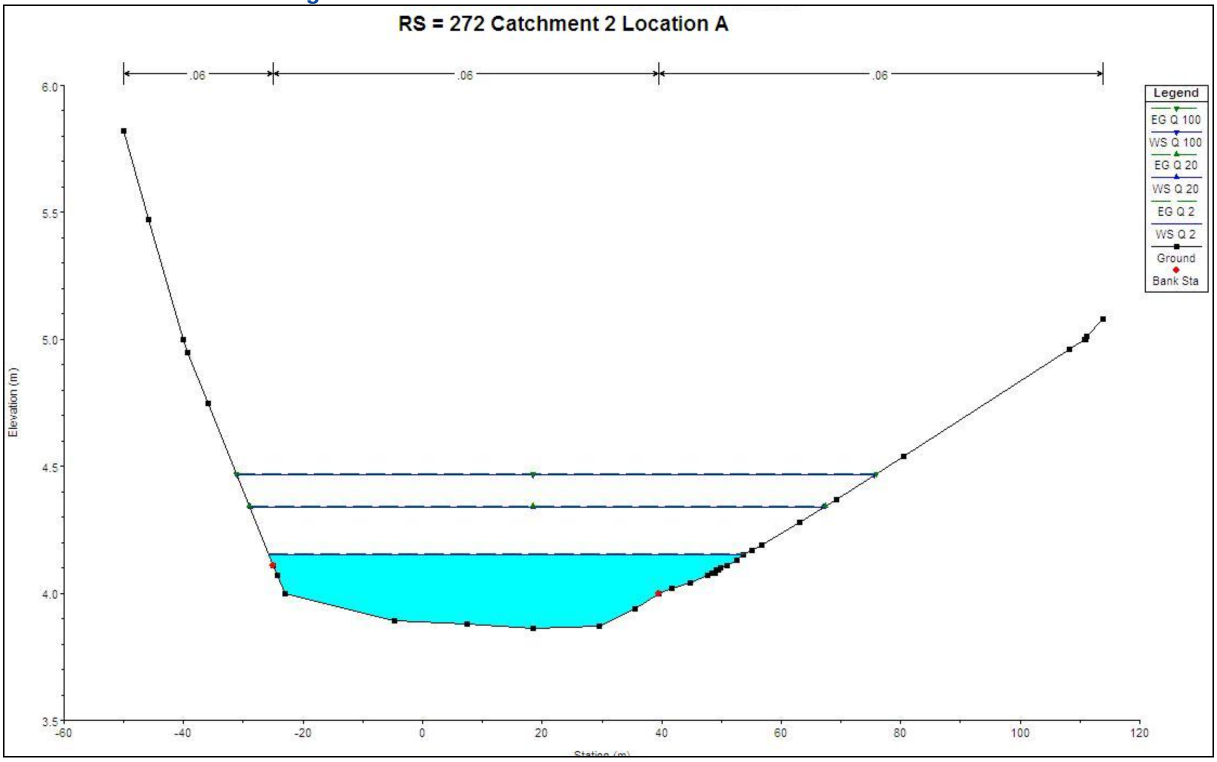


Table F-15 Surface Water Assessment - Location A

GLNG - DMPF – Surface Water Assessment -	
Location A	
Location Unnamed Drainage Feature Catchment 2	
Northing:	7371475
Easting:	315412
Site Description: *Located on the southern side of the proposed DMPF, Unnamed Drainage Feature No. 01 is a seasonal swampy area and is unmodified in nature. Numerous small channels flow in and out of the swamp, however these are ephemeral in nature and only flow when the swamp fills. The swamp contains stagnant water and large stands of established eucalypts.*	
Channel Depth:	*Up to 1.5m*
Channel Width:	*Up to 80m*
Floodplain Slope:	*L 1:50, R 1:50*
Bank Slope:	*LB 1:50, RB 1:50*
Channel Banks: Swamp area is very stable with only small channels flowing in and out of swamp showing minor signs of erosion The swamp profile is approximately convex section, with very mild slopes without undergrowth.	
Substrate Type: The bed substrate is of low compaction with >60% clays and silts present in the swamp. The inflow and outflow channels contain alluvial material with sands and gravels.	
Channel Bed: The channel bed is additionally covered in silt, stagnant water and small and large pieces of wooden debris.	
Water Quality: Ponded water has a high turbidity and is milky in colour. The site assessment detected neither oils nor odours from the water or associated sediment.	
Floodplain: Woodland currently grazed by cattle.	

Appendix F

Figure F-7 Hec-Ras Result for Catchment 2 Location A

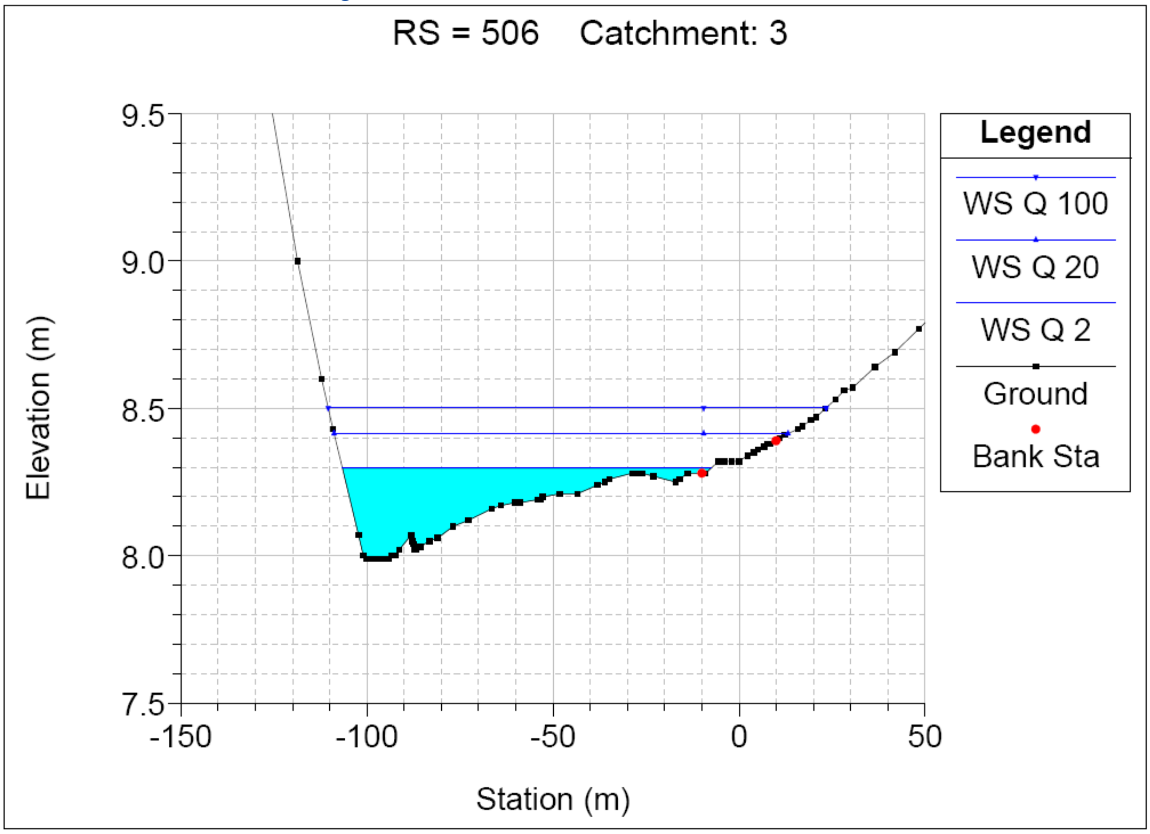


Catchment 3

Table F-16 Catchment 3 Site Assessment

Catchment Size:	0.871 *km²*		
Average Channel Slope:	25 *m/km*		
Catchment Storage:	Well defined System of small watercourses		
Catchment relief:	Rolling With Slopes 1-4%		
	Q2	**Q20**	**Q100**
Duration (mins)	52.9		
Intensity (mm)	51.0	86.0	114.0
Flow (m^3/s)	4.2	13.2	23.1
Depth (m)	0.30	0.42	0.51

Figure F-8 Hec-Ras Result for Catchment 3



Appendix F

Table F-17 Surface Water Assessment - Location B

GLNG - DMPF – Surface Water Assessment -	
Location B	
Location Name Unnamed Drainage Feature Catchment 3	
Northing:	7371614
Easting:	317589
Site Description: *Ephemeral Drainage line on south east of facility. Part of Un-named catchment 3. Vegetated with native grasses and some reeds, open eucalypt woodland*	
Channel Depth:	*0.2m*
Channel Width:	*1m*
Floodplain Slope:	*L 1:50, R 1:50*
Bank Slope:	*LB 1:50, RB 1:50*
Channel Banks: Unmodified channels. Fairly undefined mounding along various subtle U-shaped channels. Good bank stability and flat floodplain.	
Substrate Type: Clayey Matrix Dominated with greater than 60% fine sediment, interstitial spaces virtually absent. Cobble, pebble and gravel fractions not present.	
Channel Bed: Stable bed with low compaction of silts and clays.	
Water Quality: Ephemeral stream with no water present	
Floodplain: No distinct flood plain	

Photo 1 - Looking Upstream Photo 2 - Looking Upstream Photo 3 - Looking Downstream

Table F-18 Surface Water Assessment Location C

GLNG - DMPF – Surface Water Assessment -	
Location C	
Location Name Unnamed Drainage Feature Catchment 3	
Northing:	7371470
Easting:	315808
Site Description: *Alluvial splay at end of defined ephemeral channel/watercourse. Adjacent existing site track in south east of proposed facility*.	
Channel Depth:	*0.2m*
Channel Width:	*10m*
Floodplain Slope:	*L 1:30, R 1:40*
Bank Slope:	*L 1:30, R 1:40*
Channel Banks: Generally Concave bank shape with very low flat banks less than 1:10 slope	
Substrate Type: Angular sediment with moderate deposition of well graded gravel material. 5-32% fine sediment, low availability of interstitial spaces.	
Channel Bed: Defined channel fans out and sheet flow occurs with some infiltration into ground.	
Water Quality: Ephemeral stream with no water present. Suspected area of groundwater connection and infiltration	
Floodplain: Symmetrical floodplain. Alluvial splay at end of watercourse suggest connection with groundwater at this point. Groundwater bore located very close to this vicinity.	

Appendix F

Figure F-9 Hec-Ras Result for Catchment 3 Location C

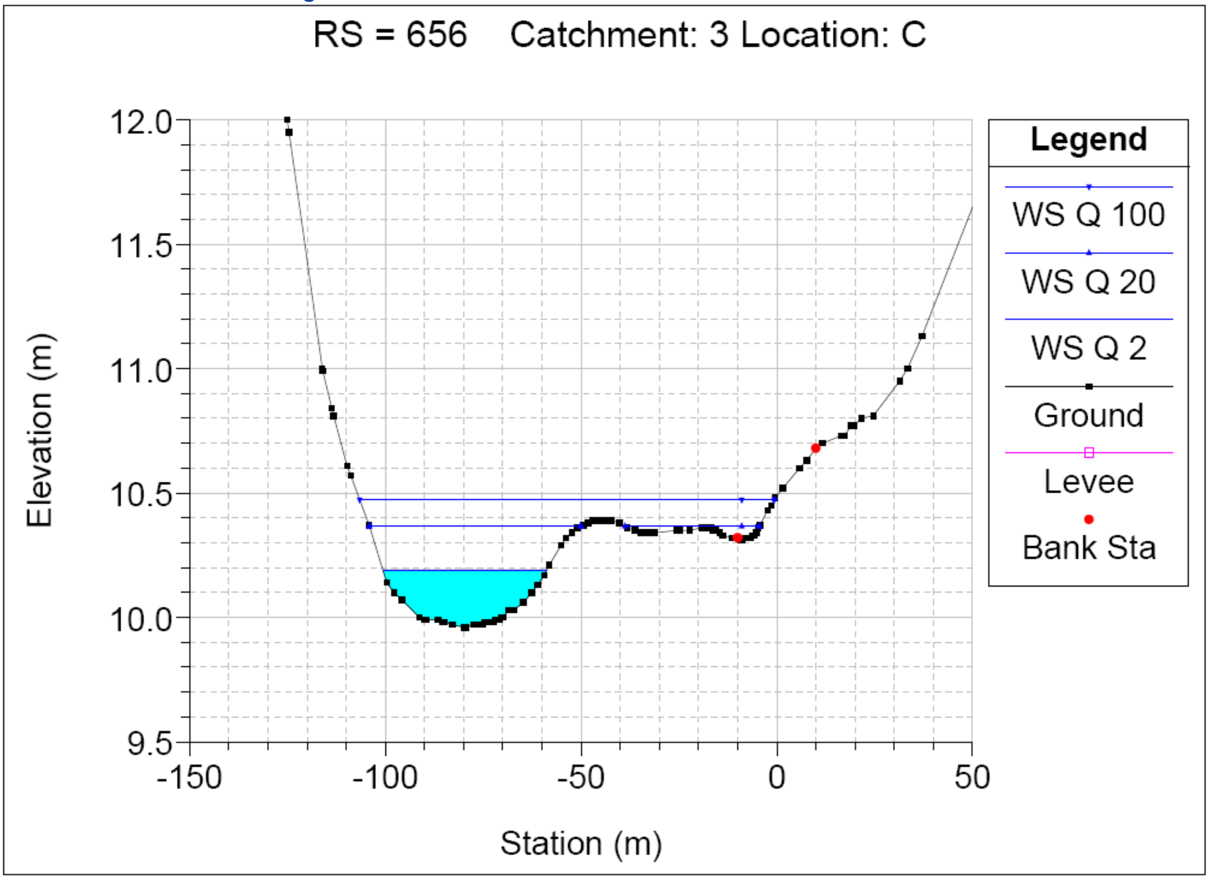


Table F-19 Surface Water Assessment - Location D

GLNG - DMPF – Surface Water Assessment -	
Location D	
Location Unnamed Drainage Feature Catchment 3	
Northing:	7371360
Easting:	316071
Site Description: Wide shallow alluvial channel to south of proposed facility in broad wooded valley	

Channel Depth:	*0.5m*
Channel Width:	*10m variable*
Floodplain Slope:	*L 1:20, R 1:20*
Bank Slope:	*LB 1:50, RB 1:50*
Channel Banks: broad valley with no defined main channel, but multiple small channels with significant crossover	
Substrate Type: 5-32% fine sediment, low availability of interstitial spaces. Angular well graded sandy gravel with moderate compaction	
Channel Bed: vegetated mid channel bars throughout valley and interdispersed with alluvial channels	
Water Quality: Ephemeral- none present	
Floodplain: Broad wooded valley no defined flood plain	
Photo 1_- Looking Upstream Photo 2 - Looking Downstream Photo 3 - Substrate	

Appendix F

Figure F-10 Hec-Ras Result for Catchment 3 Location D

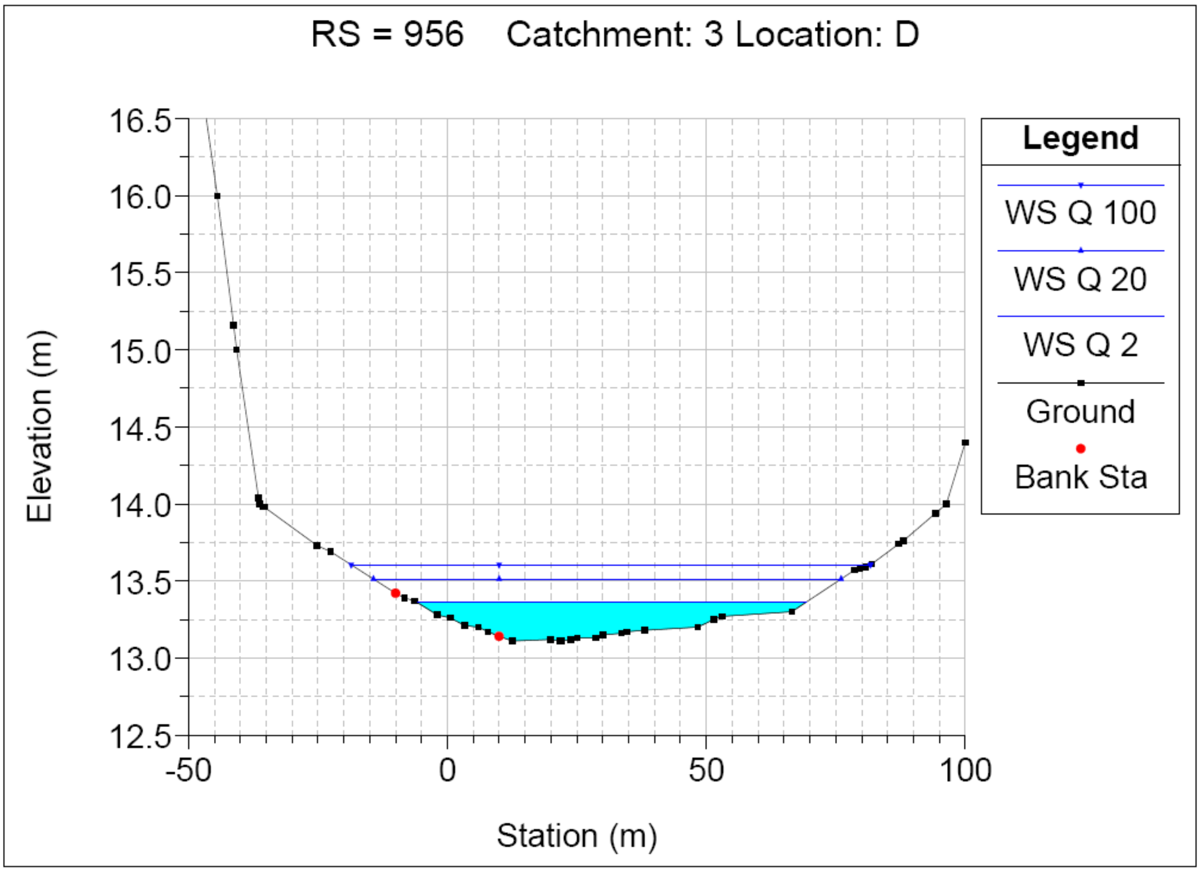


Table 12-1 Surface Water Assessment - Location E

GLNG - DMPF – Surface Water Assessment - Location E	
Location Unnamed Drainage Feature Catchment 3	
Northing:	7371506
Easting:	316106
Site Description: Drainage depression approximately 10m downstream of intersection of two small poorly defined drainage depressions. Heavily vegetated banks and surrounding area. Open eucalypt forest. Dense mid storey. In catchment 3	

Channel Depth:	*0.25m*
Channel Width:	*2m*
Floodplain Slope:	*L 1:50, R 1:50*
Bank Slope:	*LB 1:15, RB 1:20*
Channel Banks: Moderate to Good stability. Low flat banks, covered in leaf litter. Well established vegetation in channel	
Substrate Type: 32-60% fine sediment, low availability of interstitial spaces. Sandy gravel with low compaction	
Channel Bed: vegetated and poorly defined	
Water Quality: Ephemeral- none present	
Floodplain: Poorly defined approximately 10 to 15 m wide	
Photo 1_- Looking Upstream 10m Photo 2 - Looking Upstream Photo 3 - Looking Downstream Photo 4 - Substrate	

Appendix F

Catchment 4

Table F-20 Catchment 4 Site Assessment

Catchment Size:	0.692 *km²*		
Average Channel Slope:	23 *m/km*		
Catchment Storage:	Well defined System of small watercourses		
Catchment relief:	Rolling With Slopes 1-4%		
	Q2	**Q20**	**Q100**
Duration (mins)	35		
Intensity (mm)	63.0	106.0	141.0
Flow (m^3/s)	4.4	13.8	24.3
Depth (m)	0.41	0.52	0.59

Figure F-11 Hec-Ras Result for Catchment 4

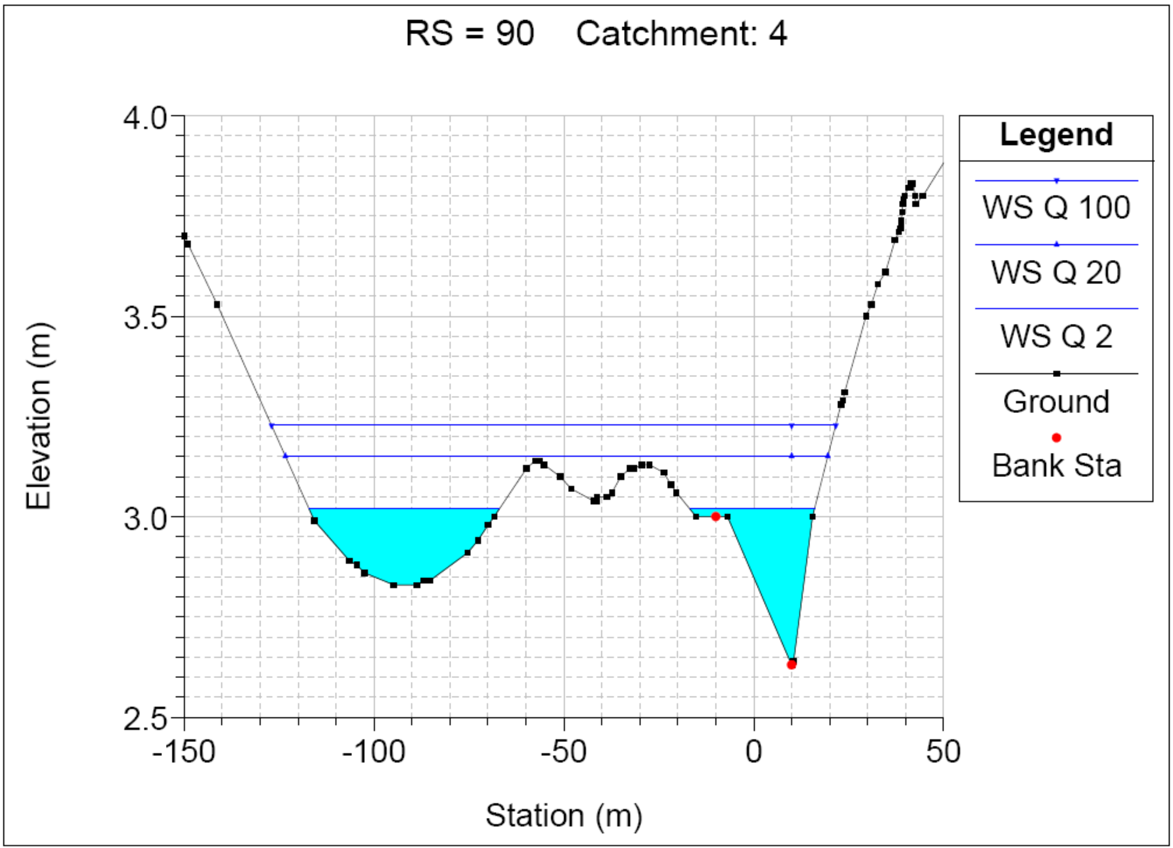


Table F-21 Surface Water Assessment - Location F

GLNG - DMPF – Surface Water Assessment -	
Location F	
Location Unnamed Drainage Feature Catchment 4	
Northing:	7371984
Easting:	316313
Site Description: Eroded ephemeral gully in catchment 4	
Channel Depth:	*2m*
Channel Width:	*3-4m*
Floodplain Slope:	*Not defined*
Bank Slope:	*LB and RB both steeper than 1V:0.5H*
Channel Banks: Moderate bank stability with very steep exposed slopes of conglomerate and clayey soils containing roots.	
Substrate Type: Open Framework: 0-5% fine sediment, high availability of interstitial spaces. Angular sediment. Well graded gravel with both deposition and erosion zones	
Channel Bed: Well defined channel bed with mid channel bars un-vegetated	
Water Quality: No water present	
Floodplain: No defined floodplain as valley is steep, it is expected that the probability of the channel bank overtopping is very low.	

Appendix F

Photo 1_- Looking Upstream Photo 2 - Looking Downstream 1 Photo 3 - Looking Downstream 2

Figure F-12 Hec-Ras Result for Catchment 4 Location F

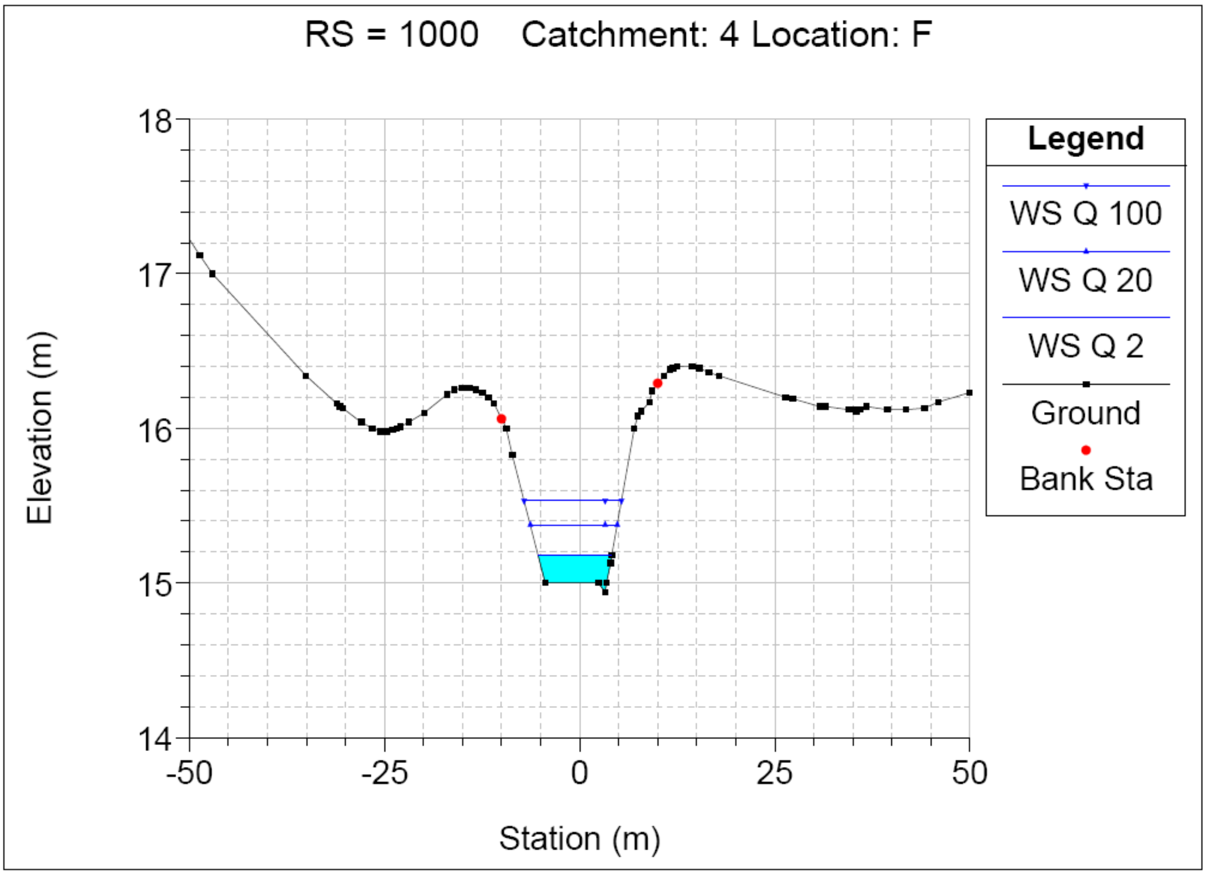


Table F-22 Surface Water Assessment - Location G

GLNG - DMPF – Surface Water Assessment - Location G	
Location Unnamed Drainage Feature Catchment 4	
Easting:	7371667
Northing:	316142

Site Description: Eroded channel at top of catchment gully head. Limited vegetation with channel. Bedrock outcrops. Ephemeral.	
Channel Depth:	*1.5m*
Channel Width:	*3-4m*
Floodplain Slope:	-
Bank Slope:	*LB>1V:0.5H, RB 1V:0.5H*
Channel Banks: Moderate bank stability with very steep exposed slopes of rock and soils containing roots. Some bank erosion evident.	
Substrate Type: Mixture of medium to coarse sediments to rocks 300mm in diameter. Angular gravel and pebbles	
Channel Bed: 5-32% fine sediment, moderate availability of interstitial spaces. Moderate bed compaction. Areas of rock on bed.	
Water Quality: Ephemeral –no water present	
Floodplain: No distinct floodplain in gully	
Photo 1 - Looking Upstream Photo 2 - Looking Downstream Photo 3 - Looking Substrate	

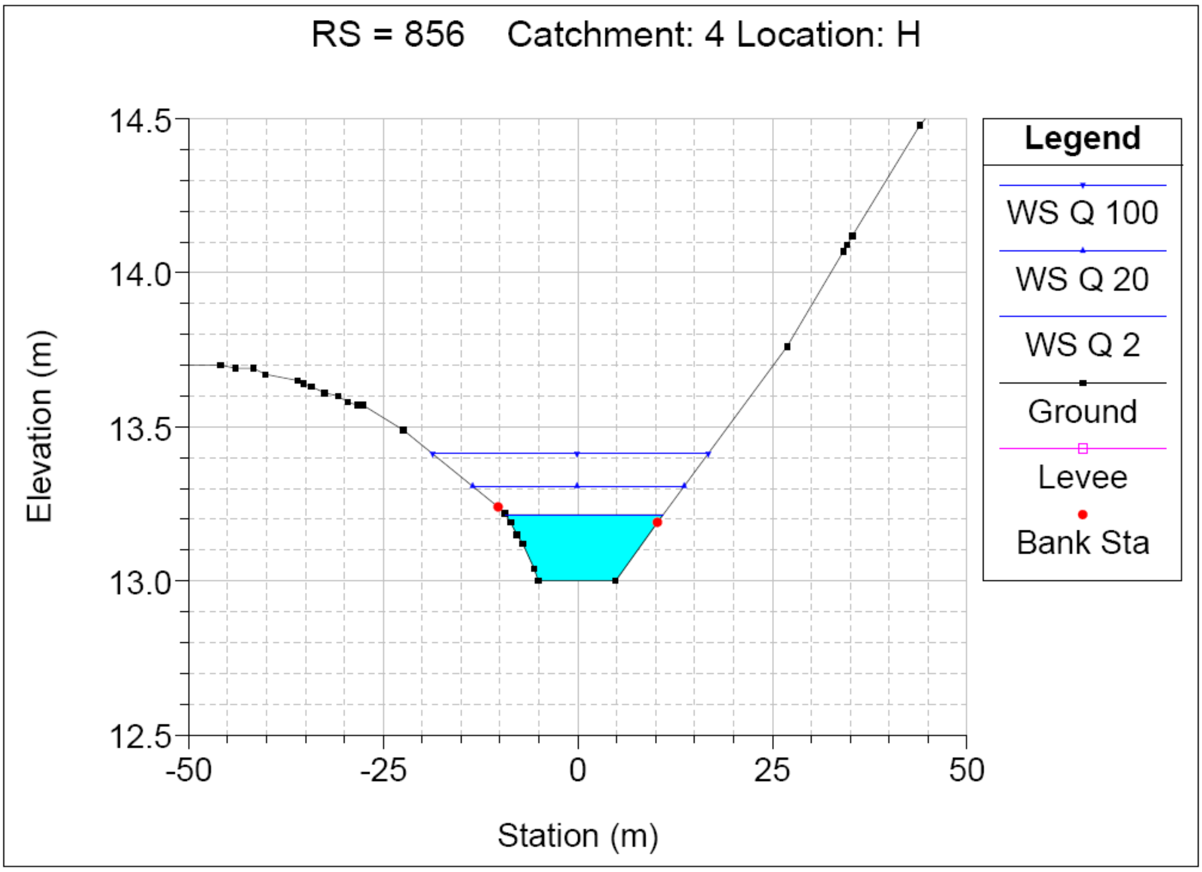
Appendix F

Table F-23 Surface Water Assessment - Location H

GLNG - DMPF – Surface Water Assessment -	
Location H	
Location Unnamed Drainage Feature Catchment 4	
Northing:	7372099
Easting:	316257
Site Description: Confluence of drainage paths in catchment 4, east of facility. Ephemeral stream with incised channel.	
Channel Depth:	*1.8-2m*
Channel Width:	*6m*
Floodplain Slope:	*Not defined*
Bank Slope:	*LB undercut, RB vertical with step*
Channel Banks: Moderate bank stability with very steep exposed slopes of rock and soils containing roots. Bank erosion and undercutting evident.	
Substrate Type: Open framework: 0-5% fine sediment, high availability of interstitial spaces. Well graded gravel	
Channel Bed: Moderate Erosion and Deposition in bed angular gravel present	
Water Quality: Ephemeral – no water present	
Floodplain: no distinct floodplain in valley	
Photo 1_- Looking Upstream Photo 2 - Looking Upstream at tributary Photo 3 - Looking Downstream	

Photo 4 - Substrate

Figure F-13 Hec-Ras Result for Catchment 4 Location H



Catchment 5

Table F-24 Catchment 5 Site Assessment

Catchment Size:	0.126 *km²*		
Average Channel Slope:	59 *m/km*		
Catchment Storage:	Considerable Surface Depressions, Overland Flow is significant		
Catchment relief:	Hilly with average slopes 4-8%		
	Q2	**Q20**	**Q100**
Duration (mins)	10.7		
Intensity (mm)	111.0	189.0	254.0
Flow (m^3/s)	1.5	4.7	8.5
Depth (m)	0.18	0.29	0.37

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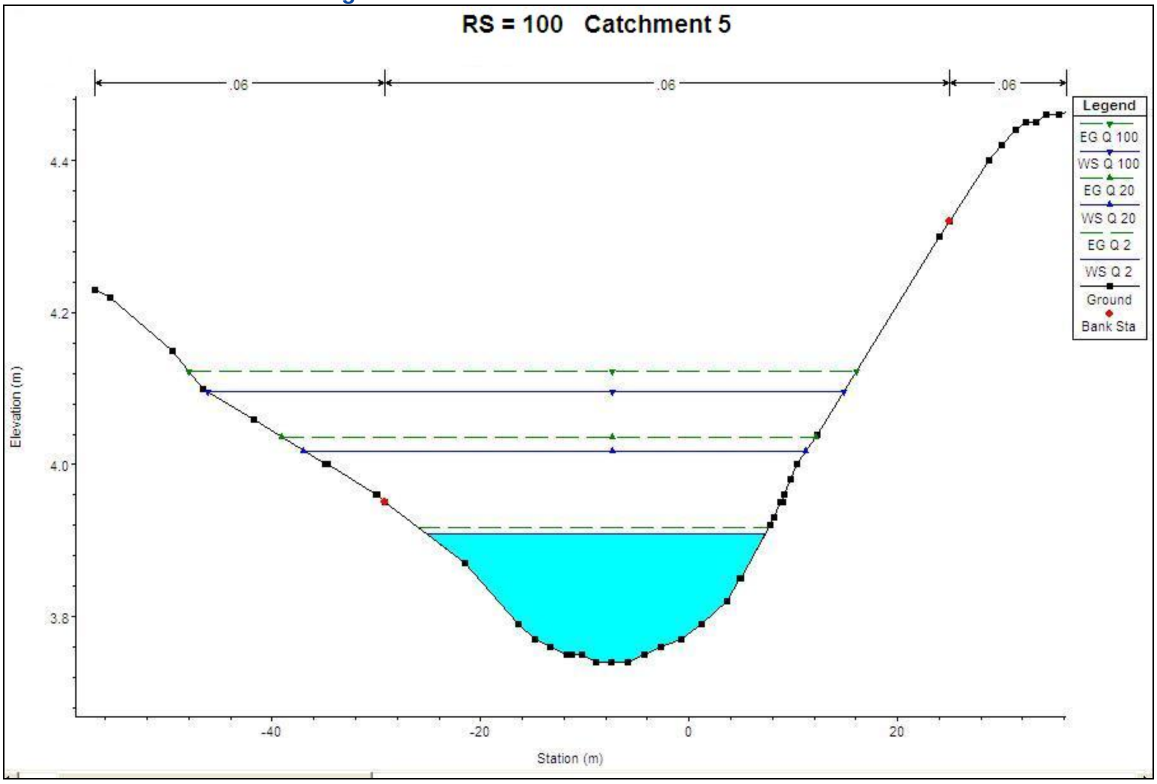
Figure F-14 Hec-Ras Result for Catchment 5



No site assessment was undertaken in catchment 5. Site observations were that catchment 6 has similar characteristics to catchment 5.

Catchment 6

Table F-25 Catchment 6 Site Assessment

Catchment Size:	0.210 *km*^{2}		
Average Channel Slope:	69 *m/km*		
Catchment Storage:	Considerable Surface Depressions, Overland Flow is significant		
Catchment relief:	Hilly with average slopes 4-8%		
	Q2	**Q20**	**Q100**
Duration (mins)	11.9		
Intensity (mm)	107.0	182.0	244.0
Flow (m^3/s)	2.4	7.6	13.5
Depth (m)	0.19	0.31	0.41

Figure F-15 Hec-Ras Result for Catchment 6

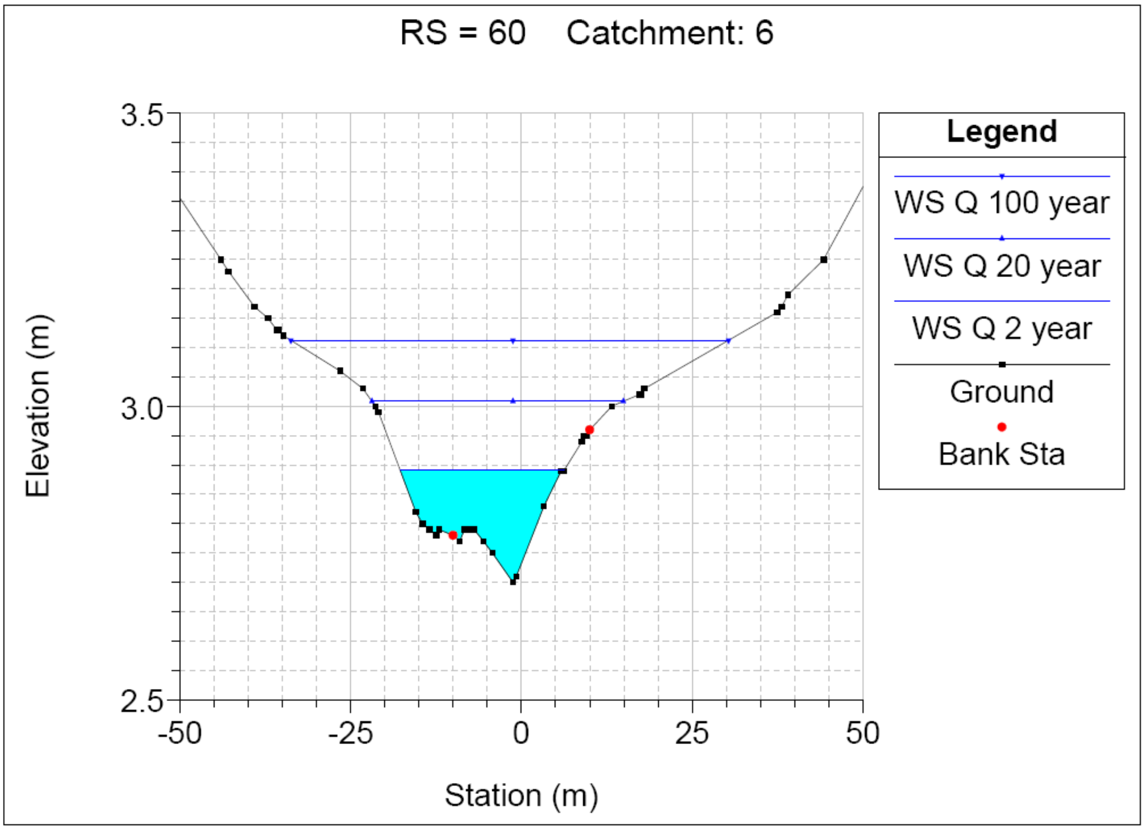


Table F-26 Surface Water Assessment - Location I

GLNG - DMPF – Surface Water Assessment - Location I	
Location Unnamed Drainage Feature Catchment 6	
Northing:	7372311
Easting:	315055
Site Description: Small meandering gully to north of facility in catchment 6. Medium density vegetation Ephemeral.	
Channel Depth:	*Up to 0.5m*
Channel Width:	*1-2m*
Floodplain Slope:	*L 1:10, R 1:10*
Bank Slope:	*LB 1:2, RB 1:2*
Channel Banks: Small mounded banks on hilly area with typical 4-8% slopes. Channel in broad valley.	

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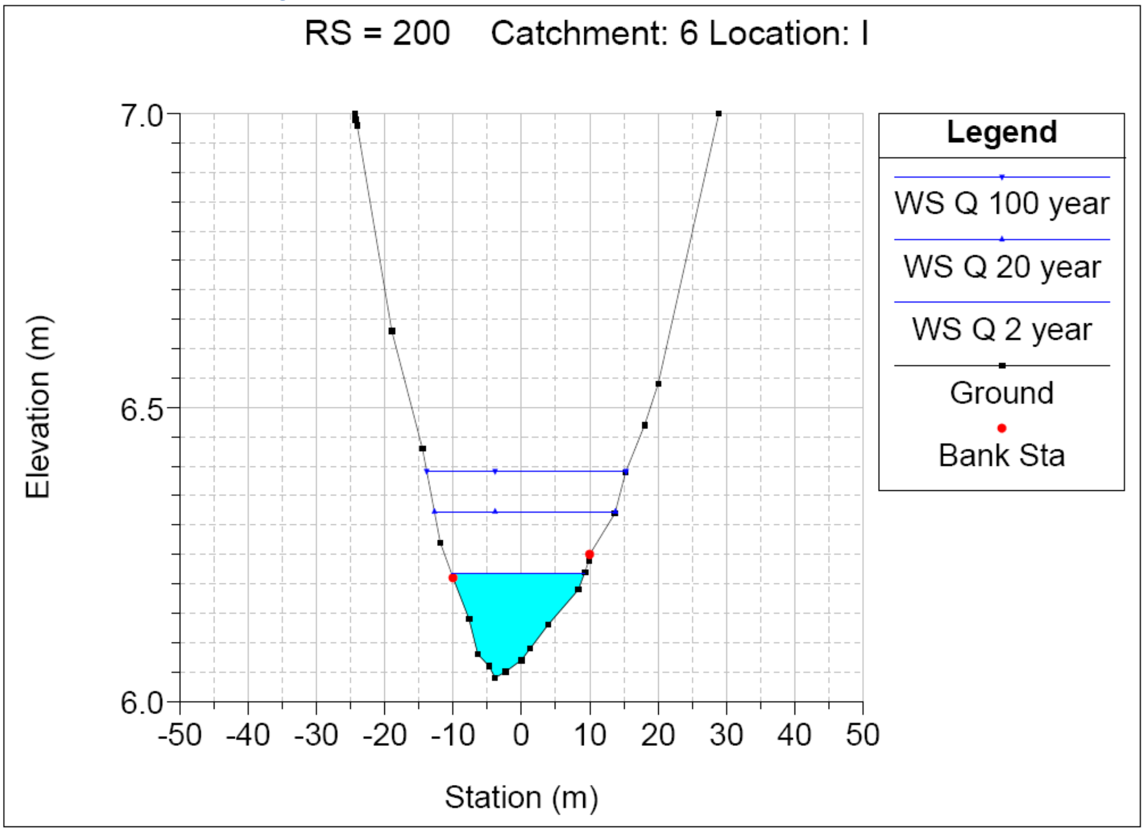
Substrate Type: Conglomerate rock exposed in patches with some gravel. Generally sub-angular
Channel Bed: Average grassed and timbered land of medium soil texture. 5-32% fine sediment, moderate availability of interstitial spaces.
Water Quality: Ephemeral – no water present
Floodplain: no distinct flood plain, gully collects localised runoff from catchment only, with sheet flow occurring in catchment parallel to gully.
Photo 1_- Looking Upstream Photo 2 - Looking Downstream

Figure F-16 Hec-Ras Result for Catchment 6 Location I



Catchment 7

Table F-27 Catchment 7 Site Assessment

Catchment Size:	0.186 *km^2*		
Average Channel Slope:	0 *m/km*		
Catchment Storage:	Considerable Surface Depressions, Overland Flow is significant		
Catchment relief:	Flat with Slopes 0-1.5%		
	Q2	**Q20**	**Q100**
Duration (mins)	35.0`		
Intensity (mm)	63.0	106.0	141.0
Flow (m^3/s)	0.7	2.3	4.1

Table F-28 Surface Water Assessment - Location J

GLNG - DMPF – Surface Water Assessment -	
Location J	
Location Unnamed Drainage Feature Catchment 6	
Northing:	7372081
Easting:	315178
Site Description: Flat estuarine saltpan/mudflat	
Channel Depth:	*n/a*
Channel Width:	*n/a*
Floodplain Slope:	*<1:500*
Bank Slope:	*n/a*
Channel Banks: No Channel.	
Substrate Type: Grey Cracked clay/estuarine mud. Tightly packed sediment, very hard to dislodge. >80% fine sediment no interstitial spaces	
Channel Bed: n/a	

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Water Quality: Tidal – no water present
Floodplain: Flat estuarine flood plain subject to tidal inundation
Photo 1 - Looking west south west Photo 2 - Looking south west

Appendix G Flood Assessment

To approximate the flood depths at the road crossing, a flood assessment of the five main drainage features, as identified in the flood hydrology Appendix F, has been undertaken.

The US Army Corps developed Hydrologic Engineering Centers River Analysis System, known commonly as HEC RAS, is a one-dimensional hydraulic estimation model. The hydraulic model was adopted for flood estimation of the 3 locations. The model inputs include geometry of the channel and floodplain, peak flows (from Table G-29) and representative hydraulic roughness coefficients.

Using a 12D digital terrain model (developed from 1m contour data), channel cross sections were extracted for each watercourse to HEC-RAS to form a simplified hydraulic model. The cross sections were further detailed with information gathered during the site visit, primarily providing channel definition. Once the series of cross-sections were developed for each assessment location, they were then exported to the HEC RAS to form a simple model of the natural channel topography.

Along with the cross-sectional data the geometric file requires a description of the bed, channel wall and floodplain roughness. Hydraulic roughness values (Mannings ‘n’) were adopted from hydraulic references based on field observations (see Table G-29 below):

Table G-29 Adopted Mannings ‘n’ Values

Surface Type	Roughness Value
Floodplains	
Light brush and trees, in winter	0.06
Heavy stand of timber, a few down trees, little undergrowth	0.08 – 0.1
Main Channel	
Clean, winding, some pools and shoals, some weeds and stones	0.04- 0.045
Clean, winding, some pools and shoals, some weeds and stones, lower stages, ineffective slopes and sections	0.05
Sluggish reaches, weedy, deep pools	0.07

Sources: Chow, 1959, Open Channel Hydraulics, McGraw-Hill Book Company, Inc.

Each model contains two boundary conditions, an upstream flow boundary and a downstream water level boundary. The inflow values were taken from the peak flows determined in the rational method hydrological analysis (Table G-30) at each location. As the downstream environment would be commonly effected by the tidal level within North China Bay, the salt marsh/estuarine flats level was simplified and a normal depth downstream boundary was adopted based on the average gradient of the drainage feature gradient.

Table G-30 Predicted peak design flow for drainage features at the edge of the estuarine flat

Catchment/Drainage Feature	Catchment Area (km^2)	2 Year ARI Peak Flow (m^3/s)	20 Year ARI Peak Flow (m^3/s)	100 Year ARI Peak Flow (m^3/s)
Catchment 1	0.137	1.3	4.0	7.0
Catchment 2	0.327	2.8	8.8	15.6
Catchment 3	0.871	4.2	13.2	23.1

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Catchment/Drainage Feature	Catchment Area (km^2)	2 Year ARI Peak Flow (m^3/s)	20 Year ARI Peak Flow (m^3/s)	100 Year ARI Peak Flow (m^3/s)
Catchment 4	0.692	4.4	13.8	24.3
Catchment 5	0.126	1.5	4.7	8.5
Catchment 6	0.210	2.4	7.6	13.5
Catchment 7 –estuarine mudflat (to proposed main embankment location)	0.186	0.7	2.3	4.1

The HEC RAS model was simulated using steady state conditions, due to the flat topographic nature of all the watercourses identified; subcritical flow conditions were also adopted.

At all locations, for all three events, the model predicted out of channel bank flooding to occur at either the 2year or 20 year ARI. Table G-31 below provides the flood depths and extents for each key watercourse location.

Table G-31 Predicted Flood Depths near start of Mudflat

Name	2yr ARI Depth (m)	20yr ARI Depth (m)	100yr ARI Depth (m)
Unnamed Drainage Feature No. 2	0.24	0.41	0.55
Unnamed Drainage Feature No. 3	0.30	0.42	0.51
Unnamed Drainage Feature No. 4	0.41	0.52	0.59
Unnamed Drainage Feature No. 5	0.18	0.29	0.37
Unnamed Drainage Feature No. 6	0.19	0.31	0.41

Additionally rational method calculations were undertaken for the proposed catchment modification to catchment 3 and 4 after construction of the facility. These results are displayed in Table G-32 and show that the reduction catchment size causes the peak flows to increase due to the reduction in stream length and time of concentration.

Table G-32 Predicted peak design flow for modified catchments 3 and 4 at edge of facility

Catchment/Drainage Feature	Catchment Area (km^2)	2 Year ARI Peak Flow (m^3/s)	20 Year ARI Peak Flow (m^3/s)	100 Year ARI Peak Flow (m^3/s)
Modified Catchment 3	0.588	5.5	17.6	31.1
Modified Catchment 4	0.431	5.1	16.2	28.9

RORB

RORB (version 6) is an Australian hydrological modelling software package used for generating hydrographs, flood volumes and routing for rural and urban catchments. It is widely used in Australia and overseas. The site catchments were broken down into various areas and input into the RORB model. A summary of Key RORB parameters used are shown in Table G-33.

Table G-33 RORB model Parameters

Parameter	Value
kc Value (Weeks –QLD)	1.40
'm' coefficient	0.8
Initial Loss (mm)	15
Continuing Loss (mm)	2.5

RORB was run using an initial/continuing loss model and due to the lack of available stream flow data was un-calibrated. Flows calculated were checked against rational method flows and found to be comparable.

A model was set up of the entire site area in both the existing conditions and with the proposed facility modifications to the site. The catchments were input as per the catchment plan in Figure 9-1 (excluding catchment 1), however the larger catchments were broken into sub areas. Catchment 3 was divided into 3 sub areas and catchment 4 was divided into 2 sub areas. It was found the critical time of concentration for the site as a whole was 1.5 hours and peak flows and flood volumes were generated for a range of return periods. Peak flood volume was generated for the long duration storm of 72 hours.

A summary of RORB results for the existing conditions model is displayed in Table G-34.

Table G-34 Existing Site Catchment RORB Results

	1:2yr ARI		1:20yr ARI		1:100 ARI	
	Peak Flow	72hr Peak Volume (ML)	Peak Flow	72hr Peak Volume (ML)	Peak Flow	72hr Peak Volume (ML)
Catchment 3	4.5	79	10.1	300	14.8	514
Catchment 4	5.1	63	11.5	238	15.9	408
Combined Total Site Catchment	12.9	220	28.7	828	41.9	1420

As expected the rational method flows calculated for the catchments are higher and represent a more conservative estimate than the RORB model. The RORB model results provide a good estimation of flood volume across the site.

The proposed model was run with special storages at the locations of the future embankments across catchment 3 and 4 with different sub catchment areas reflecting the facility layout. This allowed an estimate of the flows into the modified catchments 3 and 4 (refer Figure 9-2) and the likely design flows required for the diversion pipe network. It also gave an estimate of flood volumes that will be required to be conveyed by the diversion system. A summary of these results is shown in Table G-35.

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Table G-35 Proposed Site Catchment RORB Results

	1:2yr ARI		1:20yr ARI		1:100 ARI	
	Peak Flow	Volume	Peak Flow	Volume	Peak Flow	Volume
Modified Catchment 3	3.1	55	7.0	208	10.2	357
Modified Catchment 4	4.9	39	10.5	148	14.0	254
Facility Catchment	7.10	126	15.9	478	23.2	821

These results were used to calculate the 100 year Design Storage Allowance for the Facility for the 72 Hour duration storm. This was calculated to be 0.62 m as the Volume entering the facility is 821 ML and the Area of the facility is 1,332 km^2. This allowance does not include the runoff volumes from modified catchments 3 or 4 as these volumes will be stored in these catchments, or diverted around the facility directly into the bay.

Appendix H Water Supply Dam Yield

An estimate of the potential catchment runoff yield to the future storages in catchment 3 and 4 was made to quantify the volume of water that may be available annually for harvesting and use in facility construction/operations.

The yield assessment is based on rainfall and evaporation statistics from Gladstone Radar Station. The yield assessment assumes the actual evaporation rate from the dam storage surface is 0.6 times the pan evaporation rate and that the runoff from the catchment available for collection and harvesting is 5 % of the actual rainfall on the catchment (Nelson, Design and Construction of Small Earth Dams, 1985).

A summary of the calculations can be seen in Table H-36 and H-37 for the respective catchments. Due to the sizeable catchments and annual rainfall, significant yields are available which would be sufficient for construction and operation of the site.

Appendix H

Table H-36 Catchment 3 Storage yield

				Source : BOM Climate Data Online										
Proposed Dam Catchment Area	=	588	Ha	Evaporation data set used for Gladstone Radar Station between 1957-2008										
Proposed Dam Surface Area	=	5	Ha	Rainfall data set used for Gladstone Radar Station between 1957-2009										
Month	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JULY**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**	**TOTALS**	
Average Rainfall (mm)	*143.40*	*143.40*	*82.60*	*46.40*	*59.60*	*38.90*	*34.40*	*31.20*	*26.20*	*62.30*	*74.20*	*128.80*	871.40	mm
Mean Pan A Evaporation (mm)	195.3	165.2	164.3	132	105.4	90	96.1	108.5	132	170.5	183	195.3	1737.6	mm
Evaporation Factor	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	unitless
Estimated Evaporation (mm)	117.18	99.12	98.58	79.2	63.24	54	57.66	65.1	79.2	102.3	109.8	117.18	1042.56	mm
Runoff factor for Catchment	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	unitless
Dam Catchment Runoff (ML)	42.16	42.16	24.28	13.64	17.52	11.44	10.11	9.17	7.70	18.32	21.81	37.87	256.2	ML
Dam Evaporation Loss (ML)	5.86	4.96	4.93	3.96	3.16	2.70	2.88	3.26	3.96	5.12	5.49	5.86	52.1	ML
NET YIELD (average)	**36.30**	**37.20**	**19.36**	**9.68**	**14.36**	**8.74**	**7.23**	**5.92**	**3.74**	**13.20**	**16.32**	**32.01**	**204.1**	**ML**

Appendix H

Table H-37 Catchment 4 Storage Yield

				Source : BOM Climate Data Online										
Proposed Dam Catchment Area	=	431	Ha	Evaporation data set used for Gladstone Radar Station between 1957-2008										
Proposed Dam Surface Area	=	8	Ha	Rainfall data set used for Gladstone Radar Station between 1957-2009										
Month	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JULY**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**	**TOTALS**	
Average Rainfall (mm)	*143.40*	*143.40*	*82.60*	*46.40*	*59.60*	*38.90*	*34.40*	*31.20*	*26.20*	*62.30*	*74.20*	*128.80*	871.40	mm
Mean Pan A Evaporation (mm)	195.3	165.2	164.3	132	105.4	90	96.1	108.5	132	170.5	183	195.3	1737.6	mm
Evaporation Factor	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	unitless
Estimated Evaporation (mm)	117.18	99.12	98.58	79.2	63.24	54	57.66	65.1	79.2	102.3	109.8	117.18	1042.56	mm
Runoff factor for Catchment	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	unitless
Dam Catchment Runoff (ML)	30.90	30.90	17.80	10.00	12.84	8.38	7.41	6.72	5.65	13.43	15.99	27.76	187.8	ML
Dam Evaporation Loss (ML)	9.37	7.93	7.89	6.34	5.06	4.32	4.61	5.21	6.34	8.18	8.78	9.37	83.4	ML
NET YIELD (average)	**21.53**	**22.97**	**9.91**	**3.66**	**7.78**	**4.06**	**2.80**	**1.52**	**-0.69**	**5.24**	**7.21**	**18.38**	**104.4**	**ML**

Appendix I Risk Assessment Scale

Likelihood Scale

Likelihood is defined as a general description of probability and/or frequency (AS/NZ4360, 2004). Applied to this project it is the water quality impact within and surrounding the facility and using the following likelihood scale. The likelihood scale is presented in Table I-38.

Table I-38 Risk Assessment Likelihood Scale

Level	Likelihood	Description
1	**Rare**	**Will ONLY occur in exception circumstances**
2	**Unlikely**	**Could occur but not expected**
3	**Possible**	**Could occur at some time**
4	**Likely**	**Will probably occur in most circumstances**
5	**Almost Certain**	**Expected to occur in most circumstances**

Consequence Scale

Consequence is defined as the outcome or impact of an event (AS/NZ4360, 2004). The consequence scale is presented in Table I-39.

Table I-39 Risk Assessment Consequence Scale

Level	Consequence	Description
1	**Insignificant**	**Trivial environmental impact**
2	**Minor**	**Unreasonable interference with the environment. (Results in minor illness or injury)**
3	**Moderate**	**Clearly visible impact to aquatic ecosystem. Requires localised remediation. (Results in illness or injury)**
4	**Major**	**Damage to the environment that requires significant remediation. (Results in serious illness or injury)**
5	**Catastrophic**	**Environmental damage is irreversible, of high impact or widespread. (Results in death)**

Risk Rating Matrix

A combination of the consequences and likelihood assigned to each measure to calculate the overall risk rating. The risk rating matrix is presented in Table I-40.

Table I-40 Risk Assessment Risk Rating Matrix

Likelihood	Consequences				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	High	High	Extreme	Extreme	Extreme
Likely	Medium	High	High	Extreme	Extreme
Possible	Low	Medium	High	High	Extreme
Unlikely	Low	Low	Medium	High	Extreme
Rare	Low	Low	Medium	High	Extreme

Appendix J Hazard Matrix

Appendix J

Table J-41 Hazard Matrix

Aspect	Potential Impact	Inherent Risk rating	Mitigation Strategy	Residual Risk Rating
Construction				
Erosion and Sediment Mobilisation	Sediment from earth moving and stockpiling can enter surface water runoff during rainfall events or blown by wind and discharge to watercourses leading to deleterious effects on water quality and aquatic habitats. Potential presence of high levels of metals in soils that may enter waterways.	High	- Appropriate design (erosion and scour protection) for sections of pipeline crossing active floodplain and main channel; - Stormwater management (development, implementation and maintenance of plan), to include: • Erosion control and energy dissipation, watercourse stabilisation i.e. matting, riprap and gabions; • Stormwater controls and upstream treatment, i.e. infiltration devices and vegetation filters; • Stabilisation techniques, i.e. revegetation; - Construction to occur in dry season; - Crossings to be at right angles to direction of flow; - Stockpiling of topsoil located away from watercourses; - Vehicle wash bay to be located away from watercourses; - Minimise vegetation disturbance; - Routine inspections; and - Adopt controls to minimise risk of heavy metal runoff to surface waters	Low

Appendix J

Aspect	Potential Impact	Inherent Risk rating	Mitigation Strategy	Residual Risk Rating
Pollution	- Potentially contaminated drainage from fuel oil storage areas; - Diesel and other petroleum-based fuels and lubricants used by excavation and construction machinery; - Environmental and public health and safety issue; and - Site excavation works may expose groundwaters which have been found to have high background levels of dissolved metals in both near-surface and deeper aquifers.	High	- Chemical and fuel storage areas to be appropriately bunded; - Spill cleanup kits in accordance with Australian Standards (AS1940 and AS3780) to be located in convenient locations, i.e. work vehicles; - Refuelling to occur in bunded areas; Should a spill occur, ensure it is contained and does not enter drainage lines or watercourses; - Follow all other operational procedures; and - Any site dewatering activities will require treatment or other appropriate management controls before discharge to grade is considered	Medium
Improper disposal of all construction wastes	Litter and other construction waste can be washed into watercourses and ocean during rain events or tidal inundation, and impact receiving waters.	Medium	Develop, implement and maintain Waste Management/Disposal Plan.	Low
Works adjacent to/within drainage lines and watercourses	Trenching at watercourse crossings and vehicle access crossings can alter flow characteristics. Potential presence of high levels of metals in soils that may enter waterways.	High	- Diversion of watercourse either by low flow diversion or coffer dam with pumping; - Construction activities that will affect existing drainage channels and control measures must only be carried out after suitable stormwater management infrastructure has been implemented onsite; - Minimal disturbance by heavy earth moving equipment; - Vehicle crossings should be adequately designed for a range of flow conditions, including under road drainage; and - Adopt controls to minimise risk of heavy metal runoff to surface waters	Low

Appendix J

Aspect	Potential Impact	Inherent Risk rating	Mitigation Strategy	Residual Risk Rating
Flooding	Possibility of out-of-bank/flash flood rainfall event and regular tidal inundation of site during construction causing erosion and damage to erosion and sediment control infrastructure.	High	- Schedule construction works appropriately during wet season and where practicable, limit works within the flood plain. However, if not possible, make sure a flood risk assessment has been conducted; -Tide times to be monitored and planed for; - Stormwater management e.g. drainage diversions and bunding; and - Emergency response procedures and flood forecasting.	Medium
Lack of water supply	Inadequate dust suppression, soil compaction and washdown.	High	Develop, implement and maintain Water Supply Strategy and Emergency Plan.	Medium
Contaminant Mobilisation	Runoff from potentially contaminated drainage from fuel oil storage areas and general washdown water entering into drainage features and receiving waters, altering the physical and chemical quality of the water and receiving environment.	High	- The construction of bunded storage areas for contaminants are recommended with spill cleanup kits in accordance with Australian Standards (AS1940 and AS3780) to prevent the contamination of surrounding surface runoff; - The transfers of fuels and chemicals controlled and managed to prevent spillage outside bunded areas; - Implement control so significant leakage/spillage is immediately reported and appropriate emergency clean-up operations implemented to prevent possible mobilisation of contaminants; - Chemically contaminated areas are protected by rooving from rainfall to reduce the likelihood of overtopping; - Bunds and sumps are frequently drained, and effluent is treated appropriately; and - Any site dewatering activities will require treatment or other appropriate management controls before discharge to grade is considered.	Medium

Appendix J

Aspect	Potential Impact	Inherent Risk rating	Mitigation Strategy	Residual Risk Rating
Operation				
Erosion and Sediment Mobilisation	Permanent structures and minor earth disturbance can result in localised erosion and sediment mobilisation leading to deleterious effects on water quality and aquatic habitats.	Medium	Stormwater management to include: - Localised erosion control and energy dissipation measures; - Stabilisation techniques. Routine inspection and maintenance of existing erosion and sediment control measures.	Low
Discharges from sediment ponds	It is proposed to have two sediment dams upstream of the DMPF. Uncontrolled releases from these ponds could allow process and contaminated stormwater to enter drainage lines and receiving waters.	Medium	Sediment dams will be designed to contain up to a10yr ARI. Releases from ponds should be controlled and should occur after the water has been tested and meets license guidelines (which are to be determined)	Low
Pollution	Diesel and other petroleum-based fuels and lubricants used by operational vehicles and machinery entering watercourses.	Medium	- Chemical and fuel storage areas to be appropriately bunded; - Spill cleanup kits in accordance with Australian Standards (AS1940 and AS3780) to be located in convenient locations; - Refuelling to occur in bunded areas; Should a spill occur, ensure it is contained and does not enter drainage lines or watercourses; and - Follow all other site operational procedures.	Low
Improper disposal of all operational wastes	Litter and other operational waste can be washed into watercourses during rain events and impact receiving waters.	Low	Develop, implement and maintain Waste Management/Disposal Plan	Low

Appendix J

Aspect	Potential Impact	Inherent Risk rating	Mitigation Strategy	Residual Risk Rating
Flooding	Possibility of out-of-bank/flash flood rainfall event causing failure of erosion and sediment control infrastructure. Blockage of Diversion drainage system causing inundation of other properties/catchments.	High	- Monitoring and maintenance of erosion and sediment control features and diversion infrastructure; and - Emergency Response Procedures and flood forecasting (where practical).	Medium
Lack of water supply	Inadequate dust suppression, soil compaction and washdown.	High	Develop, implement and maintain Water Supply Strategy and Emergency Plan.	Medium
Decommissioning				
Erosion and Sediment Mobilisation	- Erosion and movement of sediment can potentially have adverse impacts on water quality. - Potential presence of high levels of metals in soils that may enter waterways.	Medium	- Implement and maintain a Decommissioning Environmental Plan. Apply sediment and erosion control measures prior to earth moving activities; and - Adopt controls to minimise risk of heavy metal runoff to surface waters	Low
Pollution	- Diesel and other petroleum-based fuels and lubricants used by operational vehicles and machinery entering watercourses. - Site excavation works may expose groundwaters which have been found to have high background levels of dissolved metals in both near-surface and deeper aquifers.	Medium	- Chemical and fuel storage areas to be appropriately bunded; - Spill cleanup kits in accordance with Australian Standards (AS1940 and AS3780) to be located in convenient locations, i.e. work vehicles; - Refuelling to occur in bunded areas; - Should a spill occur, ensure it is contained and does not enter drainage lines or watercourses; - Follow all other site operational procedures; and - Any site dewatering activities will require treatment or other appropriate management controls before discharge to grade is considered	Low
Improper disposal of all demolition wastes	Impact to receiving waters.	Medium	Develop and implement a Waste Management/Disposal Plan.	Low

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Aspect	Potential Impact	Inherent Risk rating	Mitigation Strategy	Residual Risk Rating
Works adjacent to/within drainage lines and watercourses	Infilling on-site surface water bodies or drainage lines can lead to potential loss of water storage and can adversely impact ecological habitats. Potential presence of high levels of metals in soils that may enter waterways.	High	- Diversion of drainage features before construction commences (for stable vegetated channels); - Process area diversion (sediment basins and diversion drains); - Decommissioning works that will affect existing drainage channels and control measures must only be carried out after suitable stormwater management infrastructure has been implemented on-site; - Minimal number of passes by heavy earth moving equipment; - Prior to decommissioning, development and implementation of monitoring program; and - Adopt controls to minimise risk of heavy metal runoff to surface waters	Medium
Flooding	Possibility of out-of-bank/flash flood rainfall event exceeding capacity of the storm water management system resulting in non compliant offsite discharges. Also, risk to construction workers (H&S). Blockage of Diversion drainage system causing inundation of other properties/catchments.	Medium	- Schedule decommissioning work appropriately during the wet season and try and work outside the flood plain to reduce risk from flooding and undertake a flood risk assessment has been conducted; - Stormwater management e.g. drainage diversions and bunding; and - Emergency response procedures and flood forecasting.	Medium
Lack of water supply	Dust emissions and inadequate soil compaction and washdown, fire water.	High	Develop, implement and maintain Water Supply Strategy and Emergency Plan.	Low

Appendix J

Aspect	Potential Impact	Inherent Risk rating	Mitigation Strategy	Residual Risk Rating
Contaminant Mobilisation	Runoff from potentially contaminated drainage from fuel oil storage areas and general washdown water entering into drainage features and receiving waters, altering the physical and chemical quality of the water and receiving environment.	High	- The construction of bunded storage areas for contaminants are recommended with spill cleanup kits in accordance with Australian Standards (AS1940 and AS3780) to prevent the contamination of surrounding surface runoff; - The transfers of fuels and chemicals controlled and managed to prevent spillage outside bunded areas; - Implement control so significant leakage/spillage is immediately reported and appropriate emergency clean-up operations implemented to prevent possible mobilisation of contaminants; - Chemically contaminated areas are protected by rooving from rainfall to reduce the likelihood of overtopping; - Bunds and sumps are frequently drained, and effluent is treated appropriately; and - Any site dewatering activities will require treatment or other appropriate management controls before discharge to grade is considered.	Medium
Incomplete rehabilitation	Erosion and movement of sediment, potential adverse impact to water quality.	High	Decommissioning Rehabilitation Plan (including replanting of riparian and other erosion sensitive zones).	Low

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Appendix E GLNG Marine Water Quality Report

Appendix F Site Assessment Notes

Catchment 1

Table F-13 Catchment 1 Site Assessment

Catchment Size:	*0.137 km²*		
Average Channel Slope:	*37 m/km*		
Catchment Storage:	Considerable Surface Depressions, Overland Flow is significant		
Catchment relief:	Rolling With Slopes 1-4%		
	Q2	**Q20**	**Q100**
Duration (mins)	16.1		
Intensity (mm)	91.0	154.0	206.0
Flow (m^3/s)	1.3	4.0	7.0

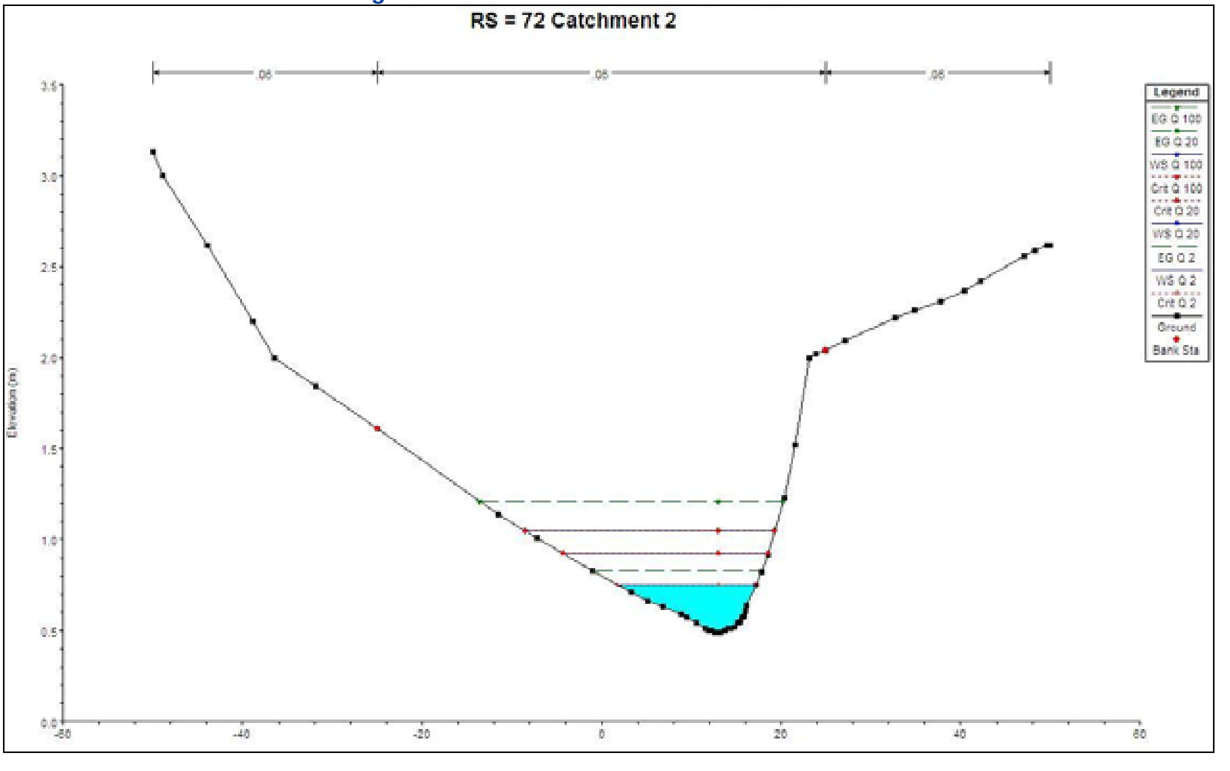
No site Assessment was undertaken in Catchment 1 as it is out with the facility footprint.

Catchment 2

Table F-14 Catchment 2 Site Assessment

Catchment Size:	0.327 *km*^{2}		
Average Channel Slope:	44 *m/km*		
Catchment Storage:	Considerable Surface Depressions, Overland Flow is significant		
Catchment relief:	Hilly with average slopes 4-8%		
	Q2	**Q20**	**Q100**
Duration (mins)	21.9		
Intensity (mm)	80.0	135.0	181.0
Flow (m^3/s)	2.8	8.8	15.6
Depth (m)	0.24	0.41	0.55

Figure F-6 Hec-Ras Result for Catchment 2

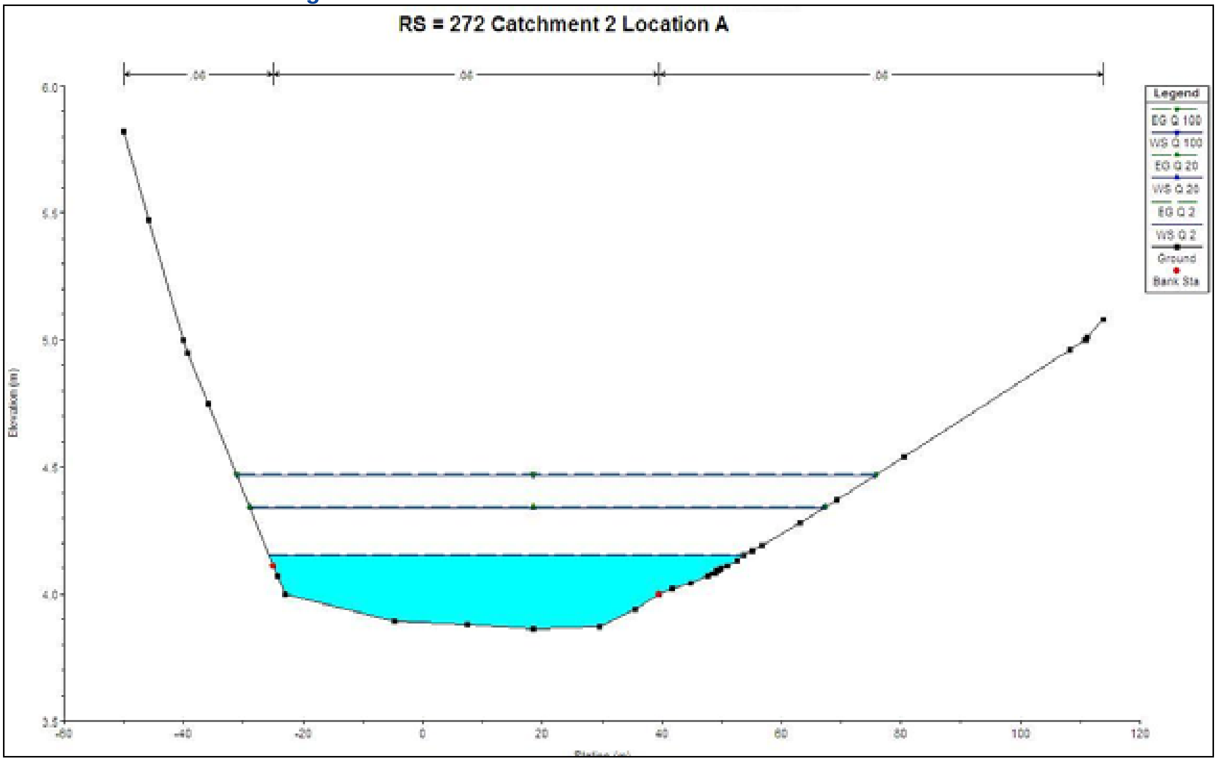


Appendix F

Table F-15 Surface Water Assessment - Location A

GLNG - DMPF – Surface Water Assessment -	
Location A	
Location Unnamed Drainage Feature Catchment 2	
Northing:	7371475
Easting:	315412
Site Description: *Located on the southern side of the proposed DMPF, Unnamed Drainage Feature No. 01 is a seasonal swampy area and is unmodified in nature. Numerous small channels flow in and out of the swamp, however these are ephemeral in nature and only flow when the swamp fills. The swamp contains stagnant water and large stands of established eucalypts.*	
Channel Depth:	*Up to 1.5m*
Channel Width:	*Up to 80m*
Floodplain Slope:	*L 1:50, R 1:50*
Bank Slope:	*LB 1:50, RB 1:50*
Channel Banks: Swamp area is very stable with only small channels flowing in and out of swamp showing minor signs of erosion The swamp profile is approximately convex section, with very mild slopes without undergrowth.	
Substrate Type: The bed substrate is of low compaction with >60% clays and silts present in the swamp. The inflow and outflow channels contain alluvial material with sands and gravels.	
Channel Bed: The channel bed is additionally covered in silt, stagnant water and small and large pieces of wooden debris.	
Water Quality: Ponded water has a high turbidity and is milky in colour. The site assessment detected neither oils nor odours from the water or associated sediment.	
Floodplain: Woodland currently grazed by cattle.	

Figure F-7 Hec-Ras Result for Catchment 2 Location A



Catchment 3

Table F-16 Catchment 3 Site Assessment

Catchment Size:	0.871 *km²*		
Average Channel Slope:	25 *m/km*		
Catchment Storage:	Well defined System of small watercourses		
Catchment relief:	Rolling With Slopes 1-4%		
	Q2	**Q20**	**Q100**
Duration (mins)	52.9		
Intensity (mm)	51.0	86.0	114.0
Flow (m^3/s)	4.2	13.2	23.1
Depth (m)	0.30	0.42	0.51

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Figure F-8 Hec-Ras Result for Catchment 3

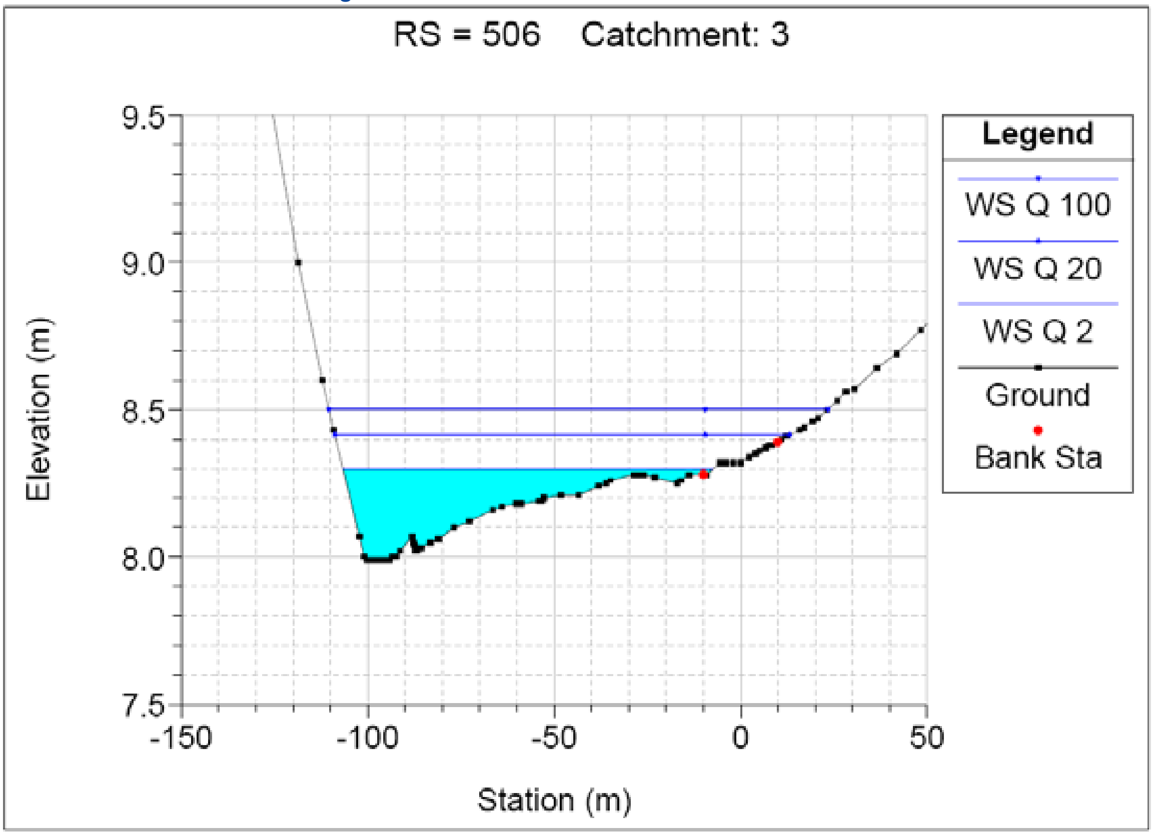

Table F-17 Surface Water Assessment - Location B

GLNG - DMPF – Surface Water Assessment -	
Location B	
Location Name Unnamed Drainage Feature Catchment 3	
Northing:	7371614
Easting:	317589
Site Description: *Ephemeral Drainage line on south east of facility. Part of Un-named catchment 3. Vegetated with native grasses and some reeds, open eucalypt woodland*	
Channel Depth:	*0.2m*
Channel Width:	*1m*
Floodplain Slope:	*L 1:50, R 1:50*
Bank Slope:	*LB 1:50, RB 1:50*
Channel Banks: Unmodified channels. Fairly undefined mounding along various subtle U-shaped channels. Good bank stability and flat floodplain.	
Substrate Type: Clayey Matrix Dominated with greater than 60% fine sediment, interstitial spaces virtually absent. Cobble, pebble and gravel fractions not present.	
Channel Bed: Stable bed with low compaction of silts and clays.	
Water Quality: Ephemeral stream with no water present	
Floodplain: No distinct flood plain	

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Photo 1 - Looking Upstream Photo 2 - Looking Upstream Photo 3 - Looking Downstream

Table F-18 Surface Water Assessment Location C

GLNG - DMPF – Surface Water Assessment -	
Location C	
Location Name Unnamed Drainage Feature Catchment 3	
Northing:	7371470
Easting:	315808
Site Description: *Alluvial splay at end of defined ephemeral channel/watercourse. Adjacent existing site track in south east of proposed facility*.	
Channel Depth:	*0.2m*
Channel Width:	*10m*
Floodplain Slope:	*L 1:30, R 1:40*
Bank Slope:	*L 1:30, R 1:40*
Channel Banks: Generally Concave bank shape with very low flat banks less than 1:10 slope	
Substrate Type: Angular sediment with moderate deposition of well graded gravel material. 5-32% fine sediment, low availability of interstitial spaces.	
Channel Bed: Defined channel fans out and sheet flow occurs with some infiltration into ground.	
Water Quality: Ephemeral stream with no water present. Suspected area of groundwater connection and infiltration	
Floodplain: Symmetrical floodplain. Alluvial splay at end of watercourse suggest connection with groundwater at this point. Groundwater bore located very close to this vicinity.	

Figure F-9 Hec-Ras Result for Catchment 3 Location C

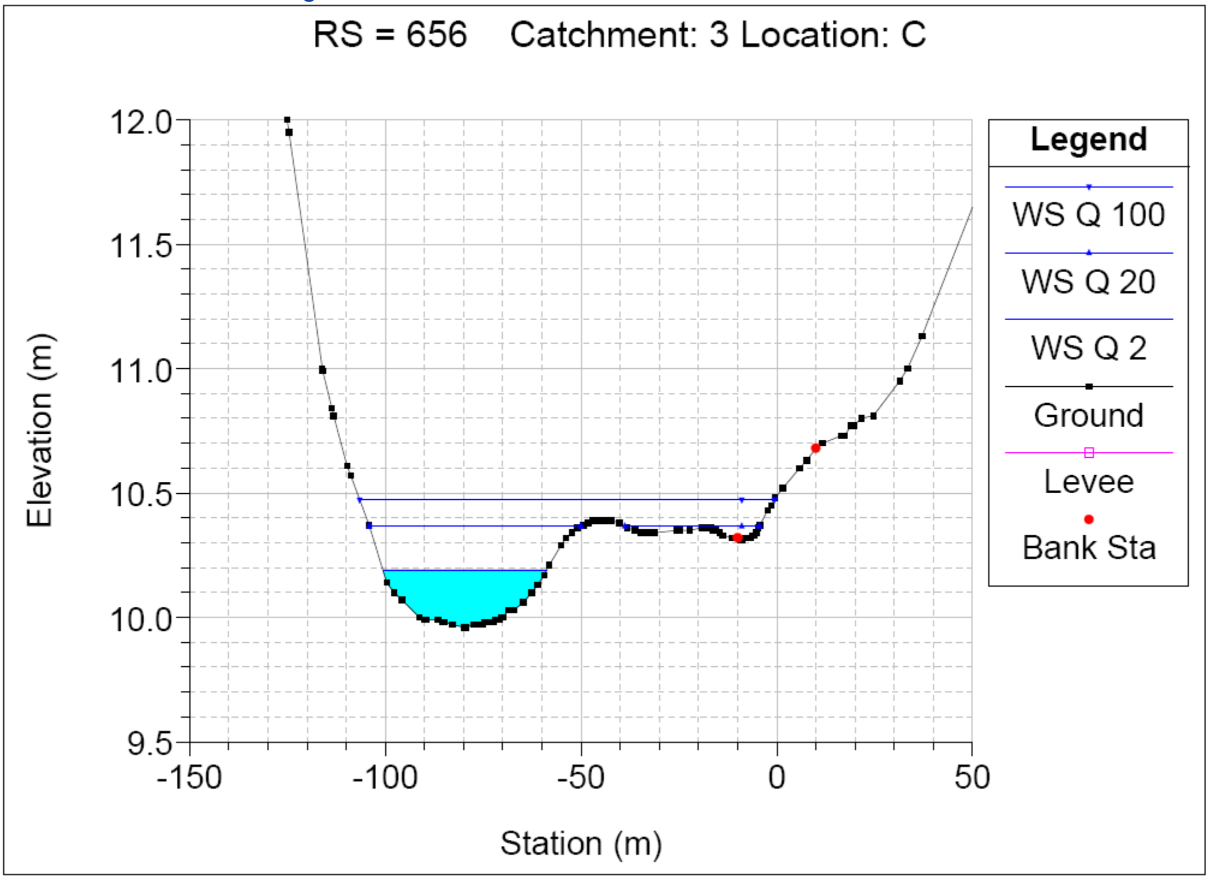

Table F-19 Surface Water Assessment - Location D

GLNG - DMPF – Surface Water Assessment -	
Location D	
Location Unnamed Drainage Feature Catchment 3	
Northing:	7371360
Easting:	316071
Site Description: Wide shallow alluvial channel to south of proposed facility in broad wooded valley	

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Channel Depth:	*0.5m*
Channel Width:	*10m variable*
Floodplain Slope:	*L 1:20, R 1:20*
Bank Slope:	*LB 1:50, RB 1:50*
Channel Banks: broad valley with no defined main channel, but multiple small channels with significant crossover	
Substrate Type: 5-32% fine sediment, low availability of interstitial spaces. Angular well graded sandy gravel with moderate compaction	
Channel Bed: vegetated mid channel bars throughout valley and interdispersed with alluvial channels	
Water Quality: Ephemeral- none present	
Floodplain: Broad wooded valley no defined flood plain	
Photo 1 - Looking Upstream Photo 2 - Looking Downstream Photo 3 - Substrate	

Figure F-10 Hec-Ras Result for Catchment 3 Location D

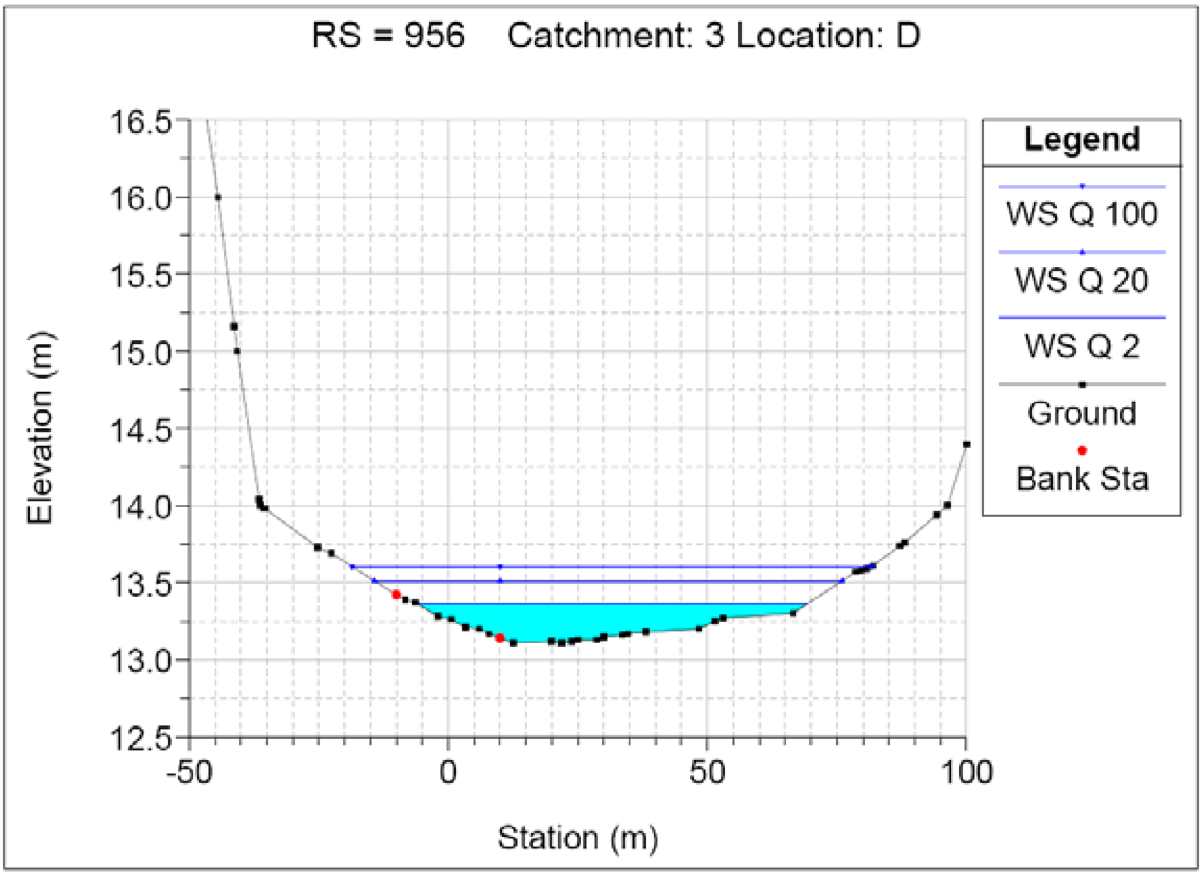

Table 12-1 Surface Water Assessment - Location E

GLNG - DMPF – Surface Water Assessment - Location E	
Location Unnamed Drainage Feature Catchment 3	
Northing:	7371506
Easting:	316106
Site Description: Drainage depression approximately 10m downstream of intersection of two small poorly defined drainage depressions. Heavily vegetated banks and surrounding area. Open eucalypt forest. Dense mid storey. In catchment 3	

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Channel Depth:	*0.25m*
Channel Width:	*2m*
Floodplain Slope:	*L 1:50, R 1:50*
Bank Slope:	*LB 1:15, RB 1:20*
Channel Banks: Moderate to Good stability. Low flat banks, covered in leaf litter. Well established vegetation in channel	
Substrate Type: 32-60% fine sediment, low availability of interstitial spaces. Sandy gravel with low compaction	
Channel Bed: vegetated and poorly defined	
Water Quality: Ephemeral- none present	
Floodplain: Poorly defined approximately 10 to 15 m wide	
Photo 1 - Looking Upstream 10m Photo 2 - Looking Upstream Photo 3 - Looking Downstream Photo 4 - Substrate	

Catchment 4

Table F-20 Catchment 4 Site Assessment

Catchment Size:	0.692 *km^2*		
Average Channel Slope:	23 *m/km*		
Catchment Storage:	Well defined System of small watercourses		
Catchment relief:	Rolling With Slopes 1-4%		
	Q2	**Q20**	**Q100**
Duration (mins)	35		
Intensity (mm)	63.0	106.0	141.0
Flow (m^3/s)	4.4	13.8	24.3
Depth (m)	0.41	0.52	0.59

Figure F-11 Hec-Ras Result for Catchment 4

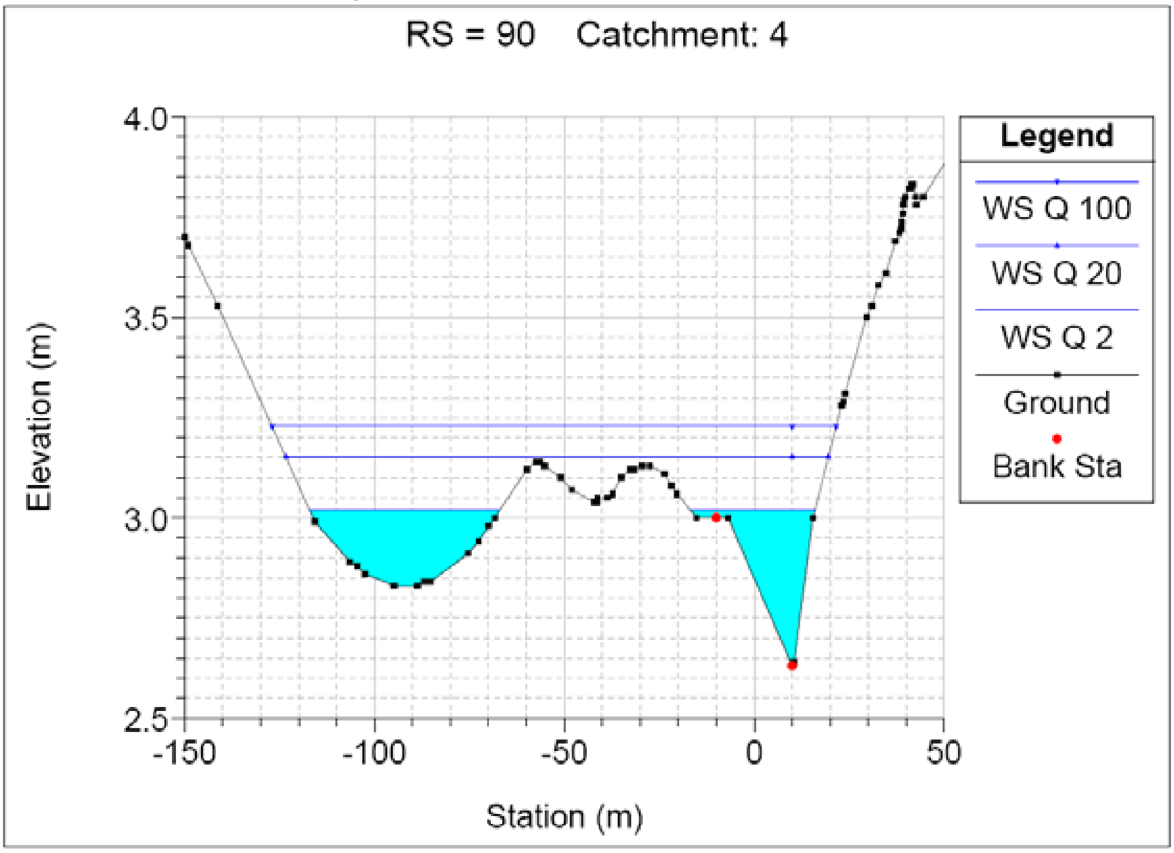

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Table F-21 Surface Water Assessment - Location F

GLNG - DMPF – Surface Water Assessment -	
Location F	
Location Unnamed Drainage Feature Catchment 4	
Northing:	7371984
Easting:	316313
Site Description: Eroded ephemeral gully in catchment 4	
Channel Depth:	*2m*
Channel Width:	*3-4m*
Floodplain Slope:	*Not defined*
Bank Slope:	*LB and RB both steeper than 1V:0.5H*
Channel Banks: Moderate bank stability with very steep exposed slopes of conglomerate and clayey soils containing roots.	
Substrate Type: Open Framework: 0-5% fine sediment, high availability of interstitial spaces. Angular sediment. Well graded gravel with both deposition and erosion zones	
Channel Bed: Well defined channel bed with mid channel bars un-vegetated	
Water Quality: No water present	
Floodplain: No defined floodplain as valley is steep, it is expected that the probability of the channel bank overtopping is very low.	

Photo 1_- Looking Upstream Photo 2 - Looking Downstream 1 Photo 3 - Looking Downstream 2

Figure F-12 Hec-Ras Result for Catchment 4 Location F

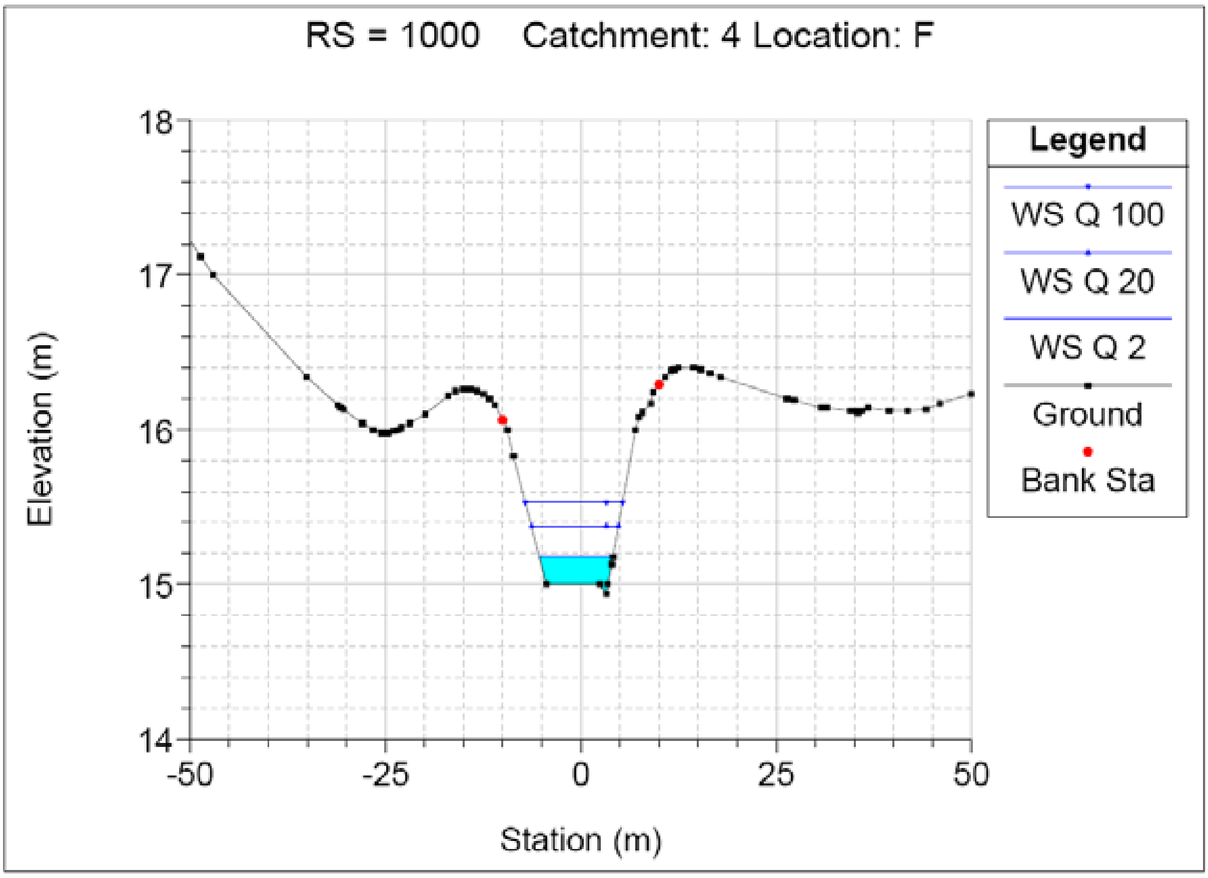

Table F-22 Surface Water Assessment - Location G

GLNG - DMPF – Surface Water Assessment - Location G	
Location Unnamed Drainage Feature Catchment 4	
Easting:	7371667
Northing:	316142

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Site Description: Eroded channel at top of catchment gully head. Limited vegetation with channel. Bedrock outcrops. Ephemeral.	
Channel Depth:	*1.5m*
Channel Width:	*3-4m*
Floodplain Slope:	-
Bank Slope:	*LB>1V:0.5H, RB 1V:0.5H*
Channel Banks: Moderate bank stability with very steep exposed slopes of rock and soils containing roots. Some bank erosion evident.	
Substrate Type: Mixture of medium to coarse sediments to rocks 300mm in diameter. Angular gravel and pebbles	
Channel Bed: 5-32% fine sediment, moderate availability of interstitial spaces. Moderate bed compaction. Areas of rock on bed.	
Water Quality: Ephemeral –no water present	
Floodplain: No distinct floodplain in gully	
Photo 1 - Looking Upstream Photo 2 - Looking Downstream Photo 3 - Looking Substrate	

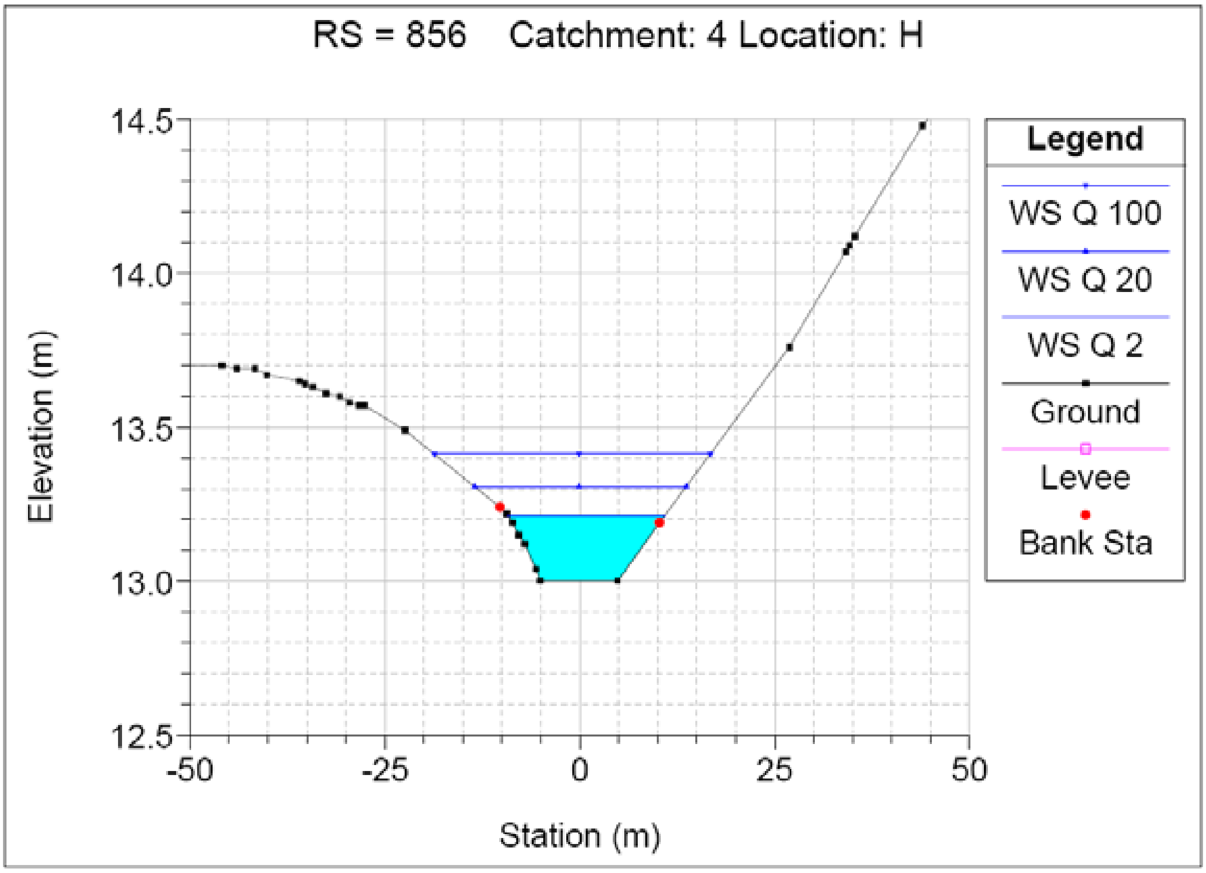
Table F-23 Surface Water Assessment - Location H

GLNG - DMPF – Surface Water Assessment -	
Location H	
Location Unnamed Drainage Feature Catchment 4	
Northing:	7372099
Easting:	316257
Site Description: Confluence of drainage paths in catchment 4, east of facility. Ephemeral stream with incised channel.	
Channel Depth:	*1.8-2m*
Channel Width:	*6m*
Floodplain Slope:	*Not defined*
Bank Slope:	*LB undercut, RB vertical with step*
Channel Banks: Moderate bank stability with very steep exposed slopes of rock and soils containing roots. Bank erosion and undercutting evident.	
Substrate Type: Open framework: 0-5% fine sediment, high availability of interstitial spaces. Well graded gravel	
Channel Bed: Moderate Erosion and Deposition in bed angular gravel present	
Water Quality: Ephemeral – no water present	
Floodplain: no distinct floodplain in valley	
Photo 1 - Looking Upstream Photo 2 - Looking Upstream at tributary Photo 3 - Looking Downstream	

Appendix F

Photo 4 - Substrate

Figure F-13 Hec-Ras Result for Catchment 4 Location H

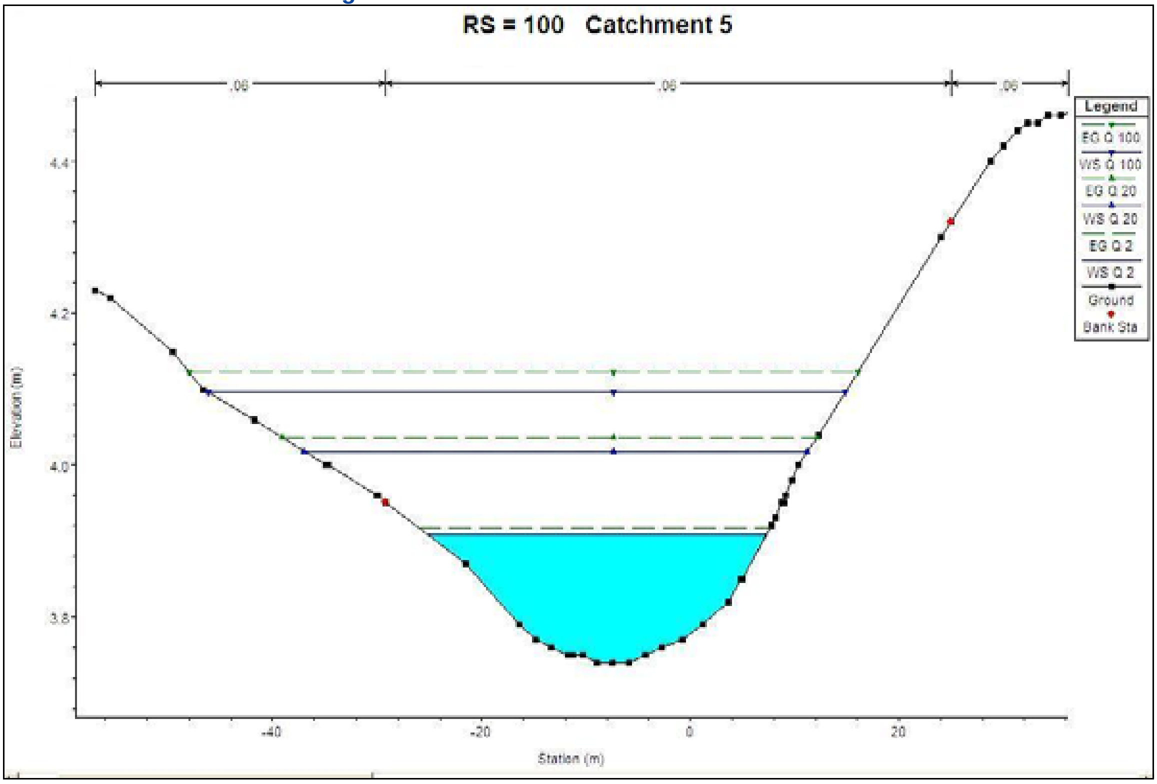


Catchment 5

Table F-24 Catchment 5 Site Assessment

Catchment Size:	0.126 *km²*		
Average Channel Slope:	59 *m/km*		
Catchment Storage:	Considerable Surface Depressions, Overland Flow is significant		
Catchment relief:	Hilly with average slopes 4-8%		
	Q2	**Q20**	**Q100**
Duration (mins)	10.7		
Intensity (mm)	111.0	189.0	254.0
Flow (m^3/s)	1.5	4.7	8.5
Depth (m)	0.18	0.29	0.37

Figure F-14 Hec-Ras Result for Catchment 5



No site assessment was undertaken in catchment 5. Site observations were that catchment 6 has similar characteristics to catchment 5.

Catchment 6

Table F-25 Catchment 6 Site Assessment

Catchment Size:	0.210 *km²*		
Average Channel Slope:	69 *m/km*		
Catchment Storage:	Considerable Surface Depressions, Overland Flow is significant		
Catchment relief:	Hilly with average slopes 4-8%		
	Q2	**Q20**	**Q100**
Duration (mins)	11.9		
Intensity (mm)	107.0	182.0	244.0
Flow (m^3/s)	2.4	7.6	13.5
Depth (m)	0.19	0.31	0.41

Appendix F

Figure F-15 Hec-Ras Result for Catchment 6

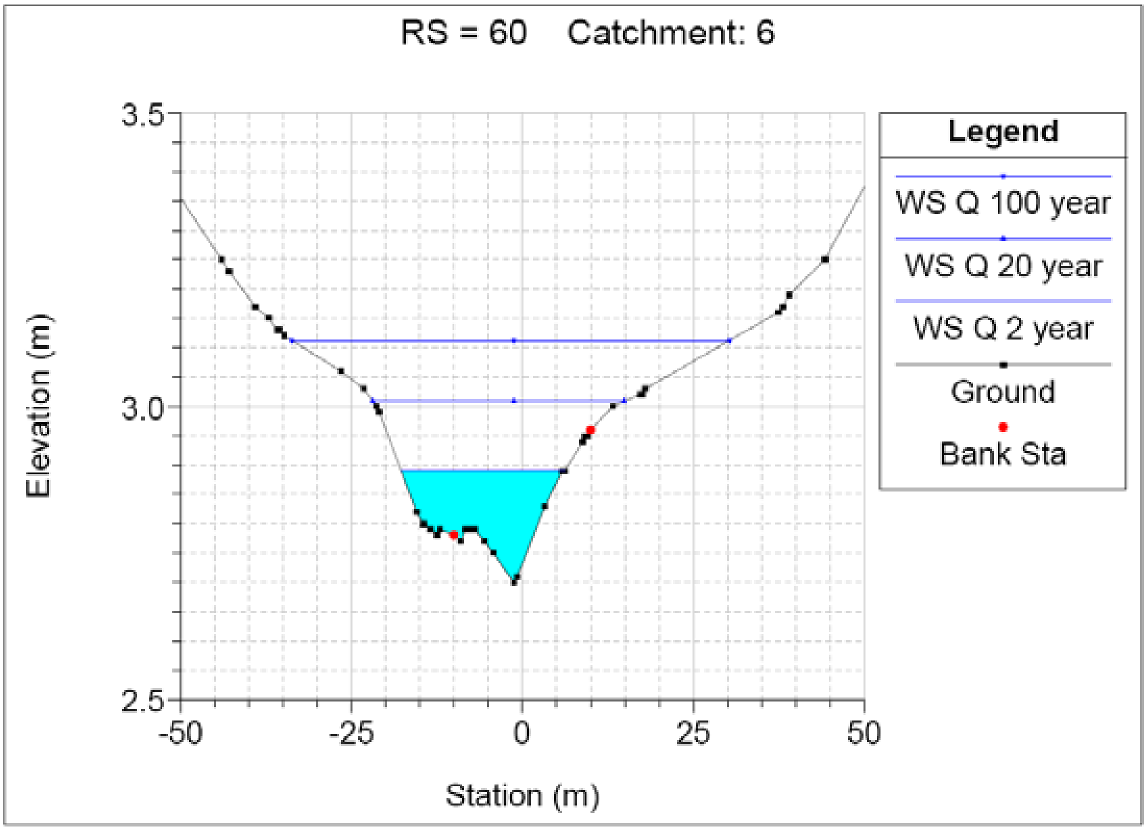
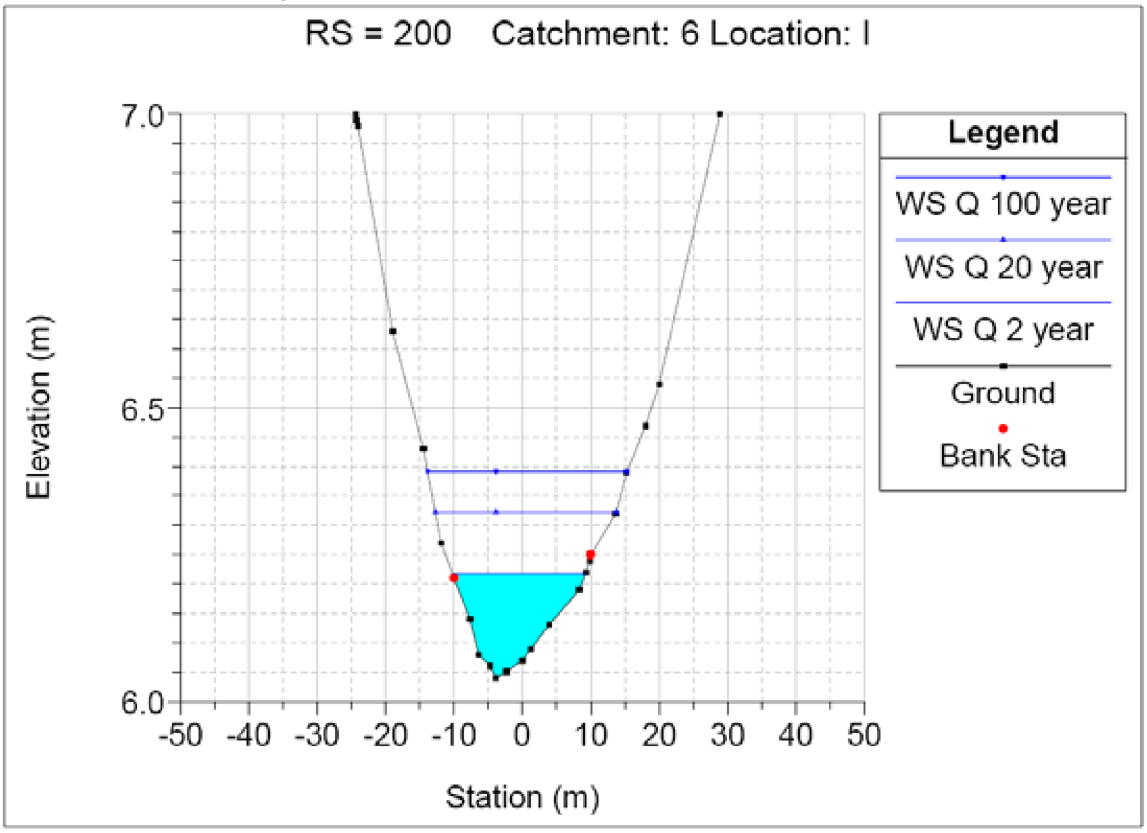


Table F-26 Surface Water Assessment - Location I

GLNG - DMPF – Surface Water Assessment - Location I	
Location Unnamed Drainage Feature Catchment 6	
Northing:	7372311
Easting:	315055
Site Description: Small meandering gully to north of facility in catchment 6. Medium density vegetation Ephemeral.	
Channel Depth:	*Up to 0.5m*
Channel Width:	*1-2m*
Floodplain Slope:	*L 1:10, R 1:10*
Bank Slope:	*LB 1:2, RB 1:2*
Channel Banks: Small mounded banks on hilly area with typical 4-8% slopes. Channel in broad valley.	

Substrate Type: Conglomerate rock exposed in patches with some gravel. Generally sub-angular
Channel Bed: Average grassed and timbered land of medium soil texture. 5-32% fine sediment, moderate availability of interstitial spaces.
Water Quality: Ephemeral – no water present
Floodplain: no distinct flood plain, gully collects localised runoff from catchment only, with sheet flow occurring in catchment parallel to gully.
Photo 1_- Looking Upstream Photo 2 - Looking Downstream

Figure F-16 Hec-Ras Result for Catchment 6 Location I



Appendix F

Catchment 7

Table F-27 Catchment 7 Site Assessment

Catchment Size:	0.186 *km^2*		
Average Channel Slope:	0 *m/km*		
Catchment Storage:	Considerable Surface Depressions, Overland Flow is significant		
Catchment relief:	Flat with Slopes 0-1.5%		
	Q2	**Q20**	**Q100**
Duration (mins)	35.0`		
Intensity (mm)	63.0	106.0	141.0
Flow (m^3/s)	0.7	2.3	4.1

Table F-28 Surface Water Assessment - Location J

GLNG - DMPF – Surface Water Assessment -	
Location J	
Location Unnamed Drainage Feature Catchment 6	
Northing:	7372081
Easting:	315178
Site Description: Flat estuarine saltpan/mudflat	
Channel Depth:	*n/a*
Channel Width:	*n/a*
Floodplain Slope:	*<1:500*
Bank Slope:	*n/a*
Channel Banks: No Channel.	
Substrate Type: Grey Cracked clay/estuarine mud. Tightly packed sediment, very hard to dislodge. >80% fine sediment no interstitial spaces	
Channel Bed: n/a	

Water Quality: Tidal – no water present
Floodplain: Flat estuarine flood plain subject to tidal inundation
Photo 1 - Looking west south west Photo 2 - Looking south west

Appendix G Flood Assessment

To approximate the flood depths at the road crossing, a flood assessment of the five main drainage features, as identified in the flood hydrology Appendix F, has been undertaken.

The US Army Corps developed Hydrologic Engineering Centers River Analysis System, known commonly as HEC RAS, is a one-dimensional hydraulic estimation model. The hydraulic model was adopted for flood estimation of the 3 locations. The model inputs include geometry of the channel and floodplain, peak flows (from Table G-29) and representative hydraulic roughness coefficients.

Using a 12D digital terrain model (developed from 1m contour data), channel cross sections were extracted for each watercourse to HEC-RAS to form a simplified hydraulic model. The cross sections were further detailed with information gathered during the site visit, primarily providing channel definition. Once the series of cross-sections were developed for each assessment location, they were then exported to the HEC RAS to form a simple model of the natural channel topography.

Along with the cross-sectional data the geometric file requires a description of the bed, channel wall and floodplain roughness. Hydraulic roughness values (Mannings 'n') were adopted from hydraulic references based on field observations (see Table G-29 below):

Table G-29 Adopted Mannings 'n' Values

Surface Type	Roughness Value
Floodplains	
Light brush and trees, in winter	0.06
Heavy stand of timber, a few down trees, little undergrowth	0.08 – 0.1
Main Channel	
Clean, winding, some pools and shoals, some weeds and stones	0.04- 0.045
Clean, winding, some pools and shoals, some weeds and stones, lower stages, ineffective slopes and sections	0.05
Sluggish reaches, weedy, deep pools	0.07

Sources: Chow, 1959, Open Channel Hydraulics, McGraw-Hill Book Company, Inc.

Each model contains two boundary conditions, an upstream flow boundary and a downstream water level boundary. The inflow values were taken from the peak flows determined in the rational method hydrological analysis (Table G-30) at each location. As the downstream environment would be commonly effected by the tidal level within North China Bay, the salt marsh/estuarine flats level was simplified and a normal depth downstream boundary was adopted based on the average gradient of the drainage feature gradient.

Table G-30 Predicted peak design flow for drainage features at the edge of the estuarine flat

Catchment/Drainage Feature	Catchment Area (km^2)	2 Year ARI Peak Flow (m^3/s)	20 Year ARI Peak Flow (m^3/s)	100 Year ARI Peak Flow (m^3/s)
Catchment 1	0.137	1.3	4.0	7.0
Catchment 2	0.327	2.8	8.8	15.6
Catchment 3	0.871	4.2	13.2	23.1

Catchment/Drainage Feature	Catchment Area (km^2)	2 Year ARI Peak Flow (m^3/s)	20 Year ARI Peak Flow (m^3/s)	100 Year ARI Peak Flow (m^3/s)
Catchment 4	0.692	4.4	13.8	24.3
Catchment 5	0.126	1.5	4.7	8.5
Catchment 6	0.210	2.4	7.6	13.5
Catchment 7 –estuarine mudflat (to proposed main embankment location)	0.186	0.7	2.3	4.1

The HEC RAS model was simulated using steady state conditions, due to the flat topographic nature of all the watercourses identified; subcritical flow conditions were also adopted.

At all locations, for all three events, the model predicted out of channel bank flooding to occur at either the 2year or 20 year ARI. Table G-31 below provides the flood depths and extents for each key watercourse location.

Table G-31 Predicted Flood Depths near start of Mudflat

Name	2yr ARI Depth (m)	20yr ARI Depth (m)	100yr ARI Depth (m)
Unnamed Drainage Feature No. 2	0.24	0.41	0.55
Unnamed Drainage Feature No. 3	0.30	0.42	0.51
Unnamed Drainage Feature No. 4	0.41	0.52	0.59
Unnamed Drainage Feature No. 5	0.18	0.29	0.37
Unnamed Drainage Feature No. 6	0.19	0.31	0.41

Additionally rational method calculations were undertaken for the proposed catchment modification to catchment 3 and 4 after construction of the facility. These results are displayed in Table G-32 and show that the reduction catchment size causes the peak flows to increase due to the reduction in stream length and time of concentration.

Table G-32 Predicted peak design flow for modified catchments 3 and 4 at edge of facility

Catchment/Drainage Feature	Catchment Area (km^2)	2 Year ARI Peak Flow (m^3/s)	20 Year ARI Peak Flow (m^3/s)	100 Year ARI Peak Flow (m^3/s)
Modified Catchment 3	0.588	5.5	17.6	31.1
Modified Catchment 4	0.431	5.1	16.2	28.9

Appendix G

RORB

RORB (version 6) is an Australian hydrological modelling software package used for generating hydrographs, flood volumes and routing for rural and urban catchments. It is widely used in Australia and overseas. The site catchments were broken down into various areas and input into the RORB model. A summary of Key RORB parameters used are shown in Table G-33.

Table G-33 RORB model Parameters

Parameter	Value
kc Value (Weeks –QLD)	1.40
‘m’ coefficient	0.8
Initial Loss (mm)	15
Continuing Loss (mm)	2.5

RORB was run using an initial/continuing loss model and due to the lack of available stream flow data was un-calibrated. Flows calculated were checked against rational method flows and found to be comparable.

A model was set up of the entire site area in both the existing conditions and with the proposed facility modifications to the site. The catchments were input as per the catchment plan in Figure 9-1 (excluding catchment 1), however the larger catchments were broken into sub areas. Catchment 3 was divided into 3 sub areas and catchment 4 was divided into 2 sub areas. It was found the critical time of concentration for the site as a whole was 1.5 hours and peak flows and flood volumes were generated for a range of return periods. Peak flood volume was generated for the long duration storm of 72 hours.

A summary of RORB results for the existing conditions model is displayed in Table G-34.

Table G-34 Existing Site Catchment RORB Results

	1:2yr ARI		1:20yr ARI		1:100 ARI	
	Peak Flow	72hr Peak Volume (ML)	Peak Flow	72hr Peak Volume (ML)	Peak Flow	72hr Peak Volume (ML)
Catchment 3	4.5	79	10.1	300	14.8	514
Catchment 4	5.1	63	11.5	238	15.9	408
Combined Total Site Catchment	12.9	220	28.7	828	41.9	1420

As expected the rational method flows calculated for the catchments are higher and represent a more conservative estimate than the RORB model. The RORB model results provide a good estimation of flood volume across the site.

The proposed model was run with special storages at the locations of the future embankments across catchment 3 and 4 with different sub catchment areas reflecting the facility layout. This allowed an estimate of the flows into the modified catchments 3 and 4 (refer Figure 9-2) and the likely design flows required for the diversion pipe network. It also gave an estimate of flood volumes that will be required to be conveyed by the diversion system. A summary of these results is shown in Table G-35.

Table G-35 Proposed Site Catchment RORB Results

	1:2yr ARI		1:20yr ARI		1:100 ARI	
	Peak Flow	Volume	Peak Flow	Volume	Peak Flow	Volume
Modified Catchment 3	3.1	55	7.0	208	10.2	357
Modified Catchment 4	4.9	39	10.5	148	14.0	254
Facility Catchment	7.10	126	15.9	478	23.2	821

These results were used to calculate the 100 year Design Storage Allowance for the Facility for the 72 Hour duration storm. This was calculated to be 0.62 m as the Volume entering the facility is 821 ML and the Area of the facility is 1,332 km^2. This allowance does not include the runoff volumes from modified catchments 3 or 4 as these volumes will be stored in these catchments, or diverted around the facility directly into the bay.

Appendix H Water Supply Dam Yield

An estimate of the potential catchment runoff yield to the future storages in catchment 3 and 4 was made to quantify the volume of water that may be available annually for harvesting and use in facility construction/operations.

The yield assessment is based on rainfall and evaporation statistics from Gladstone Radar Station. The yield assessment assumes the actual evaporation rate from the dam storage surface is 0.6 times the pan evaporation rate and that the runoff from the catchment available for collection and harvesting is 5 % of the actual rainfall on the catchment (Nelson, Design and Construction of Small Earth Dams, 1985).

A summary of the calculations can be seen in Table H-36 and H-37 for the respective catchments. Due to the sizeable catchments and annual rainfall, significant yields are available which would be sufficient for construction and operation of the site.

Appendix H

Table H-36 Catchment 3 Storage yield

				Source : BOM Climate Data Online										
Proposed Dam Catchment Area	=	588	Ha	Evaporation data set used for Gladstone Radar Station between 1957-2008										
Proposed Dam Surface Area	=	5	Ha	Rainfall data set used for Gladstone Radar Station between 1957-2009										
Month	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JULY**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**	**TOTALS**	
Average Rainfall (mm)	*143.40*	*143.40*	*82.60*	*46.40*	*59.60*	*38.90*	*34.40*	*31.20*	*26.20*	*62.30*	*74.20*	*128.80*	871.40	mm
Mean Pan A Evaporation (mm)	195.3	165.2	164.3	132	105.4	90	96.1	108.5	132	170.5	183	195.3	1737.6	mm
Evaporation Factor	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	unitless
Estimated Evaporation (mm)	117.18	99.12	98.58	79.2	63.24	54	57.66	65.1	79.2	102.3	109.8	117.18	1042.56	mm
Runoff factor for Catchment	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	unitless
Dam Catchment Runoff (ML)	42.16	42.16	24.28	13.64	17.52	11.44	10.11	9.17	7.70	18.32	21.81	37.87	256.2	ML
Dam Evaporation Loss (ML)	5.86	4.96	4.93	3.96	3.16	2.70	2.88	3.26	3.96	5.12	5.49	5.86	52.1	ML
NET YIELD (average)	**36.30**	**37.20**	**19.36**	**9.68**	**14.36**	**8.74**	**7.23**	**5.92**	**3.74**	**13.20**	**16.32**	**32.01**	**204.1**	**ML**

Appendix H

Table H-37 Catchment 4 Storage Yield

				Source : BOM Climate Data Online										
Proposed Dam Catchment Area	=	431	Ha	Evaporation data set used for Gladstone Radar Station between 1957-2008										
Proposed Dam Surface Area	=	8	Ha	Rainfall data set used for Gladstone Radar Station between 1957-2009										
Month	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JULY**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**	**TOTALS**	
Average Rainfall (mm)	*143.40*	*143.40*	*82.60*	*46.40*	*59.60*	*38.90*	*34.40*	*31.20*	*26.20*	*62.30*	*74.20*	*128.80*	871.40	mm
Mean Pan A Evaporation (mm)	195.3	165.2	164.3	132	105.4	90	96.1	108.5	132	170.5	183	195.3	1737.6	mm
Evaporation Factor	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	unitless
Estimated Evaporation (mm)	117.18	99.12	98.58	79.2	63.24	54	57.66	65.1	79.2	102.3	109.8	117.18	1042.56	mm
Runoff factor for Catchment	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	unitless
Dam Catchment Runoff (ML)	30.90	30.90	17.80	10.00	12.84	8.38	7.41	6.72	5.65	13.43	15.99	27.76	187.8	ML
Dam Evaporation Loss (ML)	9.37	7.93	7.89	6.34	5.06	4.32	4.61	5.21	6.34	8.18	8.78	9.37	83.4	ML
NET YIELD (average)	**21.53**	**22.97**	**9.91**	**3.66**	**7.78**	**4.06**	**2.80**	**1.52**	**-0.69**	**5.24**	**7.21**	**18.38**	**104.4**	**ML**

Appendix I Risk Assessment Scale

Likelihood Scale

Likelihood is defined as a general description of probability and/or frequency (AS/NZ4360, 2004). Applied to this project it is the water quality impact within and surrounding the facility and using the following likelihood scale. The likelihood scale is presented in Table I-38.

Table I-38 Risk Assessment Likelihood Scale

Level	Likelihood	Description
1	Rare	Will ONLY occur in exception circumstances
2	Unlikely	Could occur but not expected
3	Possible	Could occur at some time
4	Likely	Will probably occur in most circumstances
5	Almost Certain	Expected to occur in most circumstances

Consequence Scale

Consequence is defined as the outcome or impact of an event (AS/NZ4360, 2004). The consequence scale is presented in Table I-39.

Table I-39 Risk Assessment Consequence Scale

Level	Consequence	Description
1	Insignificant	Trivial environmental impact
2	Minor	Unreasonable interference with the environment. (Results in minor illness or injury)
3	Moderate	Clearly visible impact to aquatic ecosystem. Requires localised remediation. (Results in illness or injury)
4	Major	Damage to the environment that requires significant remediation. (Results in serious illness or injury)
5	Catastrophic	Environmental damage is irreversible, of high impact or widespread. (Results in death)

Risk Rating Matrix

A combination of the consequences and likelihood assigned to each measure to calculate the overall risk rating. The risk rating matrix is presented in Table I-40.

Appendix I

Table I-40 Risk Assessment Risk Rating Matrix

Likelihood	Consequences				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	High	High	Extreme	Extreme	Extreme
Likely	Medium	High	High	Extreme	Extreme
Possible	Low	Medium	High	High	Extreme
Unlikely	Low	Low	Medium	High	Extreme
Rare	Low	Low	Medium	High	Extreme

Appendix J Hazard Matrix

Appendix J

Table J-41 Hazard Matrix

Aspect	Potential Impact	Inherent Risk rating	Mitigation Strategy	Residual Risk Rating
Construction				
Erosion and Sediment Mobilisation	Sediment from earth moving and stockpiling can enter surface water runoff during rainfall events or blown by wind and discharge to watercourses leading to deleterious effects on water quality and aquatic habitats. Potential presence of high levels of metals in soils that may enter waterways.	High	- Appropriate design (erosion and scour protection) for sections of pipeline crossing active floodplain and main channel; - Stormwater management (development, implementation and maintenance of plan), to include: • Erosion control and energy dissipation, watercourse stabilisation i.e. matting, riprap and gabions; • Stormwater controls and upstream treatment, i.e. infiltration devices and vegetation filters; • Stabilisation techniques, i.e. revegetation; - Construction to occur in dry season; - Crossings to be at right angles to direction of flow; - Stockpiling of topsoil located away from watercourses; - Vehicle wash bay to be located away from watercourses; - Minimise vegetation disturbance; - Routine inspections; and - Adopt controls to minimise risk of heavy metal runoff to surface waters	Low

Appendix J

Aspect	Potential Impact	Inherent Risk rating	Mitigation Strategy	Residual Risk Rating
Pollution	- Potentially contaminated drainage from fuel oil storage areas; - Diesel and other petroleum-based fuels and lubricants used by excavation and construction machinery; - Environmental and public health and safety issue; and - Site excavation works may expose groundwaters which have been found to have high background levels of dissolved metals in both near-surface and deeper aquifers.	High	- Chemical and fuel storage areas to be appropriately bunded; - Spill cleanup kits in accordance with Australian Standards (AS1940 and AS3780) to be located in convenient locations, i.e. work vehicles; - Refuelling to occur in bunded areas; Should a spill occur, ensure it is contained and does not enter drainage lines or watercourses; - Follow all other operational procedures; and - Any site dewatering activities will require treatment or other appropriate management controls before discharge to grade is considered	Medium
Improper disposal of all construction wastes	Litter and other construction waste can be washed into watercourses and ocean during rain events or tidal inundation, and impact receiving waters.	Medium	Develop, implement and maintain Waste Management/Disposal Plan.	Low
Works adjacent to/within drainage lines and watercourses	Trenching at watercourse crossings and vehicle access crossings can alter flow characteristics. Potential presence of high levels of metals in soils that may enter waterways.	High	- Diversion of watercourse either by low flow diversion or coffer dam with pumping; - Construction activities that will affect existing drainage channels and control measures must only be carried out after suitable stormwater management infrastructure has been implemented onsite; - Minimal disturbance by heavy earth moving equipment; - Vehicle crossings should be adequately designed for a range of flow conditions, including under road drainage; and - Adopt controls to minimise risk of heavy metal runoff to surface waters	Low

Appendix J

Aspect	Potential Impact	Inherent Risk rating	Mitigation Strategy	Residual Risk Rating
Flooding	Possibility of out-of-bank/flash flood rainfall event and regular tidal inundation of site during construction causing erosion and damage to erosion and sediment control infrastructure.	High	- Schedule construction works appropriately during wet season and where practicable, limit works within the flood plain. However, if not possible, make sure a flood risk assessment has been conducted; -Tide times to be monitored and planed for; - Stormwater management e.g. drainage diversions and bunding; and - Emergency response procedures and flood forecasting.	Medium
Lack of water supply	Inadequate dust suppression, soil compaction and washdown.	High	Develop, implement and maintain Water Supply Strategy and Emergency Plan.	Medium
Contaminant Mobilisation	Runoff from potentially contaminated drainage from fuel oil storage areas and general washdown water entering into drainage features and receiving waters, altering the physical and chemical quality of the water and receiving environment.	High	- The construction of bunded storage areas for contaminants are recommended with spill cleanup kits in accordance with Australian Standards (AS1940 and AS3780) to prevent the contamination of surrounding surface runoff; - The transfers of fuels and chemicals controlled and managed to prevent spillage outside bunded areas; - Implement control so significant leakage/spillage is immediately reported and appropriate emergency clean-up operations implemented to prevent possible mobilisation of contaminants; - Chemically contaminated areas are protected by rooving from rainfall to reduce the likelihood of overtopping; - Bunds and sumps are frequently drained, and effluent is treated appropriately; and - Any site dewatering activities will require treatment or other appropriate management controls before discharge to grade is considered.	Medium

Appendix J

Aspect	Potential Impact	Inherent Risk rating	Mitigation Strategy	Residual Risk Rating
Operation				
Erosion and Sediment Mobilisation	Permanent structures and minor earth disturbance can result in localised erosion and sediment mobilisation leading to deleterious effects on water quality and aquatic habitats.	Medium	Stormwater management to include: - Localised erosion control and energy dissipation measures; - Stabilisation techniques. Routine inspection and maintenance of existing erosion and sediment control measures.	Low
Discharges from sediment ponds	It is proposed to have two sediment dams upstream of the DMPF. Uncontrolled releases from these ponds could allow process and contaminated stormwater to enter drainage lines and receiving waters.	Medium	Sediment dams will be designed to contain up to a10yr ARI. Releases from ponds should be controlled and should occur after the water has been tested and meets license guidelines (which are to be determined)	Low
Pollution	Diesel and other petroleum-based fuels and lubricants used by operational vehicles and machinery entering watercourses.	Medium	- Chemical and fuel storage areas to be appropriately bunded; - Spill cleanup kits in accordance with Australian Standards (AS1940 and AS3780) to be located in convenient locations; - Refuelling to occur in bunded areas; Should a spill occur, ensure it is contained and does not enter drainage lines or watercourses; and - Follow all other site operational procedures.	Low
Improper disposal of all operational wastes	Litter and other operational waste can be washed into watercourses during rain events and impact receiving waters.	Low	Develop, implement and maintain Waste Management/Disposal Plan	Low

Appendix J

Aspect	Potential Impact	Inherent Risk rating	Mitigation Strategy	Residual Risk Rating
Flooding	Possibility of out-of-bank/flash flood rainfall event causing failure of erosion and sediment control infrastructure. Blockage of Diversion drainage system causing inundation of other properties/catchments.	High	- Monitoring and maintenance of erosion and sediment control features and diversion infrastructure; and - Emergency Response Procedures and flood forecasting (where practical).	Medium
Lack of water supply	Inadequate dust suppression, soil compaction and washdown.	High	Develop, implement and maintain Water Supply Strategy and Emergency Plan.	Medium
Decommissioning				
Erosion and Sediment Mobilisation	- Erosion and movement of sediment can potentially have adverse impacts on water quality. - Potential presence of high levels of metals in soils that may enter waterways.	Medium	- Implement and maintain a Decommissioning Environmental Plan. Apply sediment and erosion control measures prior to earth moving activities; and - Adopt controls to minimise risk of heavy metal runoff to surface waters	Low
Pollution	- Diesel and other petroleum-based fuels and lubricants used by operational vehicles and machinery entering watercourses. - Site excavation works may expose groundwaters which have been found to have high background levels of dissolved metals in both near-surface and deeper aquifers.	Medium	- Chemical and fuel storage areas to be appropriately bunded; - Spill cleanup kits in accordance with Australian Standards (AS1940 and AS3780) to be located in convenient locations, i.e. work vehicles; - Refuelling to occur in bunded areas; - Should a spill occur, ensure it is contained and does not enter drainage lines or watercourses; - Follow all other site operational procedures; and - Any site dewatering activities will require treatment or other appropriate management controls before discharge to grade is considered	Low
Improper disposal of all demolition wastes	Impact to receiving waters.	Medium	Develop and implement a Waste Management/Disposal Plan.	Low

Appendix J

Aspect	Potential Impact	Inherent Risk rating	Mitigation Strategy	Residual Risk Rating
Works adjacent to/within drainage lines and watercourses	Infilling on-site surface water bodies or drainage lines can lead to potential loss of water storage and can adversely impact ecological habitats. Potential presence of high levels of metals in soils that may enter waterways.	High	- Diversion of drainage features before construction commences (for stable vegetated channels); - Process area diversion (sediment basins and diversion drains); - Decommissioning works that will affect existing drainage channels and control measures must only be carried out after suitable stormwater management infrastructure has been implemented on-site; - Minimal number of passes by heavy earth moving equipment; - Prior to decommissioning, development and implementation of monitoring program; and - Adopt controls to minimise risk of heavy metal runoff to surface waters	Medium
Flooding	Possibility of out-of-bank/flash flood rainfall event exceeding capacity of the storm water management system resulting in non compliant offsite discharges. Also, risk to construction workers (H&S). Blockage of Diversion drainage system causing inundation of other properties/catchments.	Medium	- Schedule decommissioning work appropriately during the wet season and try and work outside the flood plain to reduce risk from flooding and undertake a flood risk assessment has been conducted; - Stormwater management e.g. drainage diversions and bunding; and - Emergency response procedures and flood forecasting.	Medium
Lack of water supply	Dust emissions and inadequate soil compaction and washdown, fire water.	High	Develop, implement and maintain Water Supply Strategy and Emergency Plan.	Low

Appendix J

Aspect	Potential Impact	Inherent Risk rating	Mitigation Strategy	Residual Risk Rating
Contaminant Mobilisation	Runoff from potentially contaminated drainage from fuel oil storage areas and general washdown water entering into drainage features and receiving waters, altering the physical and chemical quality of the water and receiving environment.	High	- The construction of bunded storage areas for contaminants are recommended with spill cleanup kits in accordance with Australian Standards (AS1940 and AS3780) to prevent the contamination of surrounding surface runoff; - The transfers of fuels and chemicals controlled and managed to prevent spillage outside bunded areas; - Implement control so significant leakage/spillage is immediately reported and appropriate emergency clean-up operations implemented to prevent possible mobilisation of contaminants; - Chemically contaminated areas are protected by rooving from rainfall to reduce the likelihood of overtopping; - Bunds and sumps are frequently drained, and effluent is treated appropriately; and - Any site dewatering activities will require treatment or other appropriate management controls before discharge to grade is considered.	Medium
Incomplete rehabilitation	Erosion and movement of sediment, potential adverse impact to water quality.	High	Decommissioning Rehabilitation Plan (including replanting of riparian and other erosion sensitive zones).	Low

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