FINAL REPORT

Gladstone LNG Dredge Material Placement Facility Surface Water Assessment

Prepared for

Santos

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18 March 2009

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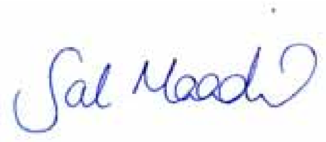

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Executive Summary

An estimated 8 million m^3 of sediment is to be dredged adjacent to the Targinie Channel to allow for navigation channel, a swing basin and berthing pocket for LNG tankers to gain access to the LNG terminal. Dredge material from this activity is proposed to be pumped as a slurry to a proposed dredge material placement facility at a site to the north of the LNG facility on Curtis Island, just to the south of Laird Point. This facility would be constructed as a bunded enclosure (to a height of 18 m) that will then have a fill capacity of approximately 13.2 million m^3..

Dredged materials will be transported hydraulically through a pipeline to the Laird Point dredge material placement facility where it will be settled. The seawater will be passed through a series of ponds and sluices prior to being returned to the marine environment.

A phased surface water assessment approach has been undertaken allowing the initial concept design for the dredge material placement facility to be assessed. Phase 1 has focused on the key impacts of the placement facility in regard to the surface water environment. A review of potential impacts identified two that may result from poor surface water management, which are the focus of this report. These are:

- non-compliant water quality discharge in to the receiving water from insufficient treatment.
- catastrophic failure of the containment embankment due to deficient stormwater management and/or design.

It is recommended that a Surface Water Management Strategy is developed to provide a basis for the management of discharges from the facility. It is suggested that the Strategy is based on findings from a water quality model and will include several different treatment methods to meet water quality guidelines and site specific objectives. To identify non-compliant discharges it is suggested that a monitoring program, correlated to trigger levels is established. It is intended that the program directly notifies operators, and potentially the regulator, when non-compliant discharges occur, for the initiation of a predetermined contingency plan, that will form part of the proposed dredge management plan.

It is anticipated that during the construction period, a significant discharge of water from dredge material dewatering and surface water runoff will require discharge offsite. It is therefore recommended that leach testing is undertaken on samples of the proposed dredge material to identify contaminants. These test results will provide guidance for the dewatering process design and adoption of surface water quality mitigation measures.

A review of other proposed dredge placement facilities within the Port, suggested that, with the six (6) cell proposed design, adapted in accordance with a water quality model, using further dredge material data, water quality licence discharge limits is likely to be achieved.

The catastrophic failure of the proposed 18m high containment embankment could result in the cascade of the dredge material into the marine environment potentially causing harm to the marine environmental Stormwater management at the dredge material placement facility is essential to the integrity of the embankment, and appropriate measures will reduce the potential of collapse.

A hazard categorisation of the embankment was undertaken to assist with the adoption of the appropriate standard of stormwater protection. The assessment identified a “high hazard” from the catastrophic failure of the embankment, implying a substantial spillway capacity was required. Whilst the categorisation of the structure should be consistent throughout the design, the assessment alternatively indicated that the impact of a failure to contain incident was considered “low hazard”. This evaluation, combined with the review of other industrial discharge agreements within the Port, resulted in the adoption of the lower hazard category “significant hazard” for the capacity to contain or design storage allowance criteria within this assessment.

Spillway and sedimentation pond capacities and arrangements were investigated using standard methodology. Both investigations provided indicative designs to achieve the required standard of protection.

Section 1 Introduction

1.1 Background

Sediment is proposed to be dredged from an area of Curtis Bay adjacent to the LNG facility on Curtis Island to provide for a navigation channel, swing basin and berthing pocket for LNG tankers to gain access to the LNG terminal. The dredged channel will connect to the established Targinie Channel. The dredging will entail removal of an estimated 8 million m^3 of sediment prior to the operation of the LNG facility with additional maintenance dredging, to retain the channel during the 20 year lifespan of the facility.

A site to the north of the LNG facility, on Curtis Island, has been selected in an options assessment, for the dredge material placement facility. This area is located to the south of Laird Point and will be referred to in this document as the Laird Point dredge material placement facility. The intention is to create a bunded area, with the construction of an 18 m high containment bund that will provide the capacity to retain the estimate capital and maintenance dredge material (13.2 million m^3) for the life of the project (Figure 1.1).

It is proposed that dredged materials will be transported hydraulically to the Laird Point dredge material placement facility. The mixture of water and sediment will be pumped directly from the dredger through a pipeline. Settling of the dredge material slurry, to remove sea water, will occur through a series of ponds and sluices at the facility with the seawater being return, after suitable treatment, into the marine environment.

1.2 Site Description

The Laird Point dredge material placement facility is located approximately 13 km northeast of Gladstone, Queensland on Curtis Island. Curtis Island is within the Curtis coast region, which consists of Raglan Creek to the north, Colosseum Inlet to the south and the Capricorn Group of islands to the east. The western boundary is defined as the landward edge of the coastal catchments (the Boyne River, Calliope River and part of the Fitzroy River catchment) within the local government areas of Gladstone City and Calliope Shire. The Curtis Island Basin has a total catchment area of 576 km^2. Curtis Island is 45 km long and a maximum of 14 km wide (ANRA, 2007). The major drainage feature on Curtis Island is Graham Creek, located in the adjacent catchment to Laird Bay. The creek channels a significant portion of surface water runoff from the southern half of Curtis Island into The Narrows, an estuarine passage separating Curtis Island from the mainland.

The LNG dredge material placement facility footprint covers some 500,000 m^2 of inter-tidal (mainly saltpan) area together with further a similar amount of land-based areas. Review of topographical maps of the study area indicate that water features at the site are limited to minor drainage features, such that the smaller upper catchments would result in water flow only occurring during and immediately after rain events. During flood events, runoff is predicted to contain high sediment loads, as flows erode the upper catchment alluvials. Downstream of the proposed LNG dredge material placement facility are the intertidal flats vegetation communities of saltpan and mangroves. These communities are protected by the Department of Primary Industry and Fisheries (DPIF).

1.3 Process Overview

Material arising from the main dredge is to be placed ashore to the south of Laird Point in a specially constructed dredge material placement facility. The following details provide an outline of the proposed dredge works, they are summarised from Laird Point Placement Facility Concept Description,(GLNG Ref: 1603-HRW-2-3.3-9038-PDF, HR Wallingford, 5th March 2009):

- The dredge operations are proposed to comprise the formation of a swing basin dredged to -13.5 m LAT linked to the Targinie Channel by a 200m wide channel dredged to -13m LAT. It is estimated 8,000,000 m^3 of material will be dredged to create the channel, berthing and manoeuvring areas.

URS

Client

Project

GLADSTONE LNG PROJECT
HYDROGEOLOGICAL ASSESSMENT
DREDGE MATERIAL PLACEMENT FACILITY

Drawn: AA | Approved: JB | Date: 22-03-2009

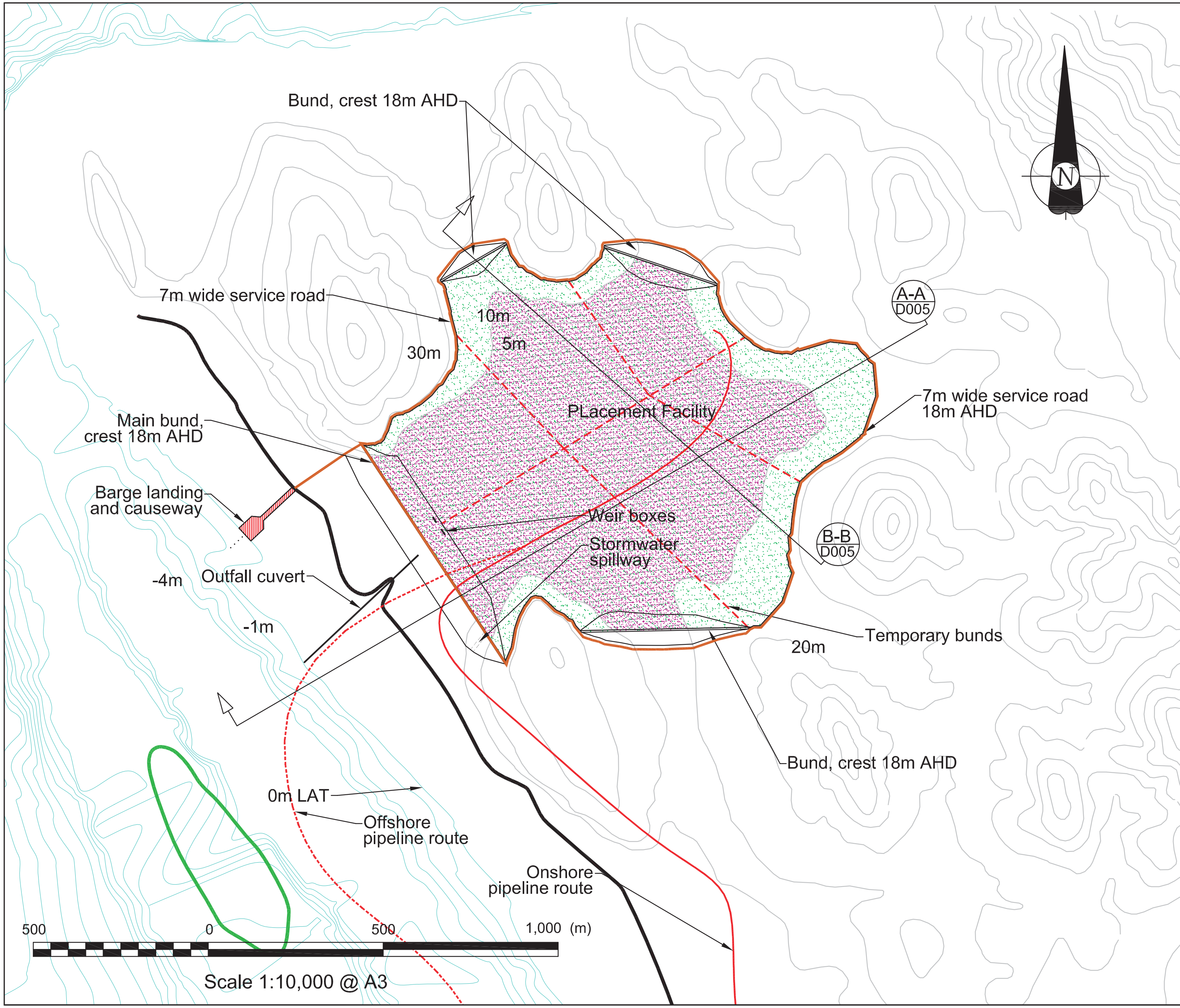
Job No.: 4262 6220 | File No. 42626220-g-788.cdr

Title

STORMWATER MEASURES
CONCEPT DESIGN

Figure: 1.1

Rev. B | A4



NOTES:

Depths are in metres relative to LAT

Land contours are in metres relative to AHD

All dimensions in metres

All co-ordinates in MGA Zone 56, Datum GDA94

Bathymetry supplied by GPC in drawing no. 906-0014, dated 28/05/08,

Layout of dredged areas is provisional and indicative

Extents of phase 1

Extents of phase 2

REVISION	DESCRIPTION	DATE

Drawing Status: DRAFT

CLIENT:

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PROJECT: GLNG

DRAWING TITLE: Detail of Laird Point Placement Facility

DRAWN BY: RER	CHECKED BY: SDU
SCALE: 1:10,000 @ A3	DATE: 05-Mar-09

GLNG DRAWING No: 1603-HRW-2-3.3-9041-PDF

DRAWING No: EBR4320\108\D003 | REV: B

- Due to the material composition, particularly the presence of pockets of hard rock, the most technically suitable and cost effective dredging plant is a large or medium sized Cutter Suction Dredgers (CSD). The CSD dredging method is also suitable as the area is generally in sheltered waters.
- A pipeline will be used to transport the dredged material from the dredging operations to the placement facility. The mixture of water and soil (a maximum of 30% solids to water ratio) particles will be pumped directly from the dredger through the pipeline into the confined area at Laird Point. It is anticipated that at least one booster pumping station will be required to convey the dredge material.
- The dredge placement facility is proposed to cover an area of approximately 120 ha, and provides air space for approximately 13.2 million m^3. The area selected is a low lying valley area (~5 m AHD), with elevated areas encompassing the site to the north, south and east (~20m AHD). To the west the valley opens up to Port Curtis, with a margin of mangroves separating the valley flow from the sea (Figure 1.1). The base of the valley is predominately salt pan, appearing to be inundated with sea water only during high tides.
- To facilitate development of this area into the dredged material placement facility, a main bund will be required across the saddle along the intertidal area. The bund is to be developed in stages, in the first instance being constructed to 10 m AHD, then later in the construction period, being increased to 18 m AHD. Three smaller bunds will also be required, two to the north and one to the south, to provide additional capacity anticipated for maintenance dredging (Figure 1.1).
- Access to the site for both plant and workforce is proposed to be via a causeway which is to be constructed on the existing tidal surface.

1.4 Scope of Work

This surface water environment assessment has included an investigation of the water resources of the proposed dredge material placement facility on Curtis Island in the context of environmental values as defined by the *Environmental Protection (Water) Policy 1997*. The value of these resources to the community and the environment will be discussed in terms of current legislation, water quality, regional hydrology, existing conditions of onsite drainage and flow regimes in a three phased assessment. The assessment has additionally assessed the potential impacts from development activities on the environmental values and reviewed potential mitigation measures.

A phased approach was undertaken due to time and resource constraints; however this has allowed for the focused evaluation on potentially significant impacts early in the option assessment. The following three phases of work has been undertaken:

Phase 1: A focused assessment on key potential impacts of the LNG dredge material placement facility in regard to the surface water environment, as part of the EIS.

Phase 2: A focussed assessment of the existing environment in relation to environmental values. The phase will include a site visit to describe the physical, chemical and biological characteristics of the study area, and may also incorporate water quality, hydrological and hydraulic assessments. This will undertaken prior to the development of the dredge management plan.

Phase 3: A consolidation of the impact assessment, considering water supply, as well as stormwater and water quality management, providing mitigation measures and undertaking a risk assessment. It is envisaged that details of the placement layout and processes will be available at this stage, enabling a comprehensive assessment of impacts to the surface water environment. This will be included in the dredge management plan.

Table 1.1 lists the phase of the investigation that addresses the Terms of Reference for an Environmental Impact Statement Gladstone LNG (Santos), August 2008.

Section 1 Introduction

Table 1-1 Terms of Reference

Terms of Reference Section	Description EIS	Section
2.5.2 Water Supply	Water usage by the Project for raw and treated water for the various processes and the sources of water for construction and operation.	Phase 3
	Any onsite water storage and treatment facilities.	Phase 3
	An assessment of the capability of the water network to provide the necessary demand.	Phase 3
2.5.6 Stormwater	Amount and nature of stormwater generated for on or offsite treatment and disposal and facilities proposed to accommodate these streams.	Phase 1 – Section 4.4 and 4.5
	Site layout plans should be provided incorporating conceptual plans for stormwater management facilities including descriptions of discharge requirements during construction and operation.	Phase 3
	Proposals for drainage structures and dams and an overall site water balance	Phase 1 – Section 4.4 and 4.5 / Phase 3
3.4 Surface Water Resources – Existing Environment	Description of existing surface water in terms of physical, chemical and biological characteristics.	Phase 2
	Description of existing surface drainage patterns, ephemeral water systems, permanent and episodic wetlands, overland flows, history of flooding including extent, levels and frequency.	Phase 2
	Environmental values of the surface waterways of the affected area in terms of: Values identified in the EPP (Water); physical integrity, fluvial processes and morphology of watercourses; hydrology of waterways, in particular the interconnectiveness of surface water and aquifers to adjoining features; and any Water Resource Plans relevant to the affected catchments.	Phase 2
3.4 Surface Water Resources – Potential Impacts and Mitigation Measures	The potential impacts the Project may have on the flow and quality of surface waters from all phases of the Project, and the proposed mitigation measures of these impacts.	Phase 1 – Section 3.2 / Phase 3
	Chemical and physical properties of any waste water including stormwater at the point of discharge	Phase 1 – Section 3.2 / Phase 3

Section 1 Introduction

Terms of Reference Section	Description EIS	Section
	into natural surface waters, and the potential effects of effluent on flora and fauna.	
	The results of a risk assessment for uncontrolled releases to water due to system or catastrophic failure, implications of such release for human health and natural ecosystems, and list strategies to prevent, minimise and contain impacts.	Phase 1 – Section 4.2

This report presents Phase 1 of the Laird Point dredge material placement facility assessment of the surface water environment.

As discussed above, Phase 1 of the assessment focuses on potential key impacts in regard to the surface water environment. A review of potential impacts identified two impacts that could result from poor water management, these are:

- non-compliant water quality discharge to the receiving environment from insufficient treatment.
- catastrophic failure of the containment embankment due to deficient stormwater management and/or design.

These impact and their potential mitigation measures are discussed in the Water Quality Management and Stormwater Management sections of the report, respectively.

Section 2 Environmental Values

The *Environmental Protection (Water) Policy 1997* (EPP, 2003) seeks to protect and/or enhance the suitability of Queensland's waters for various beneficial uses. The policy identifies environmental values for waters within Queensland and guides the setting of water quality objectives to protect the environmental values of any water resource. The environmental values include the biological integrity of the aquatic ecosystem and recreational, drinking water supply, agricultural and/or industrial uses.

Within the proposed LNG dredge material placement facility there are no named watercourses or minor tributaries. However watercourses on Curtis Island, such as Graham Creek, located in the adjacent catchment, and waters surrounding Curtis Island will be protected under the EPP Water. Additionally, the pristine "Narrows" and the Great Barrier Marine Park should be considered as receiving waters of any discharge from the site.

Local government, industry and the Gladstone Port Authority are involved in a collaborative project as part of the Gladstone Harbour Protection and Enhancement Strategy that has identified preliminary environmental values for some waterways in the Curtis Coast region.

Environmental values adopted for this project have been identified through the Strategy's preliminary environmental values (BCC, 2002) and are summarised in Table 2.1.

- Cultural Heritage:

The Curtis Coast region has a unique historical background with a diversity of features and places of cultural heritage significance including memorials, shipwrecks, middens and lighthouses. The region is of cultural significance to Indigenous Traditional Owners and fulfils an essential role in their traditional and contemporary lifestyle.

Marine areas and islands such as the Capricorn Group, The Narrows and Gladstone Harbour are within the Great Barrier Reef Region, most of which was inscribed on the World Heritage List in 1981. A World Heritage listing obliges governments to protect, conserve, present, rehabilitate and transmit to future generations these World Heritage Areas (EPP, 2003).

- Aquatic Ecosystem:

The undeveloped coastal areas within the Curtis Coast region contain sites of high conservation value such as a diversity of wetlands, seagrass beds, dugong habitat, turtle nesting beaches, coral cays and planar reefs (EPP, 2003).

The coast has been subject to a number of pressures as a result of industrial and social development. Building of the Awoonga Dam has resulted in a significant reduction in freshwater flows at the mouth of the Boyne River, which in turn has had significant adverse impacts on some fisheries and possible impacts on coastal ecosystems (EPP, 2003).

- Primary Industries:

On Curtis Island, land use is characterised largely by various areas of State owned lands (including some protected areas), national parks and forestry and cattle grazing.

The key industrial land uses in the Curtis Coast region include the Port of Gladstone; the Gladstone State Development Area and associated major infrastructure; major urban centres at Gladstone, Boyne Island, Tannum Sands and Calliope.

Commercial fisheries in the region access the inshore and offshore areas of Curtis Island and the Narrows. A significant commercial mud crab fishery also exists within Port Curtis.

- Recreation:

The recreation amenity of Curtis Island, and more generally the Curtis Coast region, is high, due to the coastal resources available and cultural sites.

Table 2.1 Environmental Values for the Watercourses and Receiving Environment of the LNG Dredge Material Placement Facility

Environmental Values	Relevance to Curtis Coast Region
Protection of high ecological value aquatic habitat	✓
Protection of slightly to moderately disturbed aquatic habitat	✓
Protection of highly disturbed aquatic habitat	X
Suitability for human consumers of aquatic food	✓
Suitability for primary contact recreation (e.g. swimming)	✓
Suitability for secondary recreation (e.g. boating)	✓
Suitability for visual (no contact) recreation	✓
Protection of cultural and spiritual values	✓
Suitability for industrial use (including manufacturing plants, power generation)	✓
Suitability for aquaculture (e.g. red claw, barramundi)	✓
Suitability for drinking water supplies	X
Suitability for crop irrigation	X
Suitability for stock watering	✓
Suitability for farm use	✓

Table Notes:

✓: River basin is suitable for the environmental value.

X: River basin is not suitable for the environmental value.

Changes to the Environmental Protection (Water) Amendment Policy (No. 1) 2008 brought into effect on the 1st January 2008 have been taken into account within this assessment.

Section 3 Surface Water Quality Management

3.1 Overview

As discussed above, non compliant discharges have been identified as one of the key impacts that could cause harm to the environment from the dredge material placement facility. The following section provides guidance on potential measures to avoid, reduce and manage the impacts to an acceptable level.

Figure 1.2, attached, provides a schematic of the proposed Surface Water Management Strategy for the dredge material placement facility. The following section provides guidance on the potential discharge requirements and processes. At this preliminary design stage it is too early to specify mitigation measures and treatment designs, but these will be assessed and included in the dredge management plan when options have been further developed.

3.2 Water Quality Guidelines

In Queensland, effluent discharges to the marine environment are regulated by the Environment Protection Authority, Queensland (EPA). 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 LNG dredge material placement facility have been established.

This assessment considers ambient water quality objectives as a guide to recommended water quality in the marine environment. However, it must be noted that these are not discharge criteria, and therefore agreement on discharge limits is required from the EPA.

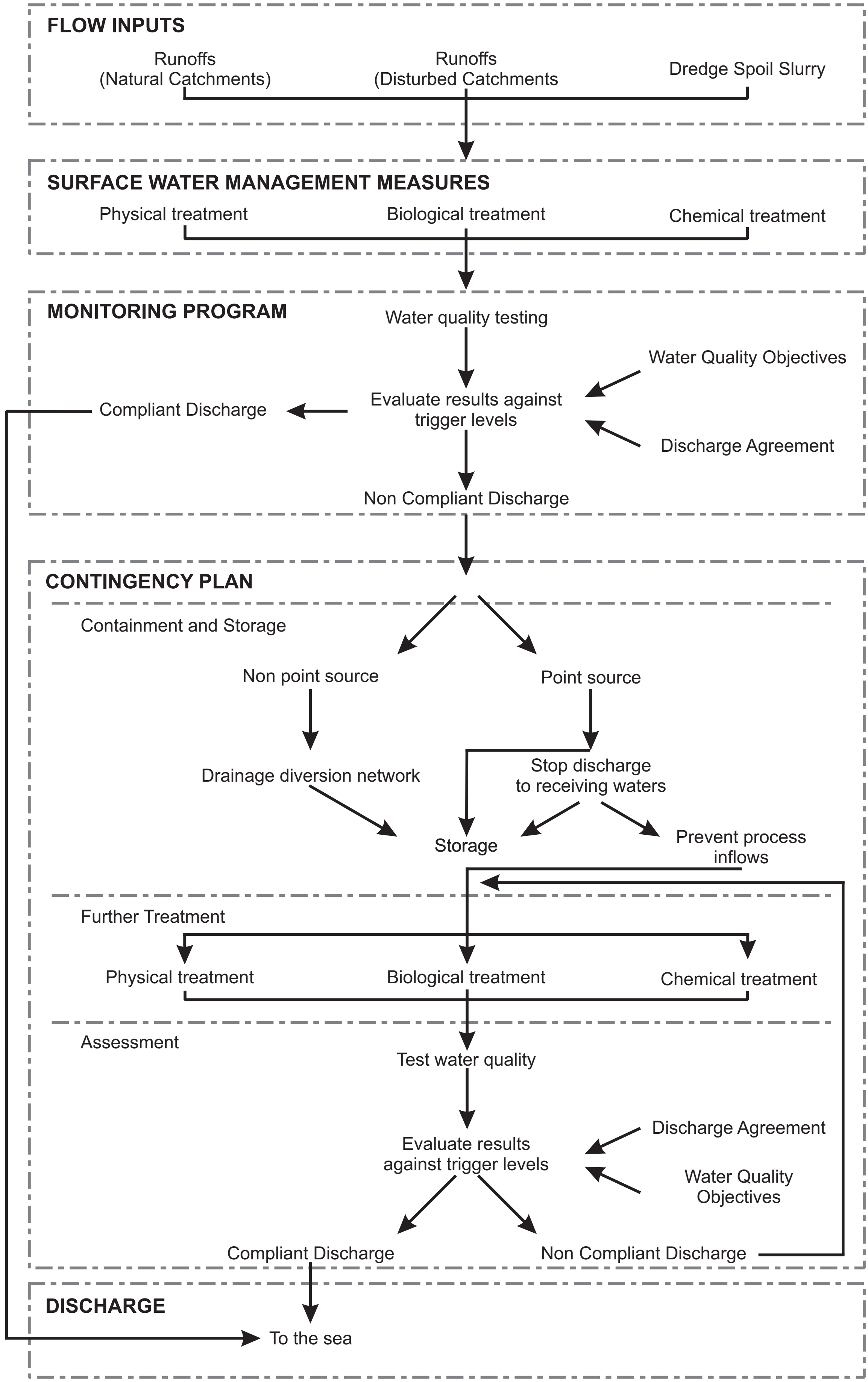
The Australian and New Zealand Environment and Conservation Council Guidelines 2000 (ANZECC) provide guideline values or descriptive statements for environmental values to protect aquatic ecosystems and human uses of waters (e.g. primary recreation, human drinking water, agriculture, stock watering).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

The Queensland Water Quality Guidelines 2006 (QWQG) developed by the Environmental Protection Agency (EPA) Queensland provide:

- guideline values that are specific to Queensland regions and water types; and
- a process/framework for deriving and applying local guidelines for waters in Queensland.

Stormwater runoff and dewatering effluent is proposed to be discharged into the marine receiving environment. In this case the receiving water is The Narrows and Great Barrier Reef World Heritage Area (GBRWHA). Relevant water quality objectives for this discharge were therefore identified from QWQG (2006) to support and protect different environmental values for the GBRWHA (refer to Table 3-1). The physio-chemical indicators were obtained from the Central Coast Region enclosed coastal values. Salinity guidelines were obtained from Appendix G of the QWQG (2006).

Monitoring of local marine water quality was undertaken by WBM (December 1998 and December 2000) for the marine environment assessment of this EIS, and discussed in detail in section 8.7. A summary of the results of this monitoring are presented in Table 3-1 and Table 3-2 for comparison against the relevant water quality guidelines. The ranges provided are taken from Site 6, Curtis Island (2), the closest water quality testing site to the anticipated discharge dredge material placement facility location. However, there is little variance in results between the six (6) testing locations. For further details of the water quality testing undertaken and the respectively results, refer to Section 8.7 and Table 8.7.2.



Client	Project	Title
URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**SURFACE WATER MANAGEMENT STRATEGY**

Drawn: AA	Approved: SM	Date: 11-02-2009	Figure: **1.2**	Rev. A
Job No.: **4262 6220**	File No. 42626220-g-789.cdr			A4

Section 3 Surface Water Quality Management

Table 3-1 Physio-chemical Water Quality Guidelines for waters of Curtis Island

Physio-Chemical Parameters	Enclosed Coastal (QWQG, 2006)	Ambient Marine Water Quality (range of results from Table 8.7.2)
Ammonia N (µg/l)	8	<5 – 64
Oxidised Nitrogen (Nitrate and Nitrite) (µg/l)	3	<5 – 46
Organic N (µg/l)	180	78 – 300
Total N (µg/l)	200	78 – 364
Filterable Reactive Phosphorus (µg/l)	6	<5 - 50
Total Phosphorous (µg/l)	20	<10 – 50
Chlorophyll-*a* (µg/l)	2.0	-
Dissolved Oxygen (%saturation)	90 – 100	82 – 120
Turbidity (NTU)	6	3 – 169
Suspended Solids (mg/l)	15	9 – 116
pH	8.0 – 8.4	7.81 – 8.37

As the QWQG (2006) do not provide guidance on heavy metal concentration, the ANZECC (2000) guidelines were used for the assessment of metal contaminants for marine water (refer to Table 3.2)

Table 3-2 Heavy metal guidelines for the waters of Curtis Island

Heavy Metal Parameters	Marine Water Guidelines (ANZECC, 2000) *	Ambient Marine Water Quality (range of results from Table 8.7.2)
Cadmium (µg/l)	5.5	<1
Copper (µg/l)	1.3	<1 – 2
Lead (µg/l)	4.4	<1
Mercury (µg/l)	0.4	<0.1
Nickel (µg/l)	70	<1 -13
Silver (µg/l)	1.4	-
Zinc (µg/l)	15	<1 - 5

*95% level of the guideline (ANZECC, 2000)

The results indicate that there is significant variation in many of the key parameters relevant to the proposed discharge from the dredge material placement facility, many of which exceed the QWQG (2006) guidelines. This includes suspended sediment and turbidity.

The WBM ambient turbidity values are also consistent with testing undertaken by GHD in February 2004 to April 2005 at Port Curtis (GHD, September 2005), with a maximum test value of 125 NTU and a 95th percentile statistic of 38 NTU

Results presented in Table 3-2 indicate that the ambient metals concentrations in marine water are below guidelines provided by ANZECC (2000).

Furthermore, two previously proposed dredge placement facilities in the Port Curtis area; The Wiggins Island Coal Terminal, and RG Tanna Coal Terminal, discuss anticipated discharge requirements in their dredge disposal plans, (Central Queensland Ports Authority, July 2007 and Central Queensland Ports Authority, September 2005, respectively). At the Wiggins Island facility a maximum allowable concentration of 50 mg/l suspended solids has been proposed, whilst the RG Tanna Coal Terminal facility proposes 60mg/l, above background levels. RG Tanna Coal also has proposed a trigger level for turbidity is implemented at 40 NTU, in accordance to the "Protection of the Marine Environment During Dredging and Dewatering" (GHD, September 2005) report.

3.3 Contaminant Assessment

An investigation of sediment in the proposed dredging area was undertaken to provide baseline information on the sediment type and identify levels of contamination present. No specific leaching tests have been conducted on potential dredge material from the proposed areas to date, and so characteristics of dewatering effluent and stormwater runoff cannot be specifically defined. Undertaking leaching test to provide additional information for the evaluation of discharged water will also allow appropriate mitigation measures and monitoring parameters to be refined. In the absence of this data, implied water quality values have been developed from existing water and soil assessments undertaken for the project and a review of other capital dredging operations in the vicinity of the proposed dredge site.

3.3.1 Dredge Sediment

In general, the dredge areas are comprised of marine deposits in the form of soft clays, loose sands and gravels. The marine sediment was generally grey brown in colour and contained shell fragments. An investigation was conducted in 2008 by URS to establish sediment baseline conditions and identify contaminants present in sediment in the proposed dredge area. Prior to this study a number of other investigations had been conducted in the vicinity of the South Passage to characterise marine sediment in view of dredging activities.

The analytical parameters tested as part of the sediment investigation were as per the requirements of the National Ocean Disposal Guidelines for Dredged Materials (NODGDM, 2002) and the Queensland Environmental Protection Agency Environmental Investigation Levels (QEPA - EILs).

A total of 105 primary samples were submitted from a number of bore holes for metals analysis including aluminium, antimony, arsenic, cadmium, chromium, copper, iIron, lead, manganese, mercury, nickel, silver, and zinc. A summary of analytical results exceeding the Investigation Levels (ILs) from the adopted guidelines is given in Table 7-1 of "Marine Sediment Investigation – Environmental Investigations of Proposed Capital Dredging at China Bay and Pipeline Crossing at the Narrows, Gladstone – Draft Report".

The majority of the samples are considered uncontaminated when compared to the various guidelines. Elevated concentrations of total metals; nickel, mercury, and antimony, were recorded in several of the samples, when compared to the NODGDM (2000). Elevated manganese, copper, arsenic, and chromium were recorded in some samples when compared to the QEPA - EILs.

It was observed that generally, nitrate, nitrite and ammonia levels in sediment samples reported concentrations less than the laboratory limit of reporting. Hydrocarbon compounds, pesticides and PCB results were also less than the respective reporting limits. All Phenol levels were recorded below NEPC (1999) guidelines.

It was noted that hydrocarbon compounds were not detected above guideline levels.

Acid Sulfate Soils

Santos commissioned GeoCoastal to collect sediment cores for environmental and ASS testing from the proposed GLNG dredge area, in June 2008, as a preliminary study to be used in conjunction with the subsequent URS marine sediment investigation.

The results from the offshore ASS assessment revealed that while shallow, near shore accreted silt/clay sediments retained a high potential acid sulfate soil (PASS), the seabed sequence within the main marine passage where dredging is proposed revealed a negative net acidity, due to the high proportion of shell material (GeoCoastal, 2008).

3.3.2 Curtis Island Groundwater

Groundwater sampling was undertaken in six bores drilled in the Curtis Island LNG facility study area, both shallow and deep. arsenic, cobalt, manganese, nickel and zinc were detected in high concentrations, exceeding ANZECC (2000) fresh water guidelines. Results were also assessed against ANZECC (2000) marine guidelines and Australian Drinking Water Guidelines (ADWG), indicating elevated concentration of Arsenic, Cobalt, and Manganese and Nickel.

For further detail of the results, refer to section 8.6 of the EIS report.

3.3.3 Other Local Dredging and Disposal

Wiggins Island

Wiggins Island is located within Port Curtis adjacent to Curtis Island. A dredge environmental management plan (Central Queensland Ports Authority, July 2007) was established for dredging works to develop the Wiggins Island Coal Terminal. The plan predicted the hydraulically delivered soil particulate distribution; this is presented below in Table 3.3.

Table 3-3 Percentage of solids in dredge material, by volume

Soil Type	Predicted Percentage of Composition
Silt with no gravel	5%
Sand with 5% gravel	45%
Clays with 10% gravel	35%
Gravel 50% clay bound	15%

As indicated above, the plan discusses the management of the fine sediments, predominantly silt and clay. The plan does not address any other contaminants likely to be a result of the runoff from the dredge material disposal.

RG Tanna Coal Terminal 4th Berth

In September 2005, the Central Queensland Ports Authority (CQPA) prepared a dredge management plan for the proposed 4th berth at the RG Tanna Coal Terminal. The project area is in deep subtidal water within the estuary of Port Curtis immediately adjacent to the main shipping channel of the Port of Gladstone. To facilitate the construction of the proposed wharf, a berth pocket was to be dredged to RL -18.8 m and a departure / approach channel to RL -16.0m. The dredge management plan established that all material to be disposed of in the reclamation area will contain concentrations of contaminants which are below the appropriate guidelines (as of May 1998).

As discussed above a supplementary report to the application of the 4th berth indicated that the ambient turbidity for Port Curtis varies considerably over time. The majority of recordings reviewed were between 0-10 NTU, with regular elevations between 20 and 40 NTU during late summer months. Evaluation of the discharge from the dewatering of the placement facility, are only greater that 38 NTU for 5% of the time.

3.4 Surface Water Management Strategy (Mitigation Measures)

It is recommended that a Surface Water Management Strategy, also referred to as a predictive monitoring program, is established for the LNG dredge material placement facility as the primary mitigation measure. The strategy, defined in Figure 1.2, may guide the selection and implementation of treatment processes, and therefore could reduce the potential impact of discharges to the receiving environment. This would be included in the DMP.

Section 3 Surface Water Quality Management

This section describes in further detail recommended components of the strategy and its execution.

3.4.1 Water Quality Modelling

A wide range of factors affect water quality, including the amount and rate of pollutant input, the patterns of water movement/exchange and internal physical and biological processes. To improve the understanding and design of water treatment processes, it is recommended a water quality model is established for the proposed dredge material placement facility. A water quality model, such as a pollutant export model, utilises contaminant characteristics of the discharge water to predict contamination concentration and treatment processes. It also provides a whole of system appreciation of water quality issues include long term pollutant accumulation.

A water quality model may provide essential support to achieve water quality objectives and develop efficient mitigation measures. It is recommended that this component of the strategy is developed by the facility designers during the conception phase until detailed design.

3.4.2 Surface Water Management Measures

The strategy will incorporate either one or a series surface water management measures to address potential impacts. The source of surface water is considered inherent to the management process and has been classified into three categories:

1) Stormwater runoff from natural catchment
2) Stormwater runoff from disturbed catchment
3) Effluent from dredge material

The use of a range of water filters already available in the natural environment is a pertinent way to improve water quality from natural catchment runoff. For instance, grassy swales (trapezoidal channels lined with vegetation) or infiltration ditches (these include a vegetated infiltration trenches within the invert of a swale), provide enhanced reduction of both particles and nutrients. It is proposed that the swales and ditches direct the natural catchment runoff away from the disturbed site and discharge directly to the marine environment. Inclusion of these mitigation and containment measures will be promoted in the facility design.

For stormwater runoff from the disturbed catchment area, (including compacted dredge material), it is recommended an engineered approach is adopted. A detention type storage, such as a sedimentation basin may provide effective removal of sediments and contaminants. The efficiency of the basin should be assessed using a water quality model prior to construction. Further detail regarding design improvements and required capacity are discussed in the following sections.

To improve compaction and reduce the storage volume required for the dredge material, dewatering ponds are to be used. The ponds use gravity to separate the sea water from the heavier dredge sediment. However, fine sediment and clay in the water take substantial time to settle and if insufficient settling occurs this can result in the release of highly turbid water, potentially impacting marine flora and fauna.

A key consideration of the design of the dewatering ponds (sedimentation ponds), is the particle size and properties of suspended particles in the water. The retention period within a sedimentation pond is essential to allow different particle sizes to settle out. The proposed sedimentation ponds design therefore adopts a series of 6 ponds (cells) to enhance the settlement performance.

The capacity of the bunded area needs to take into account the total volume of the placed material and proportion of the transport waters so that potential overflows are prevented and settlement of fines can occur. Furthermore pond depth and volumes are to be designed with an allowance to provide sufficient sediment storage and to ensure that resuspension of settled sediments does not occur. Adoption of adjustable weirs between cells allows regulation of the discharge flows. The dredge slurry/sea water passes slowly through these structures, allowing the sediment particles to settle between each pond. The inlets and outlets are to be arranged to ensure that short circuiting is avoided and detention time is maximised. The adjustable system further ensure that the system has capacity to store flows, by raising weirs, rather than reducing dredging rate, to respond to potential non compliance.

The settling rate of fines varies for clays and silts, and can only be roughly estimated using empirical methods. To provide greater certainty of the pond performance, it is suggested that column tests on the bore holes from the dredge site are undertaken. The test provides settling rates for each component of the dredge material, and estimates of required velocities to achieve settlement.

The dewatering treatment proposed for the dredge placement facilities of Wiggins Island and RG Tanna coal terminal 4th berth, is a similar process. However, both designs, with adjustable weirs and bunds creating a series of ponds, adopted four(4) cells, instead of six (6) as proposed at Curtis Island. The additional two (2) cells are considered to provide an expanded settlement zone. Furthermore, design reports for the two existing facilities discussed that numerical modelling predicted only three (3) cells were required to achieve compliant discharge, and the additional fourth cell was to provide supplementary storage during serve flood events. The model of the Wiggins Island proposed facility predicted a maximum suspended solid concentration of 37mg/l, achieving the anticipated constraint of 50mg/l.

Considering the above, the proposed 6 cell dewater process proposed at Curtis Island is likely to achieve water quality licence discharge limits, if the design is adapted in accordance with a water quality model of the process and further dredge material data.

It is recommended that a water quality model, such as that described in Section 3.4.1, is used to confirm the required duration of the retainment and other design specifications. Summarised below are techniques proposed to improve sedimentation within the ponds:

- Adopt a series of ponds to enhance the settlement performance. In this design the first pond would remove the coarse sediment, while a second sedimentation pond would remove the fine particles through extended retention.
- Design the size and shape of sedimentation ponds to optimise their efficiency. It is recommended that the design of sedimentation basins should consider:
    - A permanent pool to reduce flow velocities and provide storage of settled sediment. The basin should be designed approximately 1.5m permanent pool depth with an additional 1m for sediment to accumulate.
    - Both inlet and outlets of ponds should include localised scour protection and for process areas some form of gross pollutant trap.
    - Ideally the length to width ratios of ponds should be set to 3L:1W, to slow flow velocity within the pond.
    - Consider the surrounding environment and climatic factors
- Adopt a maintenance regime; the clearing of sediment regularly will preserve the sediment settling zone.
- Construct islands, baffles and weirs, and designing numerous inflow points, to increase the hydraulic efficiency of sediment settling.

3.4.3 Monitoring Program

The implementation of a Water Quality Monitoring Program to test, assess and record discharges is recommended. This program is intended to test both point and non-point discharges, and by evaluating results against predetermined trigger levels (which can be set below guideline or condition limits) it will provide a mechanism to assess treatment performance, enabling optimum performance to be obtained, as well as assessing compliance. The results would be used to notify operators or regulators on a routine basis of compliance issues and to trigger the implementation of a Contingency Plan to cease/prevent non-compliant discharge if required. The Monitoring Program is represented in the Surface Water Management Strategy in Figure 1.2.

It is proposed that water quality testing is undertaken as the initial step of the Program. The installation of automatic monitoring stations and telemetry at all point source discharge locations entering the receiving environment should be considered. Additionally, the testing of grab water samples should be used on a regular or "as needs" basis (for instance after storms) to ensure that the system works under increased flows. The testing parameters will depend on contaminants agreed within the discharge licence agreed from the EPA. It is anticipated that a range of heavy metals, turbidity, pH and electric conductivity will be assessed.

It is recommended that a number of monitoring sites are located downstream of the dewatering outlet. These include; directly downstream and within the sediment plume (if one exists), 50 m from the pipe, 100 m from the pipe, 200 m from the pipe and 500 m from the pipe. The plume assessment should also assess the water column profile, i.e. surface, mid-column and bottom.

The Monitoring Program could, through the use of automated sampling and telemetry, be used to classify results and alert when trigger levels are exceeded in advance of any breach of conditions. Trigger levels will be established from discharge licensing and water quality objectives for the site that are below specified limit.

3.4.4 Contingency Plan

The Surface Water Management Strategy may default to the implementation of a Contingency Plan when trigger levels are exceeded to prevent or cease non compliant discharge.

The Contingency Plan may include the following three phases:

1) Containment and Storage;
2) Further Treatment; and
3) Assessment.

Containment and Storage

Containment and storage of effluent and runoff could provide the opportunity to allow further treatment of contaminated water. This can be undertaken by:

- Expansion of drainage diversion network to capture non point sources discharges;
- Closing valves or gates to the receiving environment from point source discharges;
- If the source can be attributed to the dredge material, cease dredging, to undertake further analysis and treatment; and
- Store contaminated runoff/effluent in additional emergency storage ponds for further treatment.

Further Treatment

Further treatment processes will be adopted depending on the contaminants identified during the Monitoring Program. The water quality modelling may assist in the selection of further treatment methods. Treatment methods may include:

1) Physical treatment:
   - Sedimentation ponds or basins;
   - Dilution using uncontaminated water to reduce high concentrated contaminants.

2) Biological treatment:
   - A wide range of biological treatment can be used to improve water quality. In general, these take place in either aerobic or anaerobic environmental conditions. Fixed films or suspended flocks patterns are usually used for bacterial growth. This "purification" process enables denitrification,

de-ammonification or even removal of some micro-pollutants.

3) Chemical treatment:

- Treatments include the use of coagulants to oxidising Fe^{3+} and flocculants to settle suspended solids.

Assessment

Following any additional treatment further analysis will be required to ensure that the trigger levels are not exceeded prior to discharge into the receiving environment. In the event that trigger levels are exceeded, the Contingency Plan should remain enforced and additional treatments should be applied until the discharge is compliant.

Section 4 Stormwater Management

4.1 Overview

The potential failure of the proposed 20m high containment bund (embankment) could result in the cascade of the dredge material into the marine environment causing significant environmental damage. Effective design, construction and management of the dredge material placement facility is essential and in combination with a stormwater management plan will assist with reducing the likelihood of bund failure.

Initial concepts for the dredge material placement facility have proposed that a 10 m high embankment with 1:5 slopes and a 4 m crest is constructed. This initial embankment is proposed to be comprised of sand, clay, rock and a geotextile lining. Following the filling of this initial void with dredge material it is proposed that the embankment will be raised by an additional 10m potentially in a staged approach, using the dewatered dredge material.

4.2 Hazard Classification

Under the new Draft Manual for Dams v1.0 (2008) published by the EPA, the hazard category of an embankment can be based on a number of factors, including height, contaminant concentration, and the potential for environmental harm caused as a result of failure to contain and dam break. The following section assesses the hazard of the embankment for each of these categories to determine a resultant hazard level and inform the design criteria for stormwater management.

4.2.1 Hazard Category Based on Height

A dam is classified as being ‘regulated’ if it incorporates a man-made embankment and the height of that embankment is greater than 8 metres as measured between the crest and the lowest point of the toe of that embankment. As discussed above, the embankment proposed for the dredge material placement facility will be constructed to approximately 18 metres. As such, in accordance with the draft manual (2008), the dredge material placement facility must be assessed in the “Significant” to “High Hazard” category and not in the “Low Hazard” category.

4.2.2 Hazard Category Based on Contaminant Concentrations and Minimum Volume

A dam is considered to be regulated if it is likely to contain contaminants outside set concentrations or pH limits, at any time when the volume contained within the dam is greater than 50% of the dam crest volume, and the dam has a crest volume greater than a stipulated amount. These contaminant concentration limits are given by Table 3 of the Manual for Dams v1.0), and these are generally set above guidelines provided by ANZECC (2000) and QWQG (2006). In the case of the dredge material placement facility, this assessment has considered the following failure mechanisms:

- Failure to Contain – insufficient stormwater storage capacity, resulting in stormwater discharge into the marine environment.
- Catastrophic Failure - Failure - collapse of the embankment, resulting in dredge sediment entering the marine environment.

Failure to Contain – Contaminant Concentrations

To evaluate the hazard category of a failure to contain incident, runoff water quality was to be assessed against contaminant concentration limits (Manual for Dams v1.0). As discussed in Section 3, no dredge material specific leaching tests have been undertaken. However, as an initial assessment it has been assumed that the discharge water quality will be similar to those measured in the marine environment or in local groundwater. Maximum contaminant concentrations measured have been assessed against contaminant concentration limits:

Section 4 Stormwater Management

- Both deep and shallow groundwater samples taken at the proposed LNG facility study area (to the south of the dredge material placement facility); and
- Marine water quality samples undertaken by WBM (December 1998 and December 2000) for the marine environment assessment of this EIS.

The comparison undertaken provides some limited guidance on the contaminant types and concentrations that will need to be met within the runoff and discharges from the dredge material placement facility. It is recommended that leach testing is undertaken prior to further environmental assessment to confirm potential hazardous contaminant levels that are present. Table 4.1 summaries contaminant concentration limits (Manual for Dams v1.0) and maximum water quality measurement for groundwater and marine test locations adjacent to the proposed capital dredge area.

Table 4-1 Contaminant Concentrations - Groundwater and Marine

Contaminant	Hazardous Concentration Liquor[1]	Groundwater Maximum Values	Marine Maximum Values
Arsenic	1.0 mg/l	0.094 mg/l	0.001 mg/l
Boron	5.0 mg/l	-	5.8 mg/l[2]
Cadmium	10 µg/l	0.4 µg/l	<1 mg/l
Cobalt	1.0 mg/l	0.4 mg/l	-
Copper	1.0 mg/l	0.002 mg/l	0.002 mg/l
Lead	0.5 mg/l	<0.001 mg/l	<0.001 mg/l
Mercury	2 µg/l	<0.1 µg/l	<0.1 µg/l
Nickel	1.0 mg/l	0.094 mg/l	0.013 mg/l
Selenium	50 µg/l	-	-
Zinc	20 mg/l	0.04 mg/l	0.005 mg/l
Cyanide	10 mg/l	-	<0.005 mg/l
pH	5 – 9 (inclusive)	5.71 – 7.36	7.81 – 8.37
Chloride	2,500 mg/l	8,900 mg/l[2]	-
Fluoride	2.0 mg/l	-	4.1 mg/l[2]
Sulphate	1,000 mg/l	592 mg/l	-
EC	4,000 µS/cm	-	57,000 µS/cm[2]

Notes:

[1] Hazardous Concentration Limits provided in the Table 3 of the Manual for Dams v1.0

[2] Denoted above the

The high electrical conductivity (EC) and chloride values in the marine samples are a result of the marine environment and should be discounted in this analysis as this will be consistent with the receiving environment.

The low pH value recorded in once groundwater location was inconsistent with results taken from the other five groundwater wells all indicating pH within the acceptable range.

The fluoride and boron level in the marine water samples are elevated, and should be further investigated.

In general, the maximum concentrations of contaminants measured in the samples were below the hazardous concentration limits provided in Table 3 of Manual for Dams v1.0 (2008). However, it is recommended that further investigation including dredge material leaching testing should be undertaken to better define whether discharges of water could be of concern.

Catastrophic Failure – Contaminant Concentration

The potential failure of the embankment could result in the slumping of dredge sediment into the marine environment. Although the failure will include the discharge of stormwater runoff, the predominant impact may be as a result of the collapse of the dredge sediment both smothering and polluting the environment. To evaluate the hazard category of the material, the maximum contaminate levels of the dredge sediment samples (Marine Sediment Investigation, URS, 2009) have been assessed against contaminant guidelines provided in Table 3 of the Manual for Dams v1.0 (2008). Table 4.2 below provides a comparison of measured concentrations of selected contaminants against the guideline levels. Where dredge sediment contaminants levels are available, guideline concentrations are not exceeded. However, more assessment will be required to confirm this designation.

Table 4-2 Contaminant Concentration – Dredge Sediment

Contaminant	Hazardous Concentration Solid	Dredge Sediment Maximum Values
Arsenic	500 mg/kg	37 mg/kg
Boron	15,000 mg/kg	-
Cadmium	100 mg/kg	-
Cobalt	500 mg/kg	-
Copper	5,000 mg/kg	117 mg/kg
Lead	1,500 mg/kg	-
Mercury	75 mg/kg	0.2 mg/kg
Nickel	3,000 mg/kg /l	68 mg/kg
Selenium	150 mg/kg l	-
Zinc	35,000 mg/kg	-
Cyanide	2,500 mg/kg	-
pH	Net acid generation pH < 4.5	-

4.2.3 Hazard Category Based on Failure to Contain

The following assessment provides a description of the likely impacts to the general environment, humans, stock and economy, caused as a result of failure to contain (undertaken in accordance with the definitions of harm provided in Table 1 of the Manual for Dams v1.0).

- General Environment – As discussed in Section 4.2.2 of this report, uncontrolled discharge from the stormwater management ponds and dewatering ponds are anticipated to be below or consistent with ambient levels, however, additional analysis of sediment is recommended to confirm this. Overtopping may cause increased turbidity localised to the discharge site. It is predicted that minimal environmental impact is likely as a result of failure to contain. **Rating = Low**.
- Loss or harm to humans – The downstream marine environment is not used for human consumption or irrigation. As such there is unlikely to be any harm or loss to humans. **Rating = Low.**
- Loss of stock – The downstream marine environment will be impacted by flows resulting in higher suspended solids, however this is considered to be relatively minimal and it is unlikely that long term impacts to marine stock (such as mud crab, mullet, garfish and whiting) (refer to Appendix R) could result in harm or loss. **Rating = Low**.
- General economic loss – Commercial catch data indicates that commercial fishing areas include, Gladstone Port, Calliope and Boyne River estuaries, inshore and offshore of Curtis and Facing

Island and The Narrows. Uncontrolled discharges are considered to provide trivial harm to environmental values such as environmental nuisance. **Rating = Low**.

4.2.4 Hazard Category Based on Dam Break

The following assessment provides a description of the likely harm to the general environment, humans, stock and economy, caused as a result of dam break (undertaken in accordance with the definitions of harm provided in Table 2 of the Manual for Dams v1.0). This is to inform the overall embankment design. It should be noted that the bund will be designed, constructed and maintained in accordance with accepted standards.

- General Environment – Protected marine species were identified in the region. A list of species and potential impacts from embankment failure, are provided below, further detail of the marine environment is given in Appendix R.
  - **Dugongs** are known to forage on seagrass meadows within Port Curtis. Results of a seagrass meadow monitoring program conducted by DPIF in 2007 within Port Curtis recorded the highest density of dugong feeding trails at Wiggins Island. Dugong feeding trails were also recorded at Pelican Banks on the south eastern side of Curtis Island and the intertidal meadows to the north and south of Fishermans Landing. There are no recorded seagrass meadows at Laird Point, Curtis Island. Impacts from slumping of dredge material into the bay would result in increased turbidity and sediment loads within Port Curtis, possibly resulting in smothering of adjacent seagrass beds north of Fisherman's Landing. Impacts to seagrass meadows would impact on foraging behaviour of dugong in the area.
  - A pod of **bottlenose dolphins** was sighted at the Hamilton Point location during the marine subtidal survey. The **Indo-Pacific humpback dolphin** and **snubfin dolphin** are known to use the waters within Port Curtis. **Irrawaddy dolphins** are typically associated with shallow, coastal and estuarine waters, with most sightings recorded within 10 km of the coast, in waters less than 10 m deep, and within 10 km of a river mouth. Due to the migratory nature of this species and without longer term monitoring data, it is difficult to assess the frequency and duration of visits made by this species to the Port Curtis area, and therefore any impacts from embankment failure. However, the highly mobile nature of these mammals is likely to minimise impacts.
  - Most birds listed under EPBC are migratory and listed as overflying the marine area within Port Curtis. Impacts are likely to be minimal. Some migratory birds may lose nesting, resting and foraging sites such as existing mud banks in the vicinity of Laird Point in particular great egret and white-bellied sea eagle. However, this type of habitat is not limited in the vicinity. Contamination from dredge material may also be an issue.
  - Several **green turtles** were seen by researchers during the field surveys and it has been reported that The Narrows and the Calliope River mouth are major foraging areas (DNRM, 2005 in Connell Hatch, 2006). According to a study conducted by QDEH and GPA (1994) the l**oggerhead turtle** and **flatback turtle** utilise habitats in the outer harbour and occasionally move northward through Port Curtis into The Narrows. However there are no recognised nesting beaches inside Port Curtis, with the closest sites being used by flatback turtles at North Cliff Beach (Facing Island) and the main beach at Southend (Curtis Island), where annual numbers have been estimated at 25-50 per beach (QDEH & GPA 1994). However, turtles are unlikely to routine visitors to the shallow areas around the proposed dredge material placement facility.

  The Laird Point dredge material placement facility is located such that harm to a significant environmental value, such as protected fauna, is likely **Rating = High**
- Loss or harm to humans – The port is predominately used by large shipping vessels which are built to sustain large waves, as such people are not routinely in the path of the failure. Furthermore, there is unlikely to be any contamination of waters used for human consumption. **Rating = Low**.
- Loss of stock – as discussed previously, commercial fisheries in the region access the inshore and offshore areas of Curtis Island and The Narrows. A significant commercial mud crab fishery exists

within Port Curtis. This mud crab fishery is thought to be one of the largest in Queensland. Waves and sediment inundation are likely to impact crab environments and the deterioration of water quality is also likely to result in stock loss. **Rating = High**.

- General economic loss – An embankment failure could result dredge material subsided into the bay and would restrict the transportation of dredge material. This could result in economic loss to Santos (impact on operations) and other potential users of the placement facility. **Rating = Significant**.

4.3 Hazard Category Classification

The proposed dredge material placement facility at Laird Point has been categorised as a high hazard dam based on Queensland EPA new draft guidelines *'Manual for Assessing Hazard Categories and Hydraulic Performance of Dams Version 1.0, 21 August 2008'.* A high hazard category dam with an intended lifetime of between 51 and 100 years must be designed to:

- safely pass a design flood event of Annual Exceedence Probability (AEP) 0.00001 (ARI 100,000 year) (Section 4.4); and
- have a Design Storage Allowance (DSA) volume of AEP 0.01(Section 4.5).

Details of the hydraulic design of the embankment are provided in Sections 4.4 and 4.5.

4.4 Spillway Design Criteria

4.4.1 Overview

In accordance with the Manual for Dams v1.0, the spillway design capacity is dependent on both the hazard category for the embankment, determined in section 4.3, and the proposed life of the structure. The dredge material placement facility is proposed to be a permanent structure, therefore the maximum category, 51 to 100 years (see Table 4, Manual for Dams v1.0) was adopted. Classified as "High Hazard", the new spillway should have sufficient capacity to safely convey a 0.00001 AEP (100,000yr ARI) design flood event.

Although it is proposed that grassy swales divert the upper catchment (undisturbed) flows directly into the receiving environment (3.4.2), a design capacity of 0.01 AEP is considered appropriate for this structure. Therefore, the preliminary spillway design has included the placement footprint (1.34km^2) and the upper catchment area (1.20km^2), a total catchment of 2.54km^2.

4.4.2 Hydrology Analysis

Flood hydrology uses statistical or deterministic methods to estimate the depth of rainfall to occur and the likely flow, for any point within a catchment, for a particular probabilistic flood event. Hydrological assessments generally consider the catchment characteristic and local hydrological patterns for a range of event durations to evaluate the most critical, it is this duration that depths and flows are predicted.

The selection of hydrological estimation method was based from guidance provided in the technical reference Australian Rainfall and Runoff (AR&R) (IEAUST, 1987). AR&R Section 5.3 suggests, for small ungauged catchments when considerable data is available for a site, flood frequency, unit hydrograph or runoff routing methods are preferred.

A flood frequency analysis for the region was considered, however with no flow gauges on the island and other gauges within the Calliope region of significantly greater size, a flood frequency analysis was considered to provide poor representation of this small catchment. Again, with the lack of available data and the small catchment area, the complex unit hydrograph and runoff routing methods were also considered unsuitable.

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AR&R Section 5.3 also notes where no data is available for the site and little time is available to produce a design, a published regional method should be applied. Following this, the Rational Method was applied to estimate peak flows for design floods. The Rational Method is given by the equation:

$$Q_Y = 0.278 \cdot C_Y I_{t_c,Y} A \qquad \textit{Equation 1}$$

Where Q_Y = peak flow rate (m^3/s) of average recurrence interval (ARI) of Y years

C_Y = runoff coefficient (dimensionless) for ARI of Y years

A = area of catchment (km^2)

$I_{tc,\,Y}$ = average rainfall intensity (mm/hr) for design duration of t_c hours and ARI of Y years.

The Rational Method is a statistical relationship which relates rainfall of a particular probability to the flood discharge of the same probability. A paper titled "Design Floods for Small Rural Catchments in Queensland" (Weeks, 1991) discusses further analysis undertaken for rational methods application in Queensland. The paper was developed from an analysis of all gauged catchments in Queensland with a catchment area of less than $250km^2$ and more than 20 years of stream flow record.

Weeks (1991) suggested that the time of concentration estimated by Bransby Williams formula (IEAust, 1987) gives extended durations therefore resulting in unrealistically high runoff coefficients. The alternate Pilgrim and McDermott formula (1982) was adopted as a result of Weeks (1991) analysis this provided conservative, shorter durations. The hydrological estimations for the adjacent watercourse adopted the Pilgrim and McDermott formula, a slightly more conservative approach.

Design rainfall event storm intensities for AEP up to 1 in 100 (0.01) were derived from AR&R (IEAust, 1987). Design storm depths for the probable maximum precipitation (PMP) were determined using the Generalised Short Duration Method (Bureau of Meteorology, 2003) and the 1 in 100,000 AEP rainfall intensities were interpolated between 1 in 100 and PMP intensities using the methods outlined in (IEAust,1987)

Two methods of calculating the AEP 0.1 runoff coefficient were undertaken;

- Queensland Main Roads Department (MRD) Bridge – Branch Method (IEAust,1987), and
- Weeks (1991).

The Weeks (1991) method was developed for catchments with limited landuse and terrain information. The MRD method considered catchment characteristics and provided a higher flow estimate. In view of this, a conservative approach was adopted and the MRD method was used.

The 0.1 AEP runoff coefficient was adjusted for a range of flood probabilities using Equation 2, developed by Weeks (1991).

$$C_Y = (0.54 \cdot Log(Y) + 0.46) \cdot C_{10} \qquad \textit{Equation 2}$$

As discussed above the MRD method considers a number of catchment characteristics these include:

- Rainfall intensity
- Catchment slope
- Catchment storage
- Ground characteristic and cover

The anticipated smooth flat surface provided by the sandy dredge sediment correlated with a high runoff coefficient. This value is further extrapolated to 100% runoff in extreme rainfall events.

The runoff coefficients, intensities and peak flows determined by using the above methodology is presented below in Table 4-3

Table 4-3 Predicted peak flows

Flood Event (ARI)	100	10,000	100,000
Runoff Coefficient	189%	100%	100%
Rainfall Intensity (mm/hr)	109	227	291
Estimated Flow (m^3/s)	69	160	206

4.4.3 Hydraulic Analysis

A number of spillway layouts for the 0.00001 AEP flood event were configured using the rectangular weir equation:

$$Q = C_W \cdot L \cdot H^{\frac{3}{2}}$$ Equation 3

Where Q = discharge (m^3/s)

C = weir coefficient, 1.4

L = length of weir crest (m)

Z = depth to datum (m)

H = head on the weir measured from the crest (m)

Evaluated weir configurations are shown in Table 4.4. All designs have a 0.00001 AEP spill capacity.

Table 4-4 Spillway Design Layouts

Height (m)	Length (m)
1	146.8
1.5	79.9
2	51.9

4.5 Capacity to Contain Assessment

4.5.1 Overview

The potential failure of the proposed 20m high embankment could result in the slump of the dredged material into the marine environment. A stormwater basin, or similar, located at the upstream face of the embankment may control stormwater discharge and protect the integrity of the embankment structure.

A water balance model has been developed for the proposed dredge material placement facility to provide an assessment and indicative design parameters for the proposed sedimentation/evaporation basins. As discussed in Section 4.2, the embankment has been classified as "High Hazard" primarily on results from the catastrophic failure assessment. The capacity to contain hazard assessment, which considered impacts from overtopping of the storage, suggested that the embankment was a "Low Hazard" categorisation. Whilst the categorisation of the structure should be consistent throughout the design, the lower "Significant Hazard" category has been adopted for the spill frequency in this assessment on request by Santos. Hence, a preliminary design storage allowance of 0.1 AEP, thereby providing sufficient storage to limit the annual probability of overtopping in 1 in 10 years. This design standard is consistent with other industrial discharge licences in the port.

It is understood that all stormwater will discharge (both controlled and uncontrolled outflows) into the saltpan and mangrove communities within China Bay. Although tolerant to saline waters and moderate sediment loads the vegetation of these communities are protected under the Queensland Fisheries Act 1994 and are of high conservation significance. Protected species and predicted impacts of uncontrolled discharges are discussed in Section 4.2.3 and 4.2.4.

At this stage, the model developed in this assessment provides a reasonable estimate of sedimentation/evaporation basin dimensions required to meet the discussed design standard. However, with further development the model could be used for detailed design, investigation and planning of long-term storage and treatment facilities, as well as demonstrating compliance with statutory authority requirements (EPA).

4.5.2 Water Balance Modelling

The GoldSim modelling platform was selected for the construction of the water balance models. GoldSim is a modelling package used for visualising and dynamically simulating nearly any kind of physical, financial or organisational system. For the dredge material placement facility, the model has been developed to represent components of the water management system, which comprises a series of storages (reservoir elements) with functions that affect positive (sources) and negative (losses) rates of water to the dynamic volume and mass variation in each storage element. The software allows individual runs or stochastic simulations which are suitable for evaluating probability and risk associated with system scenarios.

This type of modelling is able to assess event runoff storage performance in response to sequential rainfall events which are often the most critical conditions for overflow risks (e.g. consecutive above average wet months or years). For this assessment, the water balance models were run over a 107 year period using synthetically developed climate data, to infer the likely frequency of discharges to the environment.

Model Requirements

The key inputs for a water balance model are:

- Contributing catchment area
- Hydrological inputs, i.e. rainfall and evaporation
- Representation of catchment runoff from various designated land types and it's storage destination.

- The capacity and level/area dimensions of each storage facility (to be determined iteratively).
- The outlet discharge relationship for each storage element.

4.5.3 Water Sources and Losses

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.

Catchment Types

The dredge material placement facility and upper catchments were divided into different catchment land types that can be considered as having relatively similar runoff quantity characteristics. The adopted catchment land types are:

- Natural, includes undistributed and rehabilitated areas.
- Hardstand areas, due to the fine sediment within the marine dredge material, the possible placement of a geo-membrane mattress under the dredge material and the compaction, limiting permeability, the placement area has been classified as hardstand.
- Direct rainfall, this includes are open water storages where the rainfall would directly contribute to the storage volume.

Catchment Data

As discussed in the Section 3.5 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 material placement area has been cleared. However following rehabilitation of the placement facility it is anticipated that the diversion ditches will fill with sediment and the upper catchment will alternatively drain to the established sedimentation basins. Stormwater management in both environmental conditions is essential.

The catchment areas for each condition were delineated using 1m contours of the study area. In general, the placement footprint was located in the downstream of the catchment. The catchment areas to be drained for each environmental condition are provided in Table 4.5 below.

Table 4-5 Basin Catchment Areas

Hardstand		Natural	Direct
Construction/Operation Phase Basin	1.34 km^2 – D	1.20km^2	D
Rehabilitated Site Basin	-	2.54km^2 – D	D

D – direct rainfall area of basin – yet to be determined

Rainfall and Evaporation Data

Long-term rainfall and evaporation for the Gladstone area were obtained from the Department of Natural Resources and Water (NRW) Data Drill system. As discussed in the LNG facility surface water assessment (Appendix O), rainfall and evaporation data was however available for the Gladstone area, but not over the 100 year time frame required to infer containment capacity of the proposed water management system.

To assess the accuracy of the SILO data, a statistical analysis was undertaken. The assessment included daily site records from the Gladstone Radar rain and evaporation gauge (station number 039326) for the period January 1958 till December 2007 to be analysed against corresponding Data Drill averages for that period.

The analysis indicated 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. Furthermore a 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 was achieved. Given this, current investigations have adopted the Data Drill rainfall and evaporation values for long-term water management simulation.

Runoff model representation

Catchment runoff processes were modelled using the Australian Water Balance Model (AWBM) type runoff model in the LNG facility assessment. The AWBM model is considered a more superior method of estimating runoff from rainfall than simpler methods using runoff coefficients.

The AWBM is a catchment water balance model that can relate runoff to rainfall with daily or hourly data, and calculates losses from rainfall for flood hydrograph modelling. The model takes account of observed variability of runoff rate in response to preceding rainfall conditions and corresponding effects on catchment wetness.

The model uses 3 surface stores to simulate partial areas of runoff. At each time step, rainfall is added to each of the 3 surface stores and evapotranspiration is subtracted. If the capacity of the store is exceeded the excess becomes runoff. The runoff recharges the baseflow store and if there is remainder it becomes surface runoff.

The natural land type parameters were calibrated using an automated calibration program known as 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.

The AWBM runoff parameters for natural land type were calibrated in the LNG facility surface water assessment (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. Table 4-6 below provides the natural land type AWBM parameters.

Table 4-6 Adopted natural land type AWBM parameters

A1	0.134
A2	0.433
A3	0.433
BFI	0.673
C1	19.292
C2	154.526
C3	914.447
K Base	0.269
K Surf	0.917

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.

Section 4 Stormwater Management

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 4.7 below provides the hardstand land type AWBM parameters.

Table 4-7 Adopted hardstand land type AWBM parameters

A1	0.134
A2	0.433
A3	0.433
BFI	0
C1	5
C2	20
C3	40
K Base	0.269
K Surf	0.917

4.5.4 Design Criteria, Assumptions and Accuracy

A brief design criteria has been established to provide an indicative design, it includes the design to incorporate:

- A Design Storage Allowance (DSA) of AEP 0.1.
- A low flow outlet, (100mm diameter pipe) to assist drawdown between wet seasons, this will provide a settling zone for sediments.
- A configuration providing a 3 to 1, length to width ratio, to improve settlement efficiency
- A permanent pool to reduce flow velocities and provide storage for settle sediment. The basin should be designed with approximately 1.5m depth with an additional 1m sediment to accumulate. The sediment accumulation capacity and process has not been modelled in this feasibility design.
- The demonstration of two environmental conditions:
  1. (Construction/Operation Phase Basin) Dredge material placement area represented as hardstand catchment type, upper catchment drainage ditches diverting flows up to a magnitude of 0.01 AEP.
  2. (Rehabilitation Site Basin) The rehabilitation of the dredge material area and failure of diversion ditches, resulting in the entire catchment contributing a natural catchment type flow to the basin.

In addition to the assumptions listed in the model schematic section of this appendix, several other assumptions were made for 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 for tidal effect. It is understood that all infrastructure will be built above the Highest Astronomical Tidal level (at approximately 18m AHD).
- Unverified discharge agreement with appropriate government authority, therefore potentially under or over estimation of design standard.

As previously discussed, the model contains several sources of potential inaccuracy, including:

- Hydrologic information of the site was unavailable, and as such synthetic data for the 107 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 placement facility layout, surface gradient and dewatering areas, and
- Model verification and calibration of the model has not been undertaken given the lack of available local gauged data.

Considering the above, whilst the accuracy of the assessment is considered adequate for EIS purposes, the evaluation provides indicative basin dimensions only. The results from this model are therefore inappropriate for design purposes. Further model refinement would be required for such an application to be made.

4.5.5 Model Results and Discussion

A key output of this investigation is the storage configuration to achieve the design standard of discharge. Both environmental conditions were simulated on an hourly time-step for 107 years (1900 - 2007), and the annual average days of overflow and volume of overflow discharge was determined. Table 4.8 below provides an indicative outline design.

Table 4-8 Indicative Design Dimensions

Storage	No.	Length	Width	Depth*	Capacity	Spill Frequency
Construction/operation Phase Basin	2	400m	130m	3.1m	644,800m^3	0.1 AEP
Rehabilitated site Basin	2	400m	130m	2.9m	603,200m^3	0.1 AEP

* Include an additional 1m for sediment accumulation.

As shown in the table above, the model predicts that similar sedimentation/evaporation basin arrangements should provide sufficient capacity to achieve a spill frequency of 0.1AEP for both the construction/operation phase and rehabilitated site. Both simulations included a low flow discharge, as described in the model design criteria section and the adoption of two basins in each condition to provide a more efficient settlement of sediment.

4.5.6 Water Balance Summary

As discussed earlier within this report, the accuracy of the water balance model is considered adequate for the intended use and should only be used to provide indicative guidance regarding facility stormwater controls. To improve the accuracy of the model and quality of output, it is suggested that accurate design dimensions of all storages, inlets and outfalls are incorporated into the model (following further progress in the design). Furthermore, where possible, the model should be calibrated and verified using local data (a monitoring programme should be established for this purpose).

The impact of uncontrolled discharges to the receiving environment from the specified sedimentation/evaporation basins, including low flow discharge, is expected to be negligible, as this will occur on average once per 10 years and reasonable water quality. To mitigate any potential impacts relating to elevated suspended solid concentrations, the design of the sediment ponds should be optimised to improve settlement performance (e.g. through inclusion of a permanent pool to reduce velocities and the construction of islands, baffles and weirs to increase the hydraulic efficiency of sediment settlement). Periodic dredging of sediments and safe disposal should also be undertaken to maintain performance.

Section 5 Summary

A phased surface water environment assessment for the dredge material placement facility has focused on two potential impacts identified:

- non-compliant water quality discharge to the receiving environmental from insufficient treatment.
- catastrophic failure of the containment embankment due to insufficient stormwater management and/or design .

The assessment recommends that a Surface Water Management Strategy is developed to provide a basis for the management of discharges from the facility. It is suggested that the Strategy is based on findings from a water quality model and will include several different treatment methods to meet water quality guidelines and site specific objectives. To identify non-compliant discharge a monitoring program is proposed that incorporates trigger levels for the appropriate water quality parameters. The program is intended to notify operators, and potentially the regulator, when non-compliant discharges occur. This would be developed as part of the dredge management plan and would feed into the design for the facility.

It is anticipated that during the construction period, a significant volume of dredge material dewatering effluent and runoff will require discharge offsite. It is therefore recommended that leach testing is undertaken on the proposed dredge sediment to identify contaminant types and concentrations to further refine the environmental assessment for the proposed dredge material placement facility. These test results will provide intrinsic guidance for the dewatering process design and adoption of surface water quality mitigation measures.

A review of other dredge placement facilities within the Port, suggested that, with the proposed six cell design for the GLNG dredge material placement facility, adapted in accordance with a water quality model and utilising further dredge material data, is likely to meet water quality licence discharge limits (assuming these are similar to existing limits in the area).

Catastrophic failure of the proposed 18 m high embankment could result in the slump of dredge material into the marine environment. Stormwater management at the dredge material placement facility is essential to the integrity of the embankment, and appropriate measures will reduce the potential of collapse.

A hazard categorisation of the embankment was undertaken to assist with the adoption of the appropriate standard of stormwater protection. The assessment identified a “High Hazard” category from the catastrophic failure of the embankment, determining a substantial spillway capacity was required. Whilst the categorisation of hazard for overtopping of stormwater management controls was lower.

Spillway and sedimentation pond capacities and arrangements were investigated using standard methodology. Both investigations provided indicative designs to achieve the required standard of protection.

Section 6 Glossary and Abbreviations

Glossary, Acronyms and Abbreviations	
ADWG	Australian Drinking Water Guidelines
ANZECC	Australian and New Zealand Environment and Conservation Council
AR&R	Australian Rainfall and Runoff
ARI	Annual Reoccurence Interval
ASS	Acid Sulphate Soils
AWBM	Australian Water Balance Model
BCC	Brisbane City Council
DPIF	Primary Industries and Fisheries (Department of)
DSA	Design Storage Allowance
AEP	Annual Exceedence Probability
EC	Electrical Conductivity
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
EPBC	Environmental Protection Biodiversity Conservation (Act)
EPP	Environmental Protection Policy
GBR WHA	Great Barrier Reef World Heritage Area
LNG	Liquified Natural Gas
ILs	Investigation Levels
MRD	Main Roads Department
N	Nitrogen
NODGDM	National Ocean Disposal Guidelines for Dredged Materials
NRW	Natural Resources and Water (Department of)
NTU	Nephelometric Turbidity Units
PMP	Probable Maximum Precipitation
QEPA – EILs	Queensland Environmental Agency Environmental Investigation Levels
QWQG	Queensland Water Quality Guidelines
RRL	Rainfall Runoff Library

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