8.3 Land

8.3.1 Topography, Geomorphology, Geology and Soils

8.3.1.1 Introduction

The following section describes the existing topography, geomorphology, geology and soils of the LNG facility study area (Figure 8.3.1). This section also provides an assessment of the potential environmental impacts and a description of proposed mitigation measures to minimise the impact of the GLNG facility development activities on soils and terrain related environmental values.

Reference should be made to the more detailed information provided in the relevant technical report in Appendix L3.

8.3.1.2 Methodology

The methodology adopted included a baseline soils and terrain investigation and impact assessment study. The baseline investigation included a:

- Desktop assessment, primarily based on interpretation of aerial photography;
- Site investigation including soil sampling; and
- Description, characterisation and testing of soil samples collected during the site investigation.

As part of the desktop assessment, aerial photograph interpretation together with existing geological, topographical and soils information were used to carry out the preliminary terrain mapping. The terrain mapping identified a series of terrain units based on geological regimes, landform types and associated soils.

Sites representative of the range of landform types evident on the aerial photographs were pre-selected for field investigation to delineate the preliminary terrain units and to identify the associated soils and/or soil associations.

A small tracked excavator supported by field personnel using quad bikes was used to access the selected sampling sites. At each inspection location, terrain characteristics were noted and where possible, test pits were excavated to a maximum depth of 1.5 m or to weathered rock, whichever was the shallower. Soil types were identified in accordance with the guidelines of the 'Australian Soil and Land Survey Field Handbook' (McDonald et al., 1990). Representative soil profile samples were collected from each of the test pits for subsequent in-house soil characterisation and indicative testing.

Agricultural Land

Refer to section 6.3.1.2 for details of agricultural land classes A to D.

In order to determine the appropriate agricultural land class, terrain units identified within the LNG facility study area have been evaluated for land suitability for (rain fed) cropping and for cattle grazing enterprises. The system of classification is based on the identification of physical and chemical limiting factors or constraints with respect to the specific land use, by adopting the following format.

- **Class 1-** High quality agricultural land with few or very minor limitations for the intended land use;
- **Class 2-** Land with minor limitations for the intended land use;
- **Class 3-** Land with moderate limitations to sustaining the intended land use;
- **Class 4-** Marginal land with severe limitations that require major inputs to sustain the intended land use; and
- **Class 5-** Unsuitable land due to extreme limitations for the intended land use.

The soil and landform limitations criteria on which the land suitability classifications were determined are provided in Appendix L1. These criteria are based on the guidelines for agricultural land evaluation published by the Queensland Department of Primary Industries (DPI - 1990), modified to some extent by inclusion of criteria proposed by Shields and Williams (1991).

Geology and Soils

Information on geology and soils was identified from the terrain mapping and confirmed from the site investigation and sampling results. Wherever possible, soil profiles have been identified or classified in terms of the following:

- Handbook of Australian Soils (Stace et al., 1968);
- Principal Profile Form (PPF) of Northcote (1974);
- Australian Soil Classification (ASC) (Isbell, 1996); and
- Australian Engineering Soil Classification (AS 1726-1993).

The suitability of materials for use as topsoil resources for rehabilitation of lands that may be disturbed during the development and operating stages of the LNG facility has also been assessed from the soil characterisation investigations and the results of the analytical data obtained. An assessment has also been made of materials that were considered to be marginal for use as topsoil material, but will have acceptable properties for the use as subsoil resources to supplement the topsoil resources if required.

Soil Erosion and Stability

The incidence of accelerated soil erosion including sheet, rill or gully erosion was assessed for the LNG facility study area based on interpretation of the aerial photography (May 1999 – 1:40,000 scale) and from field observations.

Acid Sulfate Soils

An acid sulfate soils (ASS) assessment was undertaken using a geomorphological modelling approach. This differed from the standard grid investigation specified in the *Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils in Queensland (1998)*, instead adopting a strategic sampling regime based on the identified geomorphology of the site. The aim of this approach was to minimise unnecessary drilling, sampling, analysis and costs, yet produce an ASS assessment of a superior quality to that produced under the traditional sampling regime.

The methodology adopted included:

- Identification of geological sequences where the forming of ASS was known to occur;
- Targeted sampling of areas where ASS is likely to occur and where there will be project impacts;
- Sampling of other areas as per the requirements of the EIS terms of reference (ToR);
- Collected samples were then processed by a laboratory; and
- The results of all sampling and testing were then analysed.

The sampling strategy in all onshore areas was guided by advice that the proposed activities will involve filling on *in situ* sediments, but no excavation or lowering of existing water tables. Therefore, sample field and laboratory testing was only conducted to the minimal depth required of 2 m. Coring was continued beyond the ASS assessment depth, to the pre-Holocene substrate where feasible, in order to further constrain geomorphological modelling of the site as well as contributing to the geotechnical understanding.

Offshore sampling was conducted along a transect where dredging is proposed, to a depth of either – 14 m LAT, or where very stiff pre-Holocene clay substrate prevented restricted penetration. An additional site was located in the bay where the LNG facility's Material off-loading facility (MOF) and product loading facility (PLF) are proposed to be constructed (refer to Section 8.7 and/or Appendix R3 for further details of this off-shore sampling program).

8.3.1.3 Regulatory Framework

Refer to Section 6.3.1.3 for an overview of the regulatory framework.

8.3.1.4 Existing Environmental Values

Topography and Geomorphology

The topography of the LNG facility study area shown in Figure 8.3.1 comprises low rounded hilly, intermediate steep hilly and steep high hilly lands developed on Upper Carboniferous to Lower Devonian Wandilla Formation sedimentary rock types and meta-sediments comprising mudstone, lithic sandstone, quartz greywacke, siltstone, chert, slate and local schist. The hilly crestal areas vary from approximately RL 20 - 45 m Australian Height Datum (AHD) in the low hilly lands, to approximately RL 50 - 75 m AHD in the intermediate steep hilly areas, and up to approximately RL 120 - 175+ m AHD in the high steep hilly lands. Hill and ridge slopes are mainly irregular planar to shallow concave on the lower slopes and vary from around 15 % on the lower hilly areas, increasing to 20 – 35 % in the steep hilly areas and approximately 25 – 45 %+ in the higher hilly lands. The hilly areas are separated by gently to moderately inclined (5 - 15 %) lower hill slopes and undulating lowlands with overall slopes mostly within a range of 3 – 7 %, which collectively form broad valley floors. Near flat to gently undulating alluvial plains with slopes mostly < 2 % occur in the valley bottoms. In most cases these alluvial valley flats extend towards the coast and merge with estuarine supra-tidal flats which are mostly fringed by tidal mangrove flats along the coast line.

Terrain Units

The identification of terrain units provided a basis for the description of the physical environment and as mapped, the terrain units serve to show the occurrence and distribution of geological regimes, landform types and associated soil groups and soil types that occur within the study area.

Ten terrain units were identified within the LNG facility study area and are provided in Table 8.3.1 with cross-references for each unit to the geology, landform and soil group/type. The occurrences of the ten terrain units are shown in Figure 8.3.2 where they are coloured on the basis of the geological regime in which they occur. A key to the description of the terrain mapping units is provided in Figure 8.3.3.

Table 8.3.1 Terrain Units Identified within the LNG Facility Site Area

Terrain Unit	Geological Regime	Landform Type	Soil Group / Soil Type
Qe0/9	Qe	0	9
Qe1/7-9	Qe	1	7-9
Qe2/7.3	Qe	2	7.3
Qa2/6-7	Qa	2	6-7
Cw3/5-7	Cw	3	5-7
Cw4/4-7	Cw	4	4-7
Cw5/5-7	Cw	5	5-7
Cw6/5	Cw	6	5
Cw7/4-7	Cw	7	4-7
Cw8/7.1	Cw	7	7.1

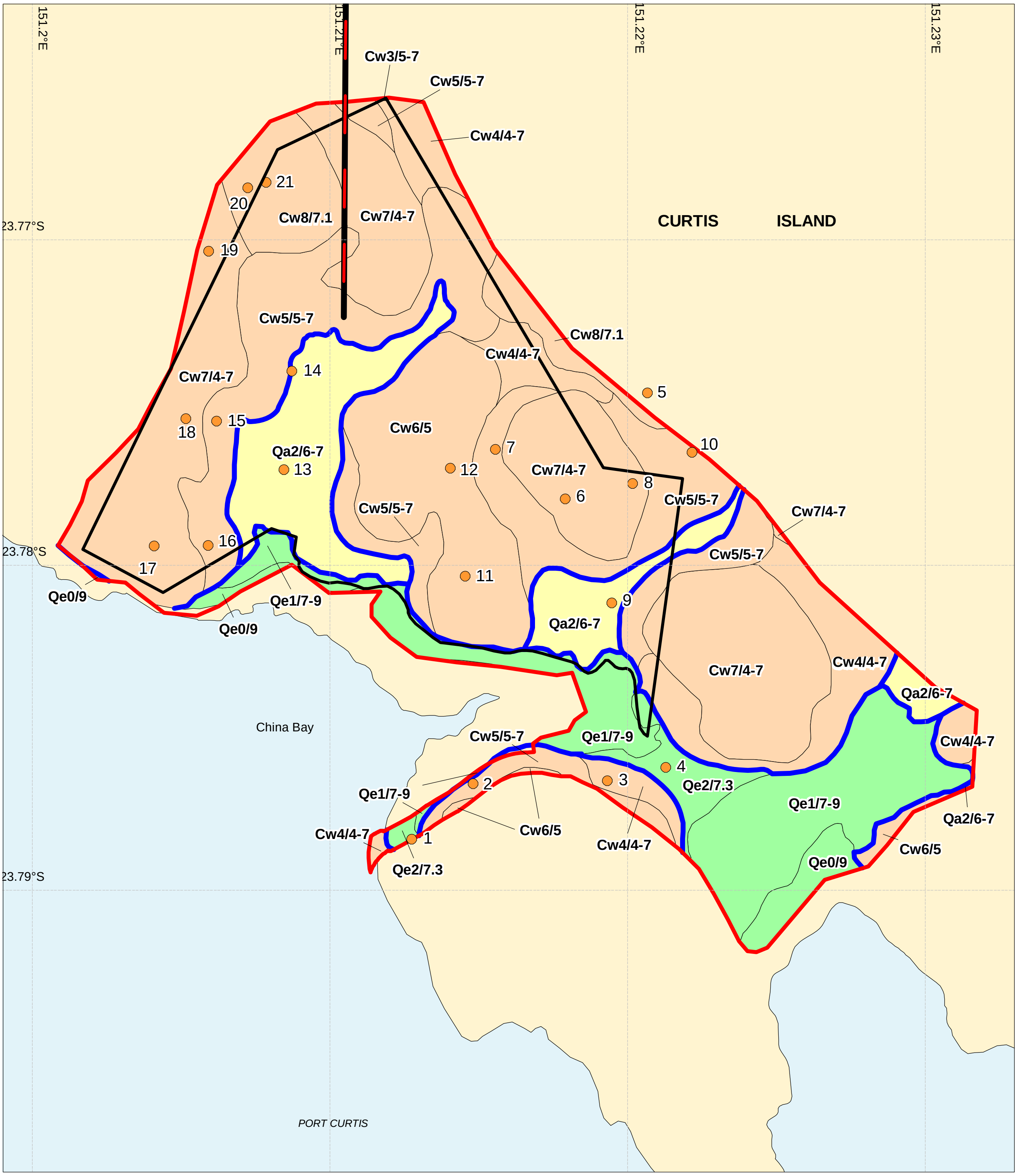
- LNG Facility Terrain Study Area
- LNG Facility Site Boundary
- Gas Transmission Pipeline
- Proposed LNG Facility Layout
- 5 Contour and Value (5m Interval)

Source 1: Copyright Bechtel Corporation 2008. All rights reserved. Contains confidential information proprietary to Bechtel not to be disclosed to third parties without Bechtel's prior written permission. Site Plan GLNG Project Curtis Island Australia - Dwg Number SK-000-00001.DGN Revision A Date 17-02-2009

Source 2: With regard to Product Loading Facility and Material Offloading Facility - These layouts are subject to alteration during detailed design development and ongoing consultation with the Gladstone Ports Corporation and the Gladstone Regional Harbour Master to ensure issues of navigation safety are appropriately addressed.

Source 3: This map may contain further data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**TOPOGRAPHY AND SITE LAYOUT LNG FACILITY**
	Drawn: VH/CA · Approved: JB · Date: 26-02-2009	Figure: **8.3.1** · Rev:B
	Job No: **4262 6220** · File No: 42626220-g-972b.wor	**A4**



N
W E
S

Geological Regime Boundary		Terrain Study Area	
Site Soil Sampling Locations		LNG Facility Site Boundary	
Qe0/9 Terrain Unit Boundary		Gas Transmission Pipeline	

0 250m 500m
Scale 1:20 000 (A4)
Datum : GDA94

NOTE: This Figure 8.3.2 must be viewed with Figure 8.3.3

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

Client	Project	Title
LNG	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**GEOLOGY AND TERRAIN UNITS LNG FACILITY**
URS	Drawn: VH/CA · Approved: JB · Date: 26-02-2009	Figure: **8.3.2** · Rev:B
	Job No: **4262 6220** · File No: 42626220-g-973b.wor	A4

Generic Key to the Identification of Terrain Units

GEOLOGICAL REGIME	
Symbol	**Description**
Qe	Quaternary (Holocene) estuarine delta and coastal marine deposits; saline silty clays, clays, saline muds and sands
Qa	Quaternary Alluvium on water courses, terraces and floodplains; clay, silt sand and gravel deposits
Cw	Carboniferous Wandilla Formation; mudstone, lithic sandstone, siltstone, jasper, chert, slate and schist

LANDFORM – TERRAIN TYPE	
Type	**Surface Form and Slope**
0	Channel floors, banks and active levees of major streams and waterways with irregular steep, and locally benched bank slopes and low flood terraces. Locally tidal mangrove and marine flats and tidal inlets with mangroves fringing.
1	Floodplains alluvial flats, lower stream terraces and flat to broadly depressional backplains, slopes typically <1%; periodically floodprone and locally poorly drained areas. Locally comprising estuarine/marine plains, extratidal and supratidal flats subject to periodic tidal inundation; slopes mostly <0.5%.
2	Flat to gently undulating or gently inclined intermediate to higher stream terraces, older alluvial plains or, floodplains and higher stream terraces, with slopes generally <2%;occasionally floodprone in lower-lying areas and along tributary drainage channels.
3	Undulating plain and gently rolling to broadly rounded rises with gently inclined planar to concave intervening lower-lying broadly depressional areas; slopes mostly in the range 1- 3%
4	Undulating to strongly undulating plains and rolling rises, locally flat to undulating upland plateau crests and undulating uplands; with slopes mostly in the range 3-7%
5	Gently to moderately inclined planar to concave intermediate to lower hill and ridge slopes or convex planar dissection slope interfluves; slopes variable mostly within the range 5-12%
6	Isolated low rounded hills and rises and low hilly lands mostly with broadly rounded crestal areas and hill slopes in the range 12-25%;
7	Steep hilly lands with mostly narrow rounded hill and ridge crests and steep irregular planar hill and ridge slopes mostly in the range 20 to 40%
8	Steep to very steep ridges and high hilly lands; mostly with narrow rounded ridge and spur crests, with slopes typically in the range 30-50%, with local subvertical rocky scarps and bluffs
9	Very steep high hilly to mountainous lands or very steep to locally sub-vertical or vertical escarpment slopes 35 ->100%

Example: **Terrain Unit Qa2/6-7**

Qa (Geological Regime) 2 (Landform) 6-7 (Soils)

SOILS	
Group	**Soil Types [1]**
0	Extensive areas of rock outcrop, locally with skeletal to shallow usually stony or gravelly soils.
1	Skeletal, rocky or gravelly soils (>60% coarse fragments) with sandy, sily, loamy or clayey soil matrix (K- Uc1, Um1, Gn1, Uf1)
2	Sand soils; shallow to deep uniform or weakly gradational profiles; includes stratified alluvial soils, residual sand soils, earthy sands (Ucl-Uc6) [2]; Rudosols or Tenosol Soil Orders [3]
3	Coarse to medium-textured soils; uniform or gradational profiles; predominantly sandy earths silty or clayey sand profiles (Uc4-5, Uml-3); Tenosols or Podosol Soil Orders.
4	Medium-textured sandy, sandy loam or silt to clay loamy surface uniform or gradational profiles, often (siliceous or ferruginous) gravelly or stony soils; (Um4-7, Gn1-2); Tenosols, Kandosols or Ferrosol Soil Orders.
5	Sandy to loamy surface duplex soils with neutral to acidic, in places strongly acidic sandy clay to medium to heavy clay subsoils (Dr1-5, Dy1-5); Chromosol or Kurosol Soil Orders.
6	Fine sandy, silty or clay loamy surface duplex soils with neutral to alkaline often calcareous, sodic and locally saline medium to heavy clay or heavy clay subsoils; (Db-Dd-Dy1-5); Chromosols, Sodosols or Calcarosols Soil Orders.
7	Uniform fine-textured (non-cracking) clay soils or gradational clay loam or light clay surface soils with acidic or alkaline often sodic and/or saline medium to heavy clay subsoils – locally incipient cracking clays; (Uf5-6); Dermosol or Hydrosol Soil Orders.
8	Uniform fine-textured (cracking) clay soils, locally with thin self-mulching surficial soils with dark grey, brown or black mostly alkaline or alkaline over acidic heavy clay subsoils; (Ug5-Ug6); Vertosols Soil Order.
9	Uniform, weakly gradational or weak duplex soils with highly organic silty to clay loamy surficial soils and seasonally or permanently saturated often gleyed and saline silty clay or medium to heavy clay subsoils; Um, Dd-Dy, Uf-Ug 5-6 profiles; Organosols, Hydrosols some Vertosol Soil Orders.

Notes:- (1) – Soil profile form and texture class
(2) - Principal Profile Form (Northcote 1974)
(3) - Australian Soil Classification (Isbell, 1996).
Dual symbols eg (2-7) indicate both soil types may be present:

NOTE: This Figure 8.3.3 must be viewed with Figure 8.3.2

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

URS

Client

Project
GLADSTONE LNG PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Title
TERRAIN UNITS IDENTIFICATION KEY

Drawn: VH/CA | Approved: JB | Date: 26-02-2009

Job No: **4262 6220** | File No: 42626220-g-973b.wor

Figure: **8.3.3** | Rev:B | **A4**

Geology

The geology of the LNG facility study area and surrounds has recently been mapped by the Geological Survey of Queensland (GSQ, 2005), as shown on the 1:100,000 Gladstone map sheet. The geological regimes that occur within the general vicinity of the proposed LNG facility study area include:

- Qe- Quaternary (Holocene) estuarine delta and coastal marine deposits, comprising saline silty clays and clays, saline muds and sands;
- Qa- Quaternary alluvium, comprising clay, silt, sand and gravel deposits; and
- Cw- Carboniferous Wandilla Formation, comprising mudstone, lithic sandstone, quartz greywacke, siltstone, jasper, chert, slate and schist.

The occurrence of the geological regimes within the LNG facility study area is shown in Figure 8.3.2.

Figure 8.3.1 also includes a series of photo-geological lineaments identified from aerial photograph interpretation. The trend of these lineaments is generally in an east-north-east, west-south-westerly direction. These lineaments are located in the central northern sector of the site and they may intersect the access road/gas transmission pipeline corridor, which runs along the north-eastern margin the LNG facility study area. These features may represent the surface expression of fault lines or geological structural trends.

Seismic Activity and Ground Stability

Queensland is seismically active, with the highest hazard region lying along the populated eastern coast and near offshore regions. Most Australian earthquakes occur in the crustal layers of the region, and in the north-east of Australia the average earthquake focal depth has been determined to be 10 km (± 0.5 km). The largest earthquakes recorded in Queensland occurred offshore of Gladstone in 1918 (Richter Magnitude (ML) 6.3) and near Gayndah in 1935 (ML 6.1). Structural damage to buildings was reported in the Rockhampton region during the Gladstone earthquake. In the Rockhampton area, the earthquake was determined to have a Modified Mercalli Intensity of VI (denotes how strongly an earthquake affects a specific place and ranges between I and XII). Modified Mercalli Intensities of VII and VIII, which are capable of causing serious damage, were also noted on Quaternary floodplain alluvium in the Rockhampton area.

In Queensland, earthquakes with the potential to cause serious damage or fatalities (ML > 5) have occurred on average about every five years during the last century, with several near misses to the State's large population centres. A high level of seismic activity runs through a belt just inland of Bundaberg spanning downwards from Gladstone through Gayndah and beyond. The recorded earthquake activity in the region is concentrated principally in two areas, namely the offshore Capricorn Group of islands and a zone extending from north of Biloela to near Monto (Anon, 1990 and McCue et al., 1993). In addition, several isolated earthquake epicentres have been recorded throughout the region.

The most recent, moderate sized earthquake within the broader region of the project site struck about 40 km from Bundaberg in 1985 and recorded an ML of 3.1.

The GLNG Project area extends over a considerable distance, with some areas of the project falling within different expected earthquake intensities. The area with the highest earthquake risk is near Gladstone due to its close proximity to an earthquake source zone as defined in Gaull et al., 1990. From the coast, approximately 200 km inland to the west along the pipeline corridor, including the area to the south through the Roma and Scotia CSG field tenements, the intensity is V on the Modified Mercalli Scale. The portions west of these areas containing the western and southern sectors of the gas transmission pipeline and all of the other CSG fields are categorised as IV (Gaull et al., 1990).

Soil Groups and Soil Types

The soil profile characteristics of the study area have been identified primarily from 21 test pits excavated as part of the field investigation program. Initial investigations were undertaken from 26 test pits after which the study area was revised resulting in a required 21 test pits. The locations of these test pits are provided in Figure 8.3.2.

With reference to the generic soil groups described in Figure 8.3.3, a general description of the main soil groups, soil types and/or soil associations and the terrain units in which they occur within the LNG facility study area, is provided in Section 6.3.1.4.

Table 8.3.2 Soil Groups Identified within the LNG facility site

Soil Group	Summary Soil Description	Soil Classification			
		Aust. Soil Group (1)	P.P.F. (2)	U.S.C. (3)	A.S.S. (4)
4	Shallow to deep (>0.5 m) mainly uniform or weakly gradational, very stony and gravelly loams to clay loam soil profiles.	Shallow Loams Gravelly Loams Lateritic Red – Yellow Earths	Um2.12 K-Um2.12 Um4.11	CL/GC-CL/GC GC-CL/GC	Brown Kandosol; Gravelly Lithic; Leptic Rudosols
5	Medium to deep (0.5 - 1.2 m) dark brown gravelly loam to gravelly clay loam surface soils, locally with a pale or bleached gravelly loam or clay loam sub-surface (A2) horizon over red-brown, brown or yellow-brown acidic medium to heavy clays or gravelly clays subsoils.	Red, Yellow & Brown Podzolic Soils Grey & Brown Soloths	Dr2.31 K-Dr3.21 Db3.51 K-Db3.51 Db1.41 K-Dy3.21 Dy3.32	GC-CL/GC/CH CL-ML/GC/CH or CL-CH ML/GM/CL-CH	Ferric Red-Brown Chromosols; Sodic Yellow & Brown Kurosols
6	Thin dark grey-brown acidic clay loamy surface duplex soils with diffusely mottled grey-brown and yellowish brown slightly acidic medium to heavy clay sub-soils over alkaline clay deep subsoils.	Brown Solodic Soils	Db2.23	CL/CH/CL-CH	Subnatric Brown Sodosols
7	Three soil type variants identified include: *Type 7.1*: Shallow to medium deep (< 0.5 - 0.8 m) uniform red-brown clay soils and gradational gravelly loam over yellow-brown to yellowish-red gravelly clay subsoils; *Type 7.2*: Medium deep (0.5 - 1.0 m) uniform silty clay over acidic structured heavy clay subsoils underlain by massive alkaline heavy clay deeper subsoils; *Type 7.3:* Medium to deep (0.5 - 1.5 m) uniform silty clay surface soils over brown or red-brown weakly structured acidic medium to heavy clay subsoils, and gradational clay loam to gravelly loam surface soils over gravelly light clay subsurface horizons transitioning to medium to heavy or heavy acidic to strongly acidic clay or gravelly clay subsoils.	Uniform Gravelly Clays Alluvial Soils Grey, Brown or Red (Non-Cracking) Clay Soils	Uf6.61 Gn4.81 Gn4.14 Uf6.31 Uf6.61 Uf6.12 Gn4.12 Gn4.11 Gn2.11	CL-CH/CH GM-GC/GC/ CL-CH or GC-CL/GC/ CL-CH CL/CH/CH CL/CL-CH CL/GC-CL/CH CL/GC-CL/CH GC-CL/CL-CH CL/CL/GC-CL	Acidic Sodic Red Dermosol, Melanic Red & Brown Dermosol Sodic Brown Dermosol Acidic-Sodic Red Dermosol; Ferric Brown Dermosol; Ferric red Dermosol

Soil Group	Summary Soil Description	Soil Classification			
9	Deep to very deep, very soft, uniform, gradational or weak duplex soil profiles, with organic silty clay to silty clay loam surface soils and seasonally or permanently saturated subsoils, typically gleyed saline clays, clayey silt, silty sand or sandy mud.	Humic Gleys Solonchaks	Uf6.41 Dg2.11	CL-ML/OL-OH	Supratidall Hydrosols; Redoxic Hydrosols
Notes: - (1) - Common Soil Group Name (Stace et.al. 1968); (2) - Principal Profile Form (Northcote 1974); (3) - Australian Engineering Soil Classification (AS 1726-1993); (4) - Australian Soil Classification (Isbell, 1996).					

With respect to the soil groups identified in Table 8.3.2, the adopted scheme allows for more than one soil type variant to be described within a particular soil group in order to differentiate between similar soils which may have somewhat differing soil profile characteristics. The soil types identified for each of the main soil groups are summarised in Table 8.3.3.

Table 8.3.3 Soil Type Descriptions

Soil Group	Soil Type 1	Soil Type 2	Soil Type 3
4	Undifferentiated: Shallow (< 0.5 m) and medium to deep (0.5 - >1.5 m) stony, gravelly and clay loam soil profiles with gravelly/stony/clay loam surface soil horizons.		
5	Undifferentiated: Medium to deep (0.5 - 1.5 m) gravelly to gravelly clay loam with a pale or bleached (A2) gravelly/clay loam sub-surface horizon. Clear/sharp change to subsoil (B) gravelly clays or acidic to neutral medium to heavy clays with blocky to prismatic structure directly underlain by variegated heavy clay substrate soils with very dense massive structure.		
6	Undifferentiated: mostly thin fine sandy loam, silt loam and clayey loam surface duplex soils, often with a pale or bleached subsurface (A2) horizon over brown, yellowish-brown or reddish brown medium to heavy or heavy clay subsoils that are neutral to alkaline, locally strongly alkaline usually with carbonate present.		
7	*Soil Type 7.1:* Shallow to medium deep (< 0.5 - 0.8 m) clay, gravelly clay loam or gravelly clay surface soils or gravelly clay sub-surface (A2) with fine gravel to coarse fragments over gravelly acidic clays or medium to heavy acidic subsoils	*Soil Type 7.2:* Medium to deep (0.5 - >1.5 m) uniform clay soil profiles with hardest acidic silty clay surface soils becoming moderately to strongly alkaline in heavy clay subsoils.	*Soil Type 7.3:* Deep (> 1.5 m) uniform or gradational silty clay or heavy clay surface soils with acidic, locally strongly acidic medium to heavy or heavy clay subsoils.
9	Undifferentiated: considerable variation in both in the vertical and horizontal directions including deep to very deep, very soft, uniform, gradational and weak duplex soil profiles with highly organic silty clay, silty clay loam surface soils and seasonally or permanently saturated subsoils, typically gleyed and saline clays, clayey silt sand or sandy mud.		

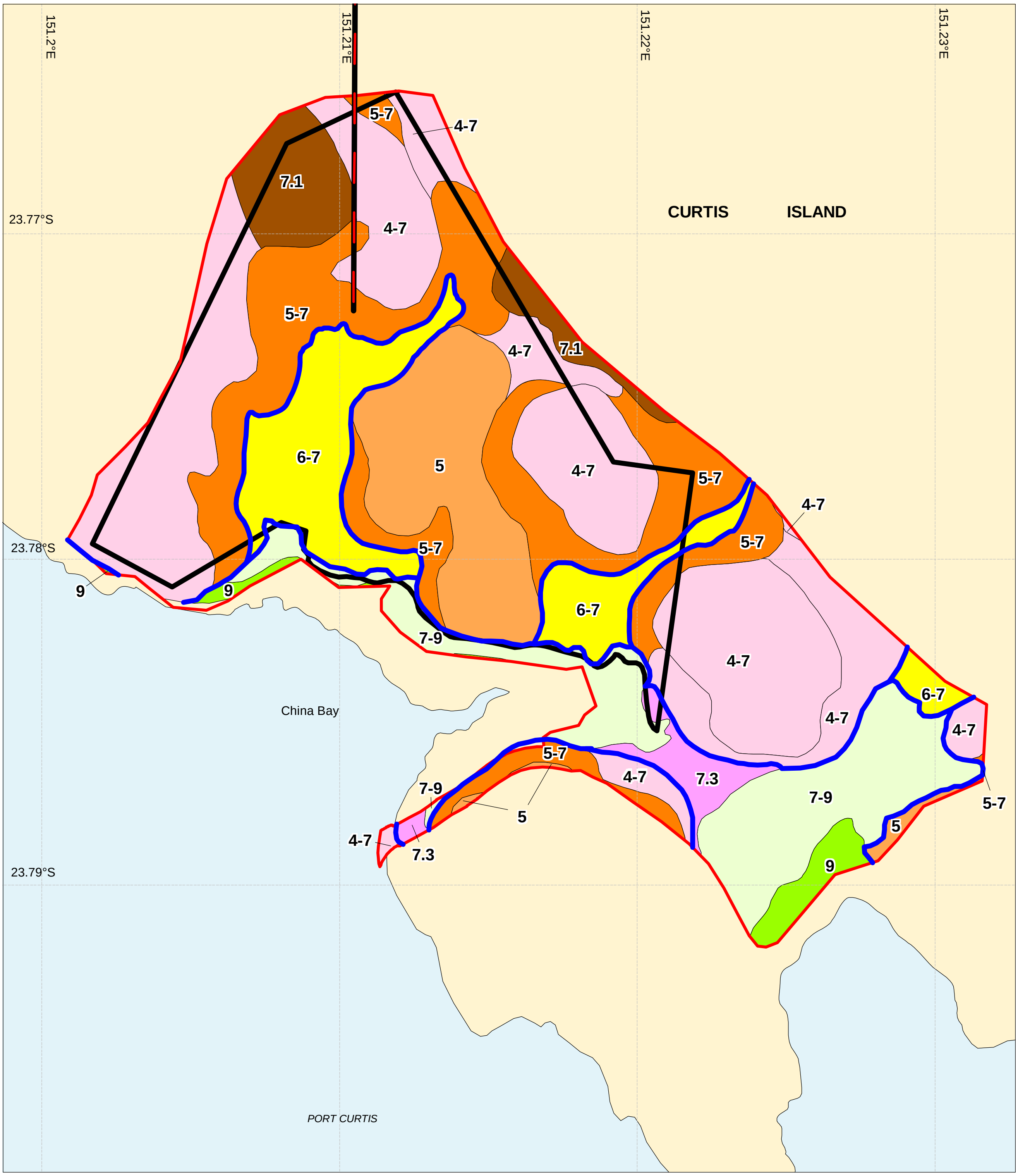
Soil Erosion

Existing and Potential Soil Erosion

Based on interpretation of the aerial photography (May 1999 – 1:40,000 scale) and from field observations, the incidence of accelerated soil erosion including sheet, rill or gully erosion appears to be low within the LNG facility study area. This is primarily due to the well-established vegetative and grass cover that exists over most of the area and the minimal impact of any grazing or other land-use activities that have been undertaken in the area. The limited erosion that is occurring is largely confined to local, narrow, shallowly incised gullies in the mid to lower slopes of the low hilly and higher hilly lands. However, clearing of vegetation and stripping of topsoil resources for site development will expose that land to potential erosion, due to the combined effects of wind erosion and/or surface runoff in the short term. Accordingly, a general qualitative assessment of erosion potential has been made on a terrain unit basis expressed as low (L), moderate (M) or high (H). Some general comments on potential site impacts are provided in Table 8.3.4.

Table 8.3.4 Soil Erosion Potential for each Terrain Unit

Terrain Unit	Erosion Potential	Description
Qe0/9	L-M	In the low-lying tidal marine/coastal flats and estuarine areas, terrain unit Qe0/9 has been rated as having low to moderate (L-M) erosion potential.
Qe1/7-9	M (wind)	The estuarine/marine coastal flats (terrain unit Qe1/7-9) and the slightly higher fringing land areas (terrain unit Qe2/7.3) have both been rated as having moderate (M) erosion potential, due in part to the lack of surface grass cover, relatively high silt content and sodic and dispersive properties of the surface soils, which may pre-dispose these areas in particular to the effects of wind erosion.
Qe2/7.3	M	The estuarine/marine coastal flats (terrain unit Qe1/7-9) and the slightly higher fringing land areas (terrain unit Qe2/7.3) have both been rated as having moderate (M) erosion potential, due in part to the lack of surface grass cover, relatively high silt content and sodic and dispersive properties of the surface soils, which may pre-dispose these areas in particular to the effects of wind erosion.
Qa2/6-7	M-H	The alluvial re-entrant valley floors (terrain units Qa2/6-7), have been rated as having moderate to high (M-H) erosion potential due to the locally high silt content and hard-setting properties of the surface soil horizons, the sodic and dispersive properties of the subsoil layers and the potential for periodic high velocity flood flows and local scouring effects.
Cw3/5-7	L-M	In the undulating hilly lands, the surficial soil horizons, to a depth of 0.5 m or more, mostly have a permeable massive, apedal tending to granular, loose soil structure and typically contain substantial amounts of fine rounded gravel to coarse stone, the combination of which promotes surface water infiltration and reduces surface water runoff. In these undulating and hilly lands, terrain units Cw3/5-7 and Cw4/4-7 (with overall surface slopes mostly < 7 % but locally include sodic and moderately dispersive soil layers) have been rated as having low to moderate (L-M) erosion potential.
Cw4/4-7	L-M	In the undulating to low hilly and hilly lands, the surficial soil horizons, to a depth of 0.5 m or more, mostly have a permeable massive, apedal tending to granular, loose soil structure and typically contain substantial amounts (40-60 %) of fine rounded gravel to coarse sub-angular stone, the combination of which promotes surface water infiltration and reduces surface water runoff. In these undulating and hilly lands, terrain units Cw3/5-7 and Cw4/4-7 (with overall surface slopes mostly < 7 % but locally include sodic and moderately dispersive soil layers) have been rated as having low to moderate (L-M) erosion potential.
Cw5/5-7	M-H	Although the overall slopes are less steep, terrain unit Cw5/5-7 has been rated as having moderate to high (M-H) erosion potential, due to its topographic position in the landscape, the potential for downslope seepage and surface runoff and the likely occurrence of sodic and moderately dispersive soil layers.
Cw6/5	M-H	Terrain units Cw6/5 which have slopes mostly in the range 12 - 25 % and soils that may include some sodic and slightly dispersive soil layers have been rated as having moderate (M-H) erosion potential.
Cw7/4-7	M-H	Terrain units Cw7/4-7 and Cw8/7.1 have also been rated as having moderate to high (M-H) erosion potential due mainly to the overall steepness of slopes, typically in the range 25 - 50 % and locally steeper.
Cw8/7.1	M-H	Terrain units Cw7/4-7 and Cw8/7.1 have also been rated as having moderate to high (M-H) erosion potential due mainly to the overall steepness of slopes, typically in the range 25 - 50 % and locally steeper.



NOTE: This Figure 8.3.4 must be viewed with Figure 8.3.5

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Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**SOILS LNG FACILITY**
	Drawn: VH/CA	Approved: JB	Date: 26-02-2009	Figure: **8.3.4**	Rev:B
	Job No: **4262 6220**	File No: 42626220-g-974b.wor	A4

SOILS LEGEND

Soil Mapping Unit	Brief Description	Topsoil/Sub-soil Stripping Guide (m)
Groups 4-7	Shallow uniform or gradational dark grey-brown gravelly loam to clay loam (Group 4) soils with very stony silt to clay loam subsoils on low rises and higher hill crests; & shallow to medium deep gradational gravelly loam over gravelly medium to heavy clay soils (Type 7.1) on upper hill slopes;	0.2/0.5
Group 5	Medium to deep dark brown silt loamy surface gravelly duplex soils with a pale gravelly clay or loam (A2) horizon, over red, red brown, yellow brown and pale grey variegated medium to heavy or heavy structured clay subsoils	0.15/0.5
Group 5-7	Medium to deep dark brown loamy surface gravelly duplex soils as for Group 5; some medium to deep gradational fine-textured clay soils (Type 7.3) with brown or red-brown acidic heavy clay subsoils occur locally on some lower footslopes	0.15/0.5
Groups 6-7	Association of thin brown silt to clay loamy surface duplex soils with diffusely mottled brown and yellowish brown alkaline sodic, moderately saline heavy clay sub-soils; together with deep uniform clay soils (Type7.2) with structured becoming massive, mottled grey and yellow-brown slightly acidic to alkaline, sodic and moderately saline heavy clay subsoils.	0.3/0.5
Soil Type 7.1	Shallow to medium deep uniform or gradational gravelly clay, gravelly clay loam or clay loam surface soils with gravelly clay or medium to heavy acidic clay subsoils underlain by HW rock	0.2/0.5
Soil Type 7.3	Deep uniform or gradational brown to yellowish red silty clay or heavy clay surface soils over red and grey diffusely mottled strongly acidic, moderately to highly saline medium to heavy clay subsoils	0.2
Groups 7-9	Mostly thin silty clay or silt loamy surface (Group 9) soils with saturated gleyed, saline clays, clayey silt, silty sand, sandy mud subsoils; some deep uniform moderately strongly saline, strongly acidic medium to heavy clay soils (Type 7.3) occur fringing the inland margins.	0
Group 9	Uniform, gradational and weak duplex soils with a thin silty clay surface soil over permanently saturated often gleyed saline clays, clayey silt, silty sand or sandy mud subsoils.	0

Note: Refer to Report Section 1.5 and Appendix A-2 in Appendix L3 for a more detailed description of soils.

NOTE: This Figure 8.3.5 must be viewed with Figure 8.3.4

Client

URS

Project
GLADSTONE LNG PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Title
SOILS LEGEND

Drawn: VH/CA | Approved: JB | Date: 26-02-2009
Job No: **4262 6220** | File No: 42626220-g-974b.wor
Figure: **8.3.5** | Rev:B | **A4**

Topsoil Resources

Useable topsoil resources are mainly confined to the surficial (A) horizon materials and in places in the upper part of the subsurface (B1) horizons, which contain seed-stock, micro-organisms, organic matter and nutrients necessary for plant growth. Soil microbial activity, organic matter content and other parameters affecting soil productivity and fertility, tend to decrease with depth.

Comments with respect to topsoil suitability and availability, and indicative stripping depths for the terrain units and associated soil types that occur within the LNG facility study area are provided in Table 8.3.5.

Table 8.3.5 Soil Group Topsoil Suitability

Soil Group	Terrain Unit	Topsoil Stripping Depth	Discussion
4	Cw4/4-7 Cw7/4-7	Upper 0.1-0.3 m (av.0.2 m) of the A horizon layer	Dependent upon the amount and size of the gravel/stone content present, potential topsoil resources in these soils are likely to be restricted to the upper 0.1-0.3 m (av.0.2 m) of the A horizon. The deeper subsoils are likely to be excessively gravelly and/or may contain silty fines which are prone to form bulldust when disturbed and reworked. Accordingly, these materials are considered to be unsuitable for use either for topsoil or as a supplementary resource.
5	Cw6/5 Cw5/5-7 Cw3/5-7	Average thickness of 0.15 m	The surficial soil horizons contain gravel and coarse stone, some of which is of colluvial origin from the higher steeper slopes. The topsoil stripping depth in these areas is likely to be limited to an average thickness of 0.15 m, primarily to make use of the organics and seed stock content of the soils. Useable supplementary soil resources may occur locally up to depths of about 0.5 m, but in general, unless the coarse-fraction material can be readily separated out, the subsurface materials are likely to be excessively stony for use either as topsoil or supplementary soil resources.
6	Qa2/6-7	Upper 0.15 m	Only the upper 0.15 m is worth recovering for the organic and seed-stock content. Where these soils occur in association with soil Type 7, blending of the Type 6 topsoil with the associated soil types will be beneficial.
7	Cw4/4-7 Cw7/4-7	Average topsoil stripping depth 0.2 m	As mapped the Group 7 soils occur in association with Group 4 soils in terrain units Cw4/4-7 and Cw7/4-7, where an average topsoil stripping depth for both the Group 4 soils and the Group 7 soils is 0.2 m. Depending on the gravel content of the subsurface materials, useable supplementary soil resources to a depth of 0.5 m may be available.
	Cw3/5-7 Cw5/5-7	Average topsoil stripping depth 0.2 m	The (Group 7) soils also occur in association with Group 5 soils in terrain unit Cw3/5-7 and Cw5/5-7, where an average topsoil stripping depth for the Group 7 soils is 0.2 m. Depending on the gravel content of the subsurface materials, useable supplementary soil resources to a depth of approximately 0.5 m may be available.
	Qa2/6-7	Average topsoil stripping depth 0.3 m	The (Group 7) soils also occur in association with lesser occurrences of Group 6 soils in terrain unit Qa2/6-7. An average topsoil stripping depth for the Group 7 soils is 0.3 m. Depending on the gravel content and/or the plasticity, structure and consistence of the subsurface materials, useable supplementary soil resources to a depth of approximately 0.5 m may be available.
	Cw8/7.1 Qe2/7.3	Average topsoil stripping depth 0.2 m	The (Group 7) soils comprise the dominant soil type in terrain unit Cw8/7.1 and local occurrences of terrain unit Qe2/7.3 fringing the estuarine/coastal flats. An average topsoil stripping depth in both of these soil/landscape situations is 0.2 m. Depending on the gravel content of the subsurface materials in the occurrences of terrain unit Cw8/7.1, useable supplementary soil resources to a depth of

Soil Group	Terrain Unit	Topsoil Stripping Depth	Discussion
			approximately 0.5 m may be available. In terrain unit Qe2/7.3, the subsurface horizons below the (0.2 m) topsoil stripping depth are strongly acidic and have increasing levels of soil salinity and are not likely to be suitable as a supplementary soil resource.
9	Qe0/9 Qe1/7-9	Not suitable	No topsoil resources are likely to be available from either of those locations.

Agricultural Land

Table 8.3.6 shows the agricultural land capability of the terrain within the LNG facility study area with the respective land classes assessed identified on the basis of terrain units, as shown in Figure 8.3.6. Figure 8.3.7 provides a key to Figure 8.3.6. The basis for the assessment of agricultural land capability is included in Appendix L3.

Table 8.3.6 Agricultural Land Capability in the LNG Facility Study Area

Terrain Unit (1)	Area (ha)	Ag. Land Class (2)	Cropping Suitability (1)		Grazing Suitability (1)		Remarks
			Class	Limitations (1)	Class	Limitations (1)	
Qe0/9	7.8	D	5	f5, w5, sa5	5	sa5, w5, f5	Mangrove mud flats
Qe1/7-9	49.3	D	5	f5, w5, sa5	5	sa5, w5, f5	Estuarine/coastal flats
Qe2/7.3	7.9	C3	5	m5, n5, sa3, w3, f4,	4	m4, n4, sa3, w2, f3, so4, a4	Slightly elevated estuarine plain
Qa2/6-7	43.5	B	3-4	m3, p3, sa3, w3, f3	2-3	m2, p2, sa3, w2, f2, so2	Alluvial valley floors
Cw3/5-7	0.03	C1	4	m4, n4, sa2-3,	2-3	m3, n3, so3 sa2-3, e2	Undulating lowlands and valley floors
Cw4/4-7	34.6	C1	4	m4, pt3, e4	3	m3, e3, n3, e3	Undulating foot-slope interfluves and saddles
Cw5/5-7	78.0	C2	4-5	m4, n4, sa2-3, e5	3-4	m3, n3-4, so3 sa2-3, e4	Mod. inclined planar to concave lower slopes
Cw6/5	41.5	C3	5	m5, e5, pg4	4	m4, e4, pg4	Low rounded hills and low hilly lands
Cw7/4-7	102.0	C3	5	m5, e5,	4-5	m4, e4, t4	Steep hilly lands
Cw8/7.1	20.0	D	5	m5, e5, t5	5	m4, e4, t5	Steep high hilly lands

(1) Refer to Appendix L3 for a Description of Terrain Units, Cropping Suitability and Grazing Suitability
(2) Agricultural Land Class in accordance with DPI/DHLGP (1993)

As mapped, the LNG facility soils site study area is 384.6 ha. Based on the cumulative areas of the terrain units that occur within the study area and the corresponding agricultural land classes determined as shown Table 8.3.6, a summary of the results of the (pre-development) land capability assessment is as follows:

- Class A land was not identified in the LNG study area;
- Class B land comprises 43.5 ha (11.3 %) of the LNG facility study area;
- Class C1 land comprises 34.6 ha (9.0 %) of the LNG facility study area;
- Class C2 land comprises 78.0 ha (20.3 %) of the LNG facility study area;

- Class C3 land comprises 151.4 ha (39.4 %) of the LNG facility study area; and
- Class D land encompasses 77.1 ha (20.0 %) of the LNG facility study area.

As there was no Class A land identified, the occurrence of Good Quality Agricultural Land (GQAL) in the LNG facility study area is limited to the alluvial valley floors mapped as terrain unit Qa2/6-7, which have been rated as Agricultural Land Class B. Collectively, these lands occupy an area of 43.5 ha (11.3 % of the LNG facility study area). If cleared of the native vegetation, due to the variable but locally high silt content in the surface soils, these areas have limited potential for sustained cultivation and dry-land crop production but are well-suited for grazing enterprises.

Land rated as Class C1 encompasses a land area of 34.6 ha (9.0 % of the LNG facility study area). This land constitutes undulating lowlands in valley floors mapped as terrain unit Cw3/5-7 and undulating gently inclined foot slope interfluves and low saddles in terrain unit Cw4/4-7. The land is suitable for occasional cultivation for the establishment of improved pastures and is well suited to grazing of native pastures.

Class C2 lands encompasses 78.0 ha (20.3 % of the LNG facility study area) and includes moderately inclined, planar to concave mid to lower hill slopes mapped as terrain unit and Cw5/5-7. These lands are mainly suited to grazing of native pastures.

Class C3 land has an area of 151.4 ha (39.4 % of the study area) and include terrain units Qe2/7.3 near the coastline and low hilly to hilly lands of terrain units Cw6/5 and Cw7/4-7. This land is only suitable for limited controlled grazing of native pastures in the low-lying coastal lands due to the presence of saline and erodible soils and due to access constraints and erosion potential in the steeper hilly areas.

Land rated as Class D constitutes non-agricultural lands and collectively encompasses a total area of 77.1 ha (20.0 % of the LNG facility study area). This includes the coastal mangrove tidal flats and the estuarine mud flats - terrain units Qe0/9 and Qe1/7-9 and the steep high hilly lands of terrain unit Cw8/7.1. These areas are largely unsuitable for grazing except for very limited grazing of the lower slope of the higher hilly areas.

Acid Sulfate Soils

The distribution of actual acid sulfate soils (AASS) is widespread laterally throughout the low lying areas that fringe the coastline, and continue down-sequence to the general 2 m depth of testing at a number of locations. As discussed in Appendix L4, the AASS is generally at a low level but is widely present. As may be anticipated, there were no AASS sediments identified in the offshore sequences. Figure 8.3.8 provides a map of ASS occurrence/absence.

Load Bearing Capacity of Marine Plains

Details on the load bearing capacity of the marine plains in the vicinity of the LNG facility study area are provided in Section 7.3.1.4.

8.3.1.5 Potential Impacts and Mitigation Measures

The overall development proposed for the LNG facility site area will involve a series of site specific development components. These include:

- The LNG facility;
- The extension of the access road and gas transmission pipeline;
- The MOF; and
- The PLF.

The combined disturbance footprint of these proposed facilities (including designated buffer zones) is shown in Figure 8.3.9**,** together with the terrain units encompassed within the overall development area. The disturbance footprint encompasses a land area of 127.1 ha and the cumulative areas of the terrain units included within each of the development components are summarised in Table 8.3.7.

Table 8.3.7 Areas of Terrain Units within the Facility Site and Associated Infrastructure Area associated with the LNG Facility Site

Terrain Units	Facility Site (ha)	MOF (ha)	PLF (ha)	Infrastructure Access Corridor Extension (ha)
Qe0/9		0.1	0.4	
Qe1/7-9	1.0	1.8	0.1	
Qe2/7.3		1.9		
Qa2/6-7	34.5	1.7	0,1	0.6
Cw3/5-7				0.03
Cw4/4-7		1.6		6.4
Cw5/5-7	30.5	5.4	0.6	5.4
Cw6/5	17.5	3.5		2.4
Cw7/4-7	8.6			0.01
Cw8/7.1				3.0
Totals	92.1	16.0	1.2	17.8

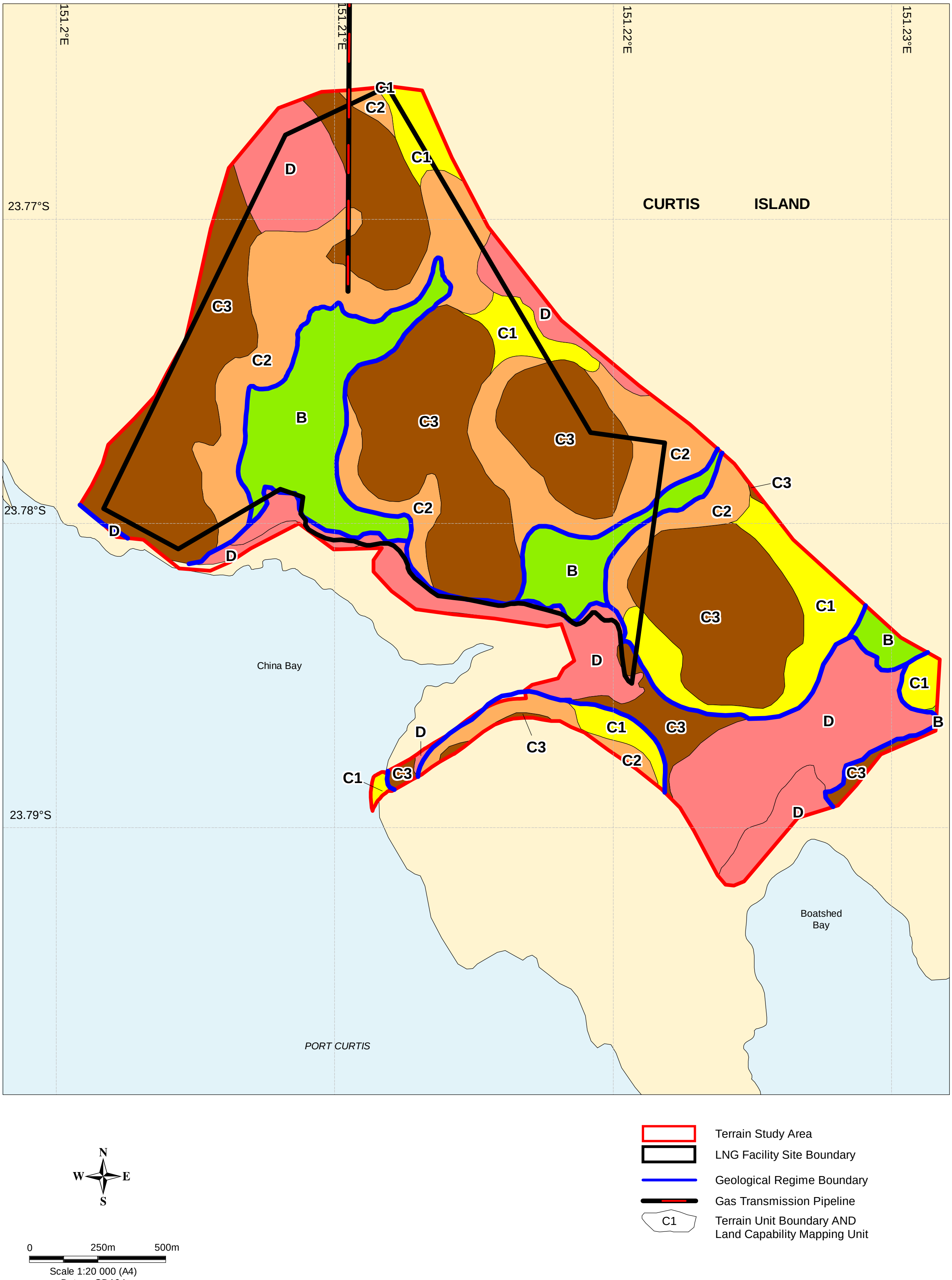
The main potential impacts relating to the development of the LNG facility site and related facilities include:

- Changes to agricultural land capability;
- Erosion potential of the development area lands when subject to clearing and earthworks;
- The occurrence of and management of problem soil areas including saline, sodic and/or dispersive soil areas;
- Management of topsoil; and
- Excavation conditions.

Soil Erosion

Potential Impacts

The steep hilly and higher hilly lands (Terrain units Cw8/7.1 and Cw7/4-7) have been rated as having medium to high erosion potential if subject to disturbance and/or clearing of vegetation, primarily due to the overall steepness of the hill slopes. Although the overall slopes are less steep, terrain units Cw6/5 and Cw5/5-7 are also rated medium to high, mainly due to the sodic and dispersive nature of the sub-soils if they become exposed and remain unprotected. In addition, terrain unit Cw5/5-7 is rated medium to high due to the topographic position in the landscape, whereby these areas may be subject to considerable surface water run-on from the adjacent higher hill slopes. Erosion potential in terrain units Cw3/5-7 and Cw4/4-7 has been rated low to moderate due to the overall, relatively gentle surface slopes and the gravelly nature of the surficial soils which permits rapid surface water infiltration.



NOTE: This Figure 8.3.6 must be viewed with Figure 8.3.7

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

Client	Project	Title	
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**AGRICULTURAL LAND SUITABILITY LNG FACILITY**	
	Drawn: VH/CA · Approved: JB · Date: 26-02-2009	Figure: **8.3.6**	Rev:B
	Job No: **4262 6220** · File No: 42626220-g-975b.wor		**A4**

LEGEND (Figure 4 – Agricultural Land Suitability)

Agricultural Land Classes	
A	Crop Land – suitable for rainfed cropping or existing irrigation lands, with limitations ranging from nil to moderate for a range of crop production.
B	Limited Crop Land - marginal lands for crops due to severe limitations for crop production; engineering and/or agronomic improvement may be required to suitable for cropping
C1	Pasture Land - suitable for sown pastures where ground disturbance is possible for pasture establishment; or, suitable for native pastures on higher fertility soils.
C2	Pasture Land - suitable for native pastures with or without the addition of improved pasture species introduced without ground disturbance.
C3	Pasture Land – suitable for light grazing of native pastures in accessible areas; otherwise, very steep land more suited for forestry, conservation or catchment protection.
D	Non-Agricultural Land - due to land tenure or use, or extreme limitations, steep slopes, shallow rocky soils, drainage-ways; land with significant habitat or conservation value.

Terrain Unit	Area (ha)	Land Suitability Classes		
		Dryland Cropping	Grazing	Ag. Land Class
Qe0/9	7.42	5	5	D
Qe1/7-9	49.31	5	5	D
Qe2/7.3	7.92	5	4	C3
Qa2/6-7	43.51	3-4	2-3	B
Cw3/5-7	0.03	4	2-3	C1
Cw4/4-7	34.62	4	3	C1
Cw5/5-7	78.04	4-5	3-4	C2
Cw6/5	41.48	5	4	C3
Cw7/4-7	101.96	5	4-5	C3
Cw8/7.1	19.95	5	5	D

Note: Refer to Table 2 and Appendix B in Appendix L3 for the basis of assessment of Land Suitability classes.

NOTE: This Figure 8.3.7 must be viewed with Figure 8.3.6

Client: LNG / URS

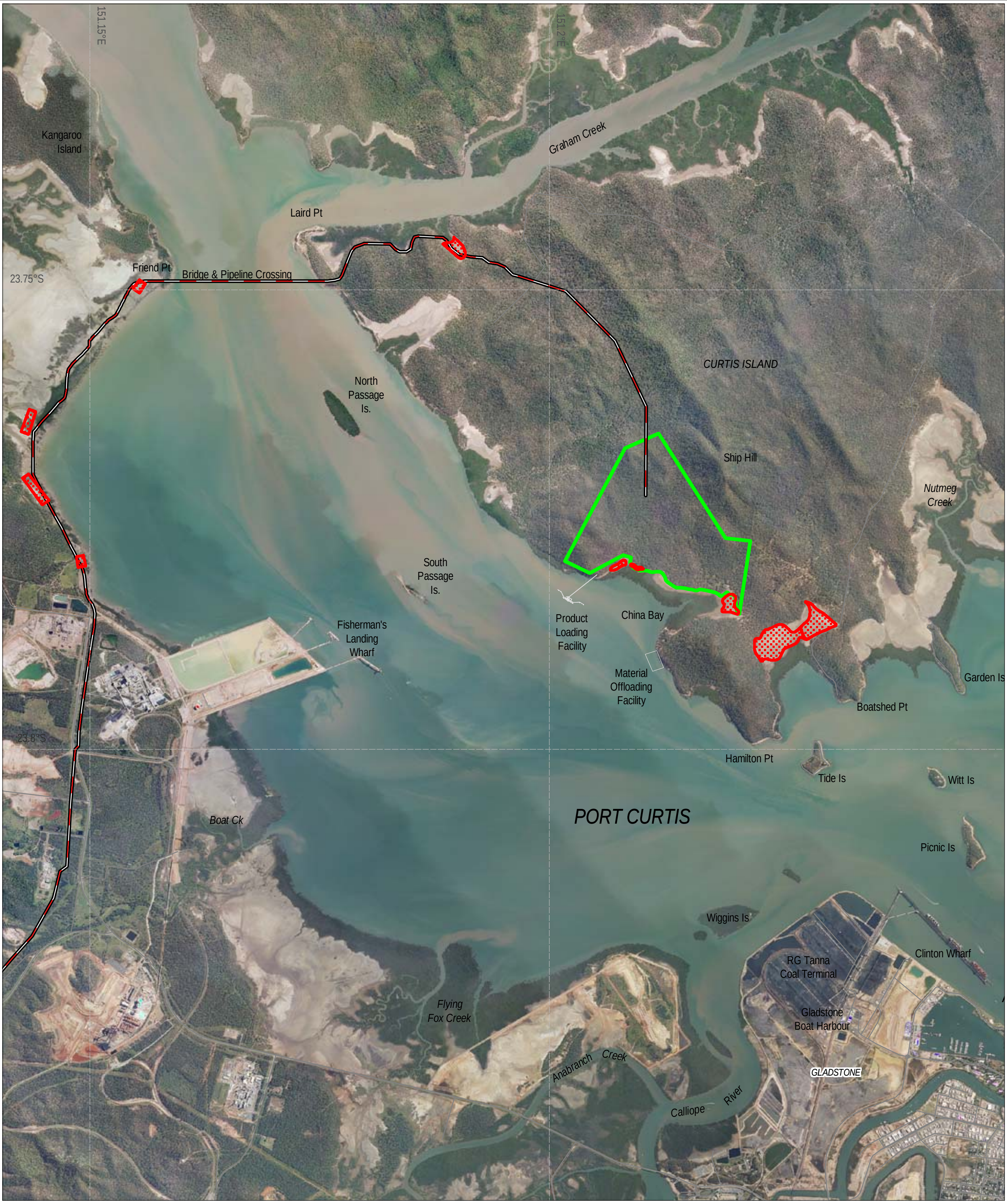
Project: GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT

Title: **LEGEND AGRICULTURAL LAND SUITABILITY**

Drawn: VH/CA | Approved: JB | Date: 12-05-2009

Job No: **4262 6220** | File No: 42626220-g-975b.wor

Figure: **8.3.7** | Rev:C | **A4**



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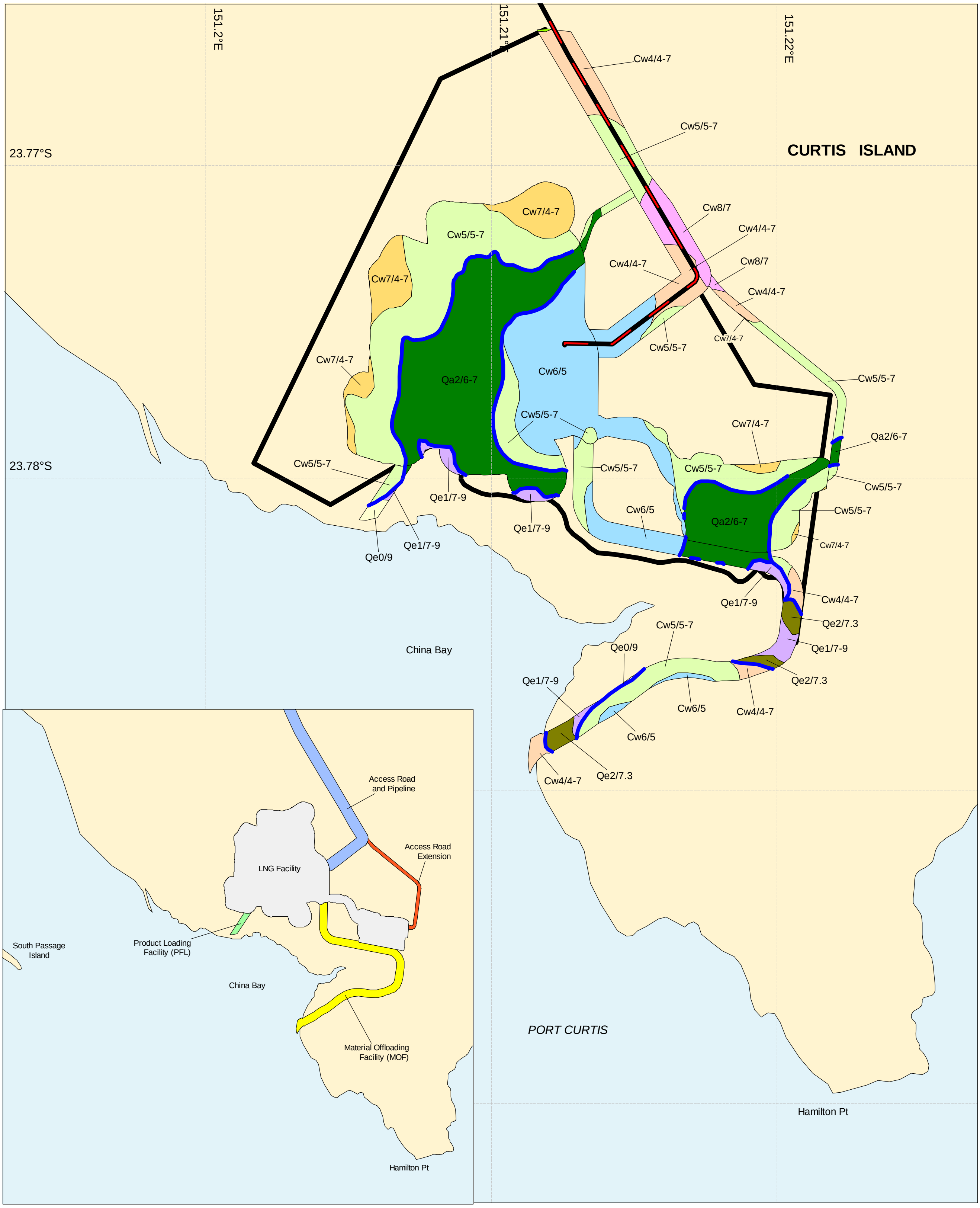
Scale 1:60 000 (A4)
Datum GDA94

Areas of Actual Acid Sulfate Soil Occurence
LNG Facility Site Boundary
Gas Transmission Pipeline

Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright. Geocoastal Figure 1-7 (11-02-2009)

Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**ACID SULFATE SOIL OCCURRENCE**

Drawn: LL	Approved: JB	Date: 26-02-2009	Figure: **8.3.8**	Rev:B
Job No: **4262 6220**	File No: 42626220-g-976b.wor			**A4**



N W E S

0 250m 500m

Scale 1:20 000 (A4)
Datum : GDA94

LNG Facility Site Boundary
Geological Regime Boundary
Gas Transmission Pipeline
Qe0/9 Terrain Unit 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	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**TERRAIN UNITS WITHIN THE LNG FACILITY AND ASSOCIATED INFRASTRUCTURE AREA DISTURBANCE FOOTPRINT**
	Drawn: VH/CA · Approved: JB · Date: 15-05-2009	Figure: **8.3.9** · Rev:B
	Job No: **4262 6220** · File No: 42626220-g-977b.wor	A4

In the lower-lying and generally flatter coastal lands and the alluvial valley floors, terrain unit Qe0/9 has low to moderate erosion potential due to the permanently saturated, fine-textured and cohesive nature of the surficial soils. Terrain units Qe1/7-9 and Qe2/7.3 are moderately susceptible to wind erosion due to the bare or sparse surface cover and the silty nature of the surface soils. Terrain unit Qa2/6-7 has been rated medium to high due to the hard-setting properties of the surface soil horizons, the sodic and dispersive properties of the subsoil layers and the potential for periodic flood flows and local scouring effects.

Approximately 113.8 ha (90 %) of the land in the facility site disturbance footprint area has been rated as having moderate to high (M-H) erosion potential where the land is subject to clearing and earthworks for site development purposes. A further 4.8 ha (3.8 %) has been rated moderate (M) and 8.5 ha (6.7 %) has been rated as having low to moderate (L-M) erosion potential.

Mitigation Measures

In order to minimise erosion on disturbed areas, the general erosion control measures outlined below will be implemented to minimise erosion and reduce sediment loss from the construction sites. General erosion control measures include the following:

- Limit the area disturbed, and clear progressively, immediately prior to construction activities commencing;
- Scheduling major earthworks activities to avoid, where possible, the higher rainfall months of December to March;
- Safeguard the surface layer by stripping and stockpiling topsoil prior to construction;
- Control runoff and sediment loss from the site using appropriate short term erosion control measures such as silt fences, hay bales, diversion mounds, etc;
- Use temporary soil diversion mounds to control runoff within and to divert water away from the construction site where practicable;
- Minimise the period that the bare soil is left exposed to erosion;
- Restrict heavy vehicle access and use of earthmoving equipment on construction sites during and immediately following periods of heavy or prolonged rainfall except on designated tracks; and
- Use sediment traps and sediment collection ponds to minimise off-site effects of erosion.

The control of erosion and sediment movement within and from the site will be employed both during the construction stage and subsequently during the operating life of the facility. Where access is required in the long term, tracks will be constructed with a gravel or sealed surface and maintained to permit all weather access. Where access is required for temporary (construction) use only, disturbed areas will be lightly ripped, restored to a stable condition and revegetated or returned to their pre-disturbance land use condition as soon as practicable following the completion of construction activities.

The general erosion control measures outlined above will be implemented where appropriate to minimise the potential effects of erosion during the site development works. More construction specific erosion control measures detailed in Section 6.3.1, will be incorporated in a site-based construction environmental management plan (EMP) for specific aspects of the development. These include erosion control measures related to:

- Infrastructure and general development areas;
- Pipelines, and/or buried services and power transmission lines;
- Access roads, service tracks and temporary access tracks;
- Recommended measures for dust suppression;
- Erosion control on sloping lands; and
- Vegetation clearing in general.

Problem Soil Areas

Salinity, Sodicity and Dispersiveness

Potential Impacts

Reference to the description and assessment of terrain units in Appendix L3, indicates terrain units with moderate and moderate to high levels of salinity, sodicity and/or dispersive properties, particularly in the deeper clay subsoil and substrate materials, occur over more than 116 ha (> 90 %) of the facility site disturbance footprint development area. It is understood that the finished level of the facility site construction platform is proposed to be RL 16.5 m ASL. To achieve this level, following stripping and stockpiling of topsoil resources, the topographically higher outer margins of the area and central lower-lying parts of the site will be subject to cut and fill earthworks operations respectively. These earthworks operations may expose areas of saline, sodic and/or dispersive soil layers within the finished surface level of the construction platform.

Mitigation Measures

Prior to commencing construction works or replacing topsoil resources, site specific geotechnical soils investigations will be undertaken to identify any area specific problem soils areas, in particular where strongly acidic and/or saline soils may occur which could give rise to corrosion of buried steel or concrete products. Where sodic and/or dispersive soils are identified and subsequently exposed as a result of earthworks, then mitigation measures such as a dolomite or gypsum-based soil conditioner to be spread and blended into the exposed surface soils will be considered to restore the ionic balance and thus reduce levels of sodicity and dispersion effects in the soils prior to commencing construction or the placement of topsoil material.

Embankment Construction or Filling on the Coastal/Estuarine Tidal Flats

Potential Impacts

Construction of the MOF, PLF and site facilities may in part, involve embankment construction or filling in an area of approximately 3.4 ha of soft saturated soils potentially containing ASS.

Mitigation Measures

Site specific ASS investigations of these areas will be undertaken to determine if Actual ASS materials are present. If found to occur, lime treatment to neutralise the acidity levels will be required, as filling over Actual ASS (very strongly acidic) materials is prohibited unless the materials are treated. The high salinity levels also create a potentially highly corrosive environment for buried steel or concrete products and any requirement for cathodic protection to mitigate corrosion effects will also be investigated.

Tidal Inundation and Site Flooding Potential

Potential Impacts

Within the LNG facility site areas identified as terrain unit Qe0/9 – tidal mangrove flats are prone to regular tidal inundation, whereas the estuarine flats and extra-tidal mud flats (terrain unit Qe1/7-9) are subject to periodic tidal inundation due to extra high tide events. Terrain units Qe2/7.3 occurring around the fringes of the estuarine flats are subject to tidal effects only on rare occasions. The alluvial valley floors (terrain unit Qa2/6-7) are rarely flood prone but may be subject to local flash flooding in the immediate vicinity of the tributary streams and area drainage ways.

Mitigation Measures

Where necessary, existing drainage lines currently flowing through the facility site development area will be re-directed and modified to link with the internal site drainage network to control potential flooding within the site. Where the site development platform encroaches onto the estuarine tidal flats, rock armouring of any proposed flood prevention levee embankments may be incorporated where necessary to protect the integrity of the embankment from tidal ingress or possible storm surge.

Sodic and/or Dispersive Soils

Sodicity is the level of exchangeable sodium in the soil and is determined using the exchangeable sodium percentage (ESP), which is the amount of exchangeable sodium expressed as a percentage of the cation exchange capacity (CEC). Sodic soils on exposure tend to exhibit the following general problems:

- Severe surface crusting;
- Likely dispersion on wetting;
- Very low infiltration and hydraulic conductivity;
- Very hard dense subsoils;
- Susceptibility to structural degradation;
- High susceptibility to severe gully erosion if exposed and unprotected; and
- High susceptibility to tunnel erosion.

Sodic and locally strongly sodic soil profiles were found to occur in the estuarine and alluvial plains in terrain units Qe2/7.3, Qa2/6-7 and on the lower foot slopes in terrain unit Cw5/5-7. In the more hilly areas, soils found in terrain units Cw7/4-7 and Cw8/7.1 and in the higher parts of terrain unit Cw5/5-7, exhibited slight to moderate levels of sodicity in the heavier clay (B and B-C) soil horizons.

Potential Impacts

Soils with medium to high levels of ESP generally tend to pre-dispose the material to dispersion. As a result the soil may become subject to rill or gully erosion if disturbed or exposed and left unprotected. However, in some situations where highly acidic soils occur (pH <5.5), this appears to counteract the dispersive effects of soil sodicity, with indicative dispersion testing indicating the majority of these sodic and strongly acidic materials being non-dispersive.

Mitigation Measures

Where strongly or very strongly sodic and/or dispersive materials are identified; these materials will not be used for rehabilitation purposes. However, should suspected sodic or dispersive materials be exposed as a result of site earthworks (subject to confirmation by appropriate soil testing), then dolomite or gypsum-based soil conditioner could be spread and blended into the exposed surface soils to restore the ionic balance and thus reduce levels of sodicity and dispersion effects in the soils prior to the placement of topsoil material.

Site Excavation Conditions

Potential Impacts

Whilst no specific site investigations were undertaken to determine the likely depth to hard rock throughout the site, some general conclusions may be drawn from the soil test pits excavated using a small tracked excavator and from the results of the groundwater drilling investigations undertaken within the LNG facility study area. Those investigations have indicated that the surficial materials including the upper levels of the highly weathered rock zone should be readily excavated to depths of at least 2 m, using conventional earth moving equipment with rock ripping capability. Excavation below 2 m to depths of up to approximately 6 - 8 m, may encounter more difficult ground conditions including stronger bands of moderately weathered to fresh rock that may locally require the use of rock breaking equipment for rock removal. The requirement to employ drilling and blasting techniques for rock removal is considered unlikely to be necessary for excavation depths of up to at least 6 - 8 m.

Mitigation Measures

Where stronger bands of rock are encountered, these may provide a suitable source of crushed aggregate and may be used for construction purposes. Alternatively any suitably strong rock sources encountered may be used for riprap or rock armouring purposes to mitigate soil erosion.

For the duration of the site development earthworks activities dust suppression measures outlined in Section 6.3 will be implemented in order to mitigate potential impacts due to dust and also to help reduce the effects of wind erosion.

Topsoil Resources

Potential Impacts

The suitability of materials for use as topsoil resources for rehabilitation of lands that may be disturbed during the development and operating stages of the project has been discussed in Section 8.3.1.4. Indicative soil stripping depths of suitable topsoil material have been determined, as shown in Figure 8.3.4. An assessment has also been made of materials that are considered to be marginal for use as topsoil material, but will have acceptable properties for the use as subsoil resources to supplement the topsoil resources if required.

Mitigation Measures

Topsoil Management

Some variability will occur within the soil types and conditions that occur within each of the terrain units in the LNG facility site area. Consequently monitoring of soil type variability by the site environmental officer or other qualified personnel with soils experience is recommended during the pre-stripping of construction sites to ensure that the maximum quantity and quality of useable topsoil resources is recovered for later use in site rehabilitation.

Topsoil Stripping

Prior to the commencement of topsoil stripping, areas will be cleared of vegetation. Earthmoving plant operators will be trained and/or supervised to ensure that stripping operations are conducted in accordance with stripping plans and *in situ* soil conditions. This will ensure that excessive clearing does not occur, all suitable topsoil material resources are salvaged and the quality of the stripped topsoil is not reduced through contamination with unsuitable soils. Care will be taken during the stripping, stockpiling, and respreading operations to ensure that moisture content of the topsoil resources is such that structural degradation of the soil is avoided and excessive compaction does not occur during the stockpiling process.

Stockpiling

Where practicable, topsoil material will be respread directly from stripped areas on to other areas being rehabilitated. Where this is not practicable, topsoil will be stored in stockpiles. Topsoil material stockpiles will be located in areas that are outside the construction project disturbance footprint area and away from drainage lines. Drainage from higher areas will be diverted around stockpiles to prevent erosion. Sediment controls will be installed immediately down-slope of the stockpiles to collect any washed sediment.

Stockpiles will be formed in low mounds of minimum height (approximately 3 m maximum) and maximum surface area, consistent with the storage area available. If the stockpile is to be retained for a period of more than 6 months, the stockpile will be deep ripped and sown with local grass seed-stock, legumes and where appropriate the use of any suitable potentially threatened (local) plant species will be considered in order to keep the soil healthy and maintain biological activity. Topsoil stockpiles will be clearly sign-posted for easy identification and to avoid any inadvertent losses. Establishment of weeds on the stockpiles will also be monitored and controlled.

Agricultural Land Capability

Potential Impacts

Facility site construction and development activities will result in changes to the pre-development land classes shown in Table 8.3.6, which will result in an overall increase of non-agricultural lands during the project life-span. On a terrain unit basis, this will result in:

- Changes to 36.9 ha of Class B land, (84.8 % of the Class B land shown in Figure 8.3.6);
- Changes to 8.03 ha of Class C1 land, (23.2 % of the Class C1land shown in Figure 8.3.6);
- Changes to 41.9 ha of Class C2 land, (53.7 % of the Class C2 land shown in Figure 8.3.6);
- Changes to 33.9 ha of Class C3 land, (22.4 % of the Class C3 land shown in Figure 8.3.6); and
- In addition to the existing 6.4 ha of Class D land that will be impacted by the proposed development, post-development there will be an overall increase of 120.7 ha of Class D land (156.5 % of the Class D land shown in Figure 8.3.6), due to the change in classification to Class D of the Class B and C land shown above, as a result of the LNG facility site development.

Mitigation Measures

The loss of agricultural land capability will be for the operational life of the LNG facility. Unless otherwise agreed, upon decommissioning of the project, structures and hard-stand areas will be removed and the land rehabilitated, with topsoil replaced in order to return the land to as near as practicable to its pre-development land use capability status, principally grazing lands.

Acid Sulfate Soils

Potential Impacts

If inappropriately managed, ASS can have a substantial environmental impact. These impacts are now well documented and range from more direct impacts such as mass mortality of marine organisms and flora, to more insidious effects such as the impact on organisms requiring carbonate for shell development, removal of the mucus layer that protects fish from viruses, and the release of high levels of iron and aluminium into receiving waters. These impacts can be further enhanced in tropical climates where both the initial conditions for the development of pyritic soils have led to elevated concentrations, and the conversion of pyrite to acid sulfate products, a bacterially catalysed process, are accelerated by temperature/moisture conditions.

The potential environmental impacts of acid sulfate soils are generally considered in terms of either:

1) PASS which may result in a range of impacts if disturbed and incorrectly managed; and
2) AASS which may present a current low level impact that the receiving environment is adjusted to, but can create an enhanced environmental impact through activity.

Potential Acid Sulfate Soil Impacts

Onshore

With the general exception of a thin capping layer, the complete Holocene-aged sedimentary sequence tested in onshore locations revealed a moderate to very high acid sulfate soil potential.

The pre-Holocene-aged substrate was consistently demonstrated to have no inherent acid sulfate soil potential, however a zone of ~0.5 m immediately below the Holocene/Pleistocene boundary commonly revealed an inheritance of moderate acid sulfate soil potential from the overlying sequence by infiltration of interstitial waters.

The assessment criteria provided by the client at the time of this study provides for no activities that will either disturb these in situ PASS soils or lower the local water table, and therefore, no environmental hazard is identified from these activities. However, an identifiable risk with surcharging these immature silt clay sediments is the production of bulges adjacent to the filled area which elevates PASS sediments above the water table (i.e. thereby elevating them into oxidising conditions leading to activation), or in more uncontrolled surcharge conditions surface blowouts of this PASS material (as has occurred at a number of locations in the past decade).

Offshore

As observed previously, the single site within the embayment north of Hamilton Point showed evidence of Holocene infiltration into the upper Pleistocene clays, and therefore the substrate in this area may have a zone of PASS immediately below the interface. This sediment may have the potential for environmental harm if disturbed, or oxidised.

Actual Acid Sulfate Soil Impacts

Onshore

The distribution of AASS was widespread laterally throughout the area and continued down-sequence to the general 2m depth of testing at a number of locations. As discussed in the preceding text, this AASS was generally at a low level but is widely present.

The potential for this acidity to provide an enhanced impact on receiving environments is recognised in legislation (Qld State Planning Policy 2/02; Dear et al., [2002]), and presents a considerable hurdle to all proposed development activities because it does not allow for any other strategy other than neutralisation (i.e. *in situ* burial by overburden or reinterment are not options allowed). The restriction on filling over AASS presents a substantial limitation on the proposal to fill existing embayment tidal sediments with dredge spoil.

The philosophy behind the legislation preventing filling over AASS may be summarised as:

- Surcharging these sediments will result in a sudden enhanced lateral expulsion of acid sulfate leachate into receiving environments; and
- Burial of contaminated soils is generally not considered a sound environmental ethos.

Debate over the positive benefit of surcharging in reducing the porosity of these sediments and thereby both restricting further oxidation and transmission of leachate have failed to impact upon legislation at this time.

Offshore

As may be anticipated, there were no AASS sediments identified in the offshore sequences.

Potential Acid Sulfate Soil

Onshore

As discussed in the above section, uncontrolled surcharging with dredge overburden could lead to activation of PASS by creating bulges around the boundary of the fill, or in extreme cases blowouts. Obviously this bulge effect will not occur in the residual soils fringing the tidal flat on the landward side, and fill/surcharge strategies should account for this by:

- Filling at a rate that controls the development of bulging; and
- Filling in a direction that will allow any minor bulging to occur on the seaward foreslope allowing the sediment to be displaced below an existing level of continuous saturation.

At the time of this study no activities that will either directly disturb these *in situ* PASS soils or lower the local water table are planned, and therefore, no environmental hazard is identified from these activities at this time.

Should activities be planned that may result in the direct disturbance of these soils they will require considerable management as the potential for impacts is high, and because of the nature of these sediments (i.e. moist, poorly cohered silt/clay with a high organic content) conventional management strategies such as reinterment and neutralisation with lime will be challenging if required.

Offshore

The results of testing for the site investigated within the embayment revealed a positive net PASS in the high range, and this is likely to be representative of these embayment sediments.

The current proposal does not plan to disturb this area other than by driving piles. However, while this plan should not lead to intentional disturbance, the logistics of controlling sediment disturbance while placing piling barges in the bay and driving piles for the trestle structure will need to be considered.

Along the main marine transect where dredging is proposed, all Holocene-aged sediments provided a negative net acidity indicating that they have excess buffering capacity. Dredging this sediment will provide no acid sulfate soils risk to the environment.

Actual Acid Sulfate Soil

Onshore

Legislative restrictions on filling over AASS presents a substantial limitation on the proposal to fill existing embayment tidal sediments with dredge spoil.

Some aspects of this particular area and the filling strategy proposed may provide a basis for examining a strategy whereby filling may occur in a controlled fashion with no harmful environmental impacts. The factors to be considered include:

- the level of AASS is generally low;
- the sediments proposed for filling have an excess of buffering capacity;
- the receiving environment is both geared to an existing level of acid export, and is a dynamic marine environment capable of rapid mixing and dilution; and
- placement of dredge spoil will be providing runoff of alkaline water into the receiving environment at the time when any enhanced export of products may occur.

Based on a consideration of these factors it is proposed that, with a regimen of testing of dredge spoil for buffering capacity, that filling could occur on these tidal flats without creating an environmental impact. Such a strategy will involve a far more minimal risk to the environment than the alternative strategy of disturbing such a high volume of volatile sediments to achieve neutralisation.

Seismic Activity and Ground Stability

Potential Impacts

The LNG facility site is spread over a small geographical area and is located some distance from the recorded recurrent earthquake activity in the region (Section 8.3.1.4).

Mitigation Measures

The design of structures to AS 1170.4:1993 (a) complies with the minimum criteria considered necessary for the protection of life, by minimising the likelihood of collapse of structures. In terms of engineering design, the stated purposes of designing structures for earthquake loads in accordance with AS 1170.4:1993 (a) are:

- Minimise the risk of loss of life from structure collapse or damage in the event of an earthquake;
- Improve the expected performance of structures; and
- Improve the capability of structures that are essential to post-earthquake recovery to function during and after an earthquake and to minimise the risk of damage to hazardous facilities.

The structures at the LNG facility site will be designed in accordance with this standard.

Identification, Monitoring and Management

Potential Impacts

The ToR require the objectives and practical measures for protecting or enhancing land-based environmental values be identified, describe how nominated standards and indicators may be achieved and how the achievement of the objectives will be measured, monitored and managed.

The main potential environmental impacts relating to the construction and infrastructure development in the LNG facility site relate to:

- Changes to agricultural land capability;
- Erosion potential of the development area lands when subject to clearing and earthworks;
- The occurrence of and management of problem soil areas including saline, sodic and/or dispersive soil areas;
- Embankment construction or filling over soft ground potentially containing ASS; and
- Excavation conditions for site earthworks and for buried services including the extension of the gas transmission pipeline within the LNG facility site area.

Mitigation Measures

The potential impacts relating to the above issues have been addressed and management strategies have been recommended to mitigate the potential environmental impacts identified. Targets to achieve the recommended acceptable levels for land rehabilitation in areas disturbed by construction and development activities will be incorporated in the construction EMP to be developed for the LNG facility site development and the associated infrastructure facilities. Monitoring of the success of the impact management strategies and the progress of land rehabilitation of disturbed areas within the facility site development area, will be carried out periodically throughout the operating life-span of the LNG facility and for a suitable period following the decommissioning of the facility by agreement with the local landholders and/or the relevant regulatory authorities.

Monitoring of surface conditions and the status of rehabilitation and/or remedial works may include the visual inspection by aerial or vehicle reconnaissance throughout the LNG facility site area and adjacent lands, in association with the installation of semi-permanent survey transects in selected areas with differing combinations of geological and soil/landscape conditions in particular in areas assessed as high constraint areas with respect to potential environmental impact. This process will assist in establishing the progress of revegetation strategies and also as a means of assessing if soil erosion is occurring and if any soil loss and/or sediment yield from monitoring sites is contained within acceptable (pre-determined) levels. This may be based on the use of the Universal Soil Loss Equation (USLE) to provide a target for predicting the long-term average rate/volume of soil loss (t/ha/y) from areas subject to on-going operational activities and/or rehabilitation.

Cumulative Impacts

Including the GLNG project there are a number of industrial facilities that are proposed for Curtis Island (Section 1.7). There is limited information available as to the planned development of these proposed projects or the scale and timing of their development. However, a qualitative assessment can be made of the possible cumulative impacts.

The proposed GLNG facility site is currently undeveloped with only a few tracks and stockyards in the vicinity. There is little potential for cumulative impacts associated with soils and terrain from adjacent land uses due to the defined catchment area within which the GLNG facility is proposed.

Other LNG facilities proposed for Curtis Island may have a similar soils and terrain risks. It is likely, however, that these facilities will include some or all of the proposed mitigation measures outlined, thereby minimising cumulative impact on the receiving environment.

Table 8.3.8 Potential Geological, Terrain and Soils Impacts and Mitigation Measures

Aspect	Potential Impact	Mitigation Measure	Objective
Construction associated			
Topsoil resources.	Loss of topsoil.	• Topsoil is to be: – Salvaged from area to be cleared for the LNG facility and temporarily stockpiled away from drainage lines, for subsequent rehab. – Sign-posted for easy identification and to avoid any inadvertent losses. – Protected by diversion drainage around stockpiles to prevent erosion. – Protected by sediment controls installed immediately down-slope to collect any washed sediment. – Deep ripped and sown with local grass seed-stock or legumes if the stockpile is to be retained for a period of more than 6 months. • Care will be taken during the stripping, stockpiling, and respreading operations to ensure that moisture content of the topsoil resources is such that structural degradation of the soil is avoided and excessive compaction does not occur. • Monitoring of soil type variability will be undertaken by qualified personnel during the topsoil pre-stripping operations to ensure that the maximum quantity and quality of useable topsoil is recovered for later use in site rehabilitation. • The establishment of weeds on the stockpiles will also be monitored and controlled. • Earthmoving plant operators will be trained and/or supervised to ensure that stripping operations are conducted in accordance with the EMP and anticipated in situ soil conditions.	Minimise topsoil loss.

Aspect	Potential Impact	Mitigation Measure	Objective
Erosion potential.	Erosion and sediment loss from disturbed areas.	• Limit area disturbed, and clear progressively, immediately prior to construction commencing. • Safeguard surface layer by stripping and stockpiling topsoil prior to construction. • Control runoff and sediment loss from the site using measures such as silt fences, hay bales, diversion mounds, etc. • Use temporary soil diversion mounds to control runoff within and to divert water away from the construction site where practicable. • Minimise period that bare soil is left exposed to erosion. • Restrict heavy vehicle access and use of earthmoving equipment during and after heavy or prolonged rainfall. • Use sediment traps and sediment collection ponds to minimise off-site effects of erosion. • Lightly rip, restore and revegetate or return disturbed areas to their pre-disturbance condition as soon as practicable.	Minimise erosion and sediment loss.
	Erosion and sediment loss from disturbed areas (Dust mitigation).	• Employ construction methods minimising exposure of disturbed areas. • Undertake revegetation or rehabilitation as soon as practicable. • Spray water on access tracks regularly for dust suppression, especially in established farming and built-up areas. • Minimise continued use of access tracks by heavy vehicles. • Consider upgrading heavy use access track with gravel or bitumen to reduce potential for degradation. • Consider temporary use of cover crops to stabilise bare soil stockpiles or other bare soil areas. • Lightly rip, restore and revegetate or return disturbed areas to their pre-disturbance condition as soon as practicable.	Minimise erosion and dust generation.
Problem soil areas.	Damage to structures, foundations and buried services caused by acidic or saline soils.	• Undertake site specific geotechnical soil investigations to identify any problem soil areas before commencing construction or replacing topsoil resources. • Undertake site specific ASS investigations to determine if Actual ASS materials are present.	Minimise impacts on structures and buried services.

Aspect	Potential Impact	Mitigation Measure	Objective
	Exposure of acid sulfate soils (ASS).	• Lime treat any ASS materials to neutralise acidity levels (Filling over untreated Actual ASS materials is prohibited). • Develop strategies to minimise the potential for activation of Potential ASS during filling / surcharging with dredge overburden.	Minimise excavation and emplacement in areas with acid sulfate soils.
Seismic activity and ground stability.	Damage to structures from seismic activity or ground instability.	• Design structures in accordance with relevant construction standards.	Minimise damage to structures from seismic activity or ground instability.
Flooding.	Potential for damage to structures and contamination of waters due to flooding.	• Where necessary, re-direct and modify existing drainage lines through site development area to link with site drainage network. • Where the site development platform encroaches onto the tidal flats, rock armouring of any levee embankments may be incorporated to protect the embankment from tidal ingress or storm surge.	Minimise damage to structures and contamination of waters due to flooding.
Operation			
Erosion potential.	Erosion and sediment loss from previously disturbed areas.	• Maintain regular monitoring program to ensure erosion control measures implemented are effective • Implement additional mitigation measures as required to address any new or ongoing problem areas • Construct tracks with a gravel or sealed surface and maintain to permit all weather access where long term access is required.	Minimise erosion and sediment loss.
	Erosion and sediment loss from disturbed areas (Dust Mitigation).	• Construct tracks with a gravel or sealed surface and maintain to permit all weather access where long term access is required.	Minimise erosion and sediment loss.
Decommissioning and Rehabilitation			
Agricultural land capability.	Sterilisation of Land.	• Remove structures and hard-stand areas and on decommissioning of the project. • Rehabilitate land as near as practicable to its pre-development use capability status, principally grazing lands (unless otherwise by agreement with the site regulatory authority).	Minimise land sterilisation.
Topsoil resources.	Loss of Topsoil.	• Refer to construction section.	Maximise topsoil retention.

Aspect	Potential Impact	Mitigation Measure	Objective
Erosion potential.	Erosion and sediment loss from disturbed areas.	• Refer to construction section.	Minimise erosion and sediment loss.
Problem soil areas.	Exposure of acid sulfate soils. Damage to structures, foundations and buried services due to differential ground movements caused by problem soils.	• Refer to construction section.	Avoid excavation in areas with acid sulfate soils. Minimise disturbance in problem and mitigation of impacts on structures and buried services.

8.3.1.6 Summary of Findings

The topography of the LNG facility study area comprises low rounded hilly lands, intermediate steep hilly and steep high hilly lands developed on Upper Carboniferous to Lower Devonian Wandilla Formation sedimentary rock types and meta-sediments comprising mudstone, lithic sandstone, quartz greywacke, siltstone, chert, slate and local schist. The hilly crestal areas vary from reduced level RL 20-45 m AHD in the low hilly areas, to about RL 50-75 m AHD in the intermediate steep hilly areas, and up to approximately RL 120-175+ m AHD in the high steep hilly lands. The hilly areas are separated by gently to moderately inclined lower hill slopes and undulating lowlands which form locally narrow, but mainly broad, valley floors. Near flat to gently undulating alluvial plains occur in the valley bottoms. In most cases these alluvial valley flats extend towards the coast and merge with estuarine supra-tidal flats which are mostly fringed by tidal mangrove flats along the coast.

The terrain units and associated soils that occur in the LNG facility study area are described in detail in Appendix L3 together with the results of soil testing carried out. The terrain unit and associated soils data determined have been used to assess the suitability and availability of topsoil resources within the study area and to characterise and map the study area in terms of its pre-development agricultural land capability.

A terrain analysis was carried out, to assess the engineering and/or environmental constraints with respect to the future development of the LNG facility site and associated infrastructure areas. A suite of terrain units were identified for the main geological regimes identified within the area, based on landform characteristics (surface form and slope) and associated soil types. Descriptions of the terrain units identified, together with an assessment of potential engineering and/or environmental constraints for site development have been determined. These data, by association, have been used to determine potential levels of environmental impacts for the LNG site development.

The main potential impacts relating to the development of the site and related facilities include:

- Changes to agricultural land capability;
- Erosion potential of the development area lands when subject to clearing and earthworks;
- The occurrence of and management of problem soil areas, including saline, sodic and/or dispersive soil areas;
- Embankment construction or filling over soft ground potentially containing ASS; and
- Excavation conditions

The potential areas of engineering or environmental impact identified above have been addressed and a range of engineering solutions or other management strategies have been recommended in order to successfully mitigate the potential environmental impacts identified. However in places where potentially high area specific environmental impacts have been identified, more detailed geotechnical site investigations including acid sulfate soil investigations will be undertaken where necessary. These pre-construction investigations will include soil sampling and soil testing as appropriate to clearly define the extent of potential problem areas and to determine the appropriate engineering solutions or management strategies required to mitigate the impact.

An ASS assessment was undertaken using a geomorphological modelling approach. The aim of this approach was to minimise unnecessary drilling, sampling, analysis and costs, yet produce an Acid Sulfate Soil assessment of a superior quality to that produced under the traditional sampling regime.

The ASS investigation undertaken has established that the occurrence and distribution of both AASS and PASS are widespread laterally throughout the area and continues down-sequence to the general 2 m depth of testing at a number of locations. As discussed in Appendix L4, the AASS is generally at a low level but is widely present. As may be anticipated, there were no AASS sediments identified in the offshore sequences. Figure 8.3.8 provides a map of ASS occurrence/absence. Potential management and mitigation measures have been recommended for various components of the proposed development in order to mitigate potential environmental impacts.

8.3.2 Land Contamination

8.3.2.1 Introduction

A land contamination assessment of the LNG facility study area and associated infrastructure (refer to Figure 8.3.10 for contaminated land study area) was conducted.

The following section provides a summary of the assessments key findings including an overview of the regulatory framework, the assessment methodology used the results of the baseline contamination status review, potential contamination sources that the project will create and how these sources (combined with any existing contamination sources) will be managed and any environmental risks mitigated. A full copy of the preliminary site investigation (PSI) is provided in Appendix M.

8.3.2.2 Methodology

The purpose of this assessment was to address the ToR by:

- Conduct a review of the existing (pre project) contamination status (baseline assessment);
- Assess what impacts these existing contamination sources may have on the proposed LNG facility development program and how these impacts will be managed and mitigated;
- Identify activities associated with the construction, operation and decommissioning of the LNG facility with the potential for land contamination; and
- Identify mitigation measures to minimise or eliminate LNG Facility development land contamination risks.

The baseline assessment comprised a PSI which involved a targeted desktop study aimed at identifying high risk sites or areas of potential concern (AOPC) within LNG facility study area.

The baseline assessment comprised a PSI conducted in accordance with the EPA (1998) *Draft Guidelines for the Assessment and Management of Contaminated Land in Queensland*.

The PSI comprised a Tier 1-3 review which included a desktop assessment, site inspection and soil investigation program.

- Tier 1 involved a review of aerial photography of the LNG facility study area to identify AOPCs. AOPCs were identified based on the presence of visible infrastructure associated with potentially contaminating activities such as chemical storage tanks, cattle dip sites and industrial facilities.
- A Tier 2 assessment was then conducted on the identified AOPCs and included:
  - a review of historical aerial photographs;
  - a search of historical titles;
  - a search of EPA land registers including the Environmental Management Register (EMR) and Contaminated Land Register (CLR); and
  - a search of local government records (e.g. development applications, chemical storage/dangerous goods licenses). The EMR records land that has been used for a notifiable activity (i.e. a land use that had the potential for land contamination) as well as land that has been impacted by a hazardous contaminant. Sites recorded on the EMR pose a low risk to human health and the environment (EPA 2006). The CLR is a register of “risk” sites and these sites have been proven to be contaminated from a previous investigation. Action is required to either remediate or mange the site to reduce risk of harm to the environment or human health.
- A Tier 3 site inspection was conducted for the five AOPCs identified in the Tier 1 -2 review, with soil investigations carried out at the Fisherman’s Hut site in accordance with EPA (1998) guidelines based on the evidence of a notifiable land use (cattle dip). Soil samples were taken from the surface and from 0.5 m below ground level and analysed for arsenic, organochlorine pesticides and organophosphate pesticides. Soil test results were compared to the following guidelines:

- The environmental investigations levels (EILs) developed by the Queensland Environmental Protection Agency (QEPA) and published in the "*Draft Guidelines for the Assessment & Management of Contaminated Land in Queensland*"; and
- The health-based investigation levels (HILs) for standard industrial/commercial 'F' exposure settings, developed by the National Environment Protection Council (NEPC), as documented in the *"National Environment Protection (Assessment of Site Contamination) Measure"* (the NEPM), published in December 1999.

The EPA has been consulted on the contaminated land study for the EIS and has supported the methodology provided above.

The assessment also included the potential for land contamination associated with the project during the construction, operation and decommissioning phases.

8.3.2.3 Regulatory Framework

An overview of the regulatory framework relating to contaminated land management is provided in Section 6.3.2.3.

8.3.2.4 Existing Environmental Values

The proposed LNG facility is located on Curtis Island situated approximately 5 km north-east of the City of Gladstone in Queensland. The island is essentially rural with undeveloped land parcels subject to cattle grazing. The island is bounded to the north-northwest by the Mackay-Capricorn Marine Park.

Baseline Contamination Assessment Findings

The Tier 1-3 assessment in the PSI identified five AOPCs (refer Figure 8.3.10). No AOPCs were identified in Lot 7 on DS220 or Lot 10 on DS220. Details for each AOPC and findings of the EPA register searches are provided in Table 8.3.9. No land parcels within the LNG facility study area were listed on the EMR or CLR.

Table 8.3.9 Areas of Potential Concern

ID	AOPC	Lot & Plan	EMR	CLR	Land use & Potential Contaminant
1	Fishermans Hut	Lot 2 on RP602284	No	No	Livestock cattle dip and concrete pads- fuel, pesticides, batteries (acid).
2	Stockyards near Fishermans Hut	Lot 9 on DS220	No	No	Stockyard and ramp- potential pesticide use.
3	Stockyards and Dam	Lot 2 on RP602284	No	No	Stockyard and Livestock Dam- potential pesticide use around stockyard.
4	Loading Hut Complex	Lot 9 on DS220	No	No	Loading facilities and machinery- potential pesticide use, lubricants and fuel.
5	Former Working Area	Lot 9 on DS220	No	No	Machining, water tank, windmill, working hut, - potential fuel and lubricants and pesticide storage.

Site inspections conducted as part of the Tier 3 inspections of the AOPC did not identify any visual evidence of soil contamination. Soil sampling was conducted at the Fishermans Hut cattle dip site due to the presence of a former cattle dip, a notifiable activity under the EP Act.

The results of soil testing at the Fishermans Hut site are presented below in Table 8.3.10. All samples exceeded the guidelines for arsenic.

Source 1: Copyright Bechtel Corporation 2008. All rights reserved. Contains confidential information proprietary to Bechtel not to be disclosed to third parties without Bechtel's prior written permission. Site Plan GLNG Project Curtis Island Australia - Dwg Number SK-000-00001.DGN Revision A Date 17-02-2009

Source 2: With regard to Product Loading Facility and Material Offloading Facility - These layouts are subject to alteration during detailed design development and ongoing consultation with the Gladstone Ports Corporation and the Gladstone Regional Harbour Master to ensure issues of navigation safety are appropriately addressed.

Source 3: This map may contain further data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**IDENTIFIED AREAS OF POTENTIAL CONCERN LNG FACILITY**
	Drawn: CA / Approved: JB / Date: 26-02-2009	Figure: **8.3.10**
	Job No: **4262 6220** / File No: 42626220-g-869b.wor	Rev:B / **A4**

Table 8.3.10 Soil Investigation Results

	Sample ID	QEPA- EIL	NEPM HILs "F"	HA#1 - Surface	HA#1 – 0.5m	HA#2 - Surface	HA#2 – 0.5m	HA#3 - Surface	HA#3 – 0.5m	HA#4 - Surface
Compound	**Units**									
Arsenic	mg/kg	20	50	707	803	787	856	1,160	951	921
Organochlorine Pesticides	mg/kg	NC	NC	ND	ND	ND	ND	ND	ND	ND
Organophosphate Pesticides	mg/kg	NC	NC	ND	ND	ND	ND	ND	ND	ND

NC= No criteria; ND= Not detected.

8.3.2.5 Potential Impacts and Mitigation Measures

The following section provides an overview of the potential contamination impacts, including those from:

- existing AOPC identified during the PSI; and
- the proposed LNG facility development activities.

Areas of Potential Concern

Potential Impacts

The five AOPCs (Table 8.3.9) were inspected and while only the Fisherman's Hut site (outside the LNG facility construction footprint) was considered significant to warrant a Tier 3 soil investigation, the potential exists to identify new AOPCs during construction activities. The potential to identify a new AOPC is relatively low, but potential earthworks can unearth contaminated areas that might not have been picked up in the PSI, for example a buried garbage pit.

The major potential land contamination impact associated with construction is the potential exposure of unknown contaminants during LNG facility construction or decommissioning, mobilisation of such contaminants offsite or exposure to contaminants by workers and the resultant health risks associated with this. The risks may relate to both past land use as well as the naturally occurring elevated trace element concentrations. The geology of the LNG facility study area as described in Section 8.3.1.4 identified naturally occurring elevations in a number of heavy metals (including arsenic, copper, chromium manganese and vanadium), which exceed the Queensland EPA EILs. Potential risks exist in relation to exposure of soil with such exceedances. Groundwater investigations (refer Section 8.6 and Appendix P) have similarly identified elevated concentrations of dissolved metals (manganese) and metalloids (arsenic) within both shallow and deeper aquifers across the study area. In addition, the marine sediment investigation program (Appendix R3) identified higher levels of metals in residual materials near the LNG facility study area. This suggests that elevated levels of metals in the area (in soils, groundwaters and marine sediments) are likely to be naturally occurring, and the EMP will have to address this issue during construction, operational or decommissioning activities.

Mitigation Measures

Potential mitigation measures to minimise impacts associated with both existing anthropogenic and naturally occurring soil trace metals include:

- Identify AOPC including areas with naturally elevated areas of arsenic and manganese concentrations;
- Conduct site management works so that project related impacts are minimised; or
- Avoid AOPC or remediate prior to LNG facility development activities occurring.

As part of the LNG facility development EMP, further assessment will be undertaken where newly identified areas of potential contamination are identified. In addition, site protocols will be developed to include precautions relating to the management of surface and groundwater associated with excavations which may be impacted by the naturally elevated manganese and arsenic. PASS and ASS management has been previously detailed in Section 8.3.1.5.

LNG Facility Development Activities

Potential Impacts

Potential contamination risks associated with the LNG facility primarily relate to the construction and operational phases. Three of the AOPCs are located within the LNG facility footprint, and while the risk is considered low, the potential exists to excavate contaminated soil. Other potential sources of contamination will include diesel fuel spills associated with storage and refuelling of construction equipment and the storage and treatment of ASS.

The construction phase will generate putrescible waste of approximately 12,500 m^3 per year and construction associated waste of approximately 50,000 kg per year (refer Section 5.3.3). Putrescible waste however, will not be disposed or stored on site and will be transferred offsite (refer Section 5). Marine sediment from the dredging of the access to the LNG facility will be managed as described in Section 8.17.

The operational phase will involve the storage of oils and lubricants and the generation of oily waste of approximately 50,000 L per year (refer to Section 5.3). The storage of oils and lubricants will follow Santos management standard HSHS08-Chemical Management and Dangerous Goods and will follow the relevant Australian Standards for storage. The EMP will include provisions for the management of oily wastes.

Mitigation Measures

Sewage from the operations phase will be treated and disposed of by irrigation. The irrigation area will be located and designed to ensure that:

- Sensitive areas are avoided;
- Soil erosion and soil structure damage is avoided;
- There is no surface ponding or runoff of effluent; and
- The quality of groundwater is not adversely affected.

Areas where treated wastewater is discharged to irrigation fields will be fenced and clearly marked with warning notices of the purpose of the area and not to use or drink the water. Treatment and storage systems will be designed to include alternate measures for wastewater storage and/or disposal, where conditions prevent the absorption of treated water to land (e.g. rain events). This may include wet weather storage or disposal off site. There will be no discharge of treated effluent from wet weather storages to any waters. In this way contamination of soils will be avoided.

Potentially contaminated stormwater will be stored on site in ponds and discharged via wetlands to the surrounding environment in accordance with discharge criteria (Section 8.5.5). The water quality of the effluent is not anticipated to be poor due to upstream treatment process within the LNG facility; however the potential for failure of the upstream effluent and wastewater treatment system and the potential overflow of ponds occurring at same time from holding/settlement dams to soil or nearby surface water may pose a contamination risk (albeit a very low risk).

The following contaminated land mitigation measures are recommended, but not limited to the following:

- Civil works to be undertaken at the LNG facility site will be completed in accordance to an agreed upon EMP that will address intersection of contaminated soil, soil conservation, erosion control, runoff controls, stockpile management, and ASS management.
- Stockpiles, workshop areas, chemical stores, fuel tanks and waste disposal/storage areas will be located on hardstand or compacted soil preferably under cover. Contaminated runoff from these areas will be collected and remediated or disposed of in an approved manner.
- Relevant Australian Standards (e.g. for the storage and handling of flammable and combustible liquids and dangerous goods) will be complied with, and all chemical and fuel storage areas will be bunded.
- Where practicable, hazardous chemicals and materials will be replaced with less harmful alternatives. Material safety data sheets (MSDS) for chemicals used or brought onto the sites will be accessed via the Santos intranet. The MSDS can be downloaded and printed out for use on site and is readily available to workers at all times.
- Spills will be cleaned up immediately. For significant chemical or fuel spills, the LNG Facility Emergency Response Plan will be followed and the appropriate authorities notified as soon as practicable.
- Detailed records will be kept of any activities or incidents that have the potential to result in land contamination. Records will be kept on an inventory that contains information on storage location, personnel training and disposal procedures for all chemicals, fuel and other potential contaminants used on site. Records will be maintained by Santos and reviewed regularly.
- Regular inspections of containers, bund integrity, valves, and storage and handling areas will be carried out as part of routine environmental audits.
- All staff will be trained as part of their site induction in appropriate handling, storage and containment practices for chemicals, fuel and other potential contaminants as relevant.
- Santos will utilise management procedure EHS08 Contaminated Site Management, which was developed to protect the environment, where contamination has or may have occurred.
- Where relevant Santos utilise management procedure HSH08 Chemical Management and Dangerous Goods, which was developed to manage the associated risk with the handling, use and storage of chemicals.

Cumulative Impacts

The proposed GLNG facility site is currently undeveloped with only a few tracks and stockyards in the vicinity. There are a number of industrial facilities also proposed for Curtis Island (as described in Section 1.7). There is limited information available as to the planned development of these proposed projects (including their specific site location on Curtis Island) or the scale and timing of their development; however, a qualitative assessment can be made of the possible cumulative impacts.

There is little potential for cumulative impacts associated with land contamination from adjacent land uses due to the defined catchment area within which the GLNG facility is proposed.

Other LNG facilities proposed for Curtis Island may have a similar risk of land contamination from their operations. It is likely, however, that these facilities will include some or all of the proposed mitigation measures outlined, thereby minimising cumulative impact on the receiving environment.

Table 8.3.11 provides a summary of potential land contamination impacts and mitigation measures for the LNG facility.

Table 8.3.11 Potential Impacts and Mitigation Measures

Event Name	Aspect	Potential Impact	Mitigation Strategy	Objective
Construction				
Plant chemical spills on site.	Surface Water/ Soil contamination- chemical contamination.	Storage areas- storage of fuel, oils, lubricants, solvents and other chemicals release.	• Any spills will be contained and reported. Contaminated soil will be removed and remediated and any contaminated water (e.g. stormwater in bund) treated. • Capture of first flush runoff in basins and treatment prior to discharge to Stormwater Balance Pond and constructed wetland. • Water quality and dam capacity of sediment ponds will be monitored and where exceedances identified, remediation measures adopted. • No discharge to effluent where water quality exceeds discharge criteria. • Chemicals will be stored as per Australian Standards.	To ensure no loss of hydrocarbons to the environment.
Plant fuel spills- off site.	Surface Water/ Soil- hydrocarbon contamination- breach of water containment dams.	Potentially contaminated storage pond discharge to surrounding environment.	• Any spills will be immediately contained and reported. Contaminated soil will be removed and remediated and any contaminated water (e.g. stormwater in bund) treated. • Secondary containment of fuels, as per Australian Standards. • Operational controls will be implemented minimise spilling fuels on site whilst refuelling. For example- designated fuelling areas with spill kits and anti-spill fuel nozzles. • All vehicles to be checked for integrity of fuel tank and responsible driving to prevent perforation of tank during clearing operations.	To ensure no unauthorised discharge to surrounding environment. To meet at a minimum the water quality discharge criteria for stormwater effluent.
Plant fuel spills- on site.	Surface Water/ Soil- hydrocarbon contamination.	Storage areas- storage of fuel, oils, lubricants, solvents and waste oil- loss of hydrocarbon waste to the waste water treatment system.	• Any spills will be immediately contained and reported. Contaminated soil will be removed and remediated and any contaminated water (e.g. stormwater in bund) treated. • Capture of first flush runoff in basins and treatment prior to discharge to Stormwater Balance Pond and constructed wetland. • Water quality and dam capacity of sediment ponds will be monitored and where exceedances identified, remediation measures adopted. • No discharge to effluent where water quality exceeds discharge criteria. • Secondary containment is required for fuels, as per Australian Standards. • Operational controls will be implemented minimise spilling fuels on site whilst refuelling. For example- designated fuelling areas with spill kits and anti-spill fuel nozzles.	To ensure no loss of hydrocarbons to the environment.

Event Name	Aspect	Potential Impact	Mitigation Strategy	Objective
			• All vehicles to be checked for integrity of fuel tank and responsible driving to prevent perforation of tank during clearing operations.	
Plant chemical spills off site.	Surface Water/ Soil-chemical contamination.	Spill from construction equipment during operation. Spills/ loss of other chemicals.	• Any spills will be immediately reported and contained. Contaminated soil will be removed and remediated and contaminated water treated.	To ensure no loss of or chemicals to the environment.
Plant storage tank failure.	Surface Water/ Soil-hydrocarbon contamination.	Storage areas- storage of fuel, oils, lubricants, solvents and waste oil- loss of hydrocarbon and chemicals to the receiving environment.	• Secondary containment is required for fuels, as per Australian Standards. • Any spills will be immediately contained and reported. Contaminated soil will be removed and remediated and any contaminated water (e.g. stormwater in bund) treated.	To ensure no loss of hydrocarbons or chemicals to the environment.
Plant transportation of materials to/from island-spills.	Surface Water/ Soil-hydrocarbon contamination.	Transport of fuel/chemicals, building materials.	• Even loading of barges to avoid potential loss to environment. • Fuel/ chemicals will be stored in bunded area/shipping container on barge where volume exceeds 100L during transport.	To ensure no loss of materials during barge transport.
Plant water disposal (hydrotest and stormwater runoff water to marine environment).	Surface Water/ Soil-hydrocarbon.	Hydrotest (pigging) water potentially contains elevated salts and residue biocide and anti-fouling chemicals.	• All hydrotest wastewater will be captured in detention ponds and treated prior to discharge.	To ensure produced water is appropriately treated and disposed.
Plant construction simultaneous with operations.	Surface Water/ Soil-hydrocarbon.	Diesel spill from construction equipment during operation.	• All vehicles to be checked for integrity of fuel tank and responsible driving to prevent perforation of tank during clearing operations. • Any spills will be immediately reported and contained. Contaminated soil will be removed and remediated and contaminated water treated.	To ensure no loss of fuel to the environment.

Event Name	Aspect	Potential Impact	Mitigation Strategy	Objective
		Exposure of contaminated soil within AOPC or other unknown sites including areas of soil with naturally elevated trace metals (arsenic, manganese etc.)	• Any excavation works will be evaluated for naturally elevated trace metals concentrations to determine requirements for soil disposal, as well as groundwater management of potential arsenic, manganese and other trace metals. • All works should evaluate new construction areas for past anthropogenic and potential AOPC. • Where contamination potential is identified, a Phase II Environmental Site Assessment will be undertaken to delineate contamination. • Contaminated sites will be avoided where practicable, and if disturbed will be remediated.	To prevent the disturbance of existing contaminated sites. To remediate any contaminated land to be disturbed by the pipeline development.
Operation				
Plant chemical spills on site.	Surface Water/ Soil contamination- chemical contamination.	Storage areas- storage of fuel, oils, lubricants, solvents and other chemicals to the Waste Water Treatment System.	• Any spills will be immediately contained and reported. Contaminated soil will be removed and remediated and any contaminated water (e.g. stormwater in bund) treated. • Capture of first flush runoff in basins and treatment prior to discharge to Stormwater Balance Pond and constructed wetland. • Water quality and dam capacity of sediment ponds will be monitored and where exceedances identified, remediation measures adopted. • No discharge to effluent where water quality exceeds discharge criteria. • Chemicals will be stored as per Australian Standards.	To ensure no loss of hydrocarbons to the environment.
Plant fuel spills- off site.	Surface Water/ Soil- hydrocarbon contamination- breach of waste water treatment system (WWTS).	Potentially contaminated storage pond discharge to surrounding environment.	• Any spills will be immediately contained and reported. Contaminated soil will be removed and remediated and any contaminated water (e.g. stormwater in bund) treated. • Secondary containment of fuels, as per Australian Standards.	To ensure no unauthorised discharge to surrounding environment. To meet at a minimum the water quality discharge criteria for stormwater effluent.
Plant fuel spills- on site.	Surface Water/ Soil- hydrocarbon contamination.	Spills from storage of fuel, oils, lubricants, solvents and waste oil.	• Any spills will be immediately contained and reported. Contaminated soil will be removed and remediated and any contaminated water (e.g. stormwater in bund) treated. • Capture of first flush runoff in basins and treatment prior to discharge to stormwater balance pond and constructed wetland.	To ensure no loss of hydrocarbons to the environment.

Event Name	Aspect	Potential Impact	Mitigation Strategy	Objective
			• Water quality and dam capacity of sediment ponds will be monitored and where exceedances identified, remediation measures adopted. • No discharge to effluent where water quality exceeds discharge criteria.	
Plant chemical spills off site.	Surface Water/ Soil-chemical contamination.	Spill from construction equipment during operation. Spills/ loss of other chemicals.	• All vehicles to be checked for integrity of fuel tank and responsible driving to prevent perforation of tank during clearing operations. • Any spills will be immediately reported and contained. Contaminated soil will be removed and remediated and contaminated water treated.	To ensure no loss of or chemicals to the environment.
Plant storage tank failure.	Soil-hydrocarbon/chemical contamination.	Potential soil and groundwater impacts.	• Any spills will be immediately contained and reported. Contaminated soil will be removed and remediated and any contaminated water (e.g. stormwater in bund) treated. • Secondary containment of fuels, as per Australian Standards.	To ensure no loss of or hydrocarbons or chemicals to the environment.
Plant water disposal (hydrotest and process water to marine env).	Surface Water/ Soil-hydrocarbon.	Hydrotest water potentially contains elevate salts, residue biocide and anti-fouling chemicals.	• All hydrotest wastewater will be captured in detention ponds and treated prior to discharge. Treatment may be conducted onsite via WWTS else trucked to a wastewater treatment facility.	To ensure produced water is appropriately treated and disposed.
Plant construction simultaneous with operations.	Surface Water/ Soil-hydrocarbon.	Exposure of contaminated soil within AOPC or other unknown sites including areas of soil with naturally elevated trace metals (arsenic, manganese etc.)	• Any excavation works will be evaluated for naturally elevated trace metals concentrations to determine requirements for soil disposal, as well as groundwater management of potential arsenic, manganese and other trace metals. • All works should evaluate new construction areas for past anthropogenic and potential AOPC. • Where contamination potential is identified, a Phase II Environmental Site Assessment will be undertaken to delineate contamination. • Contaminated sites will be avoided where practicable, and if disturbed will be remediated.	To prevent the disturbance of existing contaminated sites. To remediate any contaminated land to be disturbed by the pipeline development.
Decommissioning and Rehabilitation				
Plant chemical spills on site.	Surface Water/ Soil-chemical contamination.	Spills/ loss of other chemicals or fuels.	• All vehicles to be checked for integrity of fuel tank and responsible driving to prevent perforation of tank during clearing operations. • Any spills will be immediately reported and contained. Contaminated soil will be	To ensure no loss of or chemicals to the environment.

Event Name	Aspect	Potential Impact	Mitigation Strategy	Objective
			removed and remediated and contaminated water treated.	
Plant fuel spills- off site.	Surface Water/ Soil- hydrocarbon contamination- breach of Waste Water Treatment System (WWTS).	Potentially contaminated storage pond discharge to surrounding environment.	• Any spills will be immediately contained and reported. Contaminated soil will be removed and remediated and any contaminated water (e.g. stormwater in bund) treated.	To ensure no unauthorised discharge to surrounding environment. To meet at a minimum the water quality discharge criteria for stormwater effluent.
Plant fuel spills- on site.	Surface Water/ Soil- hydrocarbon contamination.	Storage areas- storage of fuel, oils, lubricants, solvents and waste oil- loss of hydrocarbon waste to the Waste Water Treatment System.	• Any spills will be immediately contained and reported. Contaminated soil will be removed and remediated and any contaminated water (e.g. stormwater in bund) treated. • Capture of first flush runoff in basins and treatment prior to discharge to Stormwater Balance Pond and constructed wetland. • Water quality and dam capacity of sediment ponds will be monitored and where exceedances identified, remediation measures adopted. • No discharge to effluent where water quality exceeds discharge criteria.	To ensure no loss of hydrocarbons to the environment.
Plant storage tank failure.	Soil- hydrocarbon/ chemical contamination. Storage areas (oils, lubricants, chemicals).	Potential residual contamination with past spills.	• During removal of infrastructure, sampling should be conducted at base to ensure the removal of any residual soil contamination prior to reinstatement of area.	To ensure no net change in soil characteristics as a result of the LG facility construction and operation.
Plant water disposal (hydrotest and process water to marine env).	Surface Water/ Soil- hydrocarbon.	Removal of WWTS infrastructure (effluent storage pond, constructed wetland) and disposal of accumulated sludge (salts, boron, fluoride, and other water parameters).	• Ponds will be managed in accordance with proposed end use including: – Left insitu where arrangement with stakeholder exists for continued use of facility; and – Excavated to remove accumulated sludge and potential contaminants prior to reinstatement of landform. • Base sampling of WWTS structures to determine any remedial requirements to ensure no offsite loss of contaminants.	To ensure hydrotest treatment facilities are appropriately remediated.

8.3.2.6 Summary of Findings

Baseline Contamination Assessment

A total of five AOPCs were identified and investigated. No land parcels were listed on the EMR or CLR as having potential for contamination.

Evidence of a notifiable activity (cattle dip) was identified at the Fishermans Hut site AOPC with arsenic contamination in the surface soil (0 - 0.5 m below ground level) identified. This site is outside of the LNG facility footprint and it is not proposed to disturb the site. No other sites investigated as AOPCs indicated the presence of notifiable activities or land contamination.

The naturally elevated trace metals in the study area as part of the geological and groundwater baseline assessments (arsenic and manganese) pose ongoing management issues during the construction phase. Any works disturbing soil and potentially intersecting the groundwater aquifer (shallow) will require management measures including the treatment of any groundwater and surface water in excavations and trigger waste disposal requirements where offsite disposal is required. These management requirements will be incorporated into the EMP for the LNG facility.

LNG Facility Development Activities

A review of potential sources of land contamination associated with the construction, operation and decommissioning of the LNG facility identified potential sources of contamination. These potential sources of contamination can be minimised by adopting the mitigation measures outlined in Table 8.3.11, which in turn protects the soil and groundwater from potential impact.