6.3 Land

6.3.1 Topography, Geomorphology, Geology and Soils

6.3.1.1 Introduction

The following section describes the existing topography, geomorphology, geology and soils of the CSG fields study area, provides the results of the impact assessment undertaken and proposes a series of mitigation measures to minimise the impact of proposed CSG fields development activities on soils and terrain related environmental values.

The south - eastern limit of the CSG fields study area lies between the Moonie and Weir Rivers, about 60 km east of the town of Westmar. The north - western limit of the study area is adjacent to the Nogoa River, about 16 km north - east of Emerald.

Terrain features are described firstly at a broad level of detail across the CSG fields study area, then at a greater level of detail over the Reasonably Foreseeable Development (RFD) areas of Roma, Fairview and Arcadia Valley – these are respectively called the Roma CSG field, Fairview CSG field and the Arcadia Valley CSG field and collectively the RFD area. Note Comet Ridge field was not included in this assessment.

Reference should be made to the more detailed information provided in the relevant technical report in Appendix L1.

6.3.1.2 Methodology

Terrain mapping was undertaken primarily from the interpretation of aerial photographs with reference to existing geological, topographical and soils information and background data sources. This was followed by a site reconnaissance inspection to provide the basis for identifying ‘terrain units’ which occur within the study area.

As mapped, a terrain unit comprises a single or recurring area of land that is considered to have a unique combination of physical attributes in terms of bedrock, surface slope and form, and soil/substrate conditions. Accordingly, engineering and environmental characteristics determined at one location may be extrapolated to other occurrences of the same terrain unit.

Data sources used included CSIRO regional land resources data, satellite imagery and existing geological, topographical and soils information. Landform and soil profiles have been mapped and described according to the Australian Soil and Land Survey Field Handbook (McDonald et al., 1990) and the Australian Soil Classification (Isbell, 2002).

The terrain mapping methodology was used to identify the existing environmental values (as they relate to soils and terrain) which enabled an assessment of potential impacts to be undertaken. Based on this, proposed mitigation measures have been developed to minimise the risk of environmental harm occurring from proposed CSG fields development activities.

Landscape Units

Landscape units across the CSG fields study area were identified from a combination of geological regimes and slope classes. The geological regime represents the simplified geological grouping based on the existing Geological Survey of Queensland (GSQ) mapping. Slope classes were derived from NASA Shuttle Radar Topography Mission 90 m Digital Elevation Models (DEMs) processed using ESRI ArcGIS, ArcMap, 3D Analyst and Spatial Analyst software. Slope classes were assigned as follows:

- Slope Class 1: 0 - 2 % indicative surface slope;
- Slope Class 2: >2 - 5 % indicative surface slope;

- Slope Class 3: >5 - 12 % indicative surface slope;
- Slope Class 4: >12 - 25 % indicative surface slope;
- Slope Class 5: >25 - 50 % indicative surface slope; and
- Slope Class 6: >50 % indicative surface slope.

Initially, the geological regime - slope class units contained many small unmappable areas at the reporting scale of 1:250,000 and it was clear that a smoothing or averaging process was required to produce mappable areas of ground slope. Accordingly, landscape unit boundaries were modified by hand in order to aggregate small areas and simplify the mapping where required. Within a particular geological regime, areas of mappable extent with a characteristic slope class were recognised and delineated, and that process was then repeated over the whole area of the geological regime, and ultimately over the entire CSG fields study area. Consideration was given to maintaining a single slope class as much as possible within a mapped area, however because of the presence of many very small areas of other (usually adjacent) slope classes, all mapped areas to some extent included a mixture of slope classes, one of which was dominant or characteristic. Steeper slopes within a mapped area assumed greater weighting in the mapping process. For example, where two slope classes occurred equally in a mapped area the applied landscape unit designation favoured the steeper class. The numeral in the landscape unit notation can thus be considered to be indicative of the number of its characteristic slope class.

The landscape unit boundaries produced were then digitised into the project Geographic Information System (GIS). Notation of each landscape unit consisted of alphabetic characters that identified the geological regime, followed by a numeral identifying the indicative slope class number. For example, the landscape unit Jm3 consisted of indicative slope class 3 occurring within the Jurassic mudstone/sandstone geological regime Jm.

Agricultural Land

An assessment of the agricultural land capability was carried out to provide a benchmark of existing/potential agricultural land capability. As required in the EIS Terms of Reference (ToR) and in accordance with State Planning Policy 1/92: *Development and the Conservation of Agricultural Land*, the assessment was based on the four class system for defining Good Quality Agricultural Land (GQAL) as detailed in the Planning Guidelines - Department of Primary Industries (DPI) and the Department of Housing and Local Government (DPI/DHLGP - 1993) as summarised below:

- ***Class A*****:** Crop land - land suitable for current and potential crops with limitations to production which range from nil to moderate levels.
- ***Class B:*** Limited crop land - land that is marginal for current and potential crops due to severe limitations, but is suitable for pastures. Engineering and/or agronomic improvements may be required before the land is considered suitable for sustainable cropping/cultivation.
- ***Class C:*** Pasture land - land suitable for improved or native pastures due to limitations which preclude continuous cultivation for crop production. Three sub-classes have been identified as follows:
  - C1; Some areas may tolerate an occasional cultivation for improved pasture and suitable for native pastures.
  - C2; Areas primarily suited to grazing of native pastures, with or without the addition of improved pasture species but without ground disturbance.
  - C3; Land that is suited to restricted light grazing of native pastures in accessible areas, otherwise steep to very steep hilly lands more suited for forestry, conservation or catchment protection.
- ***Class D:*** Non - agricultural land - land not suitable for agricultural uses due to extreme limitations. This may comprise undisturbed land with significant habitat, conservation and/or catchment values, or land that may be unsuitable because of very steep slopes, shallow soils, rock outcrop or poor drainage conditions.

6.3.1.3 Regulatory Framework

Key statutory instruments governing land management relevant to the CSG fields study area of the GLNG Project include:

- *Environment Protection and Biodiversity Conservation Act 1999*, Commonwealth;
- *Environmental Protection Act 1994* (Qld) (EP Act); and
- State Planning Policies and Guidelines.

Environment Protection and Biodiversity Conservation (EPBC) Act 1999

The Commonwealth *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* is the key piece of legislation for the Commonwealth Government to provide for the protection of the environment and heritage, especially matters of national environmental significance and areas (whether natural, Indigenous, historic or other) of significant heritage value to Australia (Protected matters). Among other things, the Act promotes biodiversity conservation, heritage protection and recognises the role of Indigenous people in the conservation of Australia's biodiversity. It is designed to provide for the conservation of biodiversity through the protection of threatened species and ecological communities, migratory, marine and other protected species listed under the act.

In general, the EPBC Act streamlines the national environmental assessment and approvals process, protects Australian biodiversity and integrates the management of important natural and cultural places. The Act is administered by the Commonwealth Department of the Environment, Water, Heritage and the Arts (DEWHA).

Environmental Protection Act 1994

The *Environmental Protection Act 1994* (EP Act) aims to protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (being ecologically sustainable development).

State Planning Policies and Guidelines

State Planning Policy 1/92: *Development and the Conservation of Agricultural Land* involves an assessment based on the four class system for defining Good Quality Agricultural Land (GQAL) as detailed in the Planning Guidelines - Department of Primary Industries (DPI) and the Department of Housing and Local Government (DPI/DHLGP - 1993); Guidelines for sampling and analysis of Acid Sulfate Soils (ASS) in Queensland 1988 (Revision 4); and State Planning Policy 2/02, Guideline Planning and Management of development involving Acid Sulfate Soils.

6.3.1.4 Existing Environmental Values

Topography and Geomorphology

The south - eastern limit of the CSG fields study area lies between the Moonie and Weir Rivers, about 60 km east of the town of Westmar. The north - western limit of the study area is adjacent to the Nogoa River, about 16 km north - east of Emerald.

The lowest elevations within the study area are approximately 200 m above sea level and are located in the floodplain of the Dawson River near Taroom and the Nogoa River floodplain near Emerald. The highest elevations in the study area are approximately 940 m above sea level, occurring on the crest of Mount Hutton west of Injune, and approximately 1,230 metres on plateau remnants in the Buckland Plateau to the west of Arcadia Valley. These elevated areas are only of small extent inside the CSG fields, but on the Buckland Plateau to the west of the CSG fields more extensive areas occur.

The Great Dividing Range, separating the headwaters of northward and eastward flowing streams (including the Dawson River) from southward and westward flowing streams (such as the Balonne River), traverses the Taroom Hills physiographic region in the northern part of the Roma field, then in a north north-west direction to the Buckland Plateau.

Notable topographic features within the CSG fields study area include:

- Broad areas of low - relief undulating terrain and alluvial plains, interrupted by occasional low hills, across the southern part of the study area including the Roma CSG field;
- Near - level to strongly undulating plateau surface remnants cut by very steep - sided ravines and terminating in precipitous sandstone escarpments, occurring in the central part of the study area, including the Fairview and Arcadia Valley CSG fields; and
- The broad alluvial plains and foot slopes of the Arcadia - Comet valley feature extending northward from the northern margin of the Fairview CSG field to the northern limit of the study area adjacent to the Nogoa River.

The surface slopes occurring within the CSG fields study area vary from near - level in parts of the alluvial plains to very steep (and in places vertical) sandstone escarpments and ravine slopes in the Expedition Range.

Figure 6.3.1 and Figure 6.3.2 are maps at 1:1,500,000 scale, of elevations occurring throughout the CSG fields study area. Similarly, Figure 6.3.3 and Figure 6.3.4 are maps of surface slopes occurring throughout the entire CSG fields study area. Both of these map pairs were derived from NASA Shuttle Radar Topography Mission data with 90 m horizontal resolution. This data was used to generate the DEM for the CSG fields study area using ArcGIS 3D Analyst and Spatial Analyst software. The same software was then used to generate slope model and hill-shade datasets.

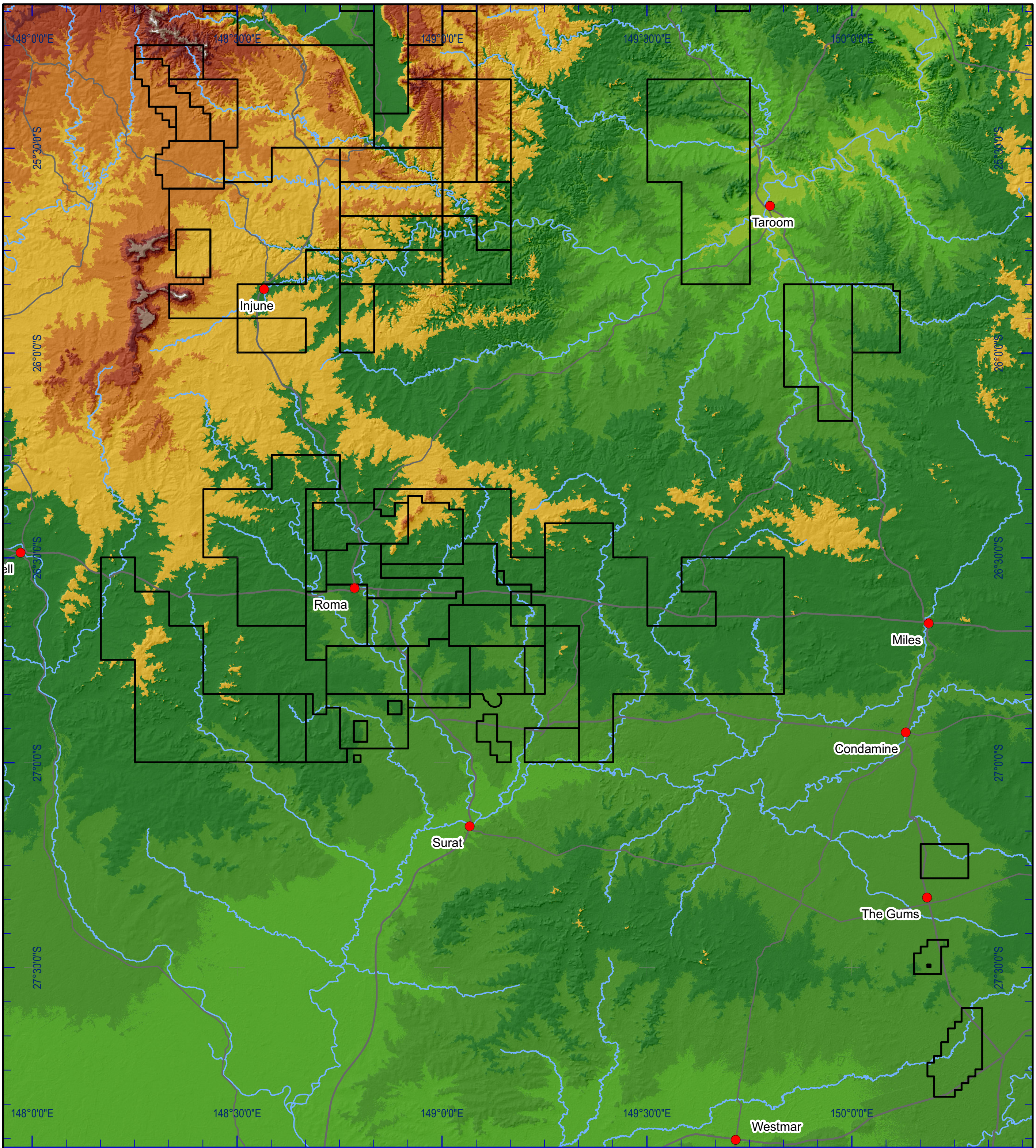
Landscape Units

The identification of landscape units provides the basis for the description and assessment of the physical environment and as mapped, show the occurrence and distribution of geological regimes, generalised surface slope classes and associated soil types which occur in the CSG fields study area.

The landscape unit mapping included in this section is as follows:

- Roma CSG field: Figures 6.3.5 to 6.3.12;
- Fairview CSG field: Figure 6.3.13; and
- Arcadia Valley CSG field: Figures 6.3.14 and 6.3.15.

The occurrence of landscape units, the areal extent (ha) and percentage (%) of the total area for each of the Roma, Fairview and Arcadia Valley CSG fields is provided in Appendix L1.



Note: Legend colours may differ slightly from Map colours due to hill shading used in the Elevation Surface Grid.

Elevation (m)

- 3 - 50
- >50 - 100
- >100 - 150
- >150 - 200
- >200 - 250
- >250 - 300
- >300 - 400
- >400 - 500
- >500 - 600
- >600 - 700
- >700 - 800
- >800 - 900
- >900

- Towns
- Major Roads
- Major Drainage
- CSG Field

N W E S

Kilometers

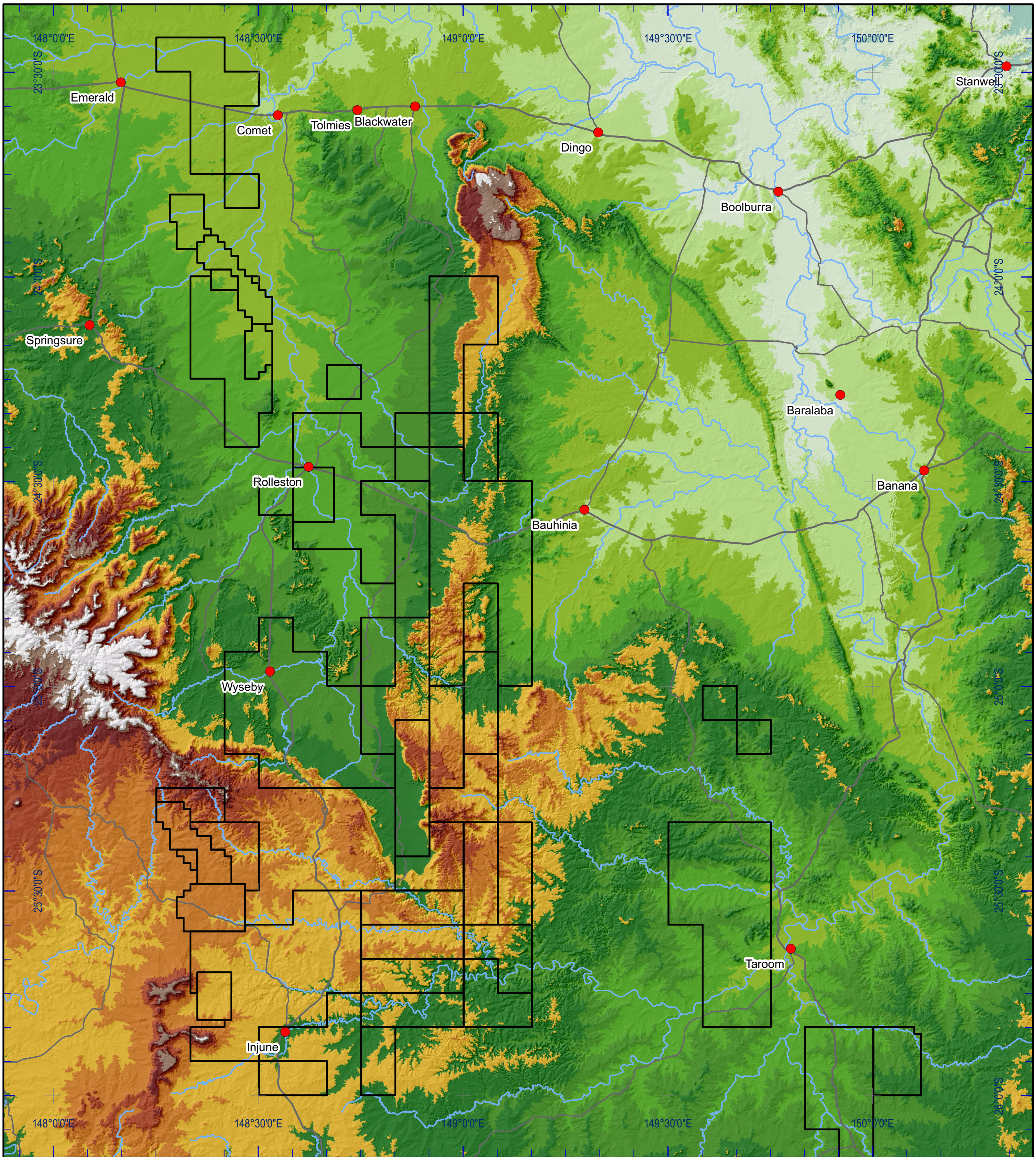
0 5 10 20 30 40 50

Scale 1:1 500 000 (A4)

Datum : GDA 94

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	**ELEVATION CSG FIELDS (SOUTHERN SECTION)**	
URS	Drawn: LL / Approved: GR / Date: 20-03-2009	Figure: **6.3.1**	Rev. A
	Job No.: **4262 6220** / File No.: 42626220-g-953.mxd		A4



Note: Legend colours may differ slightly from Map colours due to hill shading used in the Elevation Surface Grid.

Elevation (m)

- 3 - 50
- >50 - 100
- >100 - 150
- >150 - 200
- >200 - 250
- >250 - 300
- >300 - 400
- >400 - 500
- >500 - 600
- >600 - 700
- >700 - 800
- >800 - 900
- >900

- Towns
- Major Roads
- Major Drainage
- CSG Field

N W E S

Kilometers

0 5 10 20 30 40 50

Scale 1:1 500 000 (A4)
Datum : GDA 94

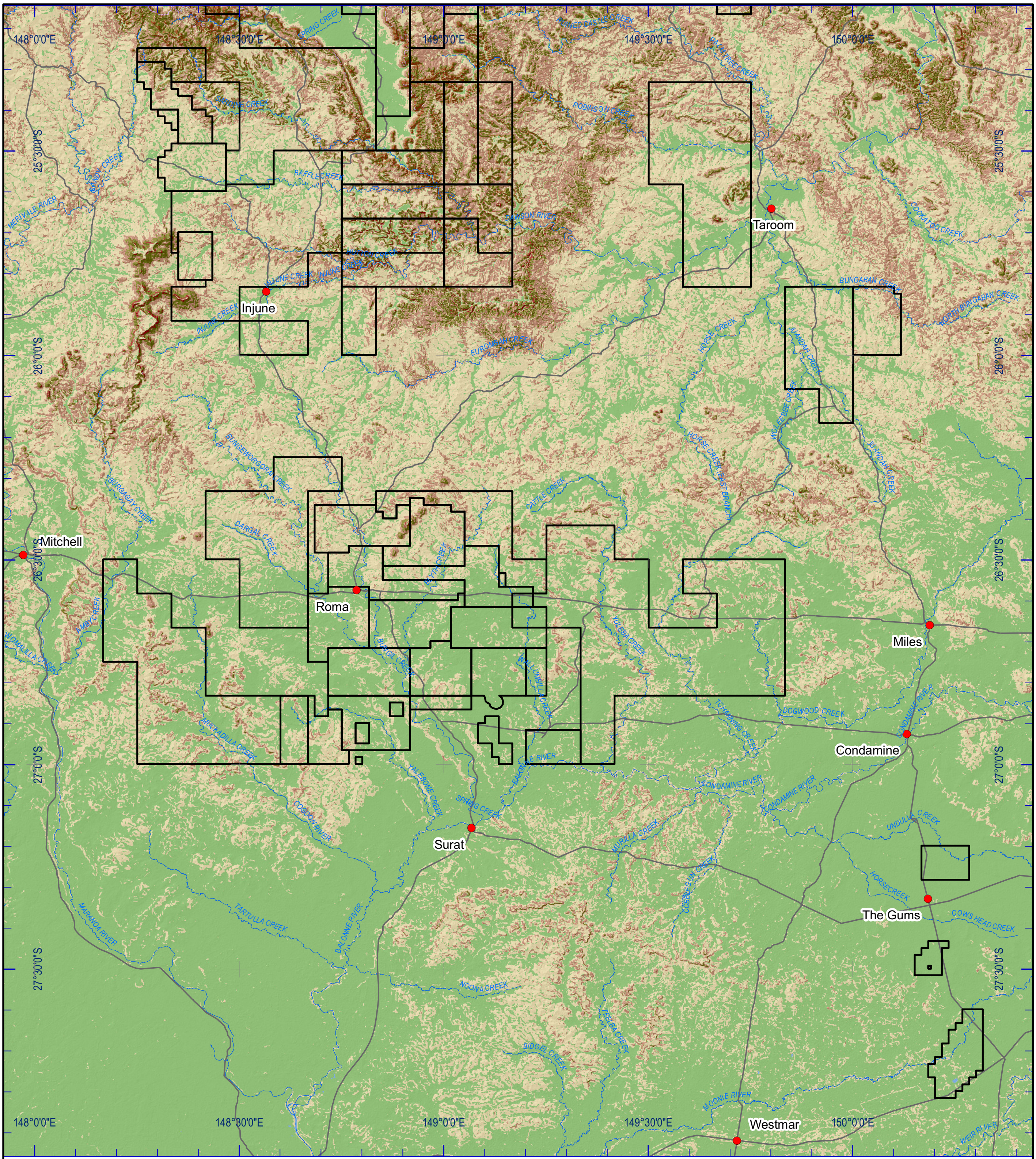
Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Client: LNG / URS

Project: GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT

Title: **ELEVATION CSG FIELDS (NORTHERN SECTION)**

Drawn: LL	Approved: JB	Date: 20-03-2009	Figure: **6.3.2**
Job No.: **4262 6220**	File No.: 42626220-g-954.mxd		Rev. A / A4



Slope Class and Slope Range %

0	0
1	0.1 - 2
2	2.1 - 5
3	5.1 - 12
4	12.1 - 25
5	25.1 - 50
6	> 50

- Towns
- Major Roads
- Major Drainage
- CSG Field

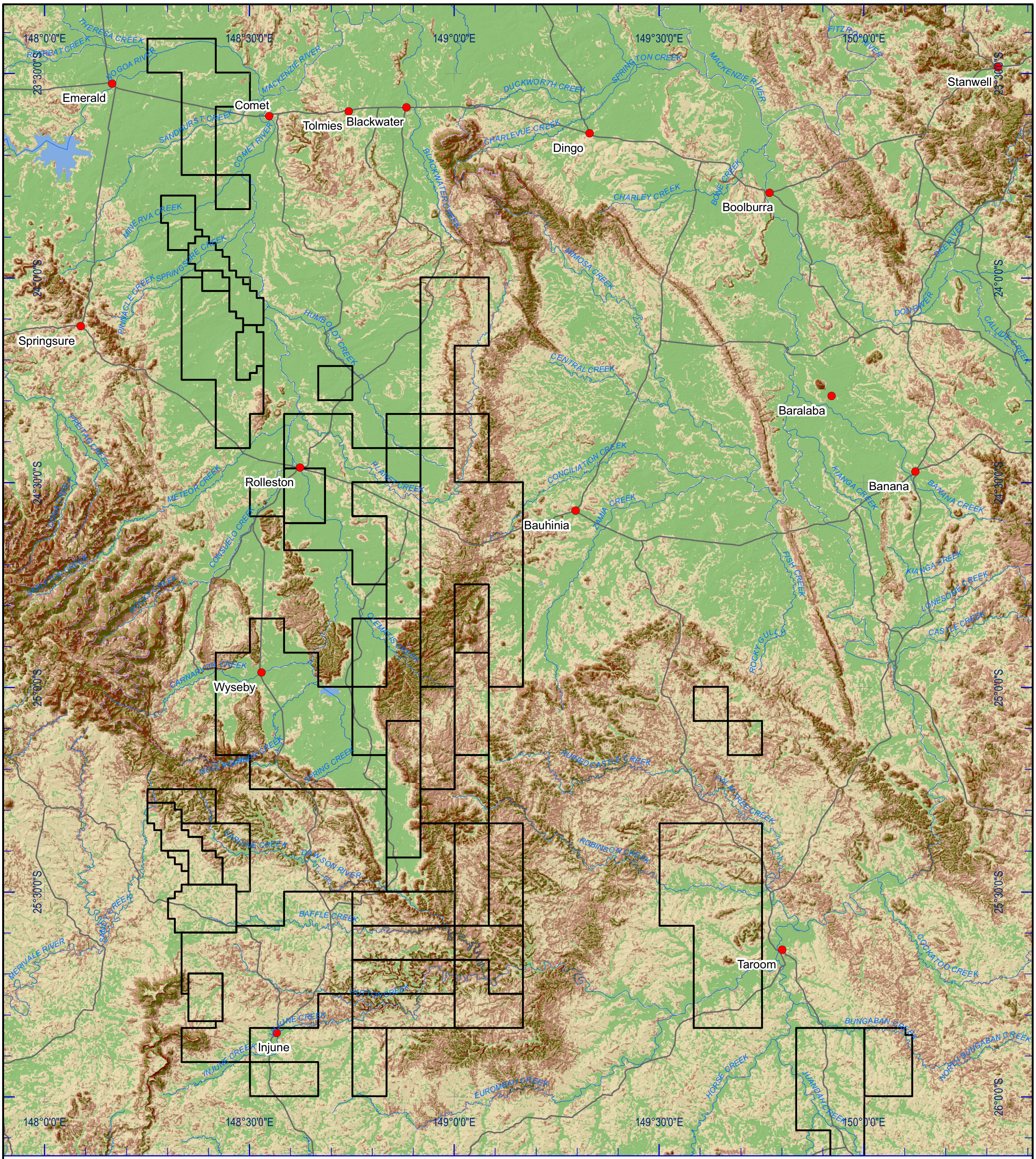
N
W E
S

Kilometers
0 5 10 20 30 40 50

Scale 1:1 500 000 (A4)
Datum : GDA 94

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	SLOPE CSG FIELDS (SOUTHERN SECTION)
	Drawn: MG / Approved: GR / Date: 16-01-2009	Figure: **6.3.3** / Rev. A
	Job No.: **4262 6220** / File No.: 42626220-g-955.mxd	A4



Slope Class and Slope Range %

Class	Slope Range %	Class	Slope Range %
0	0		
1	0.1 - 2	4	12.1 - 25
2	2.1 - 5	5	25.1 - 50
3	5.1 - 12	6	> 50

- Towns
- Major Roads
- Major Drainage
- CSG Field

N W E S

Kilometers
0 5 10 20 30 40 50

Scale 1:1 500 000 (A4)
Datum : GDA 94

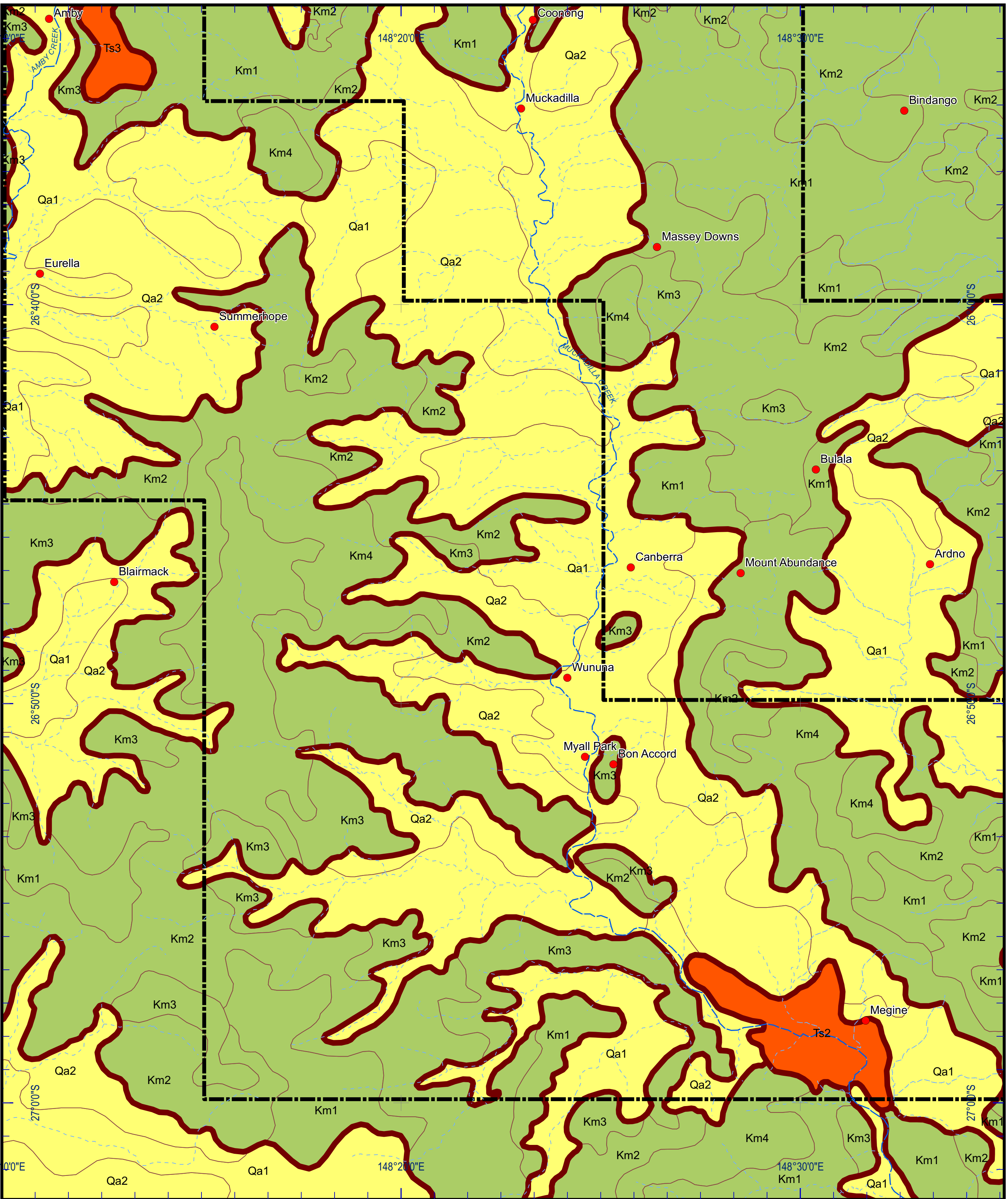
Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Client: LNG / URS

Project: GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT

Title: **SLOPE CSG FIELDS (NORTHERN SECTION)**

Drawn: MG	Approved: JB	Date: 20-03-2009	Figure: **6.3.4**	Rev. A
Job No.: **4262 6220**	File No.: 42626220-g-956.mxd			A4



Map must be viewed with Appendix A in Appendix L1 for Complete Description of Landscape Units.

Landscape Unit Reference

Qa	Ka	Jm
Ts	Km	Rm
Tv	Ja	P

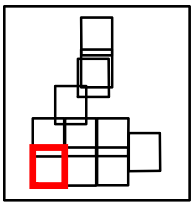
Slope Class

1 characteristic slope 0-2%
2 characteristic slope >2-5%
3 characteristic slope >5-12%
4 characteristic slope >12-25%
5 characteristic slope >25-50%
6 characteristic slope >50%

Qa1 / Qa2 — Landscape Unit Boundary with Geological Regime and Slope Class
Towns / Localities
CSG Field
Rivers, Creeks and Tributary Streams

N E S W

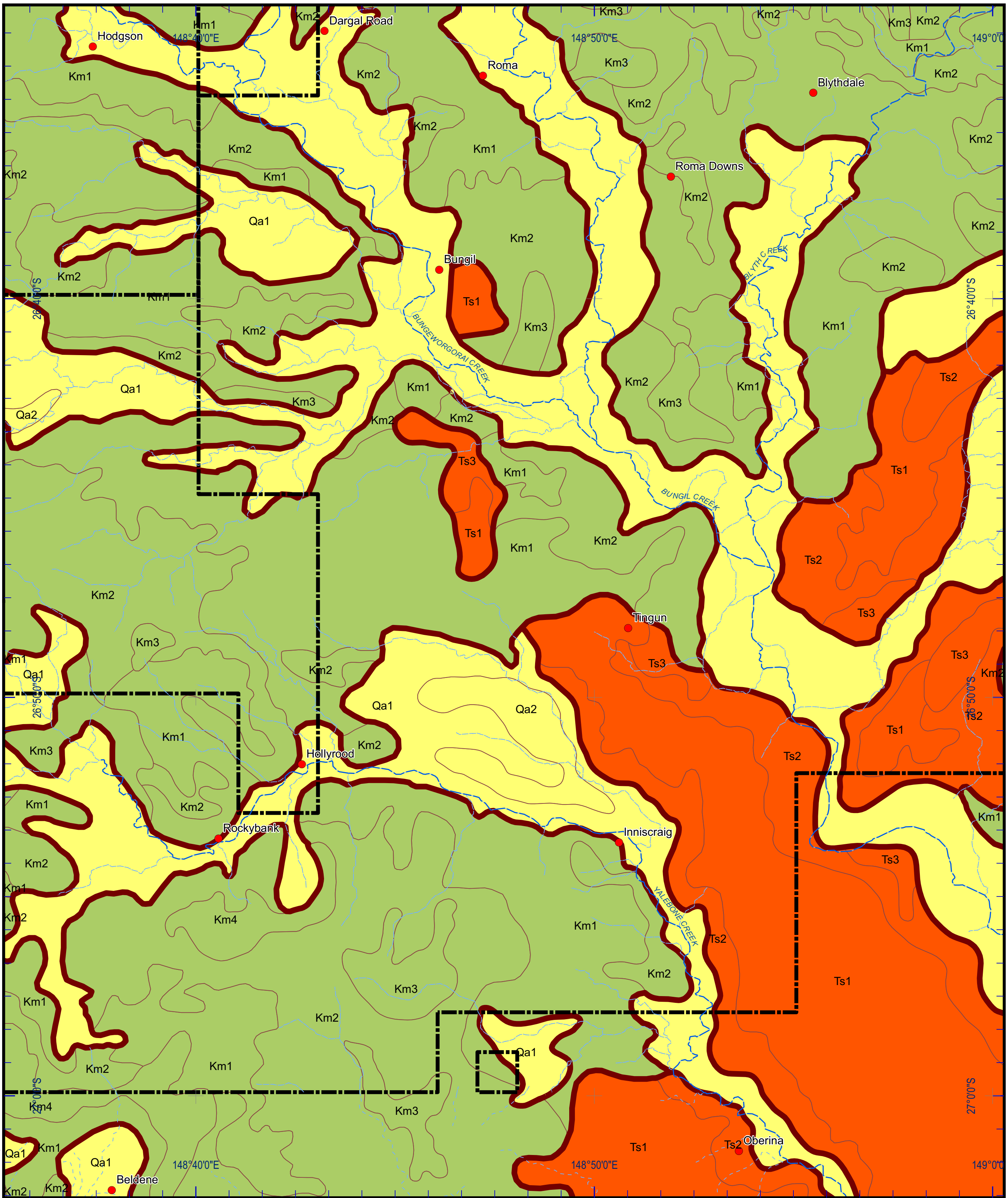
Kilometers
0 0.5 1 2 3 4 5
Scale 1:250 000 (A4)
Datum : GDA 94



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

Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	LANDSCAPE UNITS CSG FIELD ROMA (1 of 8)

Drawn: CA	Approved: JB	Date: 20-03-2009	Figure: 6.3.5
Job No.: **4262 6220**	File No.: 42626220-g-958.mxd		Rev. A
			A4



Map must be viewed with Appendix A in Appendix L1 for Complete Description of Landscape Units.

Landscape Unit Reference

Qa	Ka	Jm
Ts	Km	Rm
Tv	Ja	P

Slope Class

1 characteristic slope 0-2%
2 characteristic slope >2-5%
3 characteristic slope >5-12%
4 characteristic slope >12-25%
5 characteristic slope >25-50%
6 characteristic slope >50%

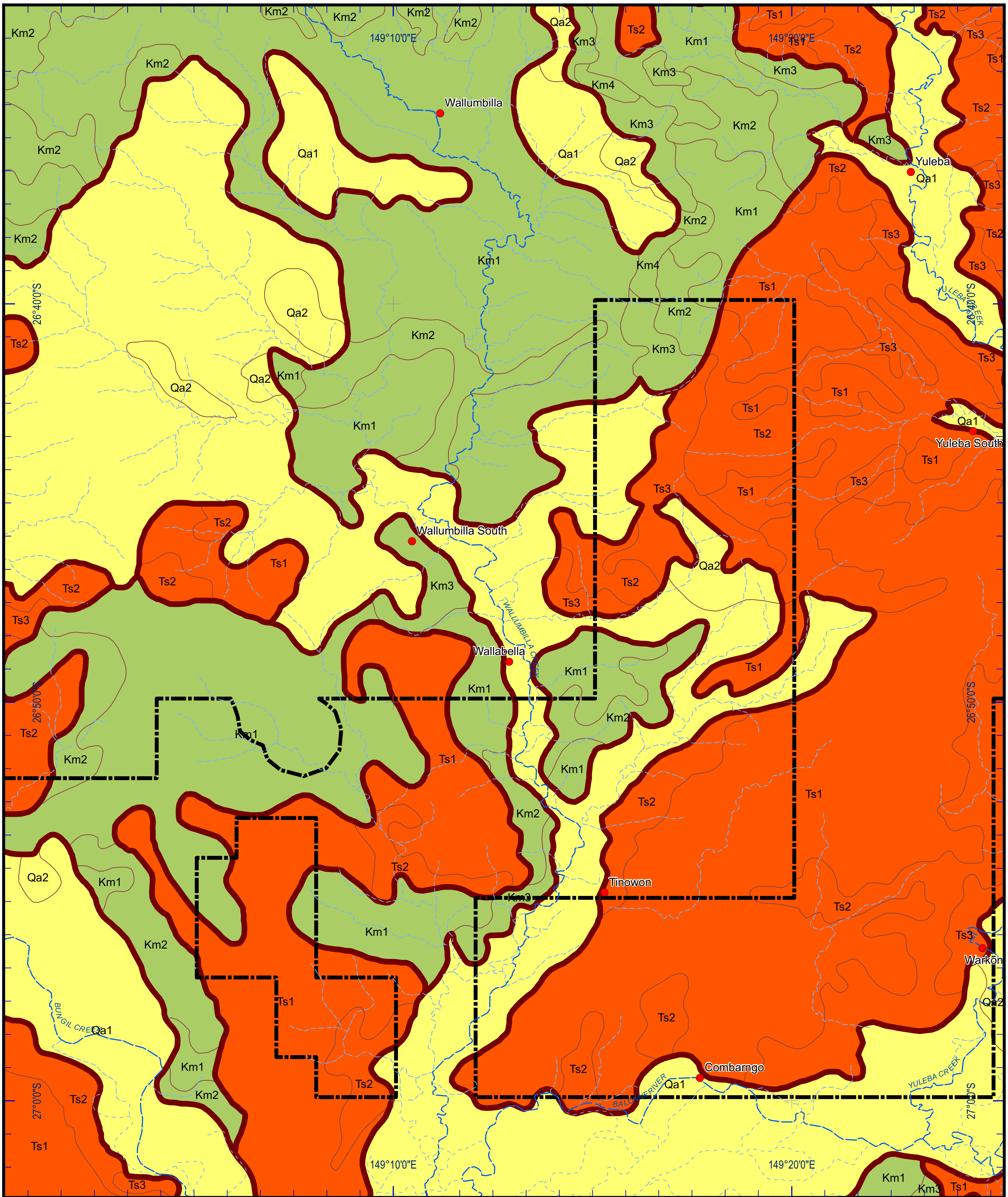
Qa1 Qa2 Landscape Unit Boundary with Geological Regime and Slope Class
Towns / Localities
CSG Field
Rivers, Creeks and Tributary Streams

N W E S

Kilometers
0 0.5 1 2 3 4 5
Scale 1:250 000 (A4)
Datum : GDA 94

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

Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**LANDSCAPE UNITS CSG FIELD ROMA (2 of 8)**
	Drawn: CA / Approved: JB / Date: 20-03-2009	Figure: 6.3.6 / Rev. A
	Job No.: **4262 6220** / File No.: 42626220-g-958.mxd	A4



Map must be viewed with Appendix A in Appendix L1 for Complete Description of Landscape Units.

Landscape Unit Reference

Qa	Ka	Jm
Ts	Km	Rm
Tv	Ja	P

Slope Class

1 characteristic slope 0-2%
2 characteristic slope >2-5%
3 characteristic slope >5-12%
4 characteristic slope >12-25%
5 characteristic slope >25-50%
6 characteristic slope >50%

Qa1 Qa2 Landscape Unit Boundary with Geological Regime and Slope Class

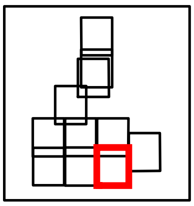
Towns / Localities

CSG Field

Rivers, Creeks and Tributary Streams

N W E S

Kilometers
0 0.5 1 2 3 4 5
Scale 1:250 000 (A4)
Datum : GDA 94



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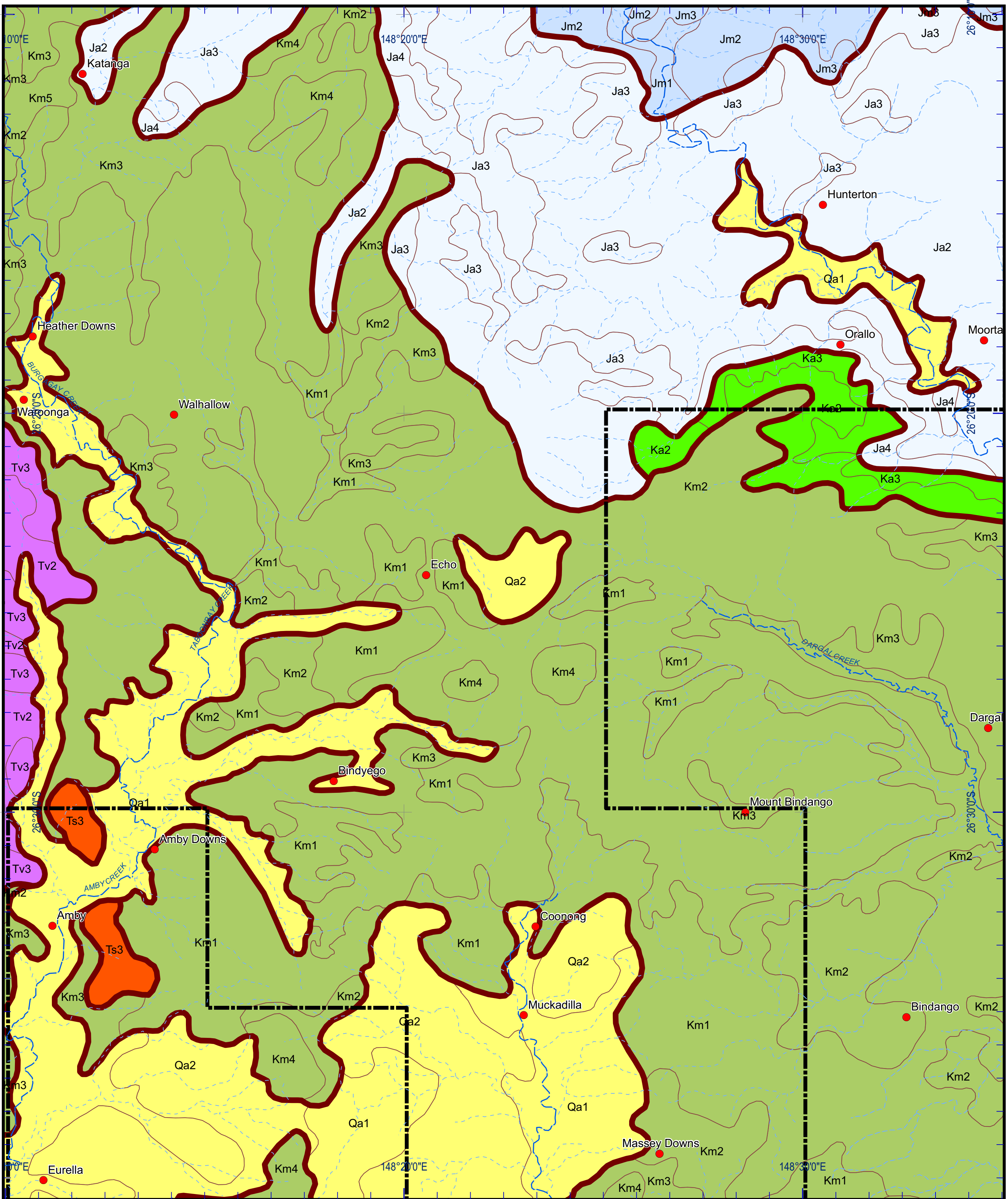
Client: LNG / URS	Project: GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT		Title: **LANDSCAPE UNITS CSG FIELD ROMA (3 of 8)**
	Drawn: CA	Approved: JB	Date: 20-03-2009
	Job No.: **4262 6220**	File No.: 42626220-g-958.mxd	Figure: 6.3.7 / Rev. A / A4



Map must be viewed with Appendix A in Appendix L1 for Complete Description of Landscape Units.

Landscape Unit Reference

Qa	Ka	Jm
Ts	Km	Rm
Tv	Ja	P

Slope Class

1 characteristic slope 0-2%
2 characteristic slope >2-5%
3 characteristic slope >5-12%
4 characteristic slope >12-25%
5 characteristic slope >25-50%
6 characteristic slope >50%

Qa1 Qa2 Landscape Unit Boundary with Geological Regime and Slope Class

Towns / Localities

CSG Field

Rivers, Creeks and Tributary Streams

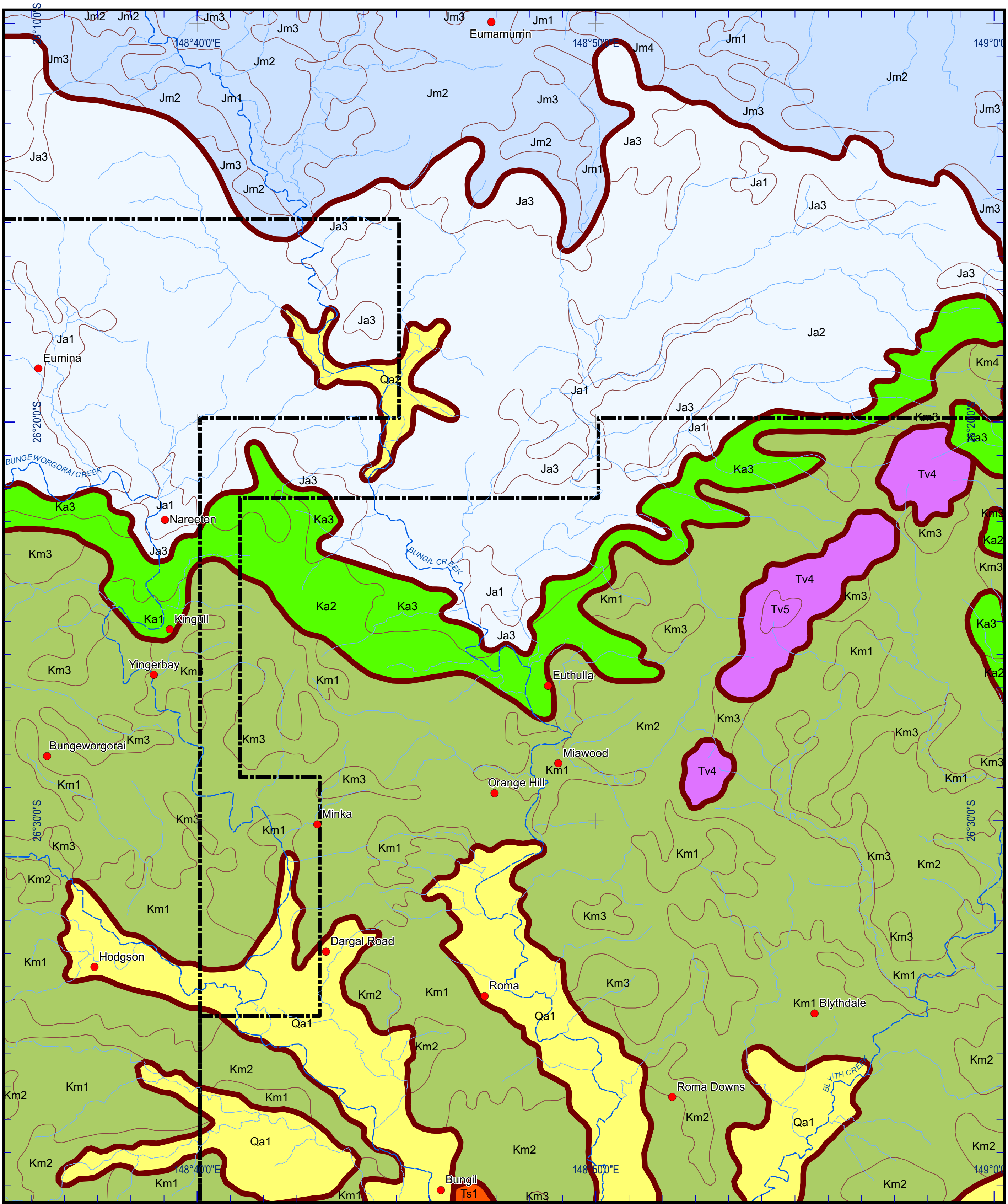
N W E S

Kilometers
0 0.5 1 2 3 4 5

Scale 1:250 000 (A4)
Datum : GDA 94

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

Client	Project	Title	
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**LANDSCAPE UNITS CSG FIELD ROMA (4 of 8)**	
	Drawn: CA · Approved: JB · Date: 20-03-2009	Figure: 6.3.8	Rev. A
	Job No.: **4262 6220** · File No.: 42626220-g-958.mxd		A4



Map must be viewed with Appendix A in Appendix L1 for Complete Description of Landscape Units.

Landscape Unit Reference

- Qa
- Ts
- Tv
- Ka
- Km
- Ja
- Jm
- Rm
- P

Slope Class

1 characteristic slope 0-2%
2 characteristic slope >2-5%
3 characteristic slope >5-12%
4 characteristic slope >12-25%
5 characteristic slope >25-50%
6 characteristic slope >50%

Qa1 Qa2 Landscape Unit Boundary with Geological Regime and Slope Class

Towns / Localities

CSG Field

Rivers, Creeks and Tributary Streams

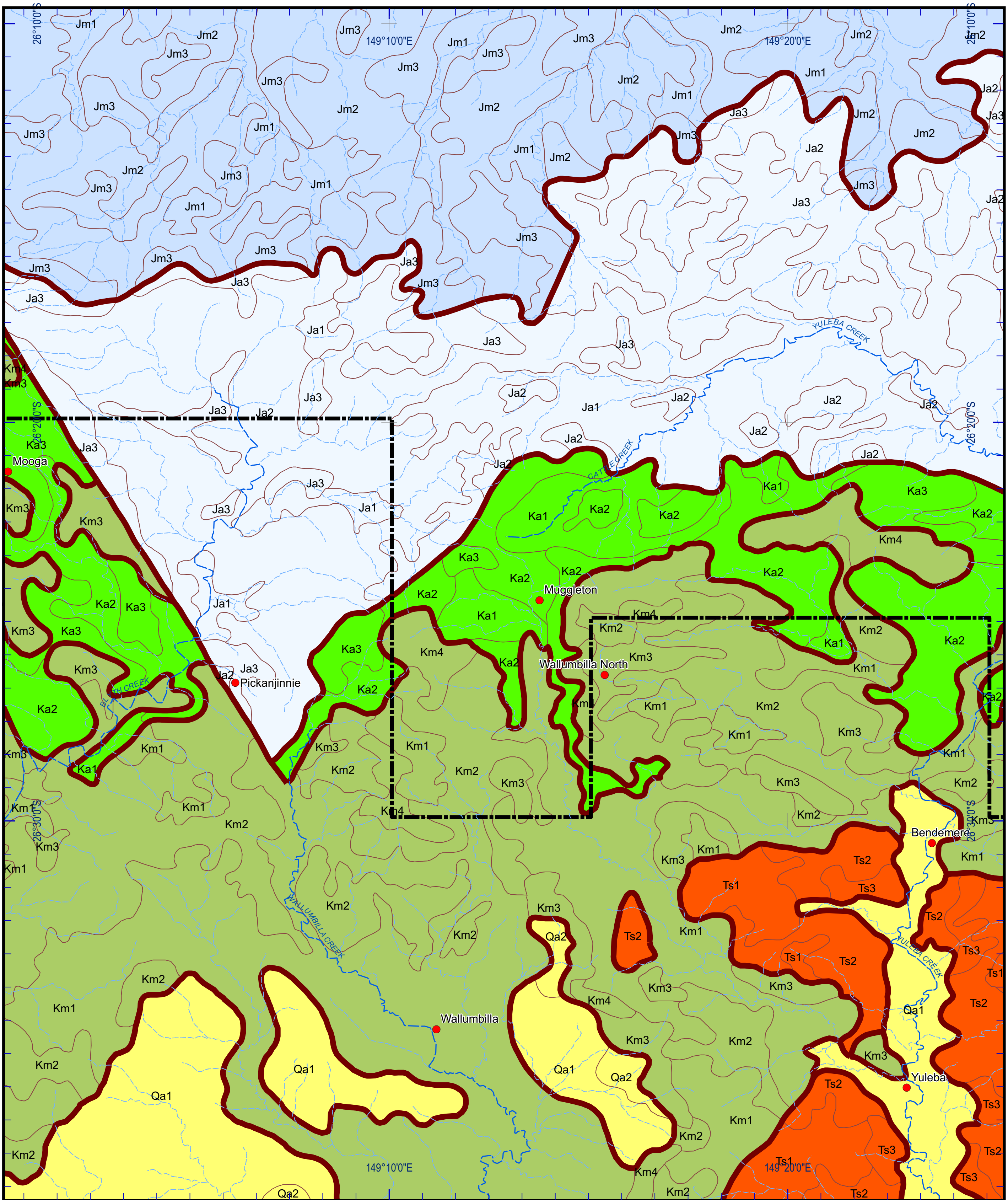
N W E S

Kilometers
0 0.5 1 2 3 4 5
Scale 1:250 000 (A4)
Datum : GDA 94

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

Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	LANDSCAPE UNITS CSG FIELD ROMA (5 of 8)

Drawn: CA	Approved: JB	Date: 20-03-2009	Figure: 6.3.9	Rev. A
Job No.: **4262 6220**	File No.: 42626220-g-958.mxd			A4



Map must be viewed with Appendix A in Appendix L1 for Complete Description of Landscape Units.

Landscape Unit Reference

Qa, Ka, Jm, Ts, Km, Rm, Tv, Ja, P

Slope Class

1 characteristic slope 0-2%
2 characteristic slope >2-5%
3 characteristic slope >5-12%
4 characteristic slope >12-25%
5 characteristic slope >25-50%
6 characteristic slope >50%

Qa1 Qa2 Landscape Unit Boundary with Geological Regime and Slope Class

Towns / Localities

CSG Field

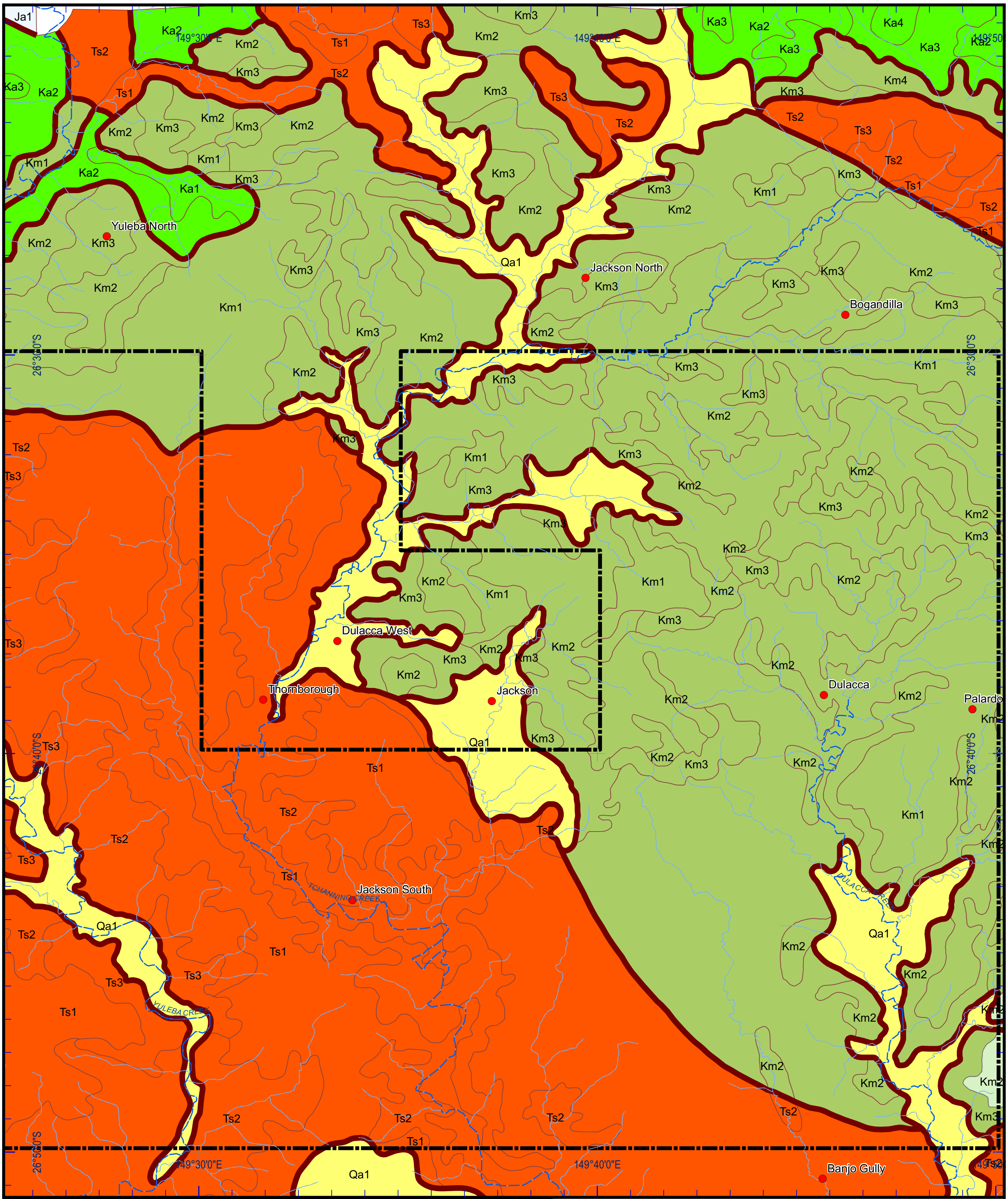
Rivers, Creeks and Tributary Streams

N W E S

Kilometers
0 0.5 1 2 3 4 5
Scale 1:250 000 (A4)
Datum : GDA 94

Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	LANDSCAPE UNITS CSG FIELD ROMA (6 of 8)

Drawn: CA	Approved: JB	Date: 20-03-2009	Figure: 6.3.10	Rev. A
Job No.: **4262 6220**	File No.: 42626220-g-958.mxd			A4



Map must be viewed with Appendix A in Appendix L1 for Complete Description of Landscape Units.

Landscape Unit Reference

Qa, Ka, Jm, Ts, Km, Rm, Tv, Ja, P

Slope Class

1 characteristic slope 0-2%
2 characteristic slope >2-5%
3 characteristic slope >5-12%
4 characteristic slope >12-25%
5 characteristic slope >25-50%
6 characteristic slope >50%

Qa1 / Qa2 — Landscape Unit Boundary with Geological Regime and Slope Class

Towns / Localities

CSG Field

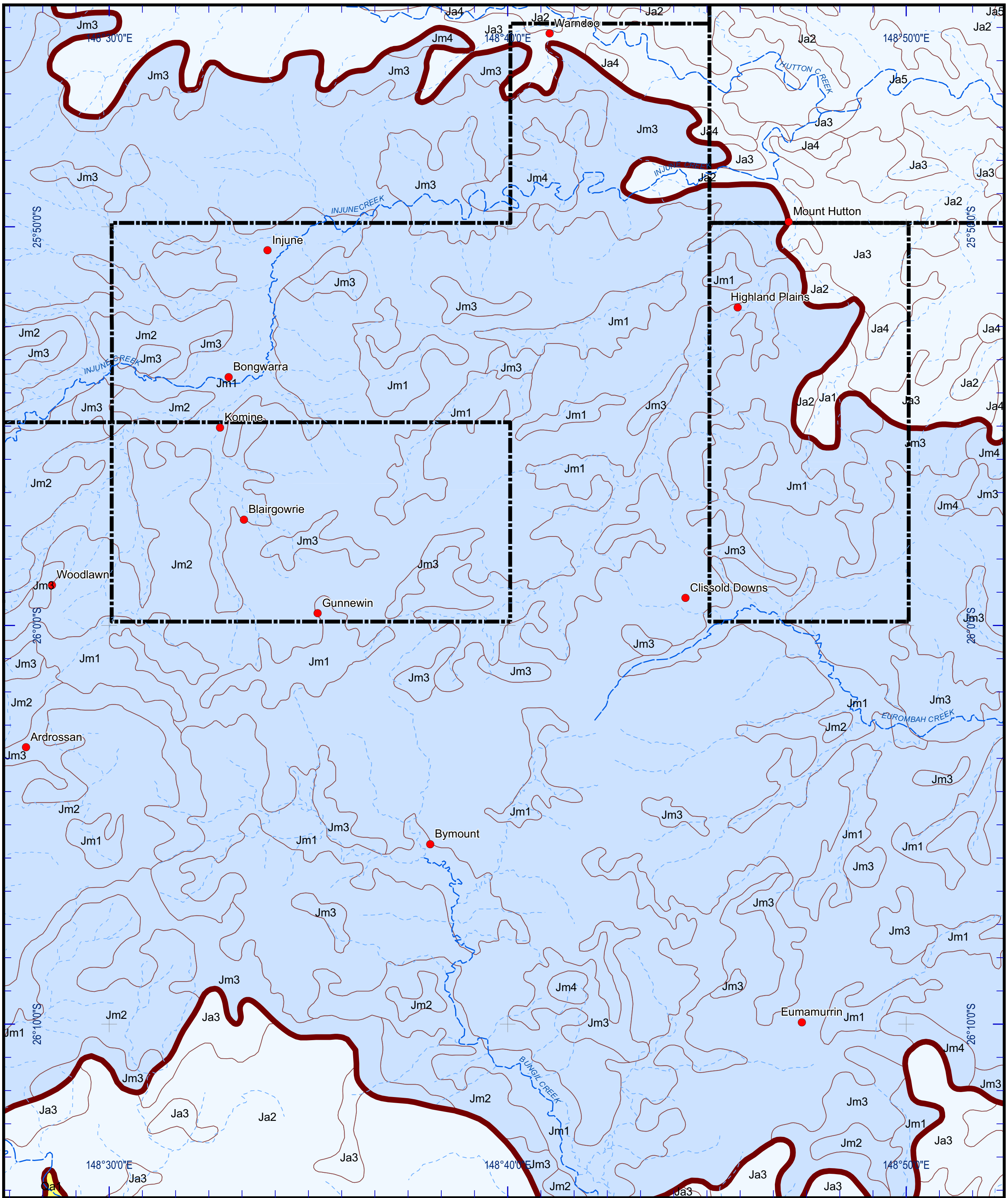
Rivers, Creeks and Tributary Streams

N, W, E, S

Kilometers
0 0.5 1 2 3 4 5
Scale 1:250 000 (A4)
Datum : GDA 94

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

Client	Project	Title
LNG	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**LANDSCAPE UNITS CSG FIELD ROMA (7 of 8)**
URS	Drawn: CA / Approved: JB / Date: 20-03-2009	Rev. A
	Job No.: **4262 6220** / File No.: 42626220-g-958.mxd	Figure: 6.3.11 / A4



Map must be viewed with Appendix A in Appendix L1 for Complete Description of Landscape Units.

Landscape Unit Reference

Qa	Ka	Jm
Ts	Km	Rm
Tv	Ja	P

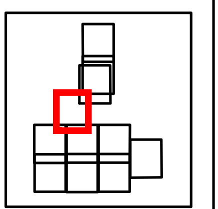
Slope Class

1 characteristic slope 0-2%
2 characteristic slope >2-5%
3 characteristic slope >5-12%
4 characteristic slope >12-25%
5 characteristic slope >25-50%
6 characteristic slope >50%

Qa1 Qa2 Landscape Unit Boundary with Geological Regime and Slope Class
Towns / Localities
CSG Field
Rivers, Creeks and Tributary Streams

N W E S

Kilometers
0 0.5 1 2 3 4 5
Scale 1:250 000 (A4)
Datum : GDA 94



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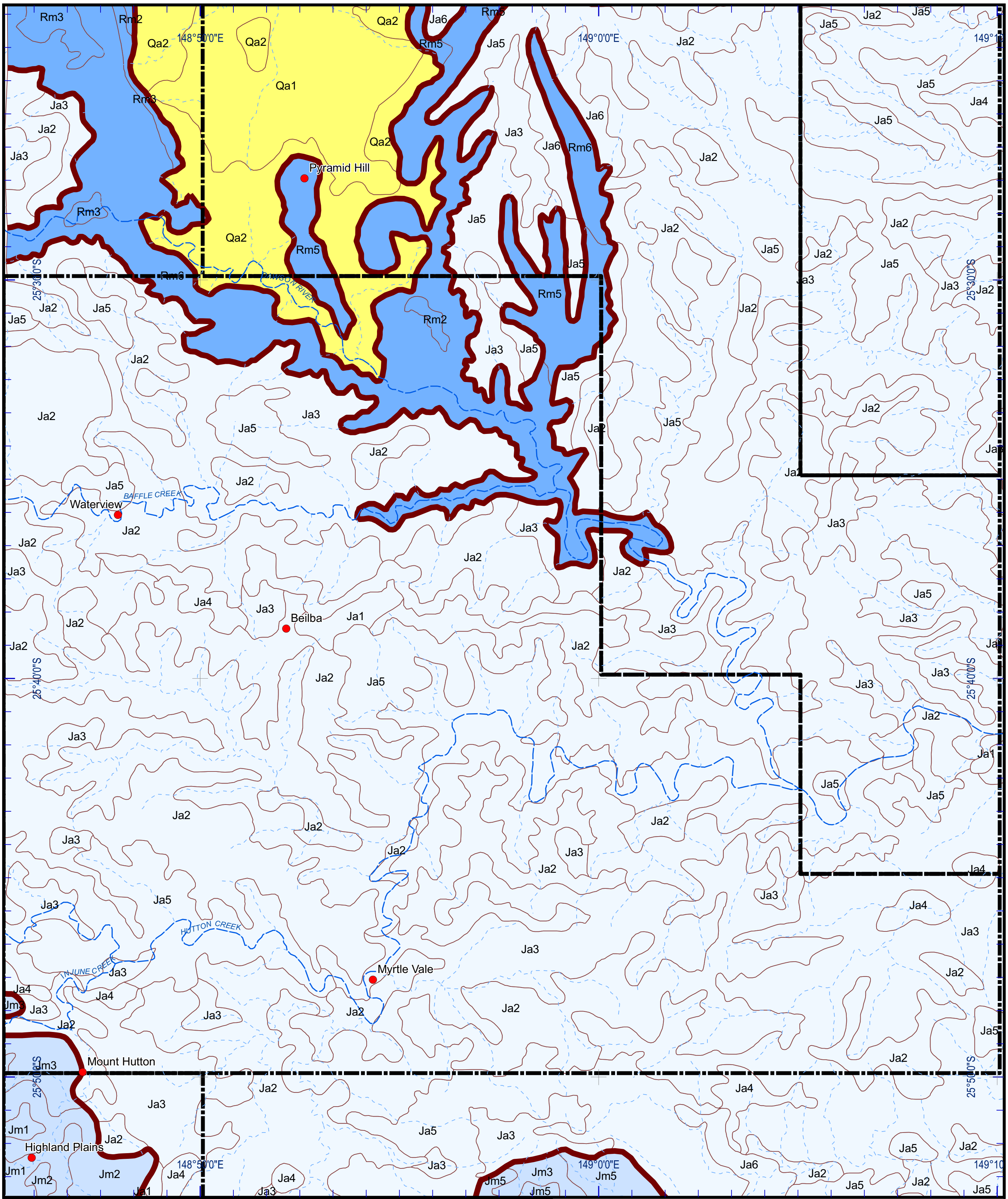
Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**LANDSCAPE UNITS CSG FIELD ROMA (8 of 8)**
Drawn: CA	Approved: JB	Date: 20-03-2009
Job No.: **4262 6220**	File No.: 42626220-g-958.mxd	Figure: 6.3.12
Rev. A	A4	



Map must be viewed with Appendix A in Appendix L1 for Complete Description of Landscape Units.

Landscape Unit Reference

Qa	Ka	Jm
Ts	Km	Rm
Tv	Ja	P

Slope Class

1 characteristic slope 0-2%
2 characteristic slope >2-5%
3 characteristic slope >5-12%
4 characteristic slope >12-25%
5 characteristic slope >25-50%
6 characteristic slope >50%

Landscape Unit Boundary with Geological Regime and Slope Class

Towns / Localities

CSG Field

Rivers, Creeks and Tributary Streams

N E S W

Kilometers
0 0.5 1 2 3 4 5
Scale 1:250 000 (A4)
Datum : GDA 94

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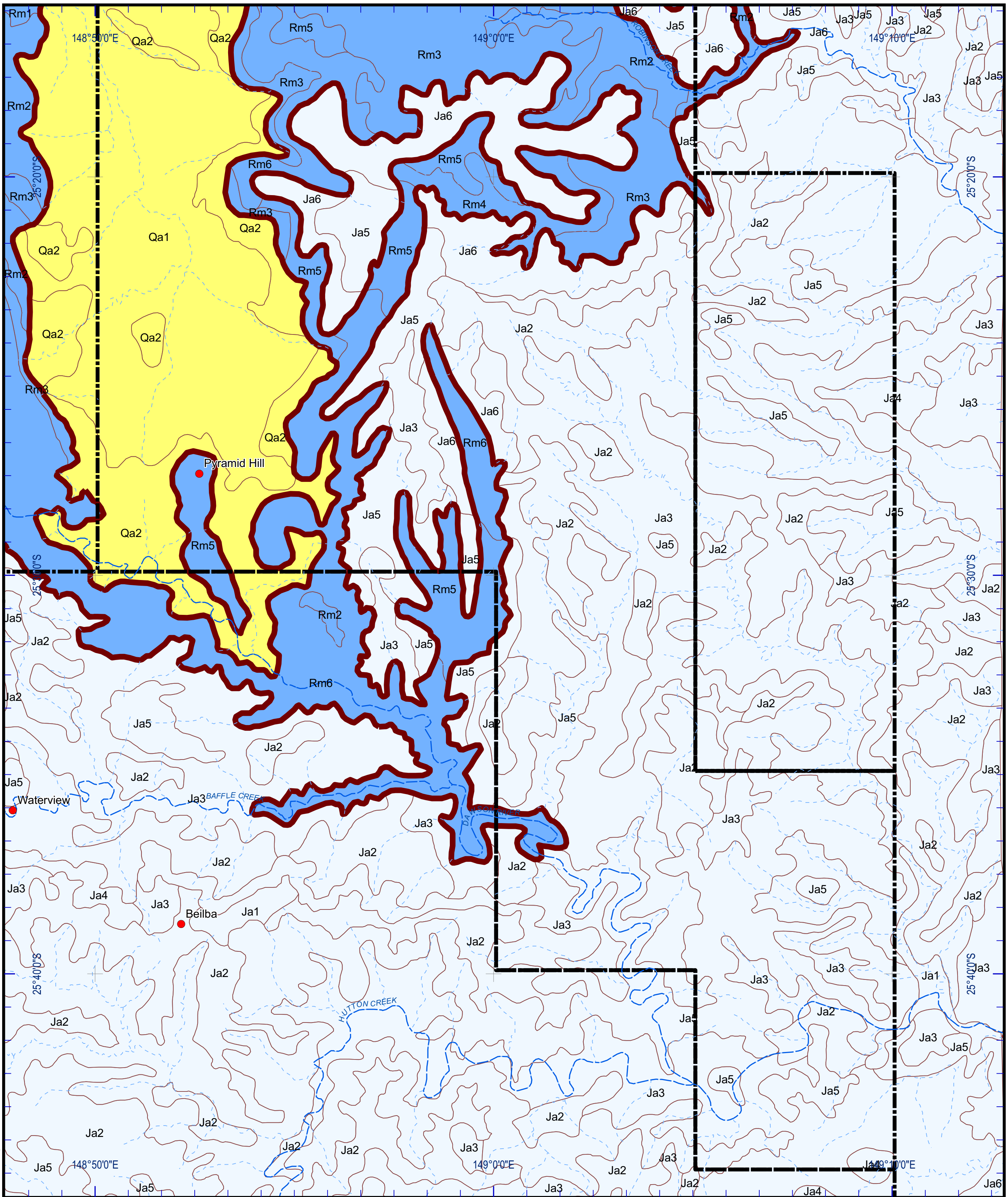
Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	LANDSCAPE UNITS CSG FIELD FAIRVIEW

Drawn: CA	Approved: JB	Date: 20-03-2009	Figure: 6.3.13	Rev. A
Job No.: **4262 6220**	File No.: 42626220-g-958.mxd			A4



Map must be viewed with Appendix A in Appendix L1 for Complete Description of Landscape Units.

Landscape Unit Reference

Qa	Ka	Jm
Ts	Km	Rm
Tv	Ja	P

Slope Class

1 characteristic slope 0-2%
2 characteristic slope >2-5%
3 characteristic slope >5-12%
4 characteristic slope >12-25%
5 characteristic slope >25-50%
6 characteristic slope >50%

Qa1 Qa2 Landscape Unit Boundary with Geological Regime and Slope Class

Towns / Localities

CSG Field

Rivers, Creeks and Tributary Streams

N W E S

Kilometers
0 0.5 1 2 3 4 5
Scale 1:250 000 (A4)
Datum : GDA 94

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Client

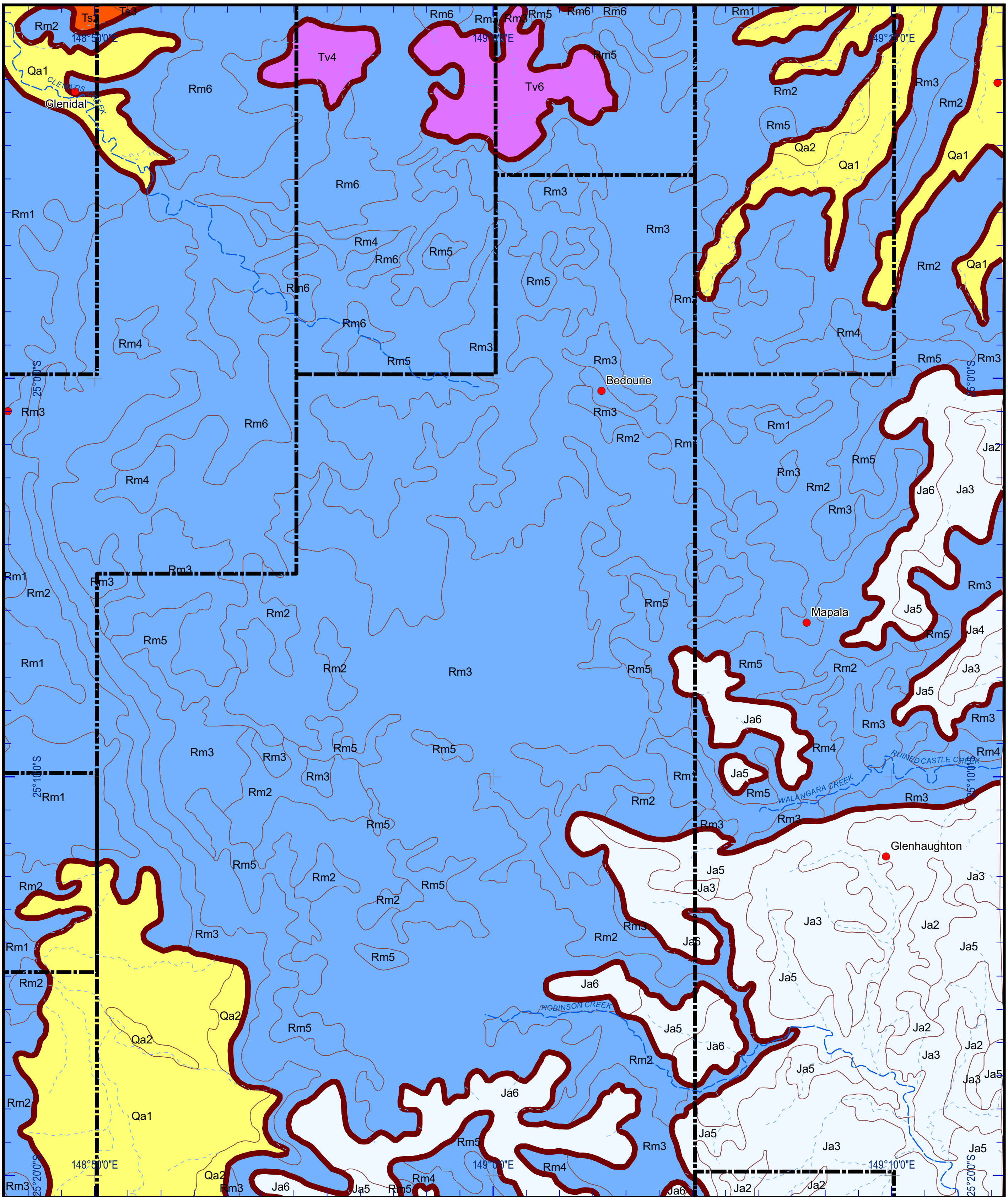
LNG

URS

Project
GLADSTONE LNG PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Title
LANDSCAPE UNITS
CSG FIELD
ARCADIA VALLEY
(1 of 2)

Drawn: CA	Approved: JB	Date: 20-03-2009	Figure: 6.3.14	Rev. A
Job No.: **4262 6220**	File No.: 42626220-g-958.mxd			A4



Map must be viewed with Appendix A in Appendix L1 for Complete Description of Landscape Units.

Landscape Unit Reference

Qa	Ka	Jm
Ts	Km	Rm
Tv	Ja	P

Slope Class

1 characteristic slope 0-2%
2 characteristic slope >2-5%
3 characteristic slope >5-12%
4 characteristic slope >12-25%
5 characteristic slope >25-50%
6 characteristic slope >50%

Qa1 Qa2 Landscape Unit Boundary with Geological Regime and Slope Class

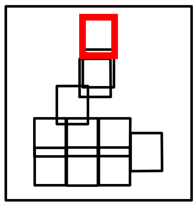
Towns / Localities

CSG Field

Rivers, Creeks and Tributary Streams

N W E S

Kilometers
0 0.5 1 2 3 4 5
Scale 1:250 000 (A4)
Datum : GDA 94



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Client: LNG / URS	Project: GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	Title: **LANDSCAPE UNITS CSG FIELD ARCADIA VALLEY (2 of 2)**
Drawn: CA	Approved: JB	Date: 20-03-2009
Job No.: **4262 6220**	File No.: 42626220-g-958.mxd	Figure: 6.3.15
Rev. A	A4	

Geology

Stratigraphy – Bowen Basin

The Early Permian to Middle Triassic Bowen Basin is a north-south trending belt extending from the vicinity of Mount Louisa (south of Home Hill, Qld) southward into northern inland NSW, south-south-east of Moree. Deposition of the Bowen Basin was concentrated in two depocentres, the Taroom Trough on the eastern edge of the basin, and the Denison Trough along its western edge. Deposition commenced in the Early Permian and extended through to the Middle Triassic. Early phases of deposition in the Taroom Trough consisted of fluvial and lacustrine sediments and volcanics, while in the Denison Trough deposition consisted of a thick succession of coals and non-marine clastic sediments. Following rifting, a subsidence phase extending from the Early to Late Permian allowed deposition of deltaic and shallow marine, predominantly clastic sediments as well as extensive coal measures. A period of accelerated subsidence followed during the Late Permian, resulting in the deposition of a very thick succession of marine and fluvial clastics, consisting of Early to Middle Triassic fluvial and lacustrine clastic sediments and further coal. A Middle to Late Triassic contractional event terminated deposition.

Stratigraphy – Surat Basin

The Early Jurassic to Early Cretaceous Surat Basin overlies the southern half of the Bowen Basin, and extends from the southern part of the Expedition Range southward to the Warrumbungle Range in New South Wales.

Within the southern CSG fields study area the predominant outcropping rocks of the Surat Basin are Cretaceous mud rocks (predominantly mudstones, siltstones and labile sandstone of the Early Cretaceous Mooga Sandstone, Bungil formation, Wallumbilla Formation, Surat Siltstone and Griman Creek Formation), and Jurassic arenites and mud rocks (typified by quartzose sandstone of the Precipice Sandstone, carbonaceous mudstone of the Evergreen Formation and predominantly quartzose Hutton Sandstone). Overlying and occurring in the surface layers of these Mesozoic rocks in some places are deep weathering profiles and surficial silcrete that developed during the Early Tertiary. Sedimentary deposition in the Middle Tertiary consisted mostly of quartzose sandstone and conglomerate.

Quaternary alluvium and soil occur in the lower-lying areas throughout the Surat and Bowen Basins, and overlie Permian, Mesozoic and Tertiary sediments and volcanics.

The geology of the CSG fields study area has been mapped by the GSQ in the Geoscience Datasets (2004 and 2008), the GSQ Regional Mapping of the Bowen Basin and the Surat Basin.

As mapped in the GSQ Geoscience datasets, several of the geological mapping units identified have similar characteristics in terms of age and rock type. To simplify the mapping process, certain of these mapping units have been combined and re - defined as *Geological Regimes*. The geological regimes and the map symbols that have been adopted as a basis for the terrain mapping are outlined in Table 6.3.1

Table 6.3.1 Geological Regime

Geological Regime	Map Symbol	Description
Quaternary alluvium	Qa	Comprising clay, silt, sand and gravel deposits; includes areas of colluvial and residual soil.
Tertiary sediments	Ts	Undivided sediments and as mapped includes Biloela Formation; sub - labile to quartzose sandstone, siltstone, mudstone, minor conglomerate coal and limestone.
Tertiary volcanic rocks	Tv	Volcanic rocks, predominantly mafic; basalt, trachyte, rhyolite.
Tertiary intrusive	Tt	Gabbro.
Cretaceous, predominantly arenitic rocks	Ka	Includes Mooga Sandstone.

Geological Regime	Map Symbol	Description
Cretaceous, predominantly mudstone rocks	Km	Includes Bungil Formation, Doncaster Formation, Coreena Member.
Jurassic, predominantly arenitic rocks	Ja	Includes Precipice Sandstone, Evergreen Formation, Hutton Sandstone, Gubberamunda Sandstone, Orallo Formation.
Jurassic, predominantly mudstone rocks	Jm	Includes Injune Creek Group, Birkhead Formation, Westbourne Formation.
Triassic, predominantly mudstone rocks	Rm	Includes Moolayember Formation, Clematis Group, Rewan Formation.
Permian sediments and volcanics	P	Includes Blackwater Group, Back Creek Group, and Reid Dome Beds.

The occurrences and distribution of the geological regimes as mapped within the CSG fields are shown in Figures 6.3.16 and 6.3.17. Note that the EIS groundwater report for the CSG fields study area (refer Appendix P1) also contains regional geology maps and a schematic geological cross section of the Fairview CSG field.

Economic Geology

The Bowen and Surat Basins are of enormous economic importance, due primarily to their extensive deposits of coal and significant volumes of CSG occurring within the coal deposits. The CSG fields occur partly within the Bowen Basin and partly within the more southerly overlying Surat Basin, although the origin of the CSG is located in the underlying Permian sediments with their extensive coal deposits.

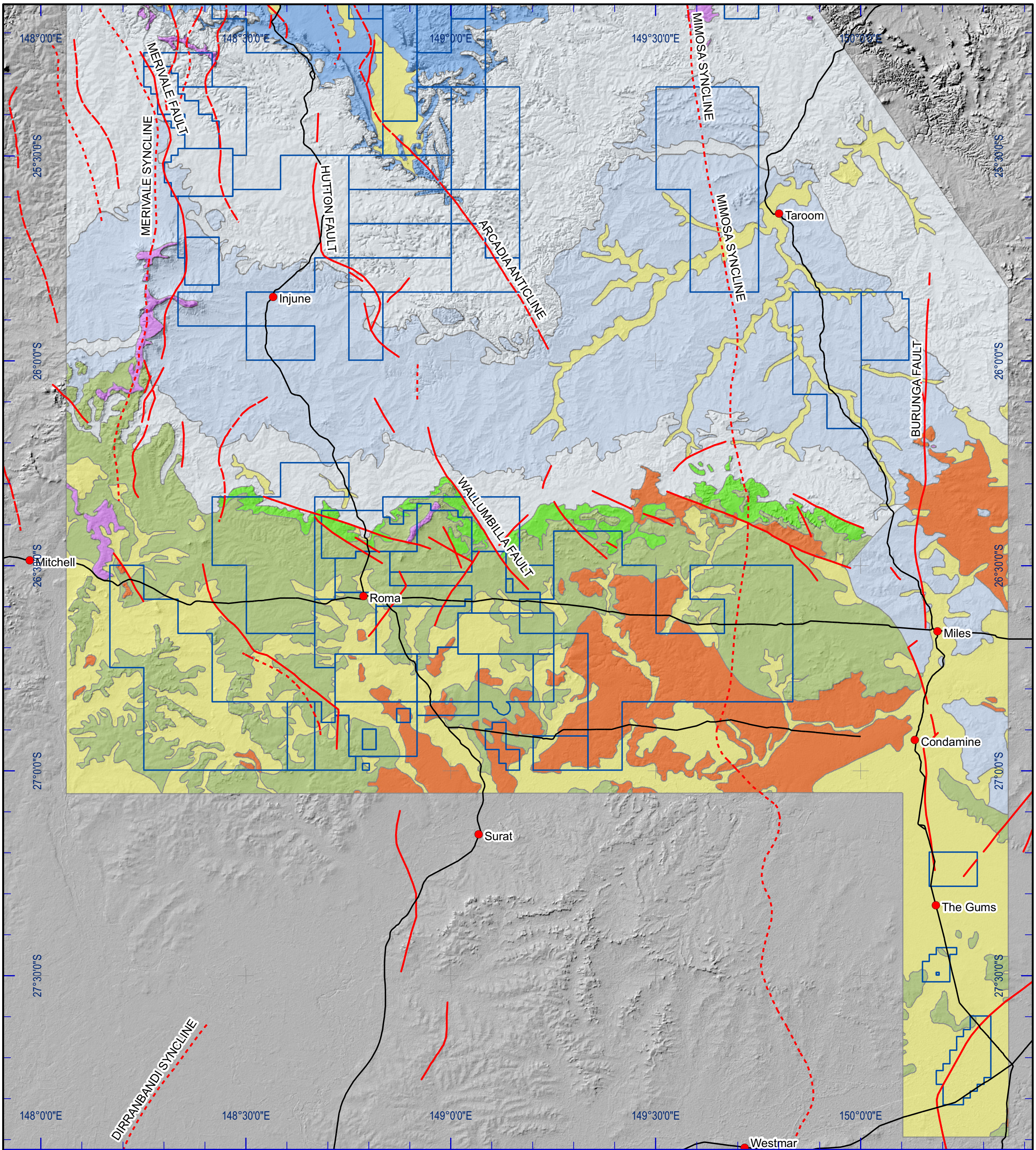
Seismicity Activity and Ground Stability

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 approximately 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 area occurred approximately 40 km from Bundaberg in 1985, and recorded a ML of 3.1.

The study area extends over a considerable distance, with some areas 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 (Gaull *et al.*, 1990). From the coast, approximately 200 km inland to the west, including the area to the south through the Roma and Scotia CSG fields, the intensity is V on the Modified Mercalli Scale. The portions west of these areas containing all of the other CSG fields are categorised as IV (Gaull *et al.*, 1990).



Geology

Qa	Ka	Jm
Ts	Km	Rm
Tv	Ja	P
Tt		

Fault
Anticline
Syncline
Towns
Major Roads
CSG Field

N W E S

Kilometers
0 5 10 20 30 40 50
Scale 1:1 500 000 (A4)
Datum : GDA 94

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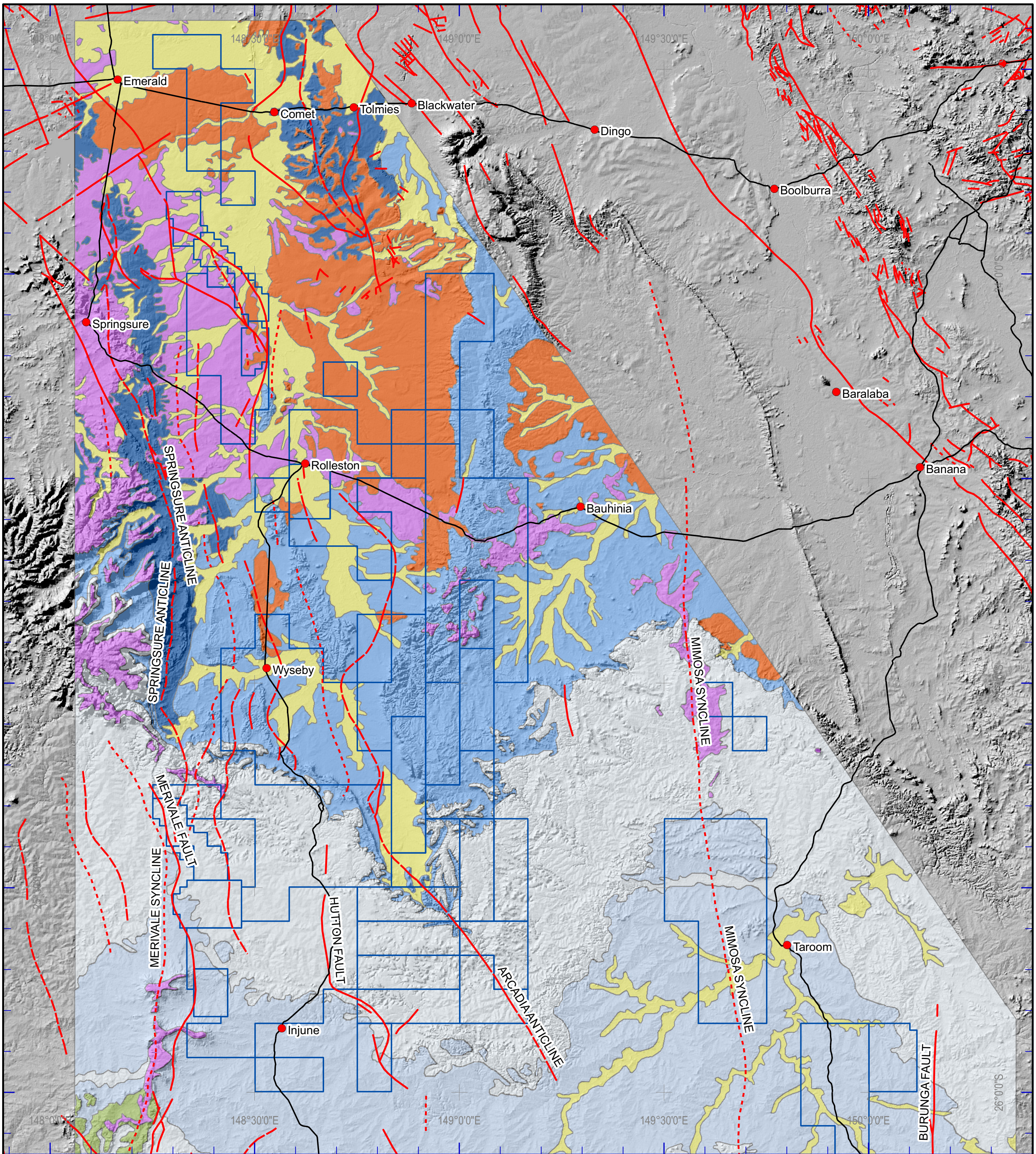
Client	Project	Title
LNG URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**GEOLOGY** **CSG FIELDS** **(SOUTHERN SECTION)**

Drawn: MG	Approved: GR	Date: 16-01-2009	Figure: **6.3.16**	Rev. A
Job No.: **4262 6220**	File No.: 42626220-g-959.mxd			A4



Geology

Qa	Ka	Jm	Fault	Towns	
Ts	Km	Rm	Anticline	Major Roads	
Tv	Ja	P	Syncline	CSG Field	
Tt					

Kilometers: 0 5 10 20 30 40 50

Scale 1:1 500 000 (A4)

Datum : GDA 94

Client: LNG / URS

Project: GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT

Title: **GEOLOGY CSG FIELDS (NORTHERN SECTION)**

Drawn: MG	Approved: JB	Date: 20-03-2009	Figure: **6.3.17**	Rev. A
Job No.: **4262 6220**	File No.: 42626220-g-960.mxd			A4

Geological Structural Features and Faults

Structural features occurring within the Bowen and Surat Basins consist predominantly of south to north or south-south-east to north-north-west trending gentle folds and faults, which have resulted from regional compression towards the west-south-west occurring from the end of the Permian to the Middle Triassic. Contractional deformation during the early part of the Late Cretaceous resulted in folding and uplift of the Surat Basin sediments as deeper thrust faults were reactivated.

As mapped by the Geological Survey of Queensland (GSQ, 2005) on the regional Surat and Bowen Basin map sheets; major anticlines, synclines and fault lines and other geological structural features that occur within the CSG fields are shown in Figure 6.3.16. The faults in particular may potentially comprise a zone of weakness in the earth's crust that may be subject to differential movement during a significant seismic event in the general area.

Soil Groups and Soil Types

Eight major soils groups have been identified within the CSG fields study area and are described within Table 6.3.2. These have been determined from various sources including the regional land systems and soils mapping by CSIRO (1967, 1968 & 1974) and the Atlas of Australian Soils (Isbell et al., 1967), which collectively cover the study area. Reference was also made to the data obtained as part of the field investigation of sections of the pipeline proposed for the Denison Trough Gas Project–Gladstone Option, prepared by CSR Oil and Gas Division (1984).

Table 6.3.2 Soils Groups Identified within the CSG Fields

Soil Group	Summary Soil Description	Soil Classification			
		Aust. Soil Group (1)	Aust. Soil Group (1)	Aust. Soil Group (1)	Aust. Soil Group (1)
1	Skeletal, rocky or gravelly soils (>60 % coarse fragments) with sandy, silty, loamy or clayey soil matrix.	Shallow rocky soils; Lithosols	K- Uc1, Um1, Gn1, Uf1	GW, GM, GP, GC	Lithosolic/Colluvic Rudosols
2	Sand soils; shallow to deep uniform or weakly gradational profiles; includes stratified alluvial soils, residual sand soils, earthy sands.	Siliceous sands Earthy sands Lithosols	(Ucl-Uc6)(2)	SP, SM,SW	Rudosol, Tenosol Podosol Soil Orders (3)
3	Coarse to medium - textured soils; uniform or gradational profiles; predominantly sandy earths with sand, silty or clayey sand over clayey sand - sandy clay soil profiles.	Sandy Earths Sandy Red-Yellow Earths	(Uc4-5, Uml-3); Gn2.11, Gn2.12	SP-SC/SC-CL /CL SC/SC-CL	Tenosols or Podosol Soil Orders.
4	Medium - textured sandy, sandy loam or silt to clay loamy surface uniform or gradational profiles with clay loam, light clay or medium clay subsoils, in places with siliceous stone and/or ferruginous gravelly lenses included.	Shallow Loams Gravelly Loams Red and Yellow Massive Earths Lateritic Red-Yellow Earths	Um2.12 K-Um2.12 Um4.11 Gn2.12 Gn2.22	CL/GC - CL/GC GC - CL/GC	Tenosols, Kandosols or Ferrosol Soil Orders.
5	Sand, loamy sand, sandy loam or loamy surface duplex soils over acidic to locally strongly acidic, in places neutral or slightly alkaline sandy clay to medium to heavy clay subsoils.	Red, Yellow & Brown Podzolic Soils ; Grey & Brown Soloths	Dr2.12, 2.22 Dy3.42, 3.22 Dy3.12, 3.32 Db1.41	SP-SC/CL or CL-CH	Ferric Red - Brown Chromosols; Sodic Yellow & Brown Kurosols

Soil Group	Summary Soil Description	Soil Classification			
		Aust. Soil Group (1)	Aust. Soil Group (1)	Aust. Soil Group (1)	Aust. Soil Group (1)
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.	Yellow, Brown, Red-brown Solodic Soils; Solodized Solonetz	Db1.33, 1.13 Dr2.13, Dy2.23, Dd1.13	ML-CL/CL-CH or CH SM-ML/CL-CH or CH	Subnatric Brown Sodosols, Chrom - osols, Sodosols or Calcarosols Soil Orders
7	Shallow uniform often gravelly fine - textured soils, medium to deep uniform fine - textured (non - cracking) clay soils or gradational often stony or gravelly clay loam or light clay surface soils over alkaline medium to heavy clay subsoils, locally sodic and saline in the deeper subsoils – some deep incipient cracking clays.	Alluvial Soils Dark brown Grey-brown or Dark Reddish-brown (Non-Cracking) Clay Soils, some Solonchaks	Uf6.31, 6.32 Uf6.61, 6.63 Uf6.32, 6.21 Gn3.22, 3.42 Gn3.93, 3.13 Gn3.12	CL/CL, SC-CL/CL-CH CL/CL-CH/CH	Dermosol or Hydrosol Soil Orders.
8	Shallow to medium to deep 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 in areas with Gilgai micro – relief.	Black Earths Grey and Brown Soils of Heavy Texture	Ug5.12, 5.21 Ug5.24, 5.25 Ug5.38, Ug5.15, 5.16	CL-CH/CH, CH/CH	Vertosols Soil Order
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).					

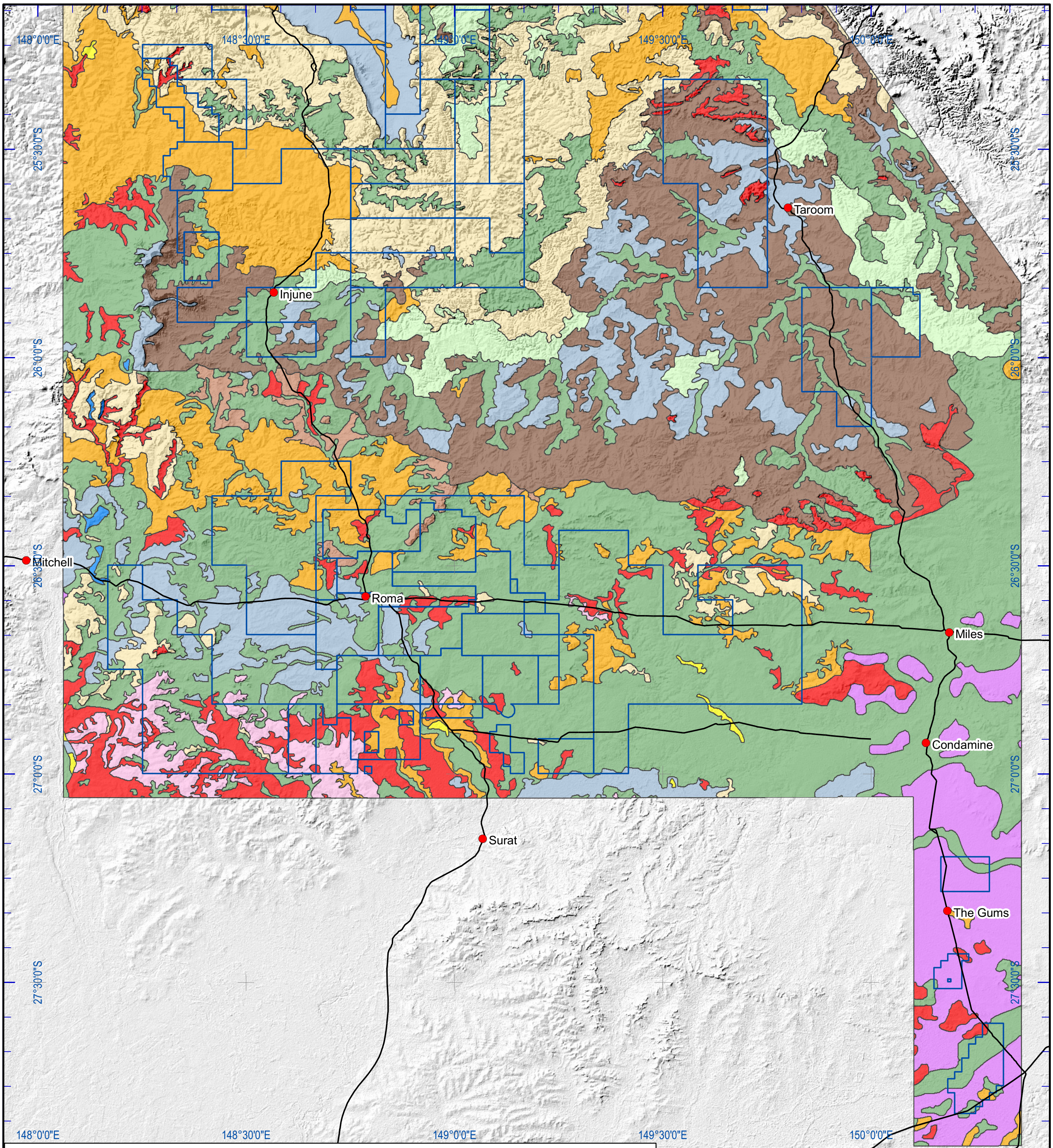
With respect to the soil groups identified in Table 6.3.2, the adopted scheme allows for more than one soil type variant to be described within a particular soil group in order to differentiate between similar soils which may have somewhat differing soil profile characteristics. The soil types identified for each of the main soil groups are summarised in Table 6.3.3.

Table 6.3.3 Soil Type Descriptions

Soil Group	Soil Type 1	Soil Type 2	Soil Type 3
1	Undifferentiated: Shallow (<0.6m) and medium to deep (0.6 - >1.0 m) rocky, stony or gravelly soils (>60 % coarse fragments) with sand, sandy loam, loam or clayey soil matrix		
2	*Soil Type 2.1:* Shallow sands (<0.6 m) residual soils often gravelly over HWR or colluvium	*Soil Type 2.2:* Medium to deep (0.6 - >1.0 m) sands (alluvial, colluvial or aeolian) including stratified alluvial deposits	*Soil Type 2.3:* Medium to deep (0.6 - >1.0 m) residual, uniform or weakly gradational sandy soils over weathered rock or deeply weathered sediments
3	*Soil Type 3.1:* Shallow (<0.6 m) mainly uniform coarse to medium textured sandy earths, sandy loam soils, often stony or gravelly	*Soil Type 3.2:* Medium to deep (0.6 - >1.0 m) mainly uniform earthy sand-sandy red and yellow earths, some Fe gravelly inclusions	*Soil Type 3.3:* Medium to deep (0.6 - >1.0 m) earthy sands-sandy red and yellow earths with Si or Fe and lateritic gravel layers included
4	*Soil Type 4.1:* Shallow (<0.6 m) gradational or uniform medium - textured gravelly loamy soils	*Soil Type 4.2:* Medium to deep (0.6 - >1.0 m) massive red-yellow earths in places with lateritic gravelly lenses	*Soil Type 4.3:* Medium to deep (0.6 - >1.0 m) structured red or brown earths

Soil Group	Soil Type 1	Soil Type 2	Soil Type 3
5	*Soil Type 5.1:* Shallow (<0.6 m) mostly sandy surface neutral to acidic duplex soils	*Soil Type 5.2:* Medium to deep (0.6 - >1.0 m) often bleached thick (>0.3 m) sandy surface yellow-brown and red-brown duplex soils with acidic locally strongly acidic clay subsoils	*Soil Type 5.3:* Medium to deep (0.6 - >1.0 m) thin (<0.3 m) fine sandy, sandy loamy or loamy surface brown, yellow-brown or red-brown duplex soils with acidic to strongly acidic subsoils
6	*Soil Type 6.1:* Shallow (<0.5 m) fine sandy to loamy surface often gravelly or stony neutral to alkaline duplex soils	*Soil Type 6.2:* Medium to deep (0.6 - >1.0 m) fine sandy to silt loamy surface often bleached duplex soils with brown, yellow-brown or red-brown alkaline, sodic and often moderately saline medium to heavy clay subsoils	*Soil Type 6.3:* Medium to deep (0.6 - >1.0 m) thick (>0.3 m) fine sandy to silt loamy surface duplex soils with neutral to alkaline usually sodic medium to heavy clay subsoils
7	*Soil Type 7.1:* Shallow to medium deep typically gravelly or stony uniform fine - textured soils or gradational clay loam over light to medium gravelly clay subsoils over weathered rock	*Soil Type 7.2:* Medium to deep (0.6 - >1.0 m) uniform clay soils or gradational clay loam or light clayey surface soils over light to medium or medium heavy slightly acidic to neutral and alkaline clay subsoils; includes fine-textured alluvial and stratified alluvial soils	*Soil Type 7.3:* Medium to deep mainly uniform dark brown, grey-brown or red-brown (non-cracking) clay soils with medium to heavy strongly alkaline or strongly acidic, sodic and locally saline clay subsoils
8	*Soil Type 8.1:* Shallow (<0.6 m) uniform cracking clays often with calcareous clay subsoils over weathered rock, typically intermediate to basic volcanic rock including basalt	*Soil Type 8.2:* Medium to deep often very deep (0.6 - >1.0 m, dark brown to very dark grey cracking clays with alkaline medium to heavy clay subsoils	*Soil Type 8.3:* Mostly deep to very deep (> 1.0 - 1.5 m), brown, dark grey-brown or dark grey cracking clay soils with strongly developed gilgai micro-relief, usually alkaline near the surface, becoming acidic to strongly acidic in the deeper subsoils. Soils in Group 6 often occur on the gilgai mounds in association with Soil Type 8.3 in the gilgai depressions.

For the purposes of the project and due to the vast area of land studied, the above soil groups and soil types have been correlated with regional soil mapping units as mapped in the Land Research Series - CSIRO (1967, 1968 & 1974) and the Atlas of Australian Soils (Isbell et al., 1967), which collectively cover the CSG fields study area. Due to the broad mapping scale (1:1,500,000), these soil mapping units typically comprise relatively coarse soil associations; with dominant, co - dominant, subdominant and minor soil types identified. The occurrence and distribution of the soil mapping units as mapped within the CSG fields study area is shown in Figures 6.3.18 and 6.3.19 and the Soil Mapping Unit Reference is presented in Figure 6.3.20.



Note: Legend colours may differ slightly from Map colours due to hill shading used in the Elevation Surface Grid.

Soils Mapping Units - Refer to Figure 6.3.20 for detailed description of soil types and soil associations.

Skeletal and Shallow Rocky Soils (Rudosols)

1 – Shallow to very shallow (mostly <0.3 m) rocky, stony or gravelly soils (>60% coarse fragments) with a sandy, loamy or clayey soil matrix.

Uniform Coarse-textured Sandy Soils (Rudosols)

2 – Medium to deep (0.6->1.0 m) some shallow, yellow, brown or red sandy residual, colluvial or alluvial soils.

Sandy Red and Yellow Earths, Red & Yellow Massive Earths (Tenosols & Kandosols)

3 – Shallow to medium deep (<0.6 m) gravelly loams and gravelly sandy to loamy red-yellow earths.

4 – Medium to deep (0.6->1.0 m) loamy red-yellow earths and lateritic red-yellow earths.

Texture Contrast (Duplex) Soils (Chromosols, Kurosols & Sodosols)

- Duplex soils with neutral to moderately acidic, locally strongly acidic subsoils.

5 – Shallow to medium deep (<0.6 m) sandy to loamy surface red, red-brown, brown or dark grey-brown acidic duplex.

6 – Medium to deep (0.6->1.0 m) thick sandy surface duplex soils with grey-brown, yellow-brown or red-brown coarsely mottled subsoils.

Texture Contrast (Duplex) Soils (Chromosols, Kurosols & Sodosols)

- Duplex soils with neutral to moderately alkaline, locally strongly alkaline subsoils

7 – Shallow to medium deep (<0.6 m) sandy to loamy surface duplex soils with red-brown, brown or grey-brown alkaline clay subsoils.

8 – Medium to deep (0.6->1.0 m) fine sandy to silt and clay loamy surface duplex soils with dark brown, brown, yellow-brown or red-brown alkaline clay subsoils.

Dark Brown & Grey-Brown Soils (Dermosols)

9 – Shallow to medium deep (<0.6 m) uniform or gradational gravelly clay soils

10 – Medium to deep (0.6->1.0 m) mainly uniform clays or gradational clay loam over clay soils.

Cracking Clay Soils (Vertosols)

11 – Shallow to medium deep (<0.6 m) cracking clay soils underlain by basalt and argillaceous sedimentary rock.

12 – Medium to deep (0.6->1.0 m) dark grey-brown, brown or black cracking soils.

13 – Medium to very deep (0.6->1.5 m) dark grey-brown cracking clay soils with intensive gilgai micro-relief.

Towns

Major Roads

CSG Field

N
W E
S

Kilometers

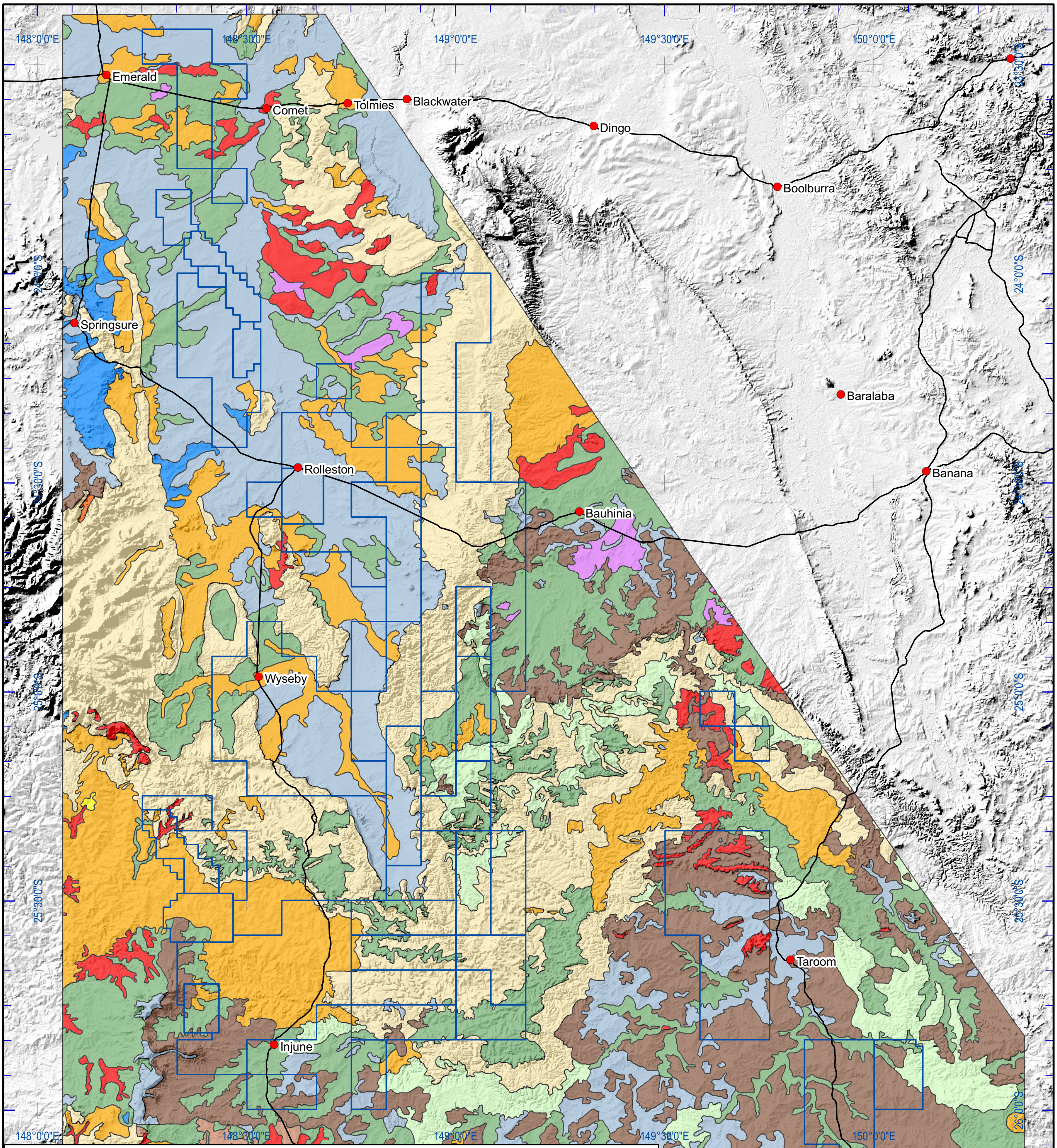
0 5 10 20 30 40 50

Scale 1:1 500 000 (A4)

Datum : GDA 94

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	**SOILS MAPPING UNITS CSG FIELDS (SOUTHERN SECTION)**	
	Drawn: LL/CA · Approved: GR · Date: 16-01-2009	Figure: **6.3.18**	Rev. A
	Job No.: **4262 6220** · File No.: 42626220-g-961.mxd		A4



Note: Legend colours may differ slightly from Map colours due to hill shading used in the Elevation Surface Grid.

Soils Mapping Units - Refer to Figure 6.3.20 for detailed description of soil types and soil associations.

Skeletal and Shallow Rocky Soils (Rudosols)

- 1 — Shallow to very shallow (mostly <0.3 m) rocky, stony or gravelly soils (>60% coarse fragments) with a sandy, loamy or clayey soil matrix.

Uniform Coarse-textured Sandy Soils (Rudosols)

- 2 — Medium to deep (0.6->1.0 m) some shallow, yellow, brown or red sandy residual, colluvial or alluvial soils.

Sandy Red and Yellow Earths, Red & Yellow Massive Earths (Tenosols & Kandosols)

- 3 — Shallow to medium deep (<0.6 m) gravelly loams and gravelly sandy to loamy red-yellow earths.
- 4 — Medium to deep (0.6->1.0 m) loamy red-yellow earths and lateritic red-yellow earths.

Texture Contrast (Duplex) Soils (Chromosols, Kurosols & Sodosols)
- Duplex soils with neutral to moderately acidic, locally strongly acidic subsoils.

- 5 — Shallow to medium deep (<0.6 m) sandy to loamy surface red, red-brown, brown or dark grey-brown acidic duplex.
- 6 — Medium to deep (0.6->1.0 m) thick sandy surface duplex soils with grey-brown, yellow-brown or red-brown coarsely mottled subsoils.

Texture Contrast (Duplex) Soils (Chromosols, Kurosols & Sodosols)
- Duplex soils with neutral to moderately alkaline, locally strongly alkaline subsoils

- 7 — Shallow to medium deep (<0.6 m) sandy to loamy surface duplex soils with red-brown, brown or grey-brown alkaline clay subsoils.
- 8 — Medium to deep (0.6->1.0 m) fine sandy to silt and clay loamy surface duplex soils with dark brown, brown, yellow-brown or red-brown alkaline clay subsoils.

Dark Brown & Grey-Brown Soils (Dermosols)

- 9 — Shallow to medium deep (<0.6 m) uniform or gradational gravelly clay soils
- 10 — Medium to deep (0.6->1.0 m) mainly uniform clays or gradational clay loam over clay soils.

Cracking Clay Soils (Vertosols)

- 11 — Shallow to medium deep (<0.6 m) cracking clay soils underlain by basalt and argillaceous sedimentary rock.
- 12 — Medium to deep (0.6->1.0 m) dark grey-brown, brown or black cracking soils.
- 13 — Medium to very deep (0.6->1.5 m) dark grey-brown cracking clay soils with intensive gilgai micro-relief.

Towns
Major Roads
CSG Field

N W E S

Kilometers
0 5 10 20 30 40 50
Scale 1:1 500 000 (A4)
Datum : GDA 94

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	**SOIL MAPPING UNITS CSG FIELDS (NORTHERN SECTION)**

Drawn: LL/CA	Approved: JB	Date: 20-03-2009	Figure: **6.3.19** / Rev. A
Job No.: **4262 6220**	File No.: 42626220-g-962.mxd		A4

Skeletal and Shallow Rocky Soils (Rudosols)

1 — Shallow to very shallow (mostly <0.3 m) rocky, stony or gravelly soils (>60% coarse fragments) with a sandy, loamy or clayey soil matrix; as mapped includes Soil Types 1-2.1, 1-4.1, 1-7.1 and some occurrences of shallow to medium deep (<0.6 m) stony or gravelly sand, sandy loam and loamy soils (Types 2.1, 3.1 & 4.1).

Uniform Coarse-textured Sandy Soils (Rudosols)

2 — Mostly medium to deep (0.6->1.0 m), some shallow yellow, brown and red sandy soils (Type 2.2 and 2.3), some shallow sands (Type 2.1) and medium to deep thick sandy duplex soils (Type 5.2 & 6.3) occur locally.

Sandy Red and Yellow Earths & Red and Yellow Massive Earths (Tenosols & Kandosols)

3 — Shallow to medium deep (<0.6 m) sandy red-yellow earths-earthy sand soils (Type 3.1), shallow gravelly loam soils and gravelly loamy red-yellow earth soils (Type 4.1); rock outcrop, broken rock and boulders may occur in parts.

4 — Medium to deep (0.6->1.0 m) loamy red-yellow earths and lateritic red-yellow earth soils (Type 4.2); some occurrences of shallow gravelly red earth soils (Type 4.1); minor occurrences of sandy to loamy surface duplex soils (Type 5.2, 5.3 & 6.2), minor deep red sandy soils (Type 2.2).

Texture Contrast (Duplex) Soils (Chromosols, Kurosols & Sodosols)

- Duplex soils with neutral to moderately acidic, locally strongly acidic subsoils

5 — Shallow to medium deep (<0.6 m) sandy to loamy surface red, red-brown, brown or dark grey-brown acidic duplex soils (Type 5.1); in parts similar but slightly acidic to alkaline duplex soils (Type 6.1) may also occur; minor deeper duplex soils (Type 5.3 & 6.2) may also occur locally.

6 — Medium to deep (0.6->1.0 m) thick sandy surface duplex soils (Type 5.2) with grey-brown, yellow-brown or red-brown coarsely mottled subsoils; similar but thinner sandy to loamy surface duplex soils (Type 5.3) also occur; some uniform sandy soils (Type 2.1, 2.3) and massive red-yellow earth soils (Type 4.1, 4.2) in parts.

- Duplex soils with neutral to moderately alkaline, locally strongly alkaline subsoils

7 — Shallow to medium deep (<0.6 m) sandy to loamy surface red, red-brown, brown or dark grey-brown alkaline duplex soils (Type 6.1); in parts, similar neutral to slightly acidic duplex soils (Type 5.1) may also occur together with some deeper duplex soils (Type 6.2); some cracking clay soils (Type 8.2) in lower-lying parts

8 — Medium to deep (0.6->1.0 m) fine sandy to silt and clay loamy surface duplex soils (Type 6.2) with dark brown, brown, yellow-brown or red-brown alkaline clay subsoils; may include some occurrences of red and yellow earth soils (4.1 & 4.2) on rises and dark brown and grey-brown soils (Type 7.3) and cracking clay soils (Type 8.2) in lower-lying parts.

Dark Brown & Grey-Brown Soils (Dermosols)

9 — Shallow to medium deep (<0.6 m) mainly uniform fine-textured gravelly clay soils (Type 7.1) often in association with shallow cracking clay soils (Type 8.1); some deeper uniform clays or gradational clay loam over clay soils (Type 7.3) and cracking clay soils (Type 8.2) on mid to lower slopes.

10 — Medium to deep (0.6->1.0 m) mainly uniform clays or gradational clay loam over clay soils (Type 7.2 & 7.3); some shallow gravelly uniform or gradational clay soils (Type 7.1) and shallow cracking clays soils (Type 8.1) on upper slopes and rises; some deeper dark grey-brown cracking clay soils (Type 8.2) in lower-lying parts.

Cracking Clay Soils (Vertosols)

11 — Shallow to medium deep (<0.6 m) cracking clay soils (Type 8.1) occurring mainly on crests and upper slopes and underlain by basalt and argillaceous sedimentary rock types, in places with shallow gravelly loams and clay loam soils (Type 4.1) and uniform gravelly clay soils (Type 7.1); some medium to deep cracking clay soils (Type 8.2) may occur on mid to lower slopes.

12 — Medium to deep (0.6->1.0 m) dark grey-brown, brown or black cracking clay soils (Type 8.2), locally in association with uniform (non-cracking) clay soils (Type 7.3) and some shallow gravelly uniform clay soils (Type 7.1) on rises; minor shallow to medium deep loamy surface duplex soils (Type 5.1, 5.3 & 6.2) may occur locally.

13 — Medium to deep or very deep (0.6->1.5 m) dark grey-brown or black cracking clay soils (Type 8.3) with intensive gilgai micro-relief, often in association with silt to clay loamy surface duplex soils (Type 6.2) on the gilgai mounds; areas of uniform (non-cracking) clay soils (Type 7.3) are also associated; some loamy red earth soils (Type 4.2) may occur locally on low rises.

Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**SOIL MAPPING UNITS** **CSG FIELDS**
	Drawn: CA · Approved: JB · Date: 20-03-2009	Figure: **6.3.20** · Rev. A
	Job No.: **4262 6220** · File No.: 42626220-g-963.mxd	A4

Soils in the Roma CSG Field

The Roma CSG field encompasses a land area of 820,664 ha. Based on the Soil Mapping Units (SMU) described in Figure 6.3.20, the occurrence and distribution of soils in the Roma field is shown in Appendix L1.

The collective extent of occurrence of the respective SMU's identified in the Roma CSG field is as follows:

- SMU 8 is widespread throughout the Roma CSG field and encompasses an area of approximately 495,339 ha (60.4 % of the field). The soils comprise mainly medium to deep, fine, sandy to silt and clay loamy surface duplex soils (Type 6.2) with dark brown, brown, yellow-brown or red-brown alkaline clay subsoils. Some occurrences of shallow to medium deep red and yellow earth soils (Type 4.1 and 4.2) occur on low rises and dark brown and grey-brown clay soils (Type 7.3) and some cracking clay soils (Type 8.2) occur in lower-lying parts of this soil mapping unit.
- SMU 6 encompasses an area of approximately 86,746 ha (10.6 % of the Roma CSG field) in the central eastern, central southern, central northern and in the north western and far north western sectors of the field. The soils comprise medium to deep thick sandy surface duplex soils (Type 5.2) together with thinner sandy to loamy surface duplex soils (Type 5.3) with neutral to moderately acidic, locally strongly acidic grey-brown, yellow-brown or red-brown often mottled sandy clay or medium to heavy clay subsoils. Some uniform sandy soils (Type 2.1 and 2.2) occur in places.
- SMU 4 encompasses an area of approximately 74,250 ha (9.0 % of the Roma CSG field), mainly on undulating rises in the south western sector, with smaller occurrences scattered throughout the Roma CSG field on low rises and where associated with tributary drainage lines. The soils include medium to deep loamy red and yellow earths, lateritic red and yellow earths and massive red and yellow earth soils (Type 4.2). Some shallow gravelly red earths (Type 4.1) and minor sandy to loamy surface red duplex soils (Type 5.2, 5.3 and 6.2) occur in places.
- SMU 12 encompasses an area of approximately 75,056 ha (9.5 % of the Roma CSG field), mainly in the central western and in the far north western sectors of the field. The soils comprise mainly medium to deep dark grey-brown, brown or brownish black cracking clay soils (Type 8.2) with alkaline to strongly alkaline medium to heavy clay subsoils. These soils often occur in association with uniform non-cracking clay soils (Type 7.3) and some shallow gravelly clay soils (Type 7.1) on rises and dissection slope interfluves.
- SMU 3 encompasses an area of approximately 45,302 ha (5.5 % of the Roma CSG field), mainly on undulating rises and low hilly lands in the south western sector of the field. The soils comprise shallow gravelly loamy soils (Type 3.1) and shallow to medium deep gravelly red earths (Type 4.1). Some medium deep duplex soils (Type 6.2) may occur in lower-lying parts.
- SMU 1 encompasses an area of approximately 23,543 ha (2.9 % of the Roma CSG field) on rises and low hilly lands mainly along the far western and north eastern margins of the field. The soils comprise skeletal to shallow rocky, stony or gravelly soils (Type 1-2.1, 1-4.1 or 1-7.1) with a sandy, loamy or clayey soil matrix respectively.
- SMU 10 encompasses an area of 9,161 ha (1.1 % of the Roma CSG field) on undulating plains with local low hills and rises in the far north western sector of the field. The soils comprise mainly medium to deep dark brown or grey-brown uniform clays or gradational clay loam over clay soils (Type 7.2), with some shallow gravelly clay soils (Type 7.1) on erosion higher hill slopes and crests of rises. Some dark grey-brown or brown cracking clay soils (Type 8.2) and non-cracking clay soils (Type 7.3) occur on depositional lower slopes.
- SMU 9 encompasses an area of approximately 6,190 ha (0.8 % of the Roma CSG field) and occurs on low hilly to hilly lands in the central northern sector of the Roma field. The soils comprise shallow to medium deep uniform gravelly clay soils (Type 7.1) often in association with shallow cracking clay soils (Type 8.1). Some deeper uniform or gradational clay soils (Type 7.3) and cracking clay soils (Type 8.2) may occur on the lower slopes and in intervening lower-lying and depressed areas.
- Minor isolated occurrences of SMU 2 encompassing a combined area of 1,166 ha (<0.1 % of the Roma CSG field) occur adjacent to tributary drainage lines in the central southern and south eastern sectors of the Roma field. These soils comprise medium to deep sandy alluvial soils (Type 2.2).

Small areas of SMU 7 encompassing 900 ha (<0.1 %) of the Roma field occur as low hilly lands in the far northern sector of the area. The soils comprise mainly shallow sandy to loamy surface grey - brown, brown or red - brown alkaline duplex soils (Type 6.1). One very small occurrence of SMU 11 encompassing 32 ha (<0.1 %) of the Roma field is located on the central western boundary of the area near Spring Hill and comprises shallow to medium deep cracking clay soils (Type 8.1).

Soils in the Fairview Field

The Fairview CSG field encompasses a land area of 116,097 ha. The occurrence and distribution of soils in the Fairview field is shown in Appendix L1.

The collective extent of occurrence of the respective SMU's identified in the Fairview CSG field is as follows:

- SMU 1 encompasses approximately 72,686 ha (62.6 % of the Fairview CSG field) and encompasses locally near level to undulating tablelands and moderately to intensively dissected plateau remnants with steep to very steep bounding slopes and scarps in the central, north eastern and south western sectors of the field. The dominant soils comprise skeletal to shallow rocky soils and shallow stony and gravelly sand soils (Type 1-2.1) on the plateau margins and predominantly sandstone rock outcrop on the steep bounding slopes and scarps. Shallow, fine, sandy or sandy loamy surface duplex soils (Type 6.1 and 5.1) occur on the shallow soil covered crestal areas in slightly higher areas away from the eroded plateau margins.
- SMU 8 encompasses approximately 35,864 ha (30.9 % of the Fairview CSG field) mainly on hilly lands in the south eastern and on undulating fluvial plains in the central northern and north western sectors of the field. The dominant soils in these areas comprise medium to deep sandy surface duplex soils (Type 6.2) with brown, yellow-brown or red-brown alkaline, sodic, medium to heavy clay subsoils. Some shallow and medium deep sandy surface duplex soils (Type 5.1 and 5.2) with brown or red-brown, neutral to acidic, clay subsoils occur on erosional slopes in lower - lying parts. Rock outcrops, boulders and shallow rocky sandy soils (Type 1 - 2.1) also occur on the steeper hill slopes.
- SMU 6 encompasses approximately 2,773 ha (2.4 % of the Fairview CSG field) and comprises an area of undulating plain along the western boundary in the north western sector of the field. The soils comprise medium to deep, mainly thick, sandy surface duplex soils (Type 5.2) with grey-brown, yellow-brown or red-brown, often coarsely mottled, acidic sandy clay to medium clay subsoils. Similar soils with thinner sandy to loamy surface duplex soils (Type 5.3) may also occur.
- SMU10 encompasses approximately 2,400 ha (2.1 % of the Fairview CSG field) and occurs as undulating to locally near flat to depressed fluvial plains in the central southern sector of the field. The soils comprise medium to deep, dark brown and grey brown soils (Type 7.2) with uniform clay or gradational clay loam over clay soil profiles. These soils often occur in association with areas of cracking clay soils (Type 8.2).
- Minor occurrences of SMU 12 comprising approximately 1,743 ha (1.5 % of the Fairview CSG field) occur in the same general vicinity as SMU 10, near the central southern boundary of the field. The soils in these areas comprise medium to deep, dark grey brown or black cracking clay soils (Type 8.2). Some medium to deep, dark grey-brown (non-cracking) clay soils (Type 7.2 or 7.3) may also occur in parts.
- A very small area of SMU 7 comprising approximately 596 ha (0.5 % of the Fairview CSG field) occurs in the south western corner of the area on erosional lower slopes of a dissected plateau remnant. The soils comprise shallow to medium deep, sandy to loamy surface duplex soils (Type 6.1) with red, red-brown or brown neutral to moderately alkaline gravelly clay subsoils. In parts, shallow gravelly neutral to acidic duplex soils (Type 5.1) may also occur.

Soils in the Arcadia Valley Field

The Arcadia Valley CSG field encompasses a land area of 194,016 ha. The occurrence and distribution of soils in the Arcadia Valley CSG field is shown in Appendix L1.

The collective extent of occurrence and order of dominance of the respective SMU's identified in the Arcadia Valley field are as follows:

- SMU 1 encompasses an area of approximately 93,817 ha (48.3 % of the Arcadia Valley CSG field) and includes moderately to intensively dissected plateau remnants and steep bounding scarps and steep dissected hilly lands with steep to very steep bounding slopes which occur in the central western, north western and south eastern sectors of the field. The dominant soils comprise skeletal to shallow rocky soils and shallow stony and gravelly sand soils (Type 1-2.1) on the upper slopes, with predominantly sandstone rock outcrop on the steep bounding slopes and scarps. Shallow fine sandy or sandy loamy surface duplex soils (Type 6.1 and 5.1) occur on the extensive mid to lower slopes.
- SMU 8 encompasses approximately 39,366 ha (20.3 % of the Arcadia Valley CSG field) comprising mainly undulating plains and tributary fluvial plains and terraces with areas of low hilly lands and rises along the margins of the unit. As mapped these soils occur in the south eastern, central and northern sectors of the field. The dominant soils comprise medium to deep thin sandy to loamy surface duplex soils (Type 6.2) with dark brown, red-brown or yellow-brown neutral to alkaline clay subsoils mostly occurring on the plains and fluvial lowlands. Sandy surface duplex soils (Type 5.2 and 5.3) with grey-brown, red-brown or yellow-brown acidic clay subsoils occur in the higher parts and low hilly areas.
- SMU 7 encompasses approximately 28,693 ha (14.8 % of the Arcadia Valley CSG field) in the central and northern sectors of the field and comprises hilly lands with extensive mid to lower foot slopes. The dominant soils comprise shallow to medium deep sandy to loamy surface duplex soils (Type 6.1) with dark brown, yellow-brown or red-brown neutral to alkaline sandy clay to medium clay subsoils. Some similar sandy surface duplex soils (Type 5.1) with acidic to neutral medium clay subsoils may also occur. Rock outcrop and boulders are common on the steeper hill slopes.
- SMU 12 encompasses approximately 20,739ha (10.7 % of the Arcadia Valley CSG field) in the central western sector of the field and comprises undulating valley plains and lowlands. The dominant soils comprise medium to deep grey-brown, brown or black cracking clay soils (Type 8.2). These soils often occur in association with uniform dark brown and grey-brown (non-cracking) clay soils (Type 7.3). Shallow to medium deep sandy to loamy surface duplex soils (Type 6.2) occur on gravelly surface colluvial fans developed along the outer margins of the SMU.
- SMU 6 encompasses approximately 10,128 ha (5.2 % of the Arcadia Valley CSG field) where formed on tributary drainage flats along the central western boundary of the field and in hilly upland areas in the central northern sector of the field. The dominant soils comprise deep thick sandy surface duplex soils (Type 5.2) with grey-brown, yellow-brown or red-brown often coarsely mottled neutral to acidic sandy clay subsoils. Similar thin sandy or sandy to loamy surface duplex soils (Type 5.3) also occur on the stream levees and alluvial plain. Shallow to medium deep sandy surface duplex soils (Type 5.2) together with shallow to medium deep dark brown and grey-grey brown uniform medium to fine-textured soils (Type 7.1) with gradational gravelly clay loam surface soils over neutral to strongly acidic clay subsoils.
- Minor occurrences of SMU 10 which encompass 1,268 ha (0.7 % of the Arcadia Valley CSG field) occur in the central and north eastern sectors of the field and comprise low hilly and hilly lands with broadly rounded upland areas. Dominant soils are medium deep dark brown and grey - brown soils (Type 7.3 and 7.1) uniform gravelly clays or gradational clay loam over neutral to strongly acidic light to medium clay subsoils. Some shallow gravelly cracking clay soils (Type 8.1) may occur on upper parts of steeper slopes and some medium deep cracking clay soils (Type 8.2) may occur on colluvial lower slopes.

Soil Erosion

The development of the production well leases and associated infrastructure areas will involve clearing and earthworks within a defined footprint. This will include areas where temporary and/or permanent access tracks are proposed. Potential environmental impacts that may result from the establishment of production well leases primarily relate to the erosion potential of the land in areas that are subject to clearing or disturbance during the site development and construction process.

Existing and Potential Soil Erosion

From examination of satellite imagery covering the general vicinity of the CSG fields study area, substantial areas are currently subject to accelerated soil erosion, in particular extensive surface sheet and rill erosion. Areas of gully erosion also occur on the approaches or adjacent to the more major stream lines. This is considered to be due to the fragile nature of the soils (particularly sodic/dispersive soils), past land clearing and possibly periods of over - grazing in these areas The areas mostly affected include a range of landform types associated with the Jurassic and Triassic sandstone geological regimes, the Silurian volcanics and Permian sedimentary and intrusive rock types and in parts in the Tertiary sediments geological regimes.

All landforms tend to have sand or sandy medium-textured surface soils which in many parts have been subject to extensive grazing and related land-use activities. Further clearing of vegetation and stripping of topsoil resources will expose the land to varying levels of erosion due to the combined effects of surface slope and form, soil conditions as well as surface run-on/runoff potential and the effects of wind erosion over time. Accordingly, a qualitative assessment of erosion potential has been made on each of the landscape units identified, with erosion potential rated simply as low (L), medium (M) or high (H).

The potential beneficial use of desalinated water or amended / treated associated water through irrigation for agricultural crop, forage crop or tree crop including forest plantations on Santos owned land or other landholdings in the CSG study area would be based on:

- development of lands of low erosion potential;
- site specific management plans which minimise erosion risk;
- development sites which have adequate land capability for landholder preferred profitable and sustainable irrigation activities involving agriculture, forestry or agroforestry;
- soils on selected development sites having chemical and physical characteristics which are compatible for sustainable production with the volumes and chemistries of irrigants intended for application over the irrigation project period.

A summary of the findings of the assessment for each of the CSG fields is provided in the following tables.

Table 6.3.4 Roma Field Erosion Potential

Erosion Potential	Potential Environmental Impact	% of Roma Field	Area (ha)	Applicable Landscape Units
Low-Moderate	Low	48.1	395,078	Qa1, Km1, Ka1, Ts1, Tv2 and Jm1
Moderate	Moderate	41.5	340,418	Ja1, Jm2, Ka2, Km2, Km3, Qa2, Ts2, Tv3 and Tv4
Moderate to High	Moderate to High	10.4	85,094	Ja2, Ja3, Ja4, Jm3, Ka3, Km4, Ts3 and Tv5
Total	**-**	**100**	**820,590**	**-**

Table 6.3.5 Fairview Field Erosion Potential

Erosion potential	Potential Environmental Impact	% of Fairview Field	Area (ha)	Applicable Landscape Units
Low-Moderate	Low	Nil	Nil	Nil
Moderate	Moderate	32.6	37, 795	Ja1, Ja5, Jm2, Qa2, Rm5 and Rm6.
Moderate to High	Moderate to High	67.4	78,267	Ja2, Ja3, Ja4, Jm3, and Rm2
Total	**-**	**100**	**116,062**	**-**

Table 6.3.6 Arcadia Valley Erosion Potential

Erosion potential	Potential environmental Impact	% of Arcadia Valley Field	Area (ha)	Applicable Landscape Units
Low-Moderate	Low	8.6	16,751	Qa1 and Rm1
Moderate	Moderate	33.9	65,676	Ja1, Ja5, Ja6, Rm4, Rm5 and Rm6
Moderate to High	Moderate to High	57.5	111,584	Ja2, Ja3, Ja4, Rm2, and Rm3
Total	**-**	**100**	**194,011**	**-**

Problem Soil Areas

Soils have been assessed as having low (L), low to moderate (L - M), moderate (M), moderate to high (M - H) or high (H) levels of limitations with respect to the occurrence of problem soil areas and by association low to high levels of potential environmental impact. The soil attributes assessed have included the likely occurrence of reactive soils (R1-3), sodic soils (So), dispersive soils (D) and soil salinity (Sa). The soil types identified may have one or a combination of problem soil attributes and in general these properties may occur throughout the profile, but more commonly occur in the deeper subsoil (B) horizons and/or in the soil substrate.

Landscape units, associated soil types and problem soil occurrences in the CSG fields study area are included in Table 6.3.7.

Table 6.3.7 Landscape Units, Soil Types and Problem Soil Occurrences

Landscape Unit	Characteristic Topography	Soil Types	Problem Soil Attributes
Qa 1	Flat to gently undulating alluvial plains, near level floodplains, backplains, stream terraces, levees, channel banks and floors; mainly slope Class 1 (<2 %)	Extensive areas of cracking clay soils (Type 8.2) and fine sandy to silt loamy duplex soils (Type 6.2) occur mainly to the west of Roma and in the Arcadia valley. Some red and yellow massive earth soils (Type 4.2) occur on alluvial plains to the south of Roma. Minor sandy surface duplex soils (Type 5.2) in parts.	M (R3, So/Sa)
Qa 2	Undulating and gently inclined older alluvial plains, outwash fans and higher parts of floodplains, alluvial terraces & levees; mainly slope Class 2 (2 - 5 %)	Cracking clay soils (Type 8.2), duplex soils (Type 6.2), red-yellow massive earths (Type 4.2) and minor sandy duplex soils (Type 5.2) as for Qa1.	M (R3, So)

Landscape Unit	Characteristic Topography	Soil Types	Problem Soil Attributes
Ts 1	Often elevated near - level to broadly rounded low interfluves and gently undulating plains; mainly slope Class 1 (<2 %)	Mostly loamy surface massive red and yellow earths and lateritic red-yellow earth soils (Type 4.2) in the central southern sector; extensive areas of sandy to loamy surface duplex soils (Type 6.2) in the south eastern sector.	L - M (So/D) in the duplex soil areas
Ts 2	Gentle to moderate slopes, broadly rounded interfluves and undulating surfaces; mainly slope Class 2 (2 - 5 %)	Mainly sandy loam to loamy surface duplex soils (Type 6.2), some massive red-yellow earth soils (Type 4.2) on crestal areas with sandy surface duplex soils (Type 5.2) on steeper slopes and slopes to drainage.	M (So/D)
Ts 3	Moderately inclined surfaces and slopes of rises and low hills; mainly slope Class 3 (5 - 12 %)	Shallow cracking clay soils (Type 8.1); some shallow dark brown and grey-brown soils (Type 7.1).	M (So/D) duplex soils lower slopes
Ts 4	Moderately steep hill slopes, jump - ups and low scarps; mainly slope Class 4 (12 - 25 %)	Shallow dark grey-brown clay or gravelly clay soils (Type 7.1) underlain by weathered volcanics.	L - M (So/D) duplex soils lower slopes
Tv 2	Gentle dissection slope inter - fluves and undulating surfaces; mainly slope Class 2 (2 - 5 %)	Shallow to medium deep cracking clay soils (Type 8.2) usually with rock cobbles and underlain by weathered volcanics.	L - M (R2)
Tv 3	Inclined surfaces and slopes of rises and low hills; mainly slope Class 3 (5 - 12 %)	Shallow cracking clay soils (Type 8.1); some shallow dark brown and grey-brown soils (Type 7.1).	L - M (R2)
Tv 4	Moderately steep hill slopes; mainly slope Class 4 (12 - 25 %)	Shallow dark grey-brown clay or gravelly clay soils (Type 7.1) underlain by weathered volcanics.	L - M (R1)
Tv 5	Steep slopes of hills and ridges; mainly slope Class 5 (25 - 50 %)	Skeletal to shallow rocky soils (Type 1-7.1) with some shallow dark grey-brown clay or gravelly clay soils (Type 7.1) on lower slopes; some rock outcrop.	L
Tv 6	Very steep to precipitous escarpment slopes and hill slopes; mainly slope Class 6 (>50 %)	Rock outcrop and skeletal to shallow rocky soils (Type 1-7.1) with some shallow dark grey-brown clay or gravelly clay soils (Type 7.1) on lower slopes.	L
Ka 1	Near - level to gently undulating plains, very gently rising broad low interfluves and intervening drainage floors; mainly slope Class 1 (<2 %)	Mostly medium to deep sandy to loamy surface duplex soils (Type 6.2).	L - M (So/D)
Ka 2	Plateau remnants, plain areas, broad low rises and strongly undulating areas with intervening narrow drainage floors; mainly slope Class 2 (2 - 5 %)	Mostly medium to deep sandy to loamy surface duplex soils (Type 6.2), some red - yellow massive earth soils (Type 4.2) along tributary drainage lines, some sandy duplex soils (Type 5.2 and 5.3) on dissection slope interfluves.	M (So/D)
Ka 3	Moderately inclined dissection slope interfluves and slopes of rises and low hills; mainly slope Class 3 (5 - 12 %)	Medium deep locally shallower sandy to loamy surface duplex soils (Type 6.2); some sandy duplex soils (Type 5.2 or 5.3) on dissection slope interfluves.	M - H (So/D)
Ka 4	Moderately steep slopes of hills and ridges; mainly slope Class 4 (12 - 25 %)	Shallow to medium deep dark brown and grey-brown gravelly clay soils (Type 7.1 and 7.2).	L

Landscape Unit	Characteristic Topography	Soil Types	Problem Soil Attributes
Km 1	Near - level plains, very gently rising broad low interfluves and local drainage floors; mainly slope Class 1 (<2 %)	Co-dominant cracking clay soils (Type 8.2) and fine sandy to silt and clay loamy surface duplex soils (Type 6.2); some areas of red-yellow massive earth soils (Type 4.2) on low rises and slopes to drainage.	M (R3, So/D/Sa)
Km 2	Plateau remnants, plain areas, broad low rises and strongly undulating areas and local narrow drainage floors; mainly slope Class 2 (2 - 5 %)	Mainly loamy surface duplex soils (Type 6.2) with some extensive areas of cracking clay soils (Type 8.2); some areas of red-yellow massive earths, locally lateritic gravelly soils (Type 4.2) on some low rises and on slopes to drainage, lateritic in parts.	M (R3, So/D)
Km 3	Inclined surfaces and slopes of rises and low hills; mainly slope Class 3 (5 - 12 %)	Medium deep locally shallower sandy to loamy surface duplex soils (Type 6.2); some sandy duplex soils (Type 5.2 or 5.3) on dissection slope interfluves.	M (So/D)
Km 4	Moderately steep slopes of hills and ridges; mainly slope Class 4 (12 - 25 %)	Shallow to medium deep dark brown and grey - brown gravelly clay soils (Type 7.1 and 7.2).	L - M (So/D)
Km 5	Steep to very steep hill and ridge slopes and escarpment slopes; mainly slope Class 5 (25 - 50 %)	Shallow to medium deep lateritic gravelly loams (Type 3.1) and skeletal to shallow rocky soils (Type 1-3.1) on upper slopes and crestal areas.	L
Ja 1	Near-level to gently sloping plateau remnants, high - level plains with intervening narrow incised drainage floors; mainly slope Class 1 (<2 %)	Mixed occurrences of fine sandy surface duplex soils (Type 6.2), thick sandy surface duplex soils (Type 5.2 and 5.3) and medium deep dark brown and grey-brown uniform clays or gradational clay loam over clay soils (Type 7.2) at lower elevations.	L - M (So/D)
Ja 2	Plateau remnants, plain areas, broad low rises and strongly undulating areas and incised narrow drainage floors; mainly slope Class 2 (2 - 5 %)	Sandy surface duplex soils (Type 5.2 and 5.3) also fine sandy duplex soils (Type 6.1, 6.2 and 6.3); locally extensive areas of dark grey and grey brown clay soils (Type 7.2) together with some minor areas of cracking clay soils (Type 8.2) at lower elevations.	M (So/D)
Ja 3	Moderately steep slopes of hills, ridges, spurs and escarpment foot slopes; mainly slope Class 3 (5 - 12 %)	Sandy surface duplex soils (Type 5.2 and 5.3) and some areas of fine sandy surface duplex soils (Type 6.1, 6.2 and 6.3); some areas of dark grey and grey-brown clay soils (Type 7.2) occur and locally extensive areas of skeletal to shallow rocky soils and shallow sandy soils (Type 1-2.1) occur in the Fairview area and in the south-eastern sector of the Arcadia Valley.	M (So/D)
Ja 4	Moderately steep slopes of hills, ridges and escarpments; mainly slope Class 4 (12 - 25 %)	Skeletal to shallow rocky soils and shallow gravelly sandy soils (Type 1-2.1) in association with areas of sandstone rock outcrop; minor occurrences of shallow to medium deep sandy surface duplex soils (Type 5.1 and 5.2) may also occur on some broader plateau crestal areas.	L
Ja 5	Steep to very steep hill and escarpment slopes and deeply incised gorges; mainly slope Class 5 (25 - 50 %)	Skeletal to shallow rocky soils and shallow gravelly sandy soils (Type 1 - 2.1) in association with areas of sandstone rock outcrop.	L
Ja 6	Very steep to precipitous escarpment and ravine slopes; mostly 25 to 50 %,locally >50 %	Skeletal to shallow rocky soils and shallow gravelly sandy soils (Type 1 - 2.1) in association with areas of sandstone rock outcrop.	L

Landscape Unit	Characteristic Topography	Soil Types	Problem Soil Attributes
Jm 1	High-level near flat plains, plateau surface remnants and drainage floors; mainly slope Class 1 (<2 %)	Mixed occurrences of medium to deep dark brown and grey-brown clay soils (Type 7.2) and cracking clay soils (Type 8.2); some areas of fine sandy to loamy surface duplex soils (Type 6.2) also occur.	M - H (R3, So/D/Sa)
Jm 2	Plateau remnants, plain areas, broad low rises and strongly undulating areas and local narrow drainage floors; mainly slope Class 2 (2 - 5 %)	Mixed occurrences of medium to deep dark brown and grey - brown clay soils (Type 7.2) and cracking clay soils (Type 8.2), together with areas of fine sandy to loamy surface duplex soils (Type 6.2).	M (R3, So/D)
Jm 3	Moderately steep slopes of hills, ridges and escarpments; mainly slope Class 3 (5 - 12 %)	Medium deep loamy surface duplex soils (Type 6.2), with some areas of shallow duplex soils (Type 6.1) and shallow dark brown and grey-brown often gravelly clay soils (Type 7.1).	M - H (So/D)
Jm 4	Moderate to steep slopes of hills, ridges and escarpments; mainly slope Class 4 (12 - 25 %)	Shallow gravelly fine sandy to loamy surface duplex soils (Type 6.1) and shallow dark brown and grey-brown often gravelly clay soils(Type 7.1); minor sandy surface duplex soils (Type 5.1 and 5.2) on some higher plateau crestal areas.	M (So/D)
Jm 5	Steep to very steep escarpment and ravine slopes; mainly slope Class 5 (25 - 50 %)	Skeletal to shallow rocky soils and shallow gravelly clay loam to clay soils (Type 1 - 7.1) in association with areas of siltstone or mudstone rock outcrop	L
Rm 1	Near-level plains, very gently rising broad low interfluves and local drainage floors; mainly slope Class 1 (<2 %)	Medium to deep cracking clay soils (Type 8.2); some areas of dark brown and grey-brown (non-cracking clay soils (Type 7.2 and 7.3); minor occurrences of shallow loamy surface duplex soils (Type 6.1).	M (R3, So/D/Sa)
Rm 2	Plateau remnants, plain areas, broad low rises and strongly undulating areas and local narrow drainage floors; mainly slope Class 2 (2 - 5 %)	Extensive occurrences of medium to deep loamy surface duplex soils (Type 6.2) together with shallow to medium deep loamy surface duplex soils (Type 6.1), areas of sandy surface duplex soils (Type 5.2 and 5.3) and dark brown and grey-brown clay soils (Type 7.2).	M (So/D)
Rm 3	Moderate slopes of hills, ridges and escarpments; mainly slope Class 3 (5 - 12 %)	Mixed occurrences of sandy and loamy surface duplex soils (Type 6.1, 6.2, 5.2 and 5.3) and dark brown and grey-brown clay soils (Type 7.1 and 7.2) as for landscape unit Rm2.	M - H (So/D)
Rm 4	Moderately steep slopes of hills, ridges and escarpments; characteristic slope Class 4 (12 - 25 %)	Skeletal to shallow rocky soils and shallow gravelly clay loam to clay soils (Type 1 - 7.1) with areas of siltstone or mudstone rock outcrop; some shallow gravelly loamy surface duplex soils (Type 6.1) and minor occurrences of loamy duplex soils (Type 6.2).	L - M (So/D)
Rm 5	Very steep escarpment and ravine slopes; mainly slope Class 5 (25 - 50 %)	Mixed occurrences of skeletal to shallow rocky soils and shallow gravelly clay loam to clay soils (Type 1-7.1) with areas of siltstone or mudstone rock outcrop; shallow to medium deep gravelly loamy surface duplex soils (Type 6.1) together with some loamy duplex soils (Type 6.2) and dark brown and grey-brown clay soils (Type 7.2) also occur.	L - M (So/D)
Rm 6	Very steep to precipitous escarpment and ravine slopes; commonly 25 to 50 % with some parts >50 %	Mainly skeletal to shallow rocky soils and shallow gravelly clay loam to clay soils (Type 1-7.1) in association with areas of sandstone, siltstone or mudstone rock outcrop.	L

A summary of the findings of the problem soil assessments within each of the Roma, Fairview and Arcadia Valley fields is provided in the following tables.

Table 6.3.8 Roma Field Problem Soils Area

Problem Soil Area Content	Potential Environmental Impact	% of Roma Field	Area (ha)	Applicable Landscape Units
Low	Low	0.1	1,160	Tv5, Ja4
Low-Moderate	Moderate	13.3	108,895	Ja1, Ka1, Km4, Ts1, Tv2, Tv3, Tv4
Moderate	Moderate	84.2	691,054	Ja2, Ja3, Jm2, Ka2, Km1, Km2, Km3, Qa1,Qa2, Ts2 and Ts3
Moderate to High and High	High	2.4	19,481	Jm1, Jm3 and Ka3
Total	-	100	820,590	-

Table 6.3.9 Fairview Field Problem Soil Areas

Problem Soil Area Content	Potential Environmental Impact	% of Fairview Field	Area (ha)	Applicable Landscape Units
Low	Low	30.9	35,844	Ja4, Ja5, Rm6
Low-Moderate	Moderate	1.7	1,956	Ja1, Rm5
Moderate	Moderate	66.8	77,521	Ja2, Ja3, Jm2, Qa2
Moderate to High and High	High	0.6	741	Jm3, Rm2
Total	**-**	**100**	**116,062**	**-**

Table 6.3.10 Arcadia Valley Problem Soil Areas

Problem Soil Area Content	Potential Environmental Impact	% of Arcadia Valley Field	Area (ha)	Applicable Landscape Units
Low	Low	24.4	47,362	Ja4, Ja5, Ja6, Rm6
Low-Moderate	Moderate	6.5	12,535	Ja1, Rm4 and Rm5
Moderate	Moderate	45.6	88,397	Ja2, Ja3,Qa1, Qa2, Rm1, Rm2
Moderate to High and High	High	23.5	45,717	Rm3
Total	**-**	**100**	**194,011**	**-**

Area Excavation Conditions

An assessment has been made on a landscape unit basis of the likely ease or difficulty of excavation and the associated impacts that occur nominally within the upper 1.5 m of the soil profile. The assessment of the excavation rating was based on the criteria outlined as follows:

- **Rating 1**: - Essentially soil - like properties throughout; some low - strength, extremely weathered (EW) to highly weathered (HW) soft rock may occur in the lower levels;
- **Rating 2**: - More difficult excavation conditions, typically comprising shallow to medium deep soils, gravelly soils etc. underlain by HW - MW (moderately weathered) rock, or gravelly colluvium. Rocky soils including rock cobbles and small to medium - size rock boulders may occur;

- **Rating 3**: - Increasing level of excavation difficulty, typically comprising shallow to medium deep soils or rocky soils underlain by MW to fresh (F) medium strength rock or closely fractured stronger rock; and
- **Rating 4**: - Skeletal to shallow rocky soils with areas of rock outcrop and/or large boulders with a high level of excavation difficulty likely to be encountered, including widely jointed, MW - F, high strength rock. High strength rock - breaking capability or rock drilling and blasting may be necessary for rock removal.

Based on the excavation ratings outlined above and with reference to the descriptions and assessment of landscape units, an indicative assessment of excavation conditions likely to be encountered within the surficial 1.5 m below natural ground level within the Roma, Fairview and Arcadia Valley CSG fields is summarised in the following tables:

Table 6.3.11 Roma Field Results of Assessment

Excavation Rating	Excavation Conditions	Level of Engineering Constraint / Environmental Impact	% of Roma Field	Area (ha)	Applicable Landscape Units
Rating 1; Rating 1 - 2	Relatively Easy	Low	91.2	748,414	Qa1, Qa2, Ts1, Ts2, Tv2, Ka1, Km1, Km2, Km3, Ja1, Ja2, Jm1, Jm2
Rating 2; Rating 2 - 3	More Difficult	Moderate	7.4	61 ,076	Ja3, Jm3, Ka2, Km4, Ts3, Tv3 and Tv4
Rating 3 Rating 3 - 4	Difficult	Moderately High to High	1.4	11,100	Ja4, Ka3, Tv5
Total	-	-	**100**	**820,590**	**-**

Table 6.3.12 Fairview Field Results of Assessment

Excavation Rating	Excavation Conditions	Level of Engineering Constraint / Environmental Impact	% of Fairview Field	Area (ha)	Applicable Landscape Units
Rating 1; Rating 1 - 2	Relatively Easy	Low	35.8	41,528	Qa2, Ja1, Ja2, and Jm2
Rating 2; Rating 2 - 3	More Difficult	Moderate	32.1	37,269	Ja3, Jm3 and Rm2.
Rating 3 Rating 3 - 4 Rating 4	Difficult	Moderately High to High	32.1	37,265	Ja4, Ja5, Rm5 and Rm6.
Total			**100**	**116,062**	**-**

Table 6.3.13 Arcadia Valley Field Results of Assessment

Excavation Rating	Excavation Conditions	Level of Engineering Constraint / Environmental Impact	% of Arcadia Valley Field	Area (ha)	Applicable Landscape Units
Rating 1; Rating 1 - 2	Relatively Easy	Low	51.8	100,507	Qa1, Qa2, Ja1, Ja2, Rm1, Rm2 and Rm3
Rating 2; Rating 2 - 3	More Difficult	Moderate	17.4	33,732	Ja3
Rating 3 Rating 3 - 4 Rating 4	Difficult	Moderately High to High	30.8	59,772	Ja4, Ja5, Ja6, Rm4, Rm5 and Rm6
Total	**-**	**-**	**100**	**194,011**	**-**

Topsoil Resources

The suitability of materials for use as topsoil resources for rehabilitation of lands that may be disturbed during the development, construction and operating stages of the CSG fields development has been assessed from the soil characterisation, indicative testing and the results of the analytical data obtained during the gas transmission pipeline and LNG facility field investigations. Additional soils data was also obtained from reference to, and interpretation of, the Land Systems and Soils mapping by CSIRO (1967, 1968 & 1974) and NRW (1995), which collectively covers the general CSG fields study area. Reference was also made to the soils data obtained as part of the field investigation of common sections of the pipeline route proposed for the Denison Trough Gas Project – Gladstone Option, undertaken as part of the EIS prepared by CSR Oil and Gas Division (1984).

Indicative stripping depths of potential topsoil resources have been determined for each of the major soil groups and soil types identified within the CSG fields study area. These are summarised in Table 6.3.14.

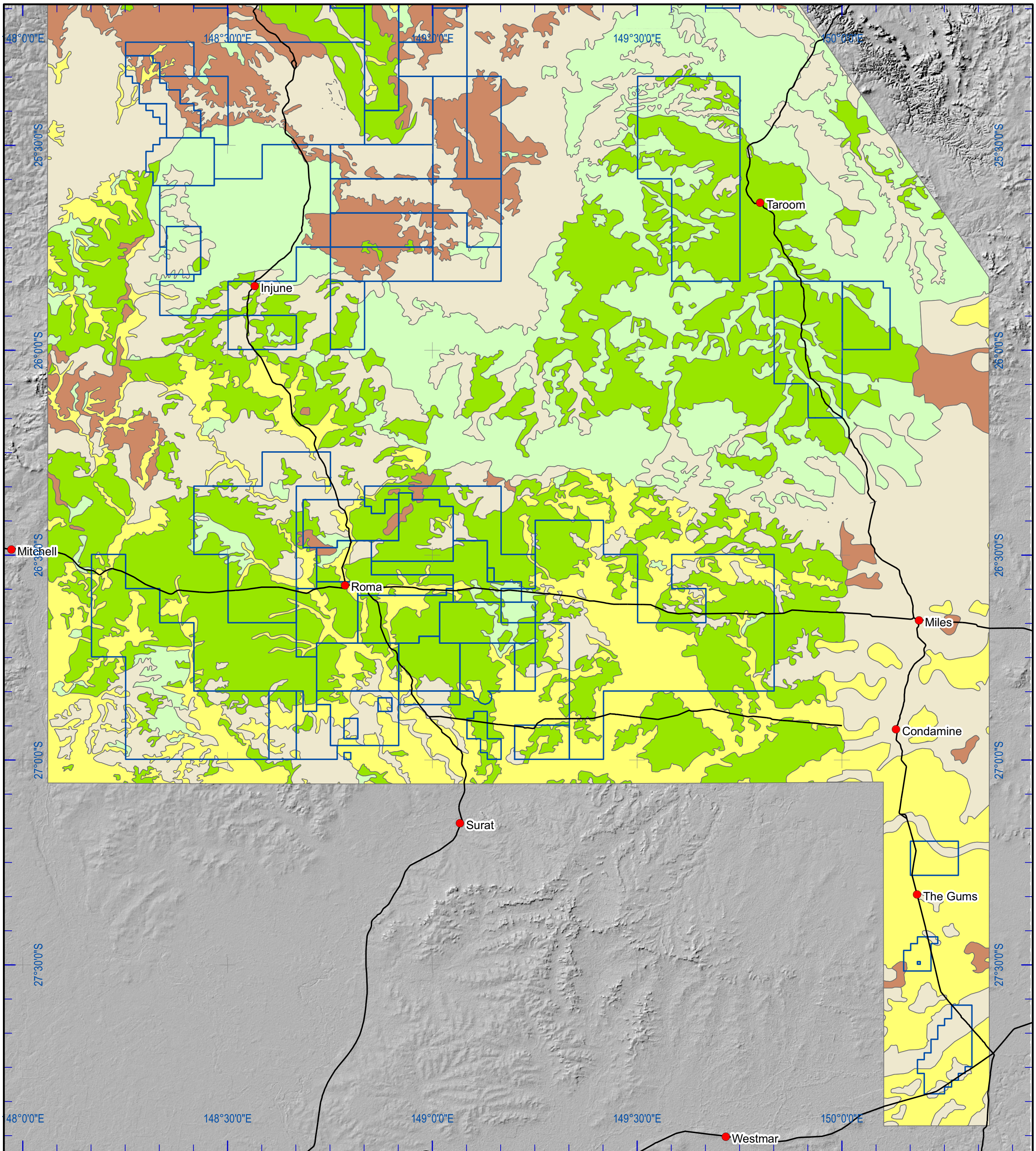
Table 6.3.14 Indicative Topsoil Resources and Stripping Depths

Soil Group	Summary Soil Description	Soil Type	Indicative Stripping Depth (m)	Remarks
1	Skeletal, rocky or gravelly soils (>60 % coarse fragments) with sandy, silty, loamy or clayey soil matrix.	1	0	Skeletal to shallow rocky soils (>60 % coarse fragments); rock outcrop and surface boulders.
2	Sand soils; shallow to deep uniform or weakly gradational profiles; includes stratified alluvial soils, residual sand soils, earthy sands.	2.1	0.1	Utilise seed stock and organics.
		2.2	0	Potential source of bedding sand.
		2.3	0.25	Humic surface soil, strongly acidic subsoils.
3	Coarse to medium - textured soils; uniform or gradational profiles; predominantly sandy earths with sand, silty or clayey sand over clayey sand - sandy clay soil profiles; in parts with siliceous (Si) stone and/or ferruginous (Fe) gravel lenses included.	3.1	0.2	Strongly acidic subsoils (>0.2 m).
		3.2	0.3	Texturally suitable (0.3 - 0.6) but low levels of soil nutrients.
		3.3	0.3	Dense (Fe) gravel may occur in the subsoil (A2) horizon (>0.3 m).
4	Medium - textured sandy, sandy loam or silt to clay loamy surface uniform or gradational	4.1	0.2	Excess gravel/stone below 0.2 m.

Soil Group	Summary Soil Description	Soil Type	Indicative Stripping Depth (m)	Remarks
	profiles with clay loam, light clay or medium clay subsoils, in places with siliceous stone and/or ferruginous gravelly lenses included.	4.2	0.3	Texturally suitable (0.3 - 0.6) but high gravel content may occur.
		4.3	0.3	Texturally suitable (0.3 - 0.6), but low soil nutrients.
5	Sand, loamy sand, sandy loam or loamy surface duplex soils over acidic to locally strongly acidic, in places neutral or slightly alkaline sandy clay to medium to heavy clay subsoils.	5.1	0.2	Strongly acidic in deeper subsoils.
		5.2	0.3	Bleached (A2) horizon (>0.3 m), source of bedding sand (0 - 0.6 m).
		5.3	0.2	Bleached (A2) horizon (>0.2 m).
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.	6.1	0.15	Shallow soils, bleached (A2) horizon, strongly alkaline subsoils.
		6.2	0.15	Thin pale or bleached layer over hard clay subsoils.
		6.3	0.25	Thick sandy A horizon, bleached A2 horizon (>0.25 m).
7	Shallow uniform often gravelly fine - textured soils, medium to deep uniform fine - textured (non - cracking) clay soils or gradational often stony or gravelly clay loam or light clay surface soils over alkaline medium to heavy clay subsoils, locally sodic and saline in the deeper subsoils - some deep incipient cracking clays.	7.1	0.2	Excess gravel/stone below 0.2 m.
		7.2	0.3	Texturally suitable (0.3 - 0.6 m), highly alkaline/calcareous below.
		7.3	0.2	Locally strongly acidic sodic and moderately highly saline in the subsoil below about 0.2 m.
8	Shallow to medium to deep 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 in areas with gilgai micro - relief.	8.1	0.2 – 0.25	Medium to coarse blocky structure (>0.15 - 0.2 m); some rock cobbles and gravel included.
		8.2	0.2 (rises)	Medium to coarse hard blocky structure below 0.2 - 0.3 m.
		8.3	0.3 m (in depressions)	Medium to coarse hard blocky structure and mod. saline below 0.2 m on gilgai mounds.

Agricultural Land

Agricultural land classes for the CGS field as a whole are shown in Figures 6.3.21 and 6.3.22. The land classes identified are based primarily on the regional compilation and mapping (at 1:250,000) of Good Quality Agricultural Lands (GQAL) in the Central West Region of Queensland – NRW (2004). Areas of the CSG fields study area not covered by the NRW (2004) mapping have been determined from interpretation of agricultural land capability data included in the Land Research Series 19 - CSIRO (1967), Series 21 – CSIRO (1968) and Series 34 - CSIRO (1974) and the digital datasets associated with those reports.



Reference - 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 be 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. (No Occurrances identified in Mapped Area)

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

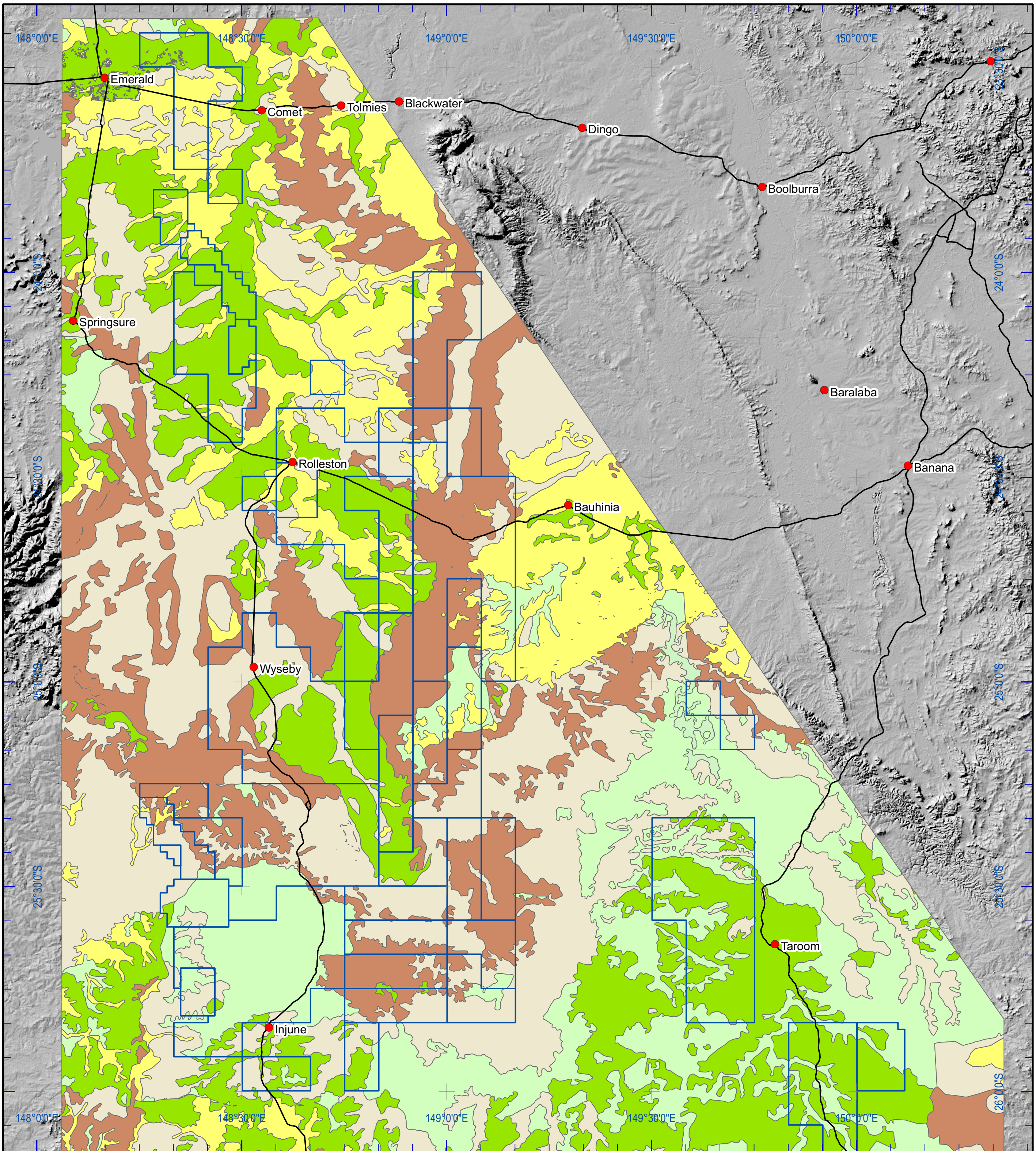
Towns
Major Roads
CSG Field

N W E S

Kilometers
0 5 10 20 30 40 50
Scale 1:1 500 000 (A4)
Datum : GDA 94

Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**AGRICULTURAL LAND CLASSES** **CSG FIELDS** **(SOUTHERN SECTION)**

Drawn: LL	Approved: GR	Date: 16-01-2009	Figure: **6.3.21**	Rev. A
Job No.: **4262 6220**	File No.: 42626220-g-965.mxd			A4



Reference - 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 be 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. (No Occurrances identified in Mapped Area)

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

Towns
Major Roads
CSG Field

N
W E
S

Kilometers
0 5 10 20 30 40 50

Scale 1:1 500 000 (A4)
Datum : GDA 94

Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**AGRICULTURAL LAND CLASSES CSG FIELDS (NORTHERN SECTION)**

Drawn: LL	Approved: JB	Date: 20-03-2009	Figure: **6.3.22**	Rev. A
Job No.: **4262 6220**	File No.: 42626220-g-966.mxd			A4

An indicative assessment of agricultural land capability has been carried out on a landscape unit basis for each of the Roma, Fairview and Arcadia Valley CSG fields. A summary of the findings of the assessment for each CSG fields is as follows.

Table 6.3.15 Roma CSG Field Land Area

Land Class[1]	% of Roma Field	Area (ha)
A	42.8	351,480
A-B	20.4	167,665
B	3.9	31,893
C1	23.0	188,332
C2	9.8	80,060
C3	0.1	1,160
Total	**100**	**820,590**

[1]For description of land classes, refer to Section 6.3.1.2, Agricultural Land.

Table 6.3.16 Fairview CSG Field Land Area

Land Class[2]	% of Fairview Field	Area (ha)
A	<0.05	27
B	1.3	1,486
C1	0.6	741
C2	65.9	76,543
C3	26.2	30,427
D	6.0	6,838
Total	**100**	**116,062**

[2]For description of land classes, refer to Section6.3.1.2, Agricultural Land.

Table 6.3.17 Arcadia Valley CSG Field Land Area

Land Class[3]	% of Arcadia Valley Field	Area (ha)
A	7.8	15,196
B	4.1	7,884
C1	10.8	20,948
C2	46.5	90,211
C3	20.7	40,177
D	10.1	19,595
Total:	**100**	**194,011**

[3]For description of land classes, refer to Section 6.3.1.2, Agricultural Land.

Acid Sulfate Soils

The EIS ToR requires that potential impacts related to the occurrence of acid sulfate soils (ASS) should be addressed. In general, ASS mainly occur in near coastal areas with a ground surface level of RL 5 m AHD or less (refer to Appendix L4). Given that the ground surface level within the CSG fields study area is typically in excess of RL 50 m AHD, the presence of ASS is not likely to be an issue.

6.3.1.5 Potential Impacts and Mitigation Measures

Soil Erosion

Potential Impacts

Erosion within the CSG well lease, access tracks and on construction sites generally cannot be eliminated completely, but implementation of the following measures will help minimise erosion and reduce sediment loss from disturbed areas.

Mitigation Measures

General erosion control measures outlined below should be implemented where necessary to minimise the potential effects of erosion during exploration, construction and the on-going operational life of the CSG fields development.

General Erosion Control Measures

Erosion on field development construction and operational sites (i.e. well leases, compressor stations, accommodation facilities, in field pipeline networks and roads etc) will be minimised by:

- Limiting the area disturbed, and clearing progressively, immediately prior to construction activities commencing;
- Planning activities with knowledge of soil types and soil characteristics;
- Scheduling major earthworks activities to avoid, where possible, the higher rainfall months of December to March;
- Safeguarding the surface layer by stripping and stockpiling topsoil prior to construction;
- Controlling runoff and sediment loss from disturbed areas using appropriate short term erosion control measures such as silt fences, hay bales, diversion mounds, etc;
- Using temporary soil diversion mounds to control runoff within and to divert water away from the construction site where practicable;
- Minimising the period that the bare soil is left exposed to erosion by rapidly establishing complete grass covers including perennial, creeping species with water truck or other irrigation if necessary;
- Using sediment traps and sediment collection ponds to minimise off-site effects of erosion;
- Where buried pipelines or other services are to be installed in sloping ground, in particular on slopes to drainage lines where surface runoff or sub-surface drainage may erode the trench backfill material, trench - breakers (vertical barriers to flow) should be installed at regular intervals to reduce flow along the trench and promote seepage to the groundwater. This will apply in particular where sodic and/or dispersive soils may occur. The locations of the trench-breakers will be identified prior to backfilling of the trench;
- A series of low water diversion mounds (contour banks) will be installed across the entire width of the working area immediately following clearing, grading and stripping of topsoil. The diversion mounds should be located every 25 - 75 m, depending on the surface gradient and soil type. Water contained by each mound will be diverted to stable vegetated land on the down-slope side of the easement or into an area protected by a silt fence if surface vegetation is sparse or absent; and

- In sloping woodland areas, felled timber and vegetative matter could be respread on the contour over the cleared working area to assist soil stabilisation and to discourage 3rd party vehicle assess into these areas.

Erosion Control on Sloping Land

- On sloping ground and in particular on slopes to drainage lines where surface runoff or sub - surface drainage along trenches housing pipelines or other buried services may erode the backfill material, trench-breakers (vertical barriers to flow) are to be installed at regular intervals to reduce flow along the trench and promote seepage to the groundwater. This will apply in particular where sodic and/or dispersive soils occur. Identify the locations of the trench-breakers prior to backfilling of the trench;
- Install a series of low water diversion mounds across the entire width of the working area immediately following clearing, grading and stripping of topsoil. Locate diversion mounds every 25 - 75 m depending on the surface gradient and soil type. Divert water contained by each mound to stable vegetated land on the down-slope side of the disturbed area or into an area protected by a silt fence if surface vegetation is sparse or absent; and
- In sloping woodland areas felled timber and vegetative matter will be respread on the contour over the cleared working area to assist soil stabilisation and to discourage access into these areas and suitable, adapted creeping grasses will be established.

Drainage Line Management

- Where pipelines or other buried services are required to cross water courses, where practicable these areas will be directionally drilled to reduce surface area disturbance and minimise environmental impact;
- In other drainage lines, if required a 50 m vegetative buffer will be retained until construction across the streambed is imminent;
- Streambed and bank materials will be graded away (upslope) from the streambed and placed in temporary stockpiles, a minimum of 50 m beyond the bank and protected on the down - slope side by a silt fence;
- Where it is necessary to divert water flow around the crossing site, it will be pumped into a geofabric - lined containment area and control released a suitable distance downstream of the crossing site;
- Temporary earth banks will be installed across the approach slopes to the drainage line to divert upslope surface runoff down stream of the crossing site;
- When the pipe installation is complete the stream bed will be re-instated using material consistent with the existing streambed material. Stream banks will be re-established to a stable slope consistent with the existing bank slopes both upstream and downstream of the crossing site. Topsoil will be replaced and the area revegetated as soon as practicable. In places it may be necessary to place jute matting or use rock armouring for erosion control purposes; and
- Stabilisation of these sites would be assisted by pushing disturbed riparian vegetation back over the re-instated area to provide seed stock augmented with seeding with adapted low growing grasses. This will also help restrict cattle from accessing the area; otherwise it may be necessary to install temporary fencing.

Dust Mitigation

- The methods employed should aim to reduce exposure of disturbed areas to the minimum period required and undertake revegetation or rehabilitation as soon as practicable after the completion of construction;
- Access tracks may require regular spraying using water trucks for dust suppression, in particular in established farming and other built-up areas;
- Continued use of access tracks by heavy vehicles tends to pulverise the soil and produce bulldust. Upgrading the access track with gravel or bitumen will help reduce the potential for bulldust to develop. This should be assessed as the field develops; and

- Temporary use of cover crops may be utilised to stabilise bare soil stockpiles or other bare soil areas.

The control of erosion and sediment movement within the CSG fields study area will be employed both during the construction stage and subsequently during the operating life. Where access is required in the long term, roads and access tracks will be constructed to Santos standards for rig roads, lease roads and field roads. In general local roads and access tracks will be sealed or constructed with a gravel 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.

Infrastructure and Development Areas

Erosion on construction areas will be minimised by:

- Limiting the area disturbed, and clearing progressively, immediately prior to construction activities commencing;
- Safeguarding the surface layer by stripping and stockpiling topsoil prior to construction;
- Using temporary soil diversion mounds to control runoff within and divert water away from the construction site where practicable;
- Minimising the period that bare soil is left exposed to erosion; and
- Using sediment traps/silt fences etc. to minimise off-site effects of erosion.

Where practicable, organic mulching and/or planting of bare soil surfaces will be undertaken to reduce the effects of wind and water erosion and dust generation.

The project environmental officer will be responsible for maintaining a regular site monitoring program to ensure that the erosion control measures implemented are effective. Where necessary, an environmental management plan (EMP) will be implemented to address any new or ongoing problem areas.

The control of erosion and sediment movement throughout the site will be necessary both during the construction stage and subsequently during the operating life of the CSG fields. Where access is required for temporary use only, disturbed areas will be lightly ripped, restored to a stable condition and re-vegetated or returned to their pre-disturbance land use condition as soon as practicable following the completion of construction. Particular attention will be paid to those areas known to include dispersive soils, to ensure that if exposed they do not remain untreated or unprotected.

The strategy outlined above provides a summary of general erosion control measures that will be adopted. As field development progresses, and the nature and location of actual field development activities is more accurately determined, additional site specific erosion control measures will be developed and implemented.

Access Roads, Service Roads and Temporary Access Tracks

The following erosion control measures will be implemented, as required:

- Major access roads will normally be sealed and constructed to appropriate engineering design standards;
- Unsealed or gravelled service tracks will be graded to a crown and provided with efficient surface drainage to prevent runoff eroding either the road surface or the adjacent land. Where necessary, low mounds angled across the track will be construction to divert runoff (at non-erosive velocity) into adjacent areas;
- Cut and fill batters associated with service tracks will be formed to a safe slope and stabilized by vegetation, stone or rock armouring, or by the use of geo-fabric where appropriate;

- Where table drains need to be established, they will be constructed to a broad dish shape, seeded with appropriate grasses and fertilized or lined appropriately, to prevent erosion. Table-drains will be slashed periodically to ensure vegetation growth is not restricting drainage flow;
- Approaches on service tracks to gully and creek crossings will be as flat as practicable. The track will be sloped to direct runoff to a table-drain constructed as above. In some vulnerable areas, it may be necessary to spread and compact coarse aggregate along the approaches to the crossing to provide permanent, stable access, and reduce erosion;
- Where provision of access across gullies or creeks cause disturbance, re-vegetation work will be undertaken; and
- All temporary construction tracks and associated disturbed areas will be ripped, seeded and fertilized when no longer required for use. Stockpiled topsoil will be re-spread before sowing. On steeper slopes the seeded areas will be protected if necessary.

Borrow Pits

For locations proposed as borrow sources, soil erosion control measures will be introduced to minimise sediment movement onto adjacent land or into streams. The following erosion control management procedures will be adopted:

- Prior to significant site disturbance, drainage works will be installed to control both external runoff entering the site and the water drainage from it;
- Runoff from land above the borrow site will be diverted around it. Runoff will be intercepted by banks and directed at a non-erosive velocity to a safe disposal area, such as a grassed waterway, or a pipe may be used to collect runoff and carry it through the site. Where the catchment above the site is large, stormwater retaining basins will be installed to augment these measures; and
- One or more banks will be located below the site to collect stormwater from it and direct it into a sediment basin to avoid damage to adjacent land or pollution of streams.

Once a borrow pit is established, the following techniques will be implemented (where necessary) as a part of on-going site management:

- Disturbance will be restricted to a minimum area consistent with efficient operation of the site;
- Excavation will be designed to minimise the accumulation of water in stagnant pools;
- Banks or channels will be located below areas yielding excessive runoff. These structures will collect the runoff before it erodes any bare areas downslope;
- Where necessary, unsurfaced tracks will be treated with gravel and/or watered to reduce the generation of dust;
- Topsoil will be progressively stripped from areas to be excavated and stockpiled separately from other excavated material. These stockpiles can take the form of wind-rows on the contour and can serve as the collector banks for runoff, so protecting land down slope;
- Where practical, cut batters which have been created by the excavation, will be formed to a stable grade and topsoil spread over them. Revegetation of batters will be carried out to prevent runoff erosion. Stabilised chutes or pipe drops may be required to carry water safely down such embankments; and
- Where necessary, diversion banks will be constructed across the site to protect rehabilitation works.

Clearing (where necessary), will be carried out progressively and immediately prior to each phase of the operation. Every effort will be made to retain some form of vegetative or grass cover for as long as practicable prior to stripping the topsoil layer. Uncontrolled surface water runoff from disturbed surface soil areas, and from any of the cracking clay soil areas with self mulching topsoils, may give rise to sheet or rill erosion with consequent sediment load increases in the local stream systems. Adequate measures will be taken to ensure that excessive erosion does not occur, and silt traps will be constructed where necessary.

Vegetation Clearing – General

- Disturbance of vegetation in construction areas will be limited to the minimum practicable;
- Selective clearing techniques and heavy duty mulching of small-medium density vegetation will be used where practicable which will cause a minimum of disturbance to surface conditions;
- Chipping/heavy duty mulching of smaller branches and foliage from the clearing operations in areas of high and very high erosion potential will provide a useful form of surface mulch to reduce surface erosion in the rehabilitation area;
- Any millable timber resources will be identified and salvaged during the site clearing process, if practicable and economically feasible;
- Clearing will be carried out in such a manner that where practicable, seed/root stock is left in the ground and surface soils are disturbed as little as possible; and

Site rehabilitation and where appropriate, re - vegetation should be carried out progressively and as soon as practicable following the completion of construction in the area.

Problem Soil Areas

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 when exposed tend to exhibit the following general problems:

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

Sodic and locally strongly sodic soil profiles tend to occur mainly in the subsoil and deeper soil horizons of Soil Group 6, to a lesser extent in Soil Group 5 and mainly in the deeper subsoils of Soil Groups 7 and 8.

Potential Impact

Soils with medium to high levels of exchangeable sodium (ESP) generally tend to pre-dispose the material to dispersion. As a result, these soils may become subject to rill and/or gully erosion if disturbed or exposed and left unprotected from the effects of rainfall or surface water infiltration. 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 sodic and dispersive soils do occur, adopting the relevant erosion control measures outlined in Section 6.3.1.5, Agricultural Land Capability Impacts and Mitigation Measures will assist in mitigating the deleterious effects of these problem soils. 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 will be spread and blended into the exposed surface soils to restore the ionic balance and thus reduce levels of sodicity and dispersion effects. The use of a suitable thickness of topsoil as a cover over sodic/dispersive soils will also help to minimise the deleterious effects of these soils.

Reactive Soils

These relate primarily to the occurrence of highly reactive (cracking) clay that occurs in the landscape units mainly with Soil Group 8.

Potential Impact

These soils exhibit substantial shrinkage and swelling characteristics due to wetting and drying cycles which may result in damage to structures, foundations and buried services (including pipelines) due to differential ground movements. The degree of shrinkage and swelling of soils and associated soil movement is dependent on the thickness of the soil profile and the clay content and the clay mineral type present.

Shallow to medium deep and deep highly reactive (Group 8) soils occur extensively throughout the CSG fields study area. These soils often occur in association with Soil Group 6 and Soil Group 7 soils.

Mitigation Measures

The impact of differential soil movement with respect to the integrity of pipeline facilities and buried services can be mitigated to a large extent by the use of an inert (sandy) padding material encasing the facility. Prior to the final engineering design being completed, detailed field investigations including drilling, soil sampling and testing will be undertaken to more clearly define the properties and extent of occurrence of these reactive soils and their potential impact on the long-term integrity of structures and/or buried services.

Soil Salinity

Potential Impact

Primary soil salinity (high levels of soluble salts) is salinity that occurs naturally within the soil profile, usually in the subsoil layers. Secondary salinity including saline surface outbreaks occur as a result of rising groundwater in these areas, usually as a result of clearing of trees and deep-rooted vegetation in higher areast of catchments and sub-catchments. In addition to deleterious effects on plant survival and growth, soils with high levels of soluble salts and/or high levels of sodicity increase the potential for corrosion of buried steel and/or concrete products.

Soils with moderate to high levels of soil salinity particularly in the deeper clay subsoil and substrate materials are likely to occur in landscape units Qa1, Km1, Jm1 and Rm1.

Mitigation Measures

In areas with saline soils, a common salinity management recommendation (e.g. DNRQ, 1997) is to (i) avoid clearing of trees and other woody vegetation in upper areas of catchments or groundwater intake areas; (ii) revegetate cleared areas as soon as practicable following disturbance; and (iii) strategically establish deep-rooted perennials including trees in downslope salinity outbreak areas. By reducing deep drainage in upper catchments and increasing plant evapotranspiration demand in lower slope/catchment areas groundwater levels are lowered and potential for secondary salinisation is reduced. Much of the existing high risk salinity areas have previously been cleared for cropping and/or grazing. In addition to the above management tools, application of periodic low salinity with a balanced ionic strength (eg calcium and magnesium fortified desalination permeate) would be able to leach plant root zone soluble salts to maintain sustainable productivity of high salinity risk soils.

Further geotechnical and soils investigations including soil resistivity surveys in the proposed CSG fields will be undertaken as part of the site specific process under the protocols developed for Phase 2 (post EIS) processes, and prior to the commencement of construction works.

Topsoil Resources

Potential Impacts

The suitability of materials for use as topsoil resources for rehabilitation of lands that may be disturbed during the construction and operating stages of the CSG fields development has been assessed from the soil characterisation, indicative testing and the results of the analytical data obtained during the gas transmission pipeline and LNG facility field investigations. Additional soils data was also obtained from reference to and interpretation of the Land Systems and Soils mapping by CSIRO (1967, 1968 & 1974) and NRW (1995) which collectively covers the general study area. Reference was also made to the soils data obtained as part of the field investigation of common sections of the pipeline route proposed for the Denison Trough Gas Project–Gladstone Option, undertaken as part of the EIS prepared by CSR Oil and Gas Division (1984). Indicative stripping depths of potential topsoil resources have been determined for each of the major soil groups and soil types identified, which are summarised in Table 6.3.14.

Mitigation Measures

Topsoil Management

Useable topsoil resources are mainly confined to the surficial (A) horizon materials and in places in the upper part of the subsurface (B1) horizons, as they 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.

Topsoil resources will be salvaged from areas likely to be disturbed as a result of clearing associated with the development of the CSG fields. The pre - stripped topsoil material will be temporarily stockpiled in the general vicinity for subsequent rehabilitation of areas disturbed by activities.

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 the EMP and anticipated *in situ* soil conditions. This will ensure that only suitable topsoil material resources are stripped and that 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.

Some variability will occur with respect to the available topsoil resources within the soil groups and soil types identified within the respective CSG fields. Accordingly, 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 resources is recovered for later use in site rehabilitation.

Stockpiling

Topsoil shall be stored in stockpiles located in areas that do not impinge on the construction 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 1.5 m maximum). If the stockpile is to be retained for a period of more than six 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

Areas identified as Class A, B and C1 land may be subject to short term disruption of existing land use during the development of the CSG fields. As these lands represent existing or potentially arable lands which are subject to regular or periodic cultivation for crop production or improved pasture, the minimum soil cover thickness above buried pipelines or services should be a minimum of 1.2 m to allow for normal cultivation practices. If in certain areas deep ripping is a normal practice or is proposed to be carried out at some future time, then the minimum cover thickness may be extended to 1.8 m, if required by the property landholder. As a general rule, pipelines or other buried services will not be located in lands considered to be suitable for cropping unless by prior arrangement with the landholder.

Mitigation Measures

As soon as practicable, temporary access tracks will be removed and disturbed land will be lightly ripped, topsoil will be replaced and the land returned as near as practicable to its pre - construction land use condition. Appropriate erosion control measures will be implemented where considered to be necessary or by agreement with the landholder.

Areas identified as Class C2 land are essentially good quality grazing lands suitable for native or improved pastures, but cultivation is not normally undertaken. When construction activities are complete the temporary access tracks will be removed unless otherwise agreed with the landholder. Elsewhere, disturbed areas will be graded to a level consistent with lands adjacent and pre - stripped topsoil will be replaced. Appropriate erosion control measures will be implemented where considered to be necessary or by agreement with the landholder.

Areas identified as Class C3 land comprise hilly and steep hilly lands, typically treed but suitable for controlled light grazing where accessible. Class D (non-agricultural) lands may include very steep, high hilly to mountainous lands, steep rocky escarpments, or major streamlines and rivers. When construction activities are complete in these areas, land management and erosion control measures described in Section 6.3.1.5, Problem Soil Areas, for sloping lands and drainage lines should be implemented. In general these areas will be revegetated as soon as practicable after construction activities have been completed.

Area Excavation Conditions

Potential Impact

Higher excavation constraints correspond to higher potential environmental impacts including the likely extent of clearing and the construction methods and types of equipment required to carry out the work. Other impacts relate to the amount of rock likely to be encountered and the suitability of the excavated spoil for pipeline or service trench backfill purposes. Where heavy rock-breaking and/or blasting is required for rock removal, the associated noise factors and the proximity to co-located infrastructure facilities or other buried services will be addressed.

Mitigation Measures

With respect to clearing of existing or natural vegetation, wherever possible this will be confined to the construction disturbance footprint. Where additional clearing is required to permit access for larger equipment, clearing will be kept to the minimum necessary to complete the work.

Where rock is encountered, wherever possible it will be reused on the construction site or removed from the site and used for erosion control rip - rap or disposed of in alternative approved locations. If there is a shortfall of trench backfill material, then suitable material (certified weed and disease free) will be imported. If there is an excess of otherwise suitable spoil material, it will be used for local rehabilitation purposes, or removed from the site to an approved disposal area.

Where heavy rock - breaking and/or drilling and blasting is necessary for rock removal, the work will be carried out during normal daylight working hours to minimise the effects of noise impacts in built - up or established farming areas (refer to the separate Noise and Vibration report in Appendix U1). In general, any blasting that may be required will be carried out in accordance with relevant local authority guidelines and AS:2885. Areas that may require the employment of drill and blasting techniques will be carefully investigated with respect to the possible co - location of other pipeline facilities and/or buried services in the general vicinity, to ensure the integrity of and any safety issues related to such facilities.

Land Suitability for the Location of Water Storage Facilities

An assessment of land suitability for the location and construction of intermediate and larger scale water storage facilities on a landscape unit basis is included in the technical report in Appendix L. The assessment is largely based on consideration of topographic suitability (assuming relatively flat or gently undulating land is preferred), together with the occurrence of deep, relatively uniform, low permeability soil/substrate conditions.

Based on the above criteria, the extent of land on a landscape unit basis that may be suitable for location and construction of water storage facilities in the Roma, Fairview and Arcadia Valley CSG fields is summarised in the following tables.

Table 6.3.18 Roma Field Land Suitability for Water Storage Facilities

Land Rating for siting Water Storage Facility	% of Roma Field	Area (ha)	Applicable Landscape Units
Suitable (S)	65.3	535,731	Jm1, Jm2, Ka1, Km1, Km2, Qa1 and Qa2
Suitable to Marginal (S-M) and Marginal (M)	29.5	241,905	Ka2, Tv2, Ja1, Ja2, Jm3, Km3, Ts1, Ts2 and Ts3
Unsuitable (U)	5.2	42,954	Tv3, Tv4, Tv5, Ja3, Ja4, Ka3 and Km4,
Total	**100**	**820,590**	**-**

Table 6.3.19 Fairview Field Land Suitability for Water Storage Facilities

Land Rating for siting Water Storage Facility	% of Fairview Field	Area (ha)	Applicable Landscape Units
Suitable (S)	1.4	1,678	Qa2, Jm2 and Rm2
Marginal (M)	35.0	40,591	Ja1, Ja2 and Jm3
Unsuitable (U)	63.6	73,793	Ja3, Ja4, Ja5, Rm5 and Rm6
Total	**100**	**116,062**	**-**

Table 6.3.20 Arcadia Valley Land Suitability for Water Storage Facilities

Land Rating for siting Water Storage Facility	% of Arcadia Valley Field	Area (ha)	Applicable Landscape Units
Suitable (S)	22.7	44,028	Qa1, Qa2, Rm1 and Rm2
Marginal (M)	29.1	56,479	Ja1, Ja2 and Rm3
Unsuitable (U)	48.2	93,504	Ja3, Ja4, Ja5, Ja6, Rm4 and Rm5
Total	**100**	**194,011**	**-**

It should be noted, that whilst an area of land may provide a suitable site in terms of topography and low permeability soil/substrate conditions, the physical and chemical properties of the soils may not be suitable for water storage embankment construction. In a manner consistent with the protocols developed under this EIS for the Phase 2 (post EIS) processes, consideration to site specific soil related investigations (refer Section 6.1) will be undertaken as part of the site specific development of the CSG fields.

Seismic Activity and Ground Stability

Potential Impact

A review of regional seismicity events and consideration of the location of potential geological hazards, primarily major geological structural features and faults, and the likelihood for damage to in-field gas/water gathering pipelines and associated facilities due to potential ground instability, has been addressed in Section 6.3.1.4 above.

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 and associated in-field gas/water pipeline facilities will be designed in accordance with this standard.

Identification, Monitoring and Management

Potential Impact

The ToR requires 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 development of the CGS fields and associated facilities 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;
- The availability, handling and management of topsoil resources for land rehabilitation purpose;
- Storage, treatment and disposal of water groundwater generated from production well leases; and
- Excavation conditions for pipelines and/or buried services.

Mitigation Measures

The potential impacts relating to these CSG fields development issues have been addressed and mitigation measures 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 for the various aspects of the project. Monitoring of the success of the impact management strategies and the progress of land rehabilitation of disturbed areas, will be carried out periodically throughout the life - span of each of the CSG production well leases and for a suitable period following the decommissioning of the field by agreement with the landholder.

Site monitoring procedures may include the visual assessment by aerial reconnaissance and inspection of operational and/or rehabilitated lands together with the installation of semi-permanent survey transects in pre-selected areas with differing combinations of geological and soil/landscape conditions. This can 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 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

Section 1 identifies other CSG development projects planned for the surrounding region. Some of these projects are up to 100 km from the GLNG Project CSG field areas and some may be within the GLNG Project future development (FD) area. There is limited information available as to the planned development of those projects or the quantity and timing of the development of the wells or associated infrastructure; however, a qualitative assessment can be made of the possible cumulative impacts.

Santos will develop the CSG fields in accordance with the EIS. There will be no other development by other petroleum producers in the tenements described in the CSG fields. Infrastructure impacts will not exceed those stated in the project description.

It is however, possible that other companies may develop CSG facilities within the CSG fields FD area as part of their planned CSG development projects in addition to the existing CSG domestic supply facilities. This will mean that there will be more CSG development in the FD area than the Santos project. As an area is developed, the number of wells will increase, but the spacing of wells will not intensify.

The total land surface area directly impacted by the activities to be undertaken on the GLNG CSG fields is estimated at 2,500 ha. This constitutes 0.37 % of the RFD area of 6,800 km^2. Accordingly the impacts described in this section affect a relatively small area of land and the impact on such areas will reduced by the application of the mitigation methods described in this section.

Generally each CSG well is expected to have an operational life of between 5 and 15 years, thus the total footprint is reduced as wells are decommissioned.

In assessing the possible cumulative impacts upon soils and land, particular regard has been taken of:

- The temporal impacts of CSG fields development; and
- The relatively small area of the land the subject of a petroleum lease that will be impacted.

Activities associated with these CSG development projects will carry a relatively small footprint as a percentage of the total land area. Depending on the number of wells developed, the impact of each CSG development project upon soils and land in the respective tenement (as described in Section 1) is likely to be similar to that of the GLNG Project. It is expected that the other CSG development projects would include some or all of the proposed mitigation measures in relation to soils and land described in this section. By utilising the mitigation methods the expectation is the minimisation of the cumulative impacts on the receiving environment.

Table 6.3.21 provides a summary of potential land impacts and mitigation measures for the CSG fields.

Table 6.3.21 Potential Land Impacts and Mitigation Measures

Aspect	Potential Impact	Mitigation Measures	Objective
Construction			
Agricultural land capability	Sterilisation of land.	Class A, B and C1 land • Soil cover thickness above buried pipelines or services should be 1.2 m. If deep ripping is a normal practice or is proposed the minimum cover thickness may be extended to 1.8 m, if required by the property landholder. • As soon as practicable, temporary access tracks will be removed, disturbed land lightly ripped, topsoil replaced and the land returned as near as possible to pre-construction land use condition. • Necessary erosion control measures will be planned with the landholder and will be promptly implemented and maintained. Class C2 land • When construction activities are complete the temporary access tracks will be removed unless otherwise agreed with the landholder. • Disturbed areas will be graded to a level consistent with lands adjacent and pre-stripped topsoil will be replaced. • Necessary erosion control measures will be planned with the landholder and will be promptly implemented and maintained. Class C3 & D land • When construction activities are complete in these areas, land management and erosion control measures will be implemented. • These areas will be revegetated as soon as practicable after construction activities have been completed.	Minimisation of land sterilisation.
Topsoil resources	Loss of topsoil.	• Topsoil resources will be salvaged from areas likely to be disturbed as a result of clearing associated with the development of the CSG fields. • 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. • Prior to the commencement of topsoil stripping, areas will be cleared of	Maximisation of topsoil retention.

Aspect	Potential Impact	Mitigation Measures	Objective
		vegetation. • The pre-stripped topsoil material will be temporarily stockpiled in the general vicinity for subsequent rehabilitation of areas disturbed by activities. • 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 resources is recovered for later use in site rehabilitation. • Topsoil shall be stored in stockpiles located in areas that do not impinge on the construction 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. • 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. Where appropriate the use of suitable potentially threatened (local) plant species will be considered. • 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 and application of Santos EHSMS procedures will ensure no new weed species are introduced on vehicles and equipment.	
Erosion potential	Erosion and sediment loss from disturbed areas (General).	• Limiting the area disturbed, and clearing progressively, immediately prior to construction activities commencing. • Safeguarding the surface layer by stripping and stockpiling topsoil prior to construction.	Minimisation of erosion and sediment loss.

Aspect	Potential Impact	Mitigation Measures	Objective
		• Control of runoff and sediment loss from disturbed areas using appropriate short term erosion control measures such as silt fences, hay bales, diversion mounds, etc. • Using temporary soil diversion mounds to control runoff within and to divert water away from the construction site where practicable. • Minimising the period that the bare soil is left exposed to erosion including the rapid establishment of appropriate grass cover. • Using sediment traps and sediment collection ponds to minimise off-site effects of erosion. • Where surface runoff or sub-surface drainage may erode the trench backfill material, trench-breakers (vertical barriers to flow) will be installed at regular intervals to reduce flow along the trench and promote seepage to the groundwater. This will apply in particular where sodic and/or dispersive soils may occur. The locations of the trench-breakers will be identified prior to backfilling of the trench. • A series of low water diversion mounds (grassed contour banks) will be installed across the entire width of the working area immediately following clearing, grading and stripping of topsoil, located every 25 - 75 m, depending on the surface gradient and soil type. Water contained by each mound will be diverted to stable vegetated land on the down-slope side of the easement or into an area protected by a silt fence if surface vegetation is sparse or absent. • In sloping woodland areas, felled timber and vegetative matter will be respread on the contour over the cleared working area supported by grass establishment as appropriate to assist soil stabilisation and to discourage 3rd party vehicle assess into these areas.	
	Erosion and sediment loss from disturbed areas (Drainage line management)	• Where pipelines or other buried services are required to cross water courses, these areas will be directionally drilled, where practicable, to reduce surface area disturbance and minimise environmental impact. • In other drainage lines, a 50 m vegetative buffer will be retained, if required, until construction across the stream bed is imminent. • Stream bed and bank materials will be graded away (upslope) from the stream bed and placed in temporary stockpiles, a minimum of 50 m	Minimisation of erosion and sediment loss

Aspect	Potential Impact	Mitigation Measures	Objective
		beyond the bank and protected on the down-slope side by a silt fence. • Where it is necessary to divert water flow around the crossing site, it will be pumped into a geofabric-lined containment area and control released a suitable distance downstream of the crossing site. • Temporary earth banks will be installed across the approach slopes to the drainage line to divert upslope surface runoff down stream of the crossing site. • When the pipe installation is complete the stream bed will be re-instated using material consistent with the existing streambed material. Stream banks will be re-established to a stable slope consistent with the existing bank slopes both upstream and downstream of the crossing site. Topsoil will be replaced and the area revegetated as soon as practicable. In places it may be necessary to place jute matting or use rock armouring for erosion control purposes. • Stabilisation of these sites may be assisted by pushing disturbed riparian vegetation back over the re-instated area to provide seedstock supported by strategic creeping grass establishment. Using temporary / solar-powered electric fencing to exclude cattle may assist site stabilisation.	
	Erosion and sediment loss from disturbed areas (Dust mitigation).	• The construction methods employed should minimise periods of exposure of disturbed areas to the elements in the construction process before site revegetation or rehabilitation is undertaken. • Access tracks may require regular spraying using water trucks for dust suppression, in particular in established farming and other built-up areas. • Continued use of access tracks by heavy vehicles tends to pulverise the soil and produce bulldust. Upgrading the access track with gravel or bitumen will help reduce the potential for bulldust to develop. This should be assessed as the field develops. • Temporary use of cover crops irrigated if necessary for quick establishment, may be utilised to stabilise bare soil stockpiles or other bare soil areas. • Disturbed areas will be lightly ripped, fertilised if necessary and restored to a stable condition and revegetated or returned to their pre-disturbance land use condition as soon as practicable following the completion of	Minimisation of erosion and dust generation.

Aspect	Potential Impact	Mitigation Measures	Objective
		construction activities.	
	Erosion and sediment loss from disturbed areas (Infrastructure and development areas).	• Limiting of the area disturbed, and clearing progressively, immediately prior to construction activities commencing. • Safeguarding of the surface layer by stripping and stockpiling topsoil prior to construction. • Use of temporary soil diversion mounds to control runoff within and divert water away from the construction site where practicable. • Minimisation of the period that bare soil unvegetated and left exposed to erosion. • Use of sediment traps/silt fences etc. to minimise off-site effects of erosion. • Where practicable, organic mulching and/or planting of bare soil surfaces will be undertaken to reduce the effects of wind erosion and dust generation. • The site environmental officer will be responsible for maintaining a regular site monitoring program to ensure that the erosion control measures implemented are effective. • Where necessary, an EMP will be implemented to address any new or ongoing problem areas. • Where access is required for temporary use only, disturbed areas will be lightly ripped, fertilised if necessary, restored to a stable condition and re-vegetated or returned to their pre-disturbance land use condition as soon as practicable following the completion of construction. • Particular attention will be paid to those areas known to include dispersive soils, to ensure that if exposed they do not remain untreated or unprotected.	Minimisation of erosion and sediment loss in infrastructure and development areas.
	Erosion and sediment loss from disturbed areas (Erosion control on sloping land)	• On sloping ground where surface runoff or sub-surface drainage along trenches housing pipelines or other buried services may erode the backfill material, install trench-breakers (vertical barriers to flow) at regular intervals to reduce flow along the trench and promote seepage to the groundwater. This will apply in particular where sodic and/or dispersive soils occur. Identify the locations of the trench-breakers prior to backfilling	Minimisation of erosion and sediment loss on sloping land.

Aspect	Potential Impact	Mitigation Measures	Objective
		of the trench. • Install a series of low water diversion mounds across the entire width of the working area immediately following clearing, grading and stripping of topsoil, located every 25 - 75 m depending on the surface gradient and soil type. Water contained by each mound will be diverted to stable vegetated land on the down-slope side of the disturbed area or into an area protected by a silt fence if surface vegetation is sparse or absent. • In sloping woodland areas felled timber and vegetative matter will be respread on the contour over the cleared working area to assist soil stabilisation and to discourage grazing animal access into these areas.	
	Erosion and sediment loss from disturbed areas (Roads & tracks).	• Major access roads will normally be sealed and constructed to appropriate engineering design standards. • Unsealed or gravelled service tracks will be graded to a crown and provided with efficient surface drainage to prevent runoff eroding either the road surface or the adjacent land. Where necessary, low mounds angled across the track will be construction to divert runoff (at non-erosive velocity) into adjacent areas. • Cut and fill batters associated with service tracks will be formed to a safe slope and stabilized by vegetation, stone or rock armouring, or by the use of geo-fabric where appropriate. • Where table drains need to be established, they will be constructed to a broad dish shape, seeded and fertilized or lined appropriately, to prevent erosion. Table-drains will be slashed periodically to ensure vegetation growth is not restricting drainage flow. • Approaches on service tracks to gully and creek crossings will be as flat as practicable. The track will be sloped to direct runoff to a table-drain constructed as above. In some vulnerable areas, it may be necessary to spread and compact coarse aggregate along the approaches to the crossing to provide permanent, stable access, and reduce erosion. • Where provision of access across gullies or creeks cause disturbance, re-vegetation work will be undertaken. • All temporary construction tracks and associated disturbed areas will be ripped, seeded and fertilized when no longer required for use.	Minimisation of erosion and sediment loss.

Aspect	Potential Impact	Mitigation Measures	Objective
		• Stockpiled topsoil will be re-spread before sowing. On steeper slopes the seeded areas will protected as requried, using jute matting for erosion control purposes.	
	Erosion and sediment loss from disturbed areas (Borrow pits).	• Prior to significant site disturbance, drainage works will be installed to control both external runoff entering the site and the water drainage from within the site. • Runoff from land above the borrow site will be diverted around it. • Runoff will be intercepted by banks, grassed if necessary, and directed at a non-erosive velocity to a safe disposal area, or a pipe may be used to collect runoff and carry it through the site. • Where the catchment above the site is large, stormwater retaining basins will be installed to augment these measures. • One or more banks will be located below the site to collect stormwater from it and direct it into a sediment basin to avoid damage to adjacent land or pollution of streams. • Disturbance will be restricted to a minimum area consistent with efficient operation of the site. • Excavation will be designed to minimise the accumulation of water in stagnant pools. • Grassed banks and waterways will be located below areas yielding significant potential runoff which will transport water at non-erosive velocities so that no downslope erosion occurs. • Where necessary, unsurfaced tracks will be treated with gravel and/or watered to reduce the generation of dust. • Topsoil will be progressively stripped from areas to be excavated and stockpiled separately from other excavated material. These stockpiles can take the form of wind-rows on the contour and can serve as the collector banks for runoff, so protecting land down slope. • Where practical, cut batters, which have been created by the excavation, will be formed to a stable grade and topsoil spread over them. • Revegetation of batters will be carried out to prevent runoff erosion. • Stabilised chutes or pipe drops may be required to carry water safely	Minimisation of erosion and sediment loss.

Aspect	Potential Impact	Mitigation Measures	Objective
		down such embankments. • Where necessary, diversion banks, grassed if necessary, will be constructed across the site to protect rehabilitation works. • Clearing, where necessary, and involving heavy duty mulching as much as possible, will be carried out progressively and immediately prior to each phase of the operation. Every effort will be made to retain some form of vegetative or grass cover for as long as practicable prior to stripping the topsoil layer. • Measures will be taken to ensure that excessive erosion does not occur, and silt traps will be constructed where necessary in disturbed surface soil areas and from any of the cracking clay soil areas, with self mulching topsoils.	
	Erosion and sediment loss from disturbed areas due to vegetation clearing.	• Disturbance of vegetation in construction areas will be limited to the minimum practicable. • Selective bulldozer clearing techniques and heavy duty mulching will be used where practicable which will cause a minimum of disturbance to surface conditions. • Chipping/heavy duty mulching of smaller branches and foliage from the clearing operations in areas of high and very high erosion potential will provide a useful form of surface mulch to reduce surface erosion in the rehabilitation area. • Any millable timber resources will be identified and salvaged during the site clearing process, if practicable and economically feasible. • Clearing/site preparation will be carried out in such a manner that where practicable, seed/root stock is left in the ground and surface soils are disturbed as little as possible. • Site rehabilitation and where appropriate, re-vegetation should be carried out progressively and as soon as practicable following the completion of construction in the area.	Minimisation of erosion and sediment loss.
Problem soil areas	Erosion and sediment loss from disturbed areas (Sodic and/or dispersive soils).	• Should sub-soil sodic or dispersive materials be exposed as a result of site preparation, dolomite or gypsum-based soil conditioner, top soil, essential plant nutrients and mulch will be spread and blended into the exposed soils with a vegetation cover adapted to such soils rapidly	Minimisation of erosion and sediment loss.

Aspect	Potential Impact	Mitigation Measures	Objective
		established. • Pre-construction soil sampling and analysis will identify areas of strongly or very strongly sodic and/or dispersive materials which will minimise the use of such materials for rehabilitation purposes.	
	Damage to structures, foundations and buried services due to differential ground movements caused by reactive soils.	• Detailed field investigations including drilling, soil sampling and testing will be undertaken to more clearly define the properties and extent of occurrence of these reactive soils and their potential impact on the long - term integrity of structures and/or buried services. • Use of an inert (sandy) padding material encasing the facility to mitigate the impact of differential soil movement in reactive soils.	Minimisation of disturbance in reactive soils and mitigation of impacts on structures and buried services.
	Impacts on plant growth and increased potential for corrosion of buried steel and/or concrete products due to soil salinity.	• Further geotechnical and soils investigations including soil resistivity surveys will be undertaken as part of the Phase 2 (post EIS) investigations, and prior to the commencement of construction works, to determine the occurrence and distribution of saline soils and where corrosion protection may be required. • Avoid clearing of trees and woody vegetation and revegetate cleared areas as soon as practicable following disturbance. • Planned periodic application of suitable water to leach excessive accumulated soluble salts in the plant root zone to reduce constraints to plant productivity and corrosiveness of soils.	Minimisation of soil salinity and mitigation of impacts on structures and buried services.
Area excavation conditions	Disturbance related to drilling and blasting of rock.	• Where heavy rock-breaking and/or drilling and blasting is necessary for rock removal, the work will be carried out during normal daylight working hours to minimise the effects of noise impacts in built-up or established farming areas. • In general, any blasting that may be required will be carried out in accordance with relevant local authority guidelines and AS: 2885. • Areas that may require the employment of drill and blasting techniques will be carefully investigated with respect to the possible co-location of other pipeline facilities and/or buried services in the general vicinity, to ensure the integrity of and any safety issues related to such facilities. • Where rock is encountered it will, wherever possible, be reused on the construction site or removed from the site and used for erosion control rip-	Minimisation of disturbance related to drilling and blasting, and optimisation of rock re-use.

Aspect	Potential Impact	Mitigation Measures	Objective
		rap or disposed of in alternative approved locations. • If there is a shortfall of trench backfill material, then suitable material (certified weed and disease free) will be imported. • If there is an excess of otherwise suitable spoil material, it will be used for local rehabilitation purposes, or removed from the site to an approved disposal area.	
Land suitability for the location of water management facilities	Potential impacts from associated water produced from CSG field wells.	• Associated water will be collected and managed in accordance with Santos' associated water management strategy. • Associated water management techniques will be dictated by area specific environmental, social and economic considerations. • In some areas associated water will be stored temporarily at local transfer sites (water management facilities). Water from the treatment process will be utilised for beneficial use, where practicable under management plans approved by state agencies and local/regional authorities representing community social, economic and environmental interests.	Optimisation of associated water use.
Seismic activity and ground stability	Damage to structures caused by seismic activity and ground stability.	• Design of structures and associated in - field gas/water pipeline facilities will be in accordance with AS1170.4:1993(a).	Minimisation of damage to structures caused by seismic activity and ground stability.
Operation			
Agricultural land capability	Sterilisation of land.	Class A, B and C1 land • Soil cover thickness above buried pipelines or services should be 1.2 m. If deep ripping is a normal practice or is proposed the minimum cover thickness may be extended to 1.8 m, if required by the property landholder. • As soon as practicable, temporary access tracks will be removed, disturbed land lightly ripped, topsoil replaced and the land returned as near as possible to pre-construction land use condition. • Erosion control measures will be collaboratively planned with the landholder and implemented. Class C2 land	Minimisation of land sterilisation.

Aspect	Potential Impact	Mitigation Measures	Objective
		• When construction activities are complete the temporary access tracks will be removed unless otherwise agreed with the landholder. • Disturbed areas will be graded to a level consistent with lands adjacent and pre-stripped topsoil will be replaced. • Erosion control measures will be collaboratively planned with the landholder and implemented. Class C3 & D land • When construction activities are complete in these areas, land management and erosion control measures will be implemented. • These areas will be revegetated as soon as practicable after construction activities have been completed.	
Erosion potential	Erosion and sediment loss from previously disturbed areas.	• Maintenance of a regular monitoring program which immediately informs management and the taking of any additional corrective actions to ensure that the erosion control measures implemented are effective. • Where necessary, implementation of additional mitigation measures to address any new or ongoing problem areas.	Minimisation of erosion and sediment loss.
	Erosion and sediment loss from disturbed areas (Dust mitigation).	• 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.	Minimisation of erosion and dust generation.
Problem soil areas	Erosion and sediment loss from disturbed areas (Sodic and/or dispersive soils).	• Maintenance of a regular monitoring program which immediately informs management and the taking of any additional corrective actions to ensure that the erosion control measures implemented are effective • Where necessary, implementation of additional mitigation measures to address any new or ongoing problem areas.	Minimisation of sediment loss and erosion in disturbed areas.
	Damage to structures, foundations and buried services due to differential ground movements caused by reactive soils.		Minimisation of disturbance in reactive soils and mitigation of impacts on structures and buried services.
	Impacts on plant growth and increased potential for corrosion of buried steel and/or concrete products due to soil salinity.		Minimisation of soil salinity and mitigation of impacts on structures and buried services.

Aspect	Potential Impact	Mitigation Measures	Objective
Land Suitability for the Location of Water Management Facilities	Potential impacts from associated water produced from CSG field wells.	• Refer to the construction section above. • In some areas associated water will be stored temporarily at local transfer sites (water management facilities). Water from the treatment process will be utilised for beneficial use, where practicable, under management plans approved by state agencies and local/regional authorities representing community social, economic and environmental interests.	Optimisation of associated water use.
Decommissioning			
Agricultural land capability	Sterilisation of land.	• Refer to the construction section above.	Minimisation of land sterilisation.
Topsoil resources	Loss of topsoil.	• Refer to the construction section above.	Maximisation of topsoil retention.
Erosion potential	Erosion and sediment loss from disturbed areas.	• Refer to the construction section above.	Minimisation of erosion and sediment loss.
	Erosion and sediment loss from disturbed areas due to vegetation clearing.	• Refer to the construction section above.	Minimisation of erosion and sediment loss.
Problem Soil Areas	Erosion and sediment loss from disturbed areas (Sodic and/or dispersive soils)	• Refer to the construction section above.	Minimisation of erosion and sediment loss.

6.3.1.6 Summary of Findings

A terrain analysis was carried out to assess the engineering and/or environmental constraints with respect to the FD of the CSG fields. A series of landscape units were identified for each of the main geological regimes identified within the region, based on landform characteristics (surface form and slope) and associated soil types. Descriptions of the landscape 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 development of the existing and future CSG fields.

The main potential environmental impacts assessed relate to the following aspects of CSG field development:

- Agricultural land classes - changes to agricultural land capability;
- Erosion potential - if the land is subject to clearing or disturbance associated with pipeline construction;
- Problem soils - the occurrence of reactive soils, sodic, dispersive and/or saline soils, acid sulfate soils;
- Excavation conditions - relates to the assessed ease or difficulty of excavation within the upper 1.5 m for construction of the pipeline network or for other buried services;
- Terrain suitability for construction of water storage facilities.

These potential impacts have been addressed in the EIS and management strategies have been recommended in order to successfully mitigate the potential environmental impacts identified. In places where potentially high environmental impacts have been identified, more detailed field investigations including site specific site investigation including soil sampling and soil testing may be undertaken to clearly define the extent of potential problem areas and to determine the appropriate level of mitigation or management required.

6.3.2 Land Contamination

6.3.2.1 Introduction

A review was undertaken of the potential for land contamination associated with the construction, operational and decommissioning phases of the proposed CSG field development. This review comprised Phase 1 of the two phase approach to the environmental assessment of CSG field development activities, as described in Section 6.1.

An indicative baseline assessment of land contamination was conducted due to the phased nature of the CSG field development, with individual site specific contamination assessments (Phase 2 assessments) to be undertaken for each facility to be constructed in the CSG field.

The Queensland EPA has been consulted on the phased approach to contaminated land assessments and confirms that this strategy is the most efficient way to assess potential contaminated land issues. The contaminated land assessment process included:

- Description of the existing land uses and potential for areas of potential concern based on the likelihood of notifiable activities under the EP Act;
- Overview of applicable contaminated land legislation and Environmental Protection Agency (EPA) guidelines;
- Identification of the potential impacts associated with the construction and operation of the CSG field development; and
- Development of possible mitigation measures which could be incorporated into the CSG field development to minimise the potential for impacts.

A full description of the CSG field development area used as the basis for the assessment is provided in Section 3.

Key findings of the contaminated land assessment for the CSG fields study area are described below, with a full copy of the assessment report provided in Appendix M.

6.3.2.2 Methodology

The study considered both the potential for existing land contamination and the potential for CSG field development associated land contamination.

6.3.2.3 Regulatory Framework

The assessment and management of contaminated or potentially contaminated land is governed by the EP Act, administered by the EPA. Assessment is also guided by the Department of Environment's *Draft Guidelines for the Assessment & Management of Contaminated Land in Queensland,* dated May 1998 (DoE, 1998) which outlines assessment criteria (environmental investigation levels) and the tiered assessment approach.

The EP Act includes a list of all 'Notifiable Activities' in Schedule 3 which have a high potential for contamination impacts. These include, but are not limited to, cattle dips, aerial spraying, landfills, chemical manufacturing or formulation, chemical storage, or mineral processing. Associated with this list are the EPA registers of contaminated sites in Queensland; the Environmental Management Register (EMR), and the Contaminated Land Register (CLR). The EP Act also sets the obligation for owners and occupiers of land to inform the Queensland EPA of any parcel/s of land that have been used for notifiable activity/s or contaminated by a hazardous substance.

The National Environmental Protection Council (NEPC) National Environmental Protection (Assessment of Site Contamination) Measures (NEPM) set health based investigation levels (HILs) for the assessment of contaminated soil and water. The environmental investigation levels (EILs) and health based investigation levels (HILs) used for the assessment of soil in this PSI include:

- The Environmental Investigations Levels (EILs) published in the "Draft Guidelines for the Assessment & Management of Contaminated Land in Queensland".

"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.

6.3.2.4 Existing Environmental Values

Land within the CSG fields study area comprises rural farmland with specific land use including grazing, cropping, forestry, and pre-existing gas field development. Infrastructure is minimal however there are a number of rural secondary roads linking the major regional road network as well as numerous gas field access roads.

A full description of the environmental values of land within and surrounding the proposed CSG field development is provided in Section 6.3.1.4.

Baseline Contamination Assessment Findings

The potential for existing land contamination considered the predominant land uses within the study area and likely notifiable activities as defined under the EP Act Schedule 3. Notifiable land uses include cattle dips, aerial spraying operational areas, landfills, chemical manufacturing or formulation, chemical storage, or mineral processing infrastructure.

Santos has existing CSG fields operating in Fairview and Roma. Due to the nature of the industry contaminated land issues are minimal. The major source of contamination observed at the existing

Santos operations is from lube oils and diesel fuel spills. Santos recognises these sources of contamination through environmental field audits and is implementing engineering controls, management controls to reduce further contamination. Santos is also treating or disposing of the hydrocarbon impacted soils at each site where leaks were documented.

6.3.2.5 Potential Impacts and Mitigation Measures

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

- Existing areas of potential concern (as described in Section 6.3.2.4 above); and
- CSG fields development activities.

Areas of Potential Concern

Potential Impacts

The major impacts associated with areas of potential concern (as discussed in Section 6.3.2.4 above) include excavation of potential contaminants during construction or decommissioning activities, and either mobilisation of such contaminants off-site or exposure of contaminants to workers and the resultant health risks associated with this.

Mitigation Measures

The potential mitigation measures to minimise these impacts include:

- Where practicable avoid CSG field development activities in know AOPC;
- Conduct site management works at the AOPCs that cannot be avoided. so that project related impacts are minimised (e.g. develop a site management plan limiting the nature of activities that can be carried out on the site);
- When excavating any existing potentially contaminated fill material, it will be segregated and the fill material will be analysed prior to removal from site. If contaminated soil is to be removed from site, the EPA regulations for waste transport and disposal will be followed; and/or
- Remediate the AOPC prior to field development activities occurring.

CSG Field Development Activities

Potential Impacts

Potential contamination risks associated with CSG field development activities primarily relate to the construction and operational phases.

The construction phase will involve the generation of drilling fluids and waste oil and chemicals associated with wells and associated infrastructure. Lists of potential wastes that may lead to possible land contamination are listed in Section 5.

The operational phase will include the operation of CSG wells, compressor stations, potentially reverse osmosis (RO) systems, injection wells, and a network of flowlines. Inappropriate storage and use of liquid wastes generated from CSG fields activities has the potential for land and water contamination. For a discussion of proper storage, handling and disposal of liquid wastes refer to Section 6.5 and Section 5 respectively.

Wastewater (associated water) from well operations will also be generated. Refer to Section 6.7 for further details on management options that are being considered for associated water.

Failure of water treatment systems (hydrocarbon removal) and the possibility of overtopping the ponds has the risk (albeit low) of contaminating nearby surface waters (refer to Section 6.5). Associated water ponds also have the potential risk of leaching from the pond through the soil to possibly the groundwater (refer to Section 6.6).

The generation of putrescible waste associated with worker accommodation during the construction and operational phases will not be disposed or stored within the CSG field development (refer Section 5). Sewage will be treated by onsite sewage treatment systems, and effluent discharged to the surrounding environment via spray irrigation.

Mitigation Measures

The following mitigation measures will be implemented:

- Stockpiles, workshop areas, chemical stores, fuel tanks and waste disposal/storage areas will be located on hardstand or compacted soil. Runoff from these areas will be collected and remediated or disposed of in an approved manner;
- Relevant Australian and Santos standards for the storage and handling of flammable and combustible liquids and dangerous goods will be complied with;
- Where practicable, hazardous chemicals and materials will be replaced with less harmful alternatives. Material safety data sheets (MSDSs) for chemicals used or brought onto the sites will be accessed via the Santos intranet “The Well”. The MSDSs can be downloaded and printed out for use on site and are readily available to workers at all times;
- Spills will be cleaned up immediately. For significant chemical or fuel spills, the site emergency response plan will be followed and the appropriate authorities notified as soon as possible;
- 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. Santos has existing databases for recording the above data, which 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 Competency Based Skills Development Program in appropriate handling, storage and containment practices for chemicals, fuel and other potential contaminants as relevant; and
- 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 extent of AOPC likely to be affected by Santos’ activities is low. Due to the nature of the industry, the potential for land contamination from CSG activities themselves are minimal. As CSG field development progresses, the number of facilities with potential to cause land contamination will increase. The proposed mitigation measures will ensure cumulative impacts will be minimal.

Expansion of Santos’ existing CSG fields and other CSG development projects may also occur in the surrounding areas such as the Bowen and Surat Basins during the life of the GLNG Project. These projects may potentially cause similar contamination of the land within the relevant tenements. The contamination impacts for those projects are expected to be localised as is the case for the GLNG Project and not result in a significant cumulative impact.

It is expected that the other CSG development projects would include some or all of the proposed mitigation measures in relation to contamination as described in this section. By utilising the mitigation methods the expectation is the minimisation of the cumulative impacts on the receiving environment. Table 6.3.22 provides a summary of potential land contamination impacts and mitigation measures for the CSG fields.

Table 6.3.22 Potential Land Contamination Impacts and Mitigation Measures

Aspect	Potential Impact	Mitigation Measures	Objective
Construction			
Surface water/Soil - Hydro carbon contamination	Hydrocarbon spill from storage areas to soils, groundwater and surface water.	• All oil storage facilities to be bunded. • Bunds to be inspected regularly for evidence of leakage. • Spills to be reported and immediately contained. • Contaminated soil to be removed and remediated. • Contaminated water (e.g. stormwater in bund) to be treated.	No loss of hydrocarbons to the environment.
	Diesel spill from construction equipment during operation.	• All vehicles, plant and equipment to be checked regularly for integrity of fuel tanks. • Responsible operating to be enforced to prevent perforation of tanks during clearing operations. • Spills to be reported and immediately contained. • Contaminated soil to be removed and remediated. • Contaminated water to be treated.	No loss of fuel to the environment.
Surface Water/ Soil - Chemical contamination	Chemical spill from construction equipment during operation. Spills/ loss of other chemicals e.g. anti - fouling agent, biocide.	• Refer to diesel spill mitigation measures above.	No loss of chemicals to the environment.
Surface Water/ Soil - Industrial waste contamination	Industrial waste spill to soils, groundwater and surface water.	• Industrial ponds to have appropriate freeboard to reduce overtopping of ponds. • Industrial waste storage tanks to be bunded. • Bunds to be inspected regularly for evidence of leakage. • Spills to be reported and immediately contained. • Contaminated soil to be removed and remediated. • Contaminated water (e.g. stormwater in bund) to be treated.	No loss of industrial waste to the environment.

Aspect	Potential Impact	Mitigation Measures	Objective
		• Industrial waste to be treated or disposed of in accordance with relevant legislation.	
Surface Water/ Soil - Nutrient contamination	Sewage treatment plant (STP) system failure.	• Treatment system to be maintained rigorously. • Outflow quality to be monitored rigorously.	No loss of untreated sewage to the environment.
AOPC	Existing contamination in the project area.	• Phase II Environmental Site Assessment (ESA) to be completed to identify any contamination. • Any identified contamination to be remediated or, Project site to be moved.	No construction in previously contaminated areas.
Operation			
Surface Water/ Soil - hydrocarbon	Wastewater storage pond and constructed wetland sludge potentially containing concentrated effluent contaminants.	• Storage pond to be lined and sludge (where present) shall be characterised prior to infilling and remediation.	No change in soil characteristics from operation of the storage pond and wetland.
Surface Water/ Soil - Hydrocarbon contamination	Hydrocarbon spill from storage areas to soils, groundwater and surface water.	• Refer to the construction section above.	No loss of hydrocarbons to the environment.
Surface Water/ Soil - Industrial waste contamination	Industrial waste spill to soils, groundwater and surface water.	• Refer to the construction section above.	No loss of industrial waste to the environment.
Surface Water/ Soil - Nutrient contamination	STP system failure.	• Refer to the construction section above.	No loss of untreated sewage to the environment.
Surface Water/ Soil - hydrocarbon	Wastewater storage pond and constructed wetland sludge potentially containing concentrated effluent contaminants.	• Refer to the construction section above.	No change in soil characteristics from operation of the storage pond and wetland.

Aspect	Potential Impact	Mitigation Measures	Objective
Decommissioning			
Surface Water/ Soil - hydrocarbon	Wastewater storage pond and constructed wetland sludge potentially containing concentrated effluent contaminants.	• Refer to the construction section above.	No change in soil characteristics from operation of the storage pond and wetland.
Surface Water/ Soil - Hydrocarbon contamination	Storage areas - Residual hydrocarbons in surrounding environment.	• Sampling to be conducted at base of bunded storage areas. • Any contaminated soil to be removed.	No change in soil characteristics as a result of CSG field operations.
Surface Water/ Soil Hydrocarbon contamination	Compressor sites - Residual hydrocarbons in surrounding environment.	• Refer to storage areas above for mitigation measures.	No change in soil characteristics as a result of CSG field operations.
Surface Water/ Soil - Salts and metals contamination	Removal of pond infrastructure and disposal of accumulated salts, boron, fluoride etc.	• Ponds to be managed in accordance with current best practices and agreed end uses including: – Leaving insitu by agreement with stakeholder. – Excavation and removal of accumulated sediment then reinstatement of landform. – Retention of lining insitu and welding of liner to enclose sediment before shaping to reinstate landform.	Appropriate pond management for end of project life.

6.3.2.6 Summary of Findings

Baseline Contamination Assessment

The contaminated land study concludes that impacts associated with the development of the CSG fields as part of the GLNG Project can be appropriately managed by implementing a range of mitigation measures including construction techniques, engineering controls, operational procedures and planning tools.

An indicative assessment was undertaken to identify land uses within the study area with the potential for land contamination. Activities within the CSG field areas include existing Santos CSG operations, conventional gas operations within the area, as well as grazing and cropping land uses.

In a manner consistent with the protocols developed under this EIS for Phase 2 (post EIS) processes, consideration to site specific land contamination investigations as part of the site specific development of the CSG fields will be undertaken.

CSG Fields Development Activities

The risk assessment for the construction, operation and decommissioning phases of the CSG fields development identified activities with the potential for land contamination. None of the activities were assessed as having a high residual risk, with all having a low risk following the adoption of proposed management measures.