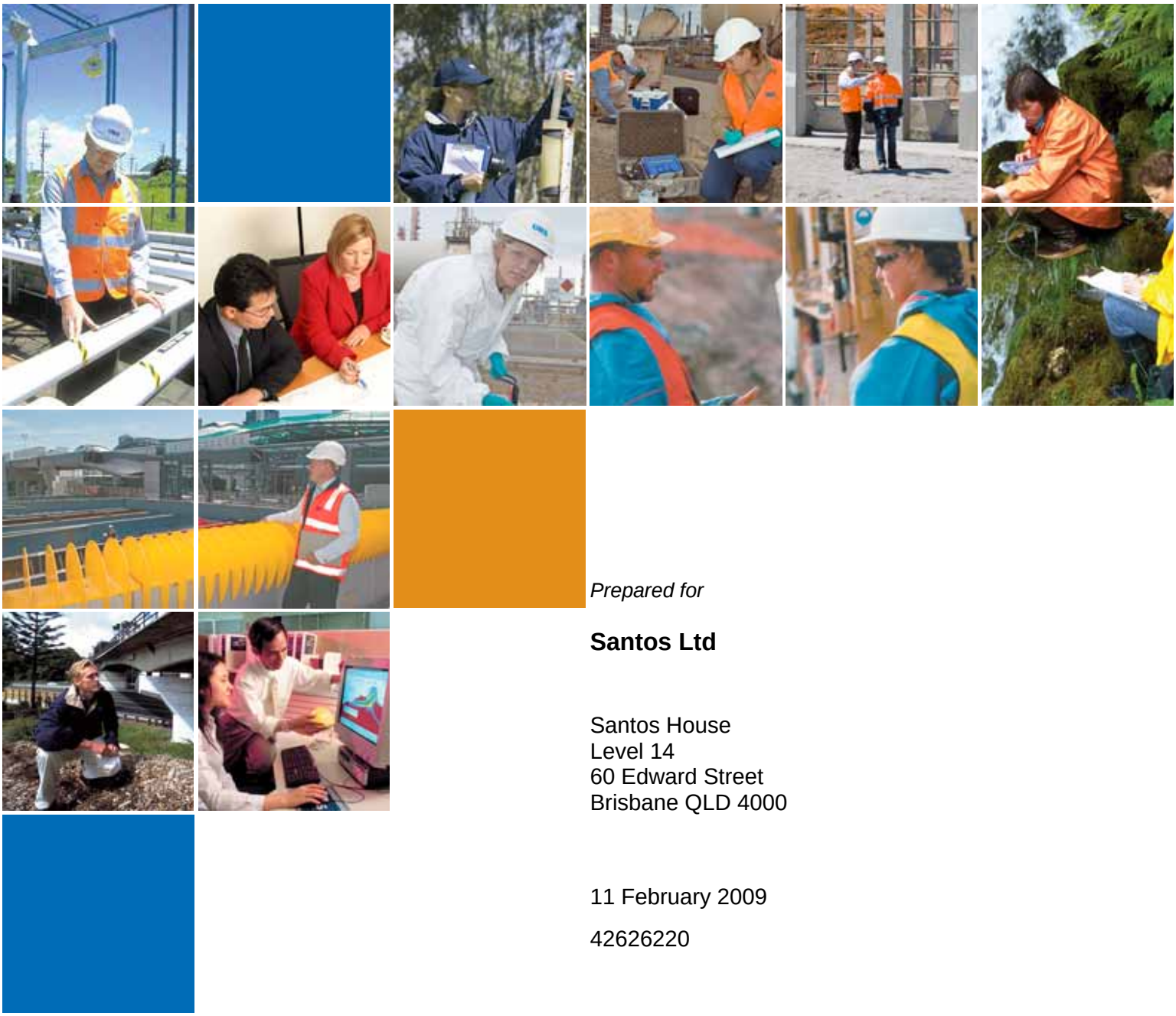
# FINAL REPORT

# GLNG Environmental Impact Statement - Coal Seam Gas Field Terrain Soils and Land Capability



*Prepared for*

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Status: Final

# Table of Contents

# Table of Contents

# Tables, Figures, Drawings, Appendices

## Tables



## Figures

# Tables, Figures, Drawings, Appendices

# Tables, Figures, Drawings, Appendices



## Appendices

# Description and Assessment of Environmental Values

Section 1

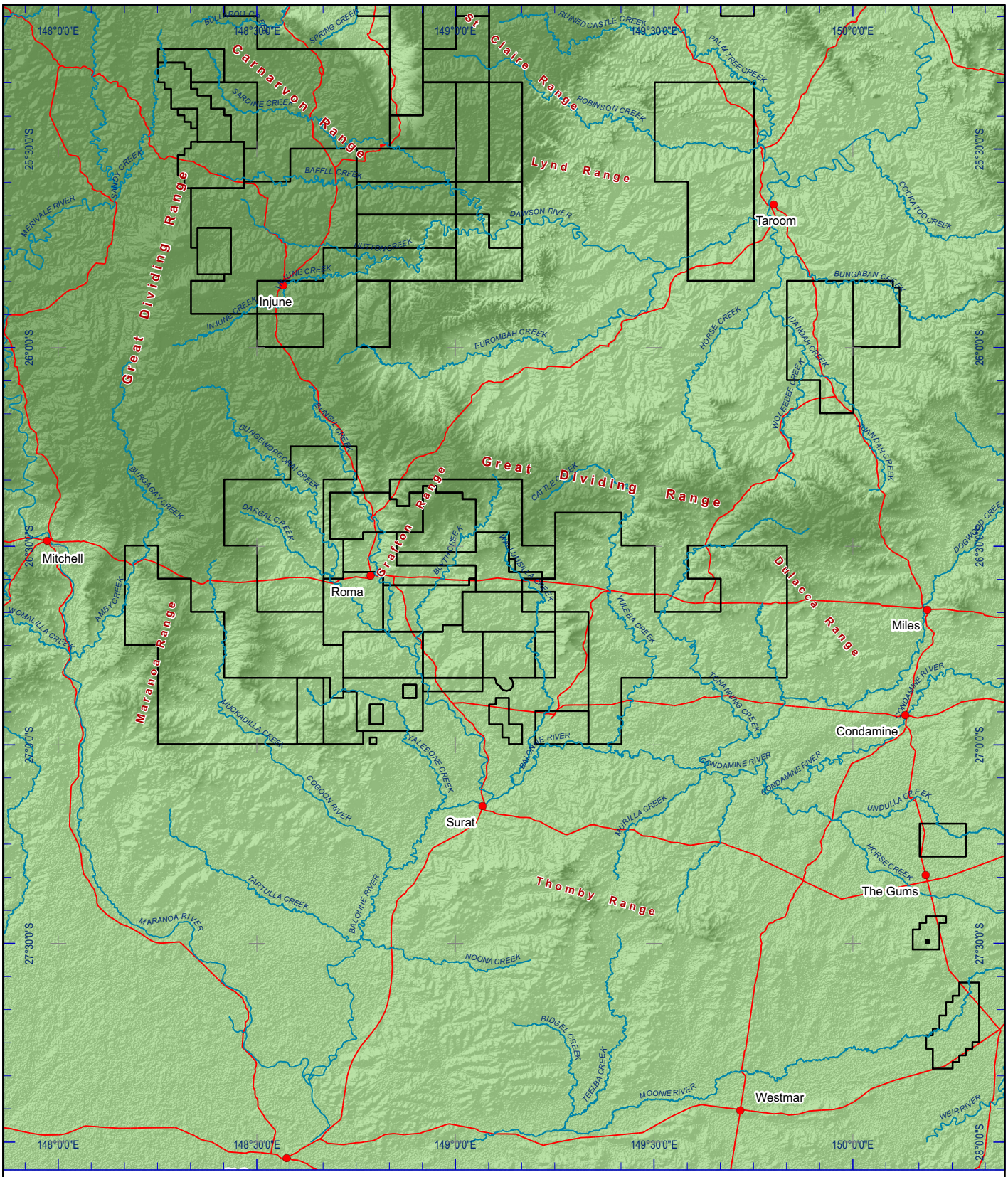
## 1.1 Introduction and Scope of Works

The Santos GLNG Project is developing coal seam gas (CSG) fields located in inland Central Queensland. The gas fields occupy a total of approximately 22 000km$^2$ between the Moonie River south of The Gums and the Nogoa River northeast of Emerald. The overall study area of 73,500 km$^2$, which includes the nine fields, has been studied in broad detail, while the Roma, Fairview and Arcadia Valley fields, have been studied and mapped at a higher level of detail as development in the fields is expected to occur in the foreseeable future. **Figures 1-1 and 1-2** show the locations of the CSG fields together with towns, main roads, streams and mountain ranges.

The Terms-of-Reference for this study require that a terrain analysis of the CSG fields be carried out as a basis for the description of the physical environment in terms of geological regimes, landform and associated soil conditions, and also as a means of identifying potential engineering and environmental impacts that may result. Measures required to mitigate any such impacts were also to be identified.

The scope of works required for the terrain, soils and land capability assessment study were as follows:

- Describe the topography and general geomorphology within the CSG fields including any significant features of the landscape and areas of high conservation values;
- Describe the geological regimes that occur within the CSG fields and identify any geological hazards or features that may impact on, or be impacted by field development activities:
- Landforms and associated soils to be mapped and described at an appropriate scale with soils described according to the Australian Soil and Field Survey Handbook McDonald et al. 1990 and the Australian Soil Classification (Isbell 2002);
- Describe and map the soils that occur within the CSG fields with comments on the likely availability of topsoil resources for rehabilitation of disturbed areas;
- Describe the likely physical and chemical properties of the soils and associated terrain types as a basis for determining the erosion potential and any likely impact on agricultural land productivity;
- Provide an assessment of soil stability including dispersion characteristics and suitability for CSG field development construction activities.
- Identify and comment on any areas that may contain acid sulfate soils (ASS); and
- Identify the occurrence of good quality agricultural lands (GQAL) with respect to potential cropping and grazing enterprises.





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| LNG / URS | GLADSTONE LNG PROJECT<br>TERRAIN, SOILS AND LAND CAPABILITY REPORT<br>CSG FIELD | **TOPOGRAPHY**<br>**CSG FIELDS**<br>**(SOUTHERN SECTION)** |

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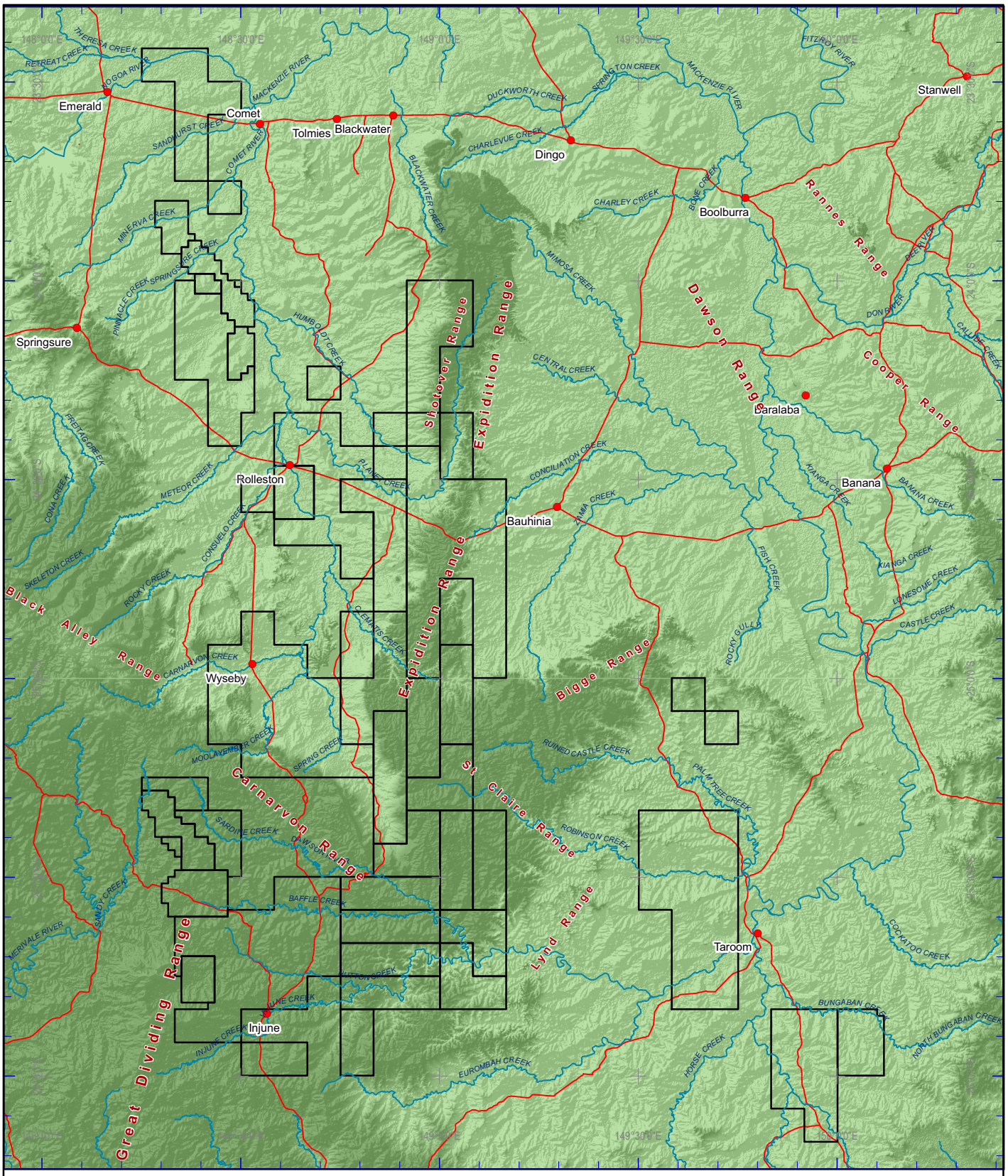






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| LNG / URS | GLADSTONE LNG PROJECT<br>TERRAIN, SOILS AND LAND CAPABILITY REPORT<br>CSG FIELD | **TOPOGRAPHY<br>CSG FIELDS<br>(NORTHERN SECTION)** |

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# Section 1 Description and Assessment of Environmental Values

## 1.2 Method of Assessment

### 1.2.1 Desktop Assessment

The terrain of the CSG field study area has been assessed in terms of geological regimes, landform types and associated soils. Terrain mapping has been carried out with reference to existing geological, topographic and soils information. This information was compiled using the background data sources listed in section 1.2.2 below which have provided the basis for identifying *Landscape Units* that occur within the CSG fields.

As mapped, a landscape unit comprises a single or recurring area of land that is considered to have a predictable 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.

Terrain features are described in this report firstly at a broad level of detail across the CSG fields, then at a higher level of detail over the three active field areas of, Roma, Fairview and Arcadia Valley.

### 1.2.2 Data Sources

The following data were used for the mapping, description and assessment of the physical environment within the CSG fields study area:

- Geological mapping derived from regional geological map sheets of the Surat Basin and the Bowen Basin included in the Geoscience Data Set compiled by the Geological Survey of Queensland (2004 and 2008;).
- Geological descriptive information from Onshore Australia web pages, Geoscience Australia http://www.ga.gov.au/oceans/ea_Onshore.jsp;
- Land resources digital data sets including CSIRO Land Research Series No. 19 (1967) – Lands of the Isaac-Comet Area Queensland; Land Research Series No. 21 (1968) – Lands of the Dawson Fitzroy Area – Queensland; Land Research Series No. 34 (1974) – Lands of the Balonne-Maranoa Area Queensland; and
- Queensland Department of Natural Resources and Water (NRW – 2004) regional compilation of mapping (1:250,000) Central West Region - Good Quality Agricultural Lands (GQAL).

### 1.2.3 Field Investigations

The terrain analysis undertaken for the CSG field study area has essentially involved a preliminary desktop assessment of terrain conditions across the area as a means of identifying areas of potential high engineering/geological constraints. In addition, areas of potentially high environmental impact that may result from construction activities in particular locations were highlighted.

## 1.3 Topography and Geomorphology

### 1.3.1 Regional Physiography in the CSG Fields

The geographic areas being considered in this report covers a considerable areal extent, between south latitude 23 degrees 25 minutes and south latitude 27 degrees 48 minutes, and between east longitude 148 degrees 10 minutes and east longitude 150 degrees 38 minutes. The CSG fields are located mostly within the following physiographic regions, from south to north:

1) **Charleville Tableland**. This region consists of somewhat elevated, gently sloping or gently undulating terrain containing broad, low interfluves formed predominantly on mudrock (lithic and feldspathic sandsone, siltstone, mudstone). The gentle terrain is interrupted by occasional lines of low sandstone hills. The upper reaches of the Balonne River and its tributaries form narrow to fairly broad alluvial plains within the tableland. Part of the Western Downs agricultural area occurs in this physiographic region.

2) **Taroom Hills**. The Taroom Hills consist of gently sloping to strongly undulating dissected upland plateau remnants of mostly broad extent formed predominantly on sandstone, with very steep ravine slopes and sandstone escarpments. Some areas within the Taroom Hills region consist of broad low interfluves similar to those in the Charleville tableland. The region is generally elevated, and includes the Carnarvon Range, which in turn forms part of the Great Dividing Range watershed.

3) **Expedition Scarplands**. This region is somewhat similar to the Taroom Hills, except that the plateau remnant areas are mostly of smaller extent, resulting in a greater proportion of the region consisting of very steep escarpments and ravine slopes. The Expedition Range is part of the Expedition Scarplands physiographic region.

4) **Mackenzie-Dawson Lowlands**. The Mackenzie-Dawson Lowlands consist predominantly of alluvial valleys and lowland plains, interrupted occasionally by residual rises and low hills. Parts of the GLNG CSG fields are located in the western arm of this region, which is drained towards the north by the Brown and Comet Rivers and their tributaries. The Arcadia Valley field is included in the southernmost part of the western arm of the Mackenzie-Dawson Lowlands physiographic region.

Additional physiographic regions occur adjacent to those described above, and fringe the CSG fields. These fringing physiographic regions are described below:

5) **Condamine Lowlands**. This region consists mainly of nearly level to gently sloping broad alluvial plains, although in the geographic area under consideration the Condamine Lowlands are relatively elevated and include the headwaters of several tributaries of the Condamine and Balonne river systems. Low residual hills and rises also occur within this physiographic region.

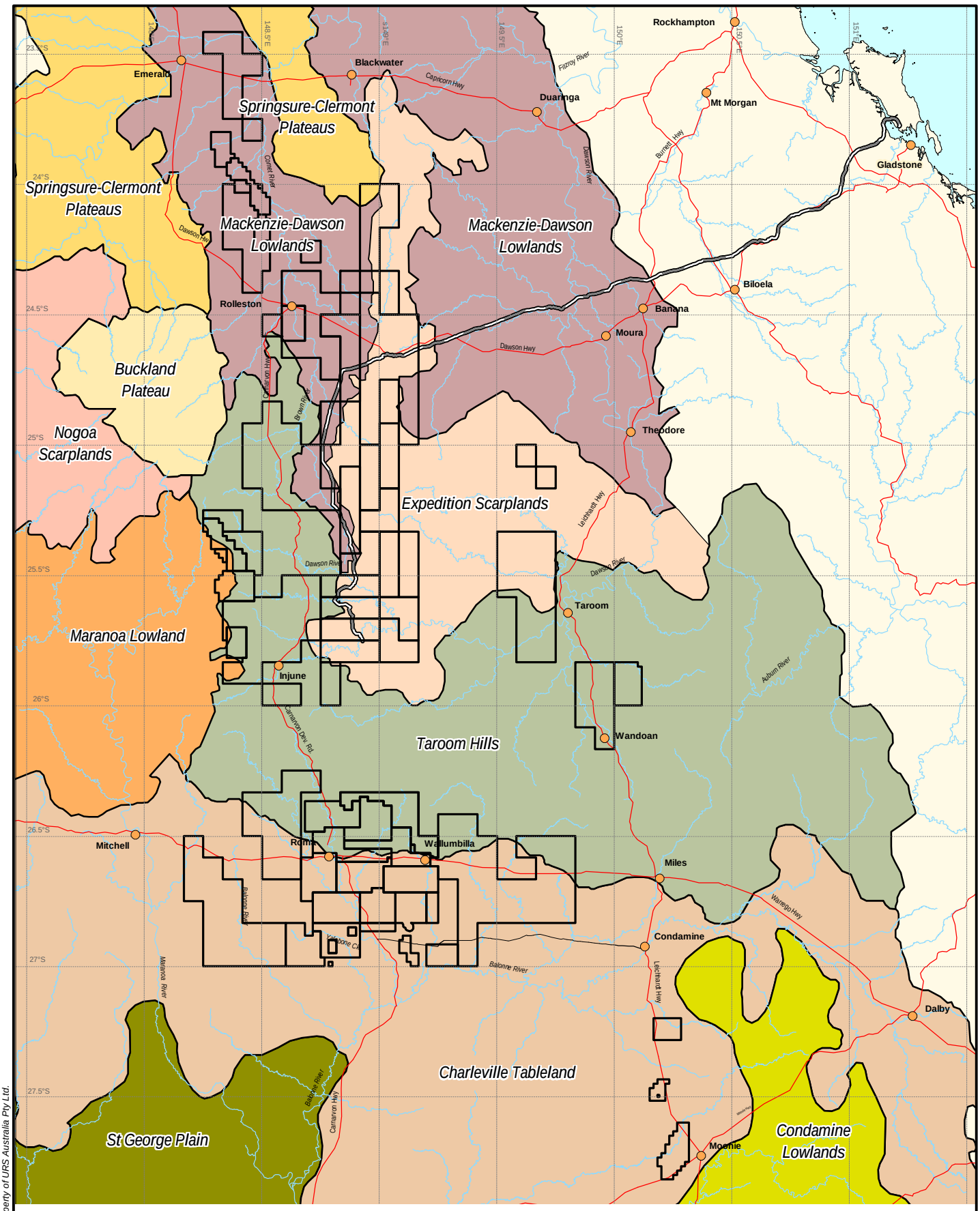
6) **St George Plain**. This region consists mainly of broad alluvial clay plains with level to very gentle slopes formed by alluvial deposition from the southward-flowing Balonne and Maranoa Rivers.

7) **Maranoa Lowland**. Only the upper reaches of the Maranoa Lowland region occur in the vicinity of the CSG fields. These upper reaches consist of moderately sloping piedmont slopes and low hills, with narrow alluvial plains of the Merivale River and its tributaries including Sandy Creek. Further to the west, the piedmont slopes and low hills tend to give way to broader plains, but that only occurs well away from the study area.

8) **Buckland Plateau**. This physiographic region consists of elevated plateau remnants and deep, steep-sided ravines. Most notably, the maximum elevations occurring in this region are above 1200 metres, and the highest in the vicinity of the GLNG project area. The Great Dividing Range continues into this plateau region from the Taroom Hills.

9) **Springsure-Clermont Plateaus**. This region consists of a complex of topographic features, including a large number of flat-topped and rounded hills with steep to moderately sloping sides, piedmont slopes and fans, gentle colluvial slopes and alluvial plains.

A map of the physiographic regions is presented as **Figure 1-3** of this report.





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GLADSTONE LNG PROJECT
TERRAIN, SOILS AND
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CSG FIELD

Title

**PHYSIOGRAPHIC REGIONS**

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### 1.3.2 Project Area Topography

The south-eastern limit of the CSG field 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 extent of the study area is approximately 495 km in the north-south direction and 240 km in the east-west direction.

The lowest elevations within the study area are approximately 200 metres 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 CSG fields are approximately 940 m above sea level, occurring on the crest of Mount Hutton west of Injune, and approximately 1230 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.

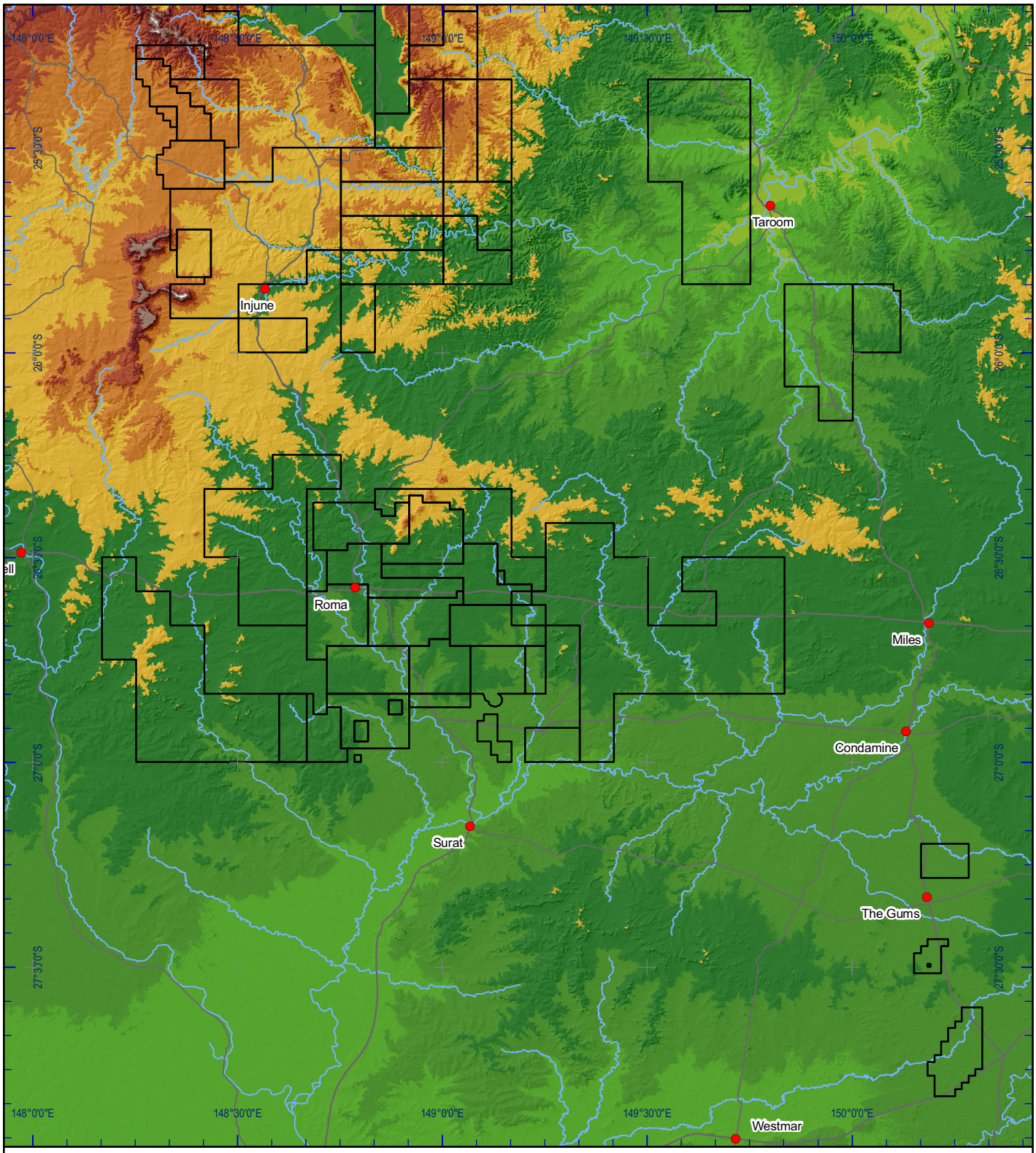
Notable topographic features within the CSG field study area include:

- 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 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 fields; and
- The broad alluvial plains and footslopes of the Arcadia-Comet valley feature extending northward from the northern margin of the Fairview field to the northern limit of the study area adjacent to the Nogoa River.

The surface slopes occurring within the CSG field 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.

**Figures 1-4 and 1-5** are maps at 1:1,500,000 scale of elevations occurring throughout the CSG field study. Similarly **Figures 1-17 and 1-18** are maps of surface slopes occurring throughout the entire CSG field 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 Digital Elevation Model for the CSG Field study area using ArcGIS 3D Analyst and Spatial Analyst software. The same software was then used to generate slope model and hill-shade datasets.

**Figures 1-6 to 1-13** are similarly derived maps at 1:250,000 scale of elevations across the Roma field area. **Figure 1-14** at 1:250, 000 scale shows elevations in the Fairview tenement, and **Figures 1-15 and 1-16** show elevations in the Arcadia Valley field also at 1:250,000 scale.




***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 / URS | GLADSTONE LNG PROJECT<br>TERRAIN, SOILS AND LAND CAPABILITY REPORT<br>CSG FIELD | **ELEVATION**<br>**CSG FIELDS**<br>**(SOUTHERN SECTION)** |

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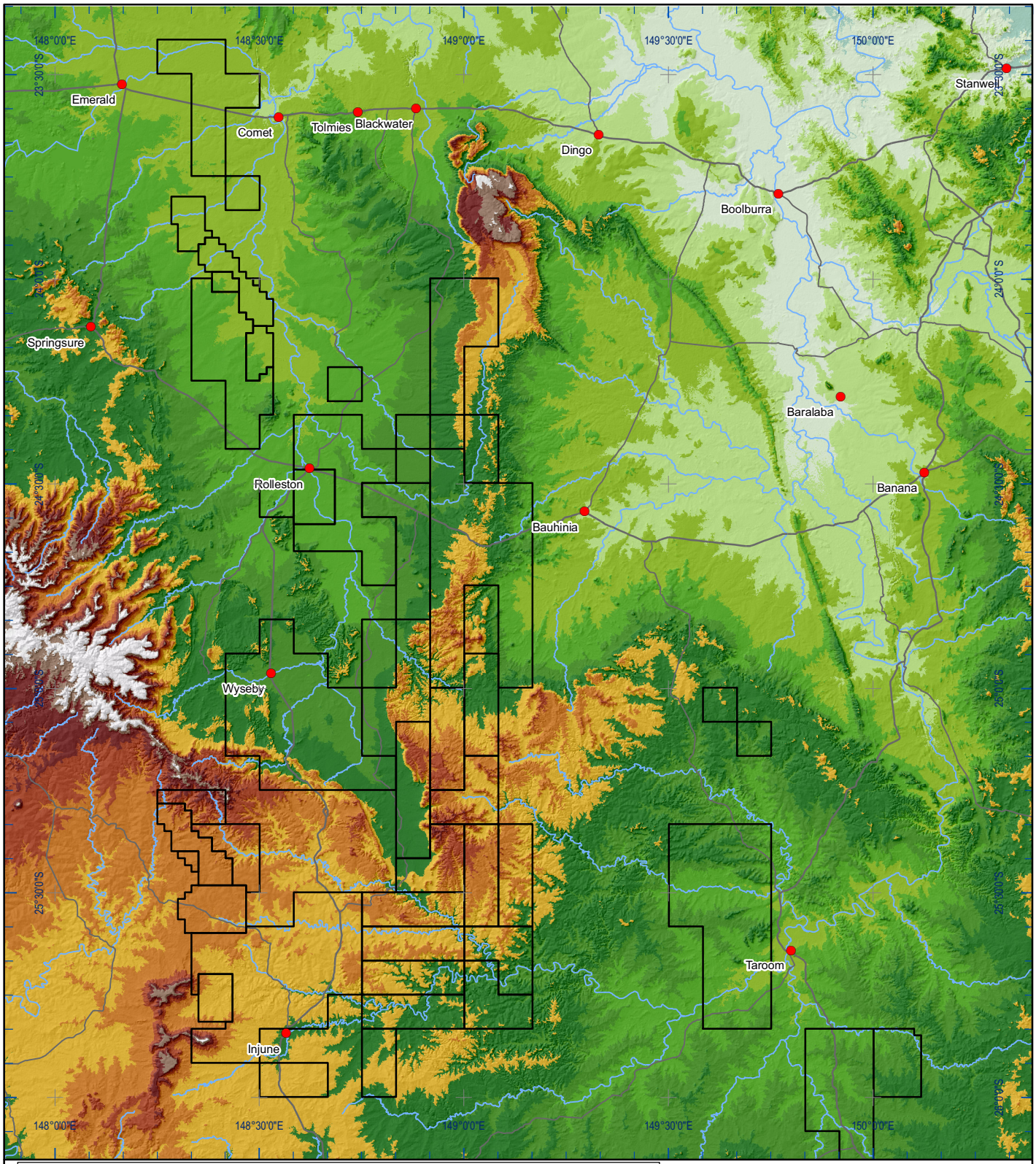


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**Elevation (m)**

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- >150 - 200
- >200 - 250
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- >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





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**CSG FIELDS**
**(NORTHERN SECTION)**

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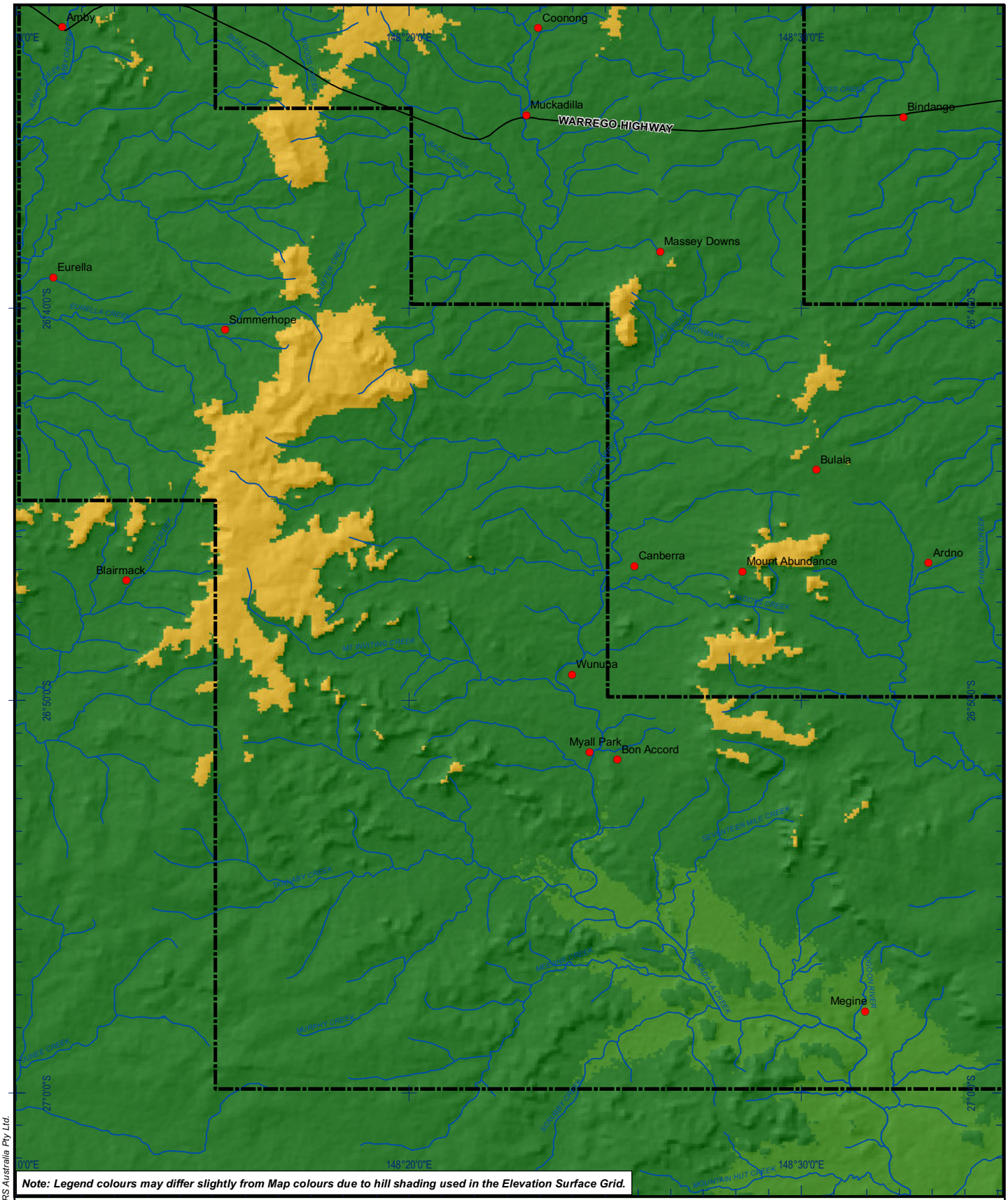


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**Elevation (m)**

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

- Towns / Localities
- Major Roads
- Rivers, Creeks and Tributary Streams
- CSG Field

N W E S

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





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CSG FIELD

Title: **ELEVATION**
**CSG FIELDS**
**ROMA**
**(1 of 8)**

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Figure: **1-6**

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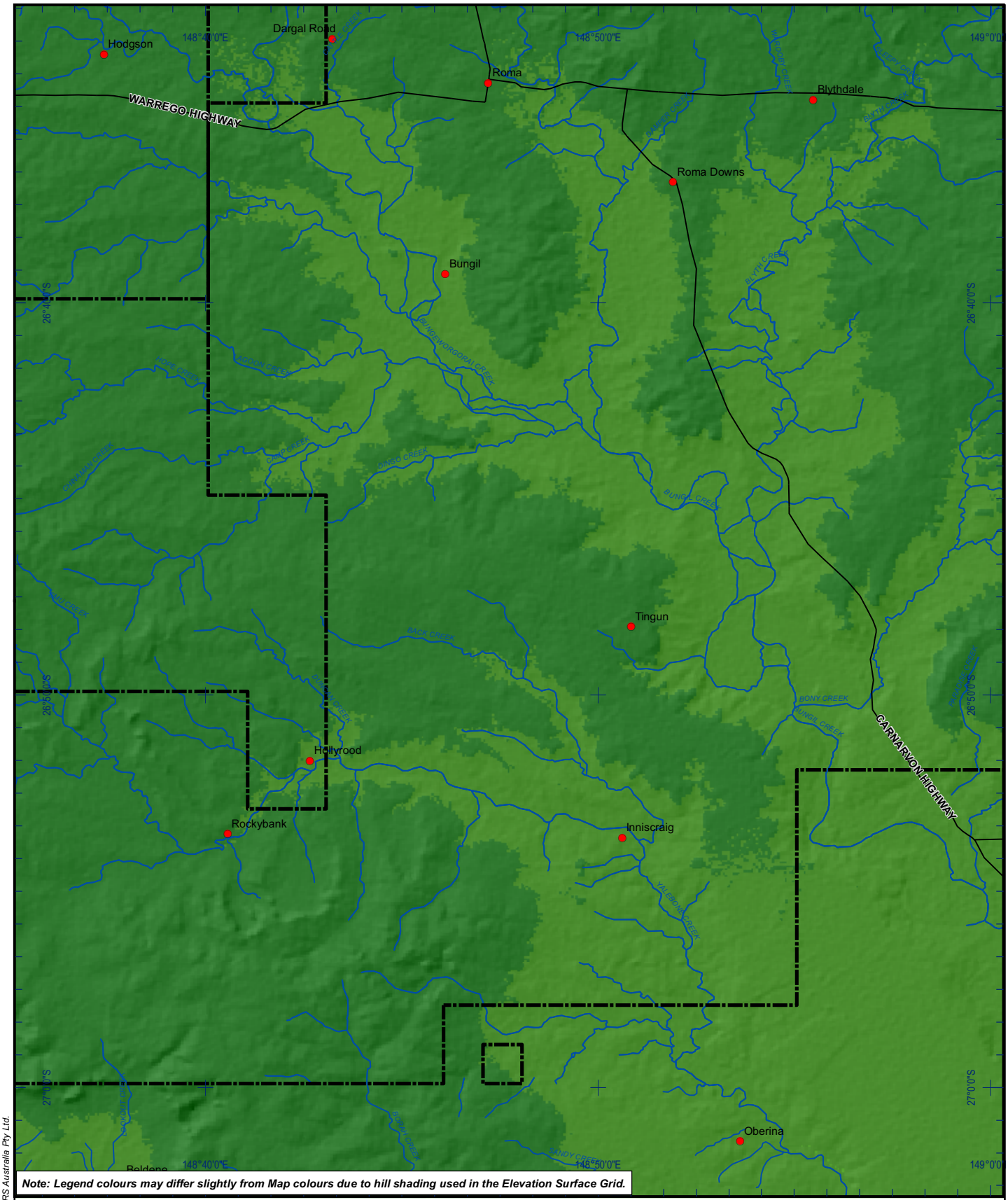


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N W E S

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





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CSG FIELD

Title: **ELEVATION**
**CSG FIELDS**
**ROMA**
**(2 of 8)**

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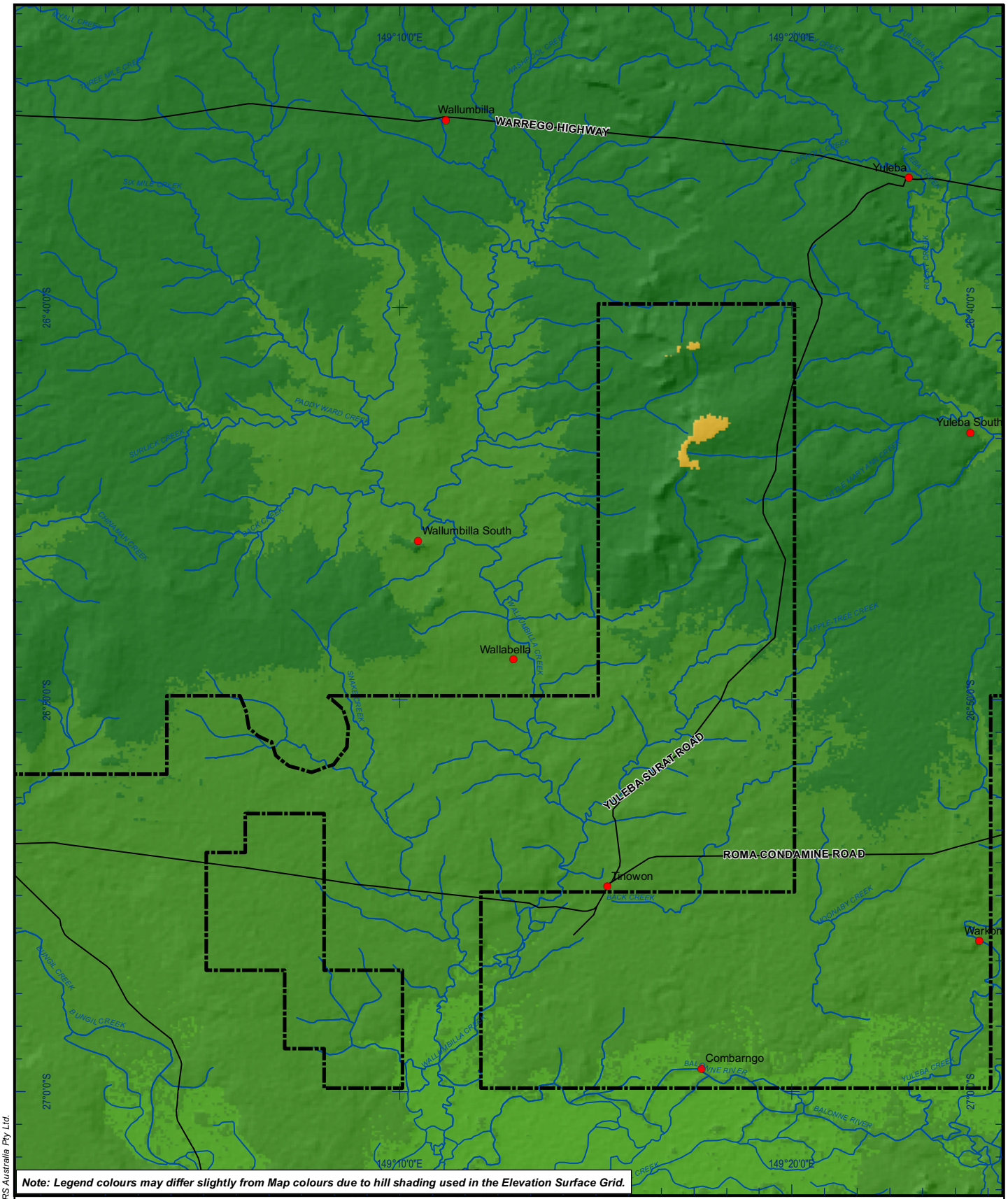






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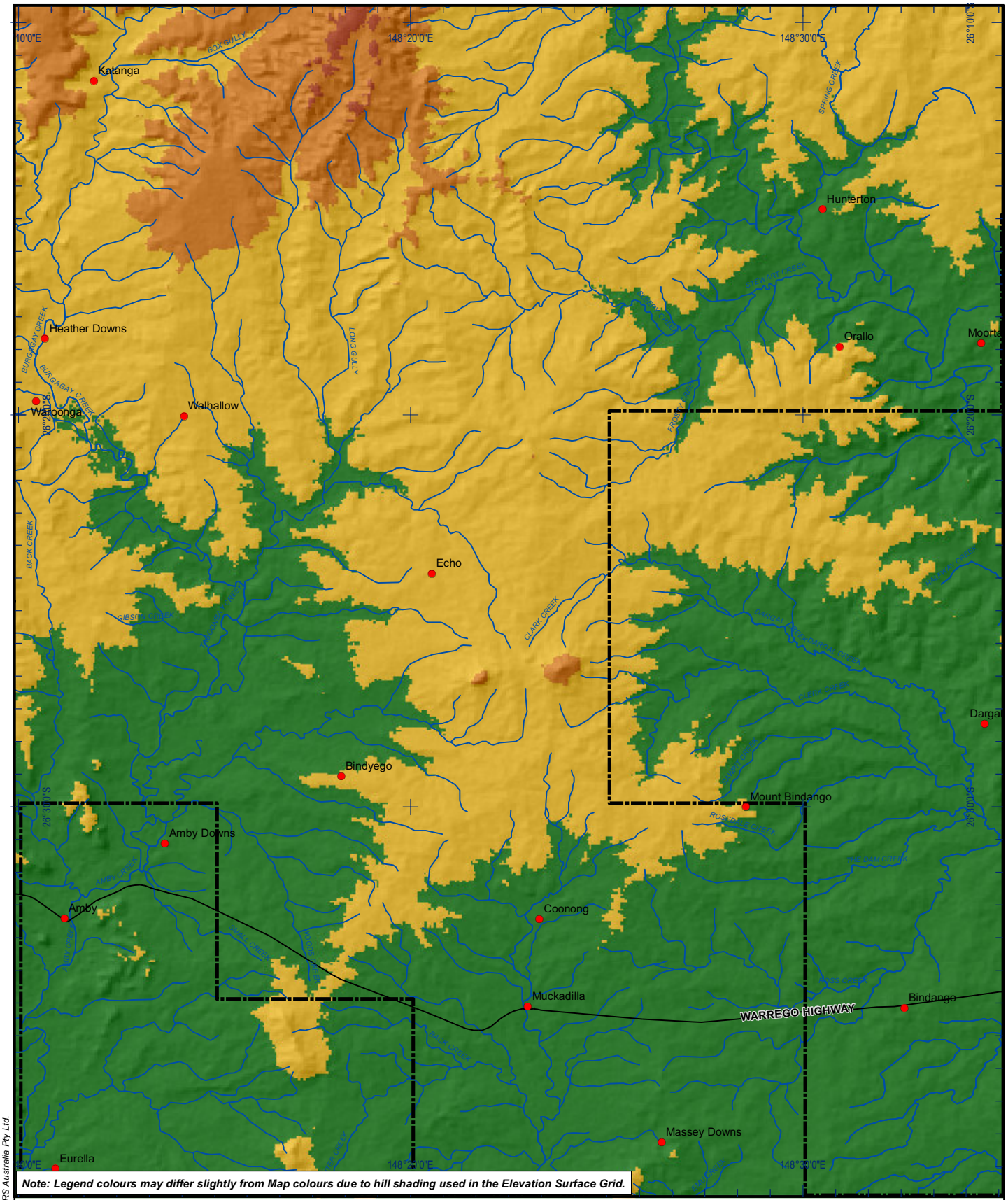






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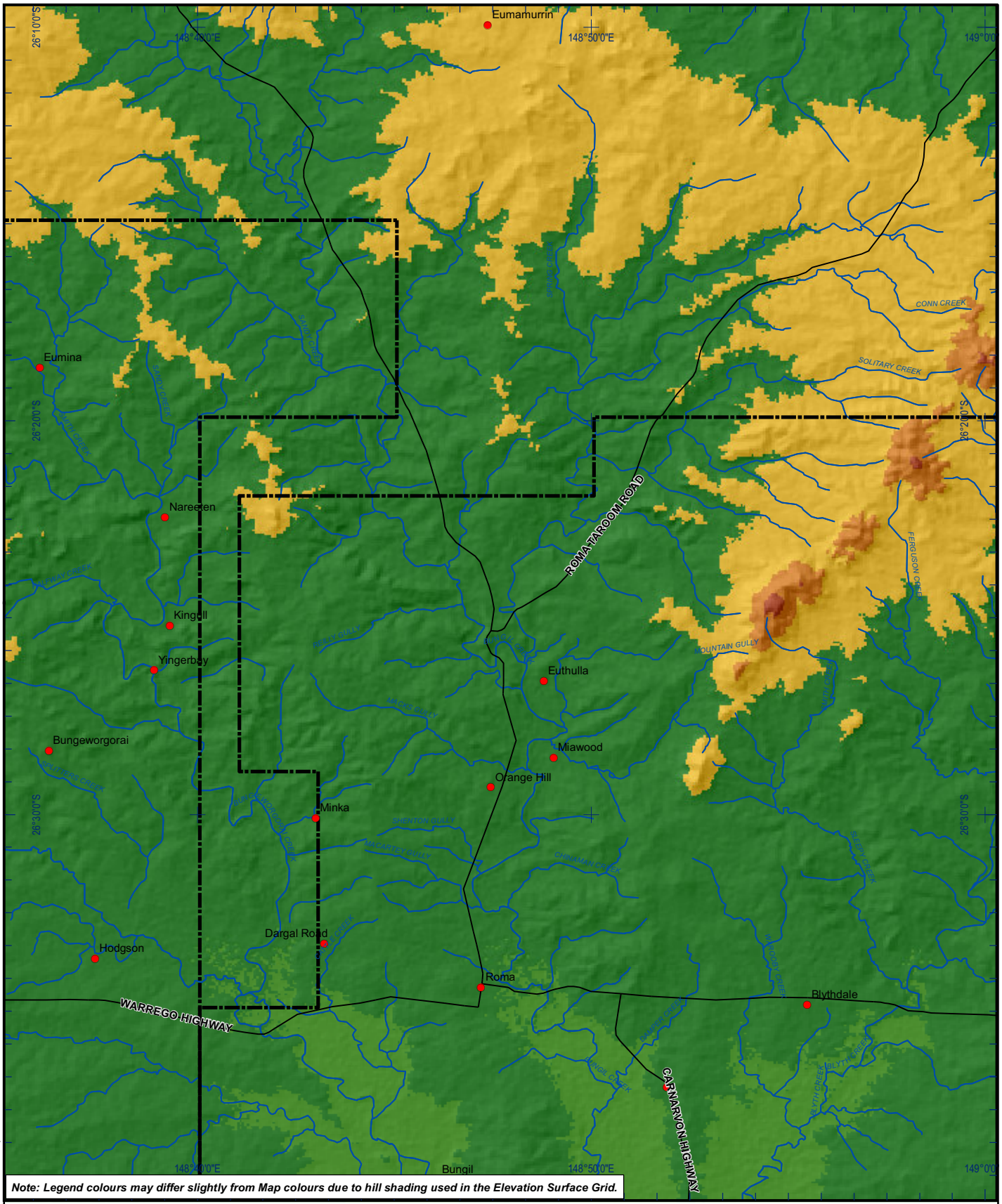


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- Towns / Localities
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- CSG Field

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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CSG FIELD

Title: **ELEVATION**
**CSG FIELDS**
**ROMA**
**(5 of 8)**

| Drawn: LL | Approved: GR | Date: 11-02-2009 |
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| Job No.: 4262 6220 | File No.: 42626220-g-700.mxd | |

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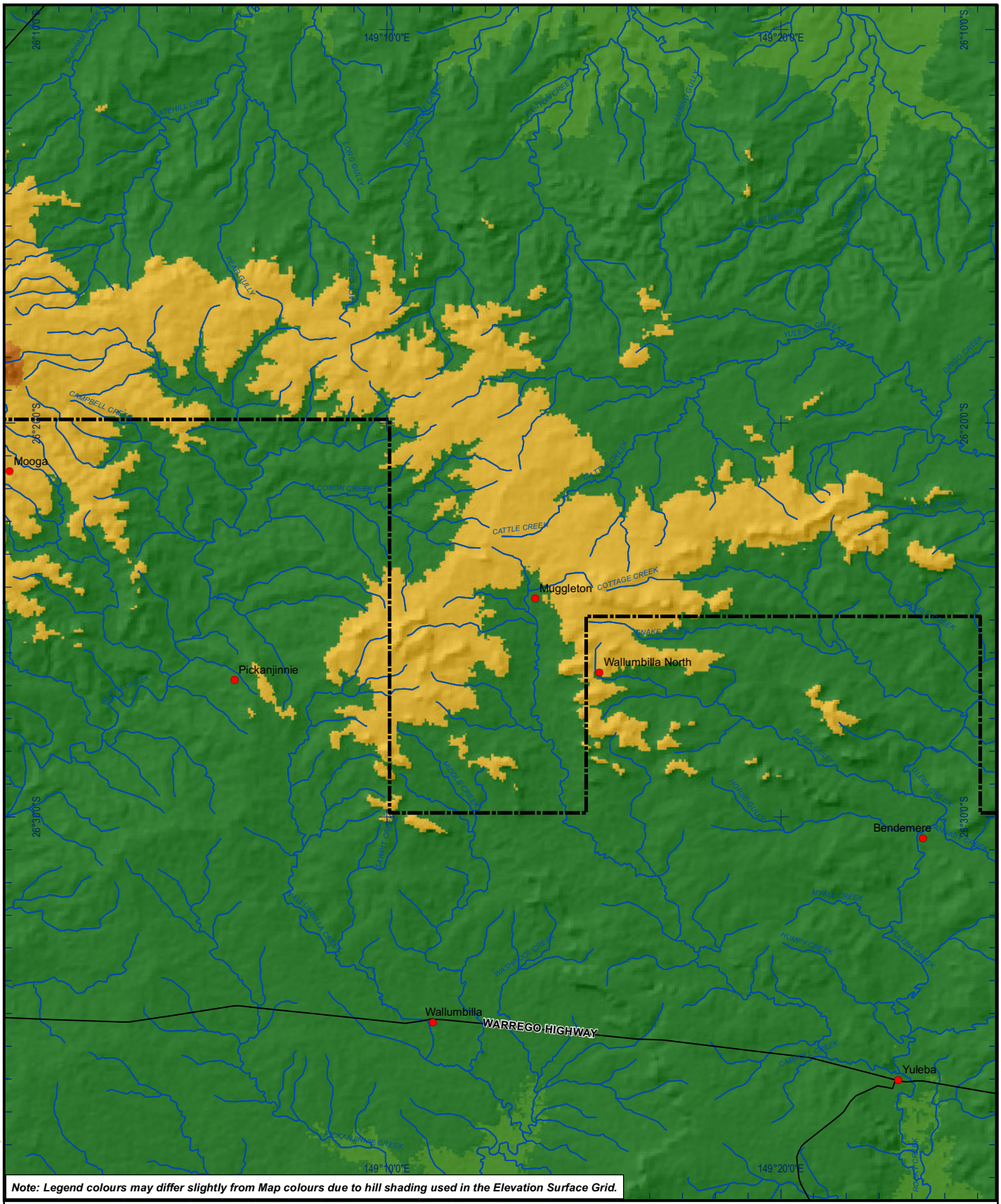


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N W E S

Kilometers
0 0.5 1 2 3 4 5

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





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TERRAIN, SOILS AND LAND CAPABILITY REPORT
CSG FIELD

Title: **ELEVATION**
**CSG FIELDS**
**ROMA**
**(6 of 8)**

| Drawn: LL | Approved: GR | Date: 11-02-2009 |
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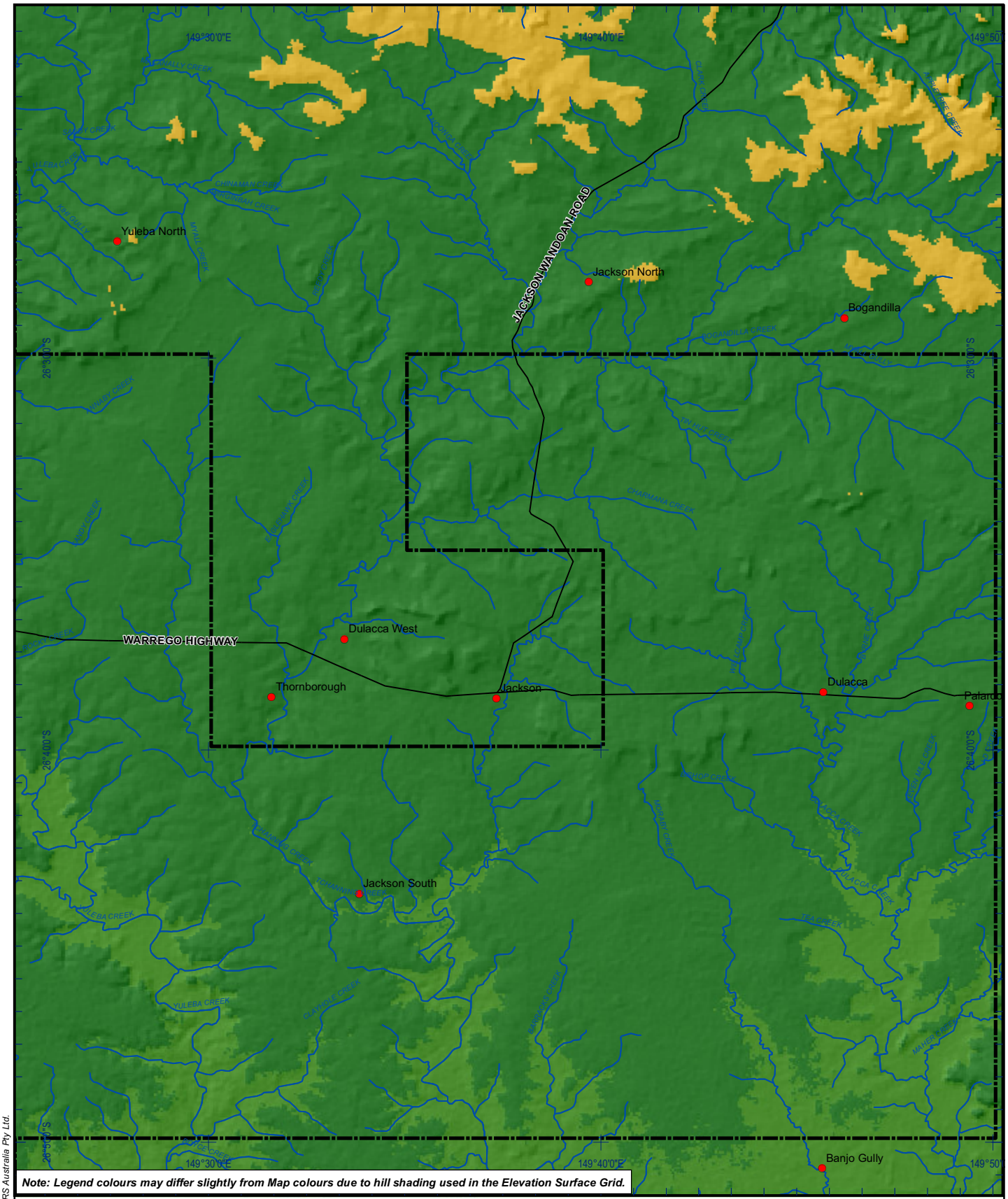


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CSG FIELD

Title: **ELEVATION**
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**ROMA**
**(7 of 8)**

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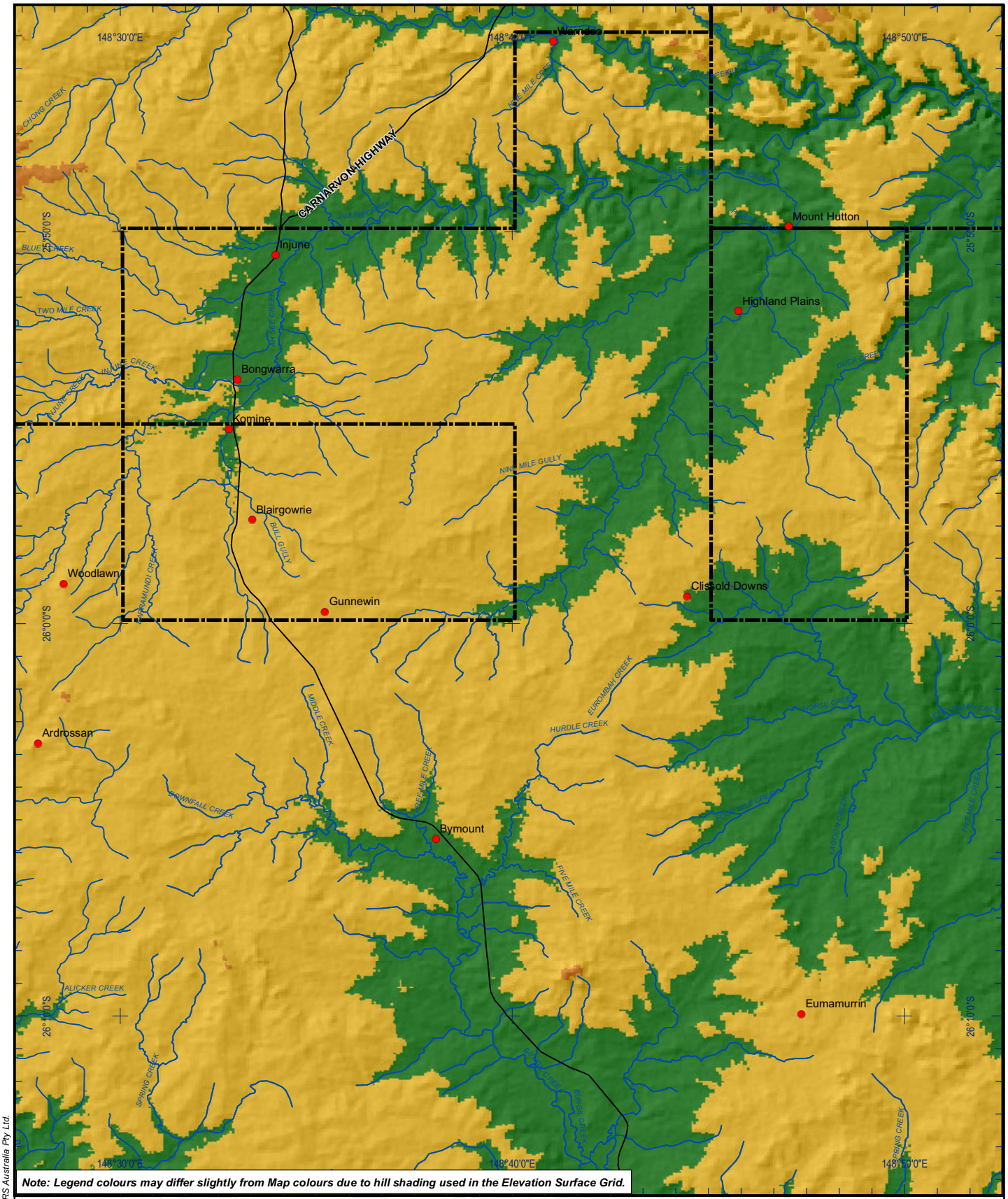






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| | Drawn: LL / Approved: GR / Date: 11-02-2009 | Figure: **1-13** | Rev. A |
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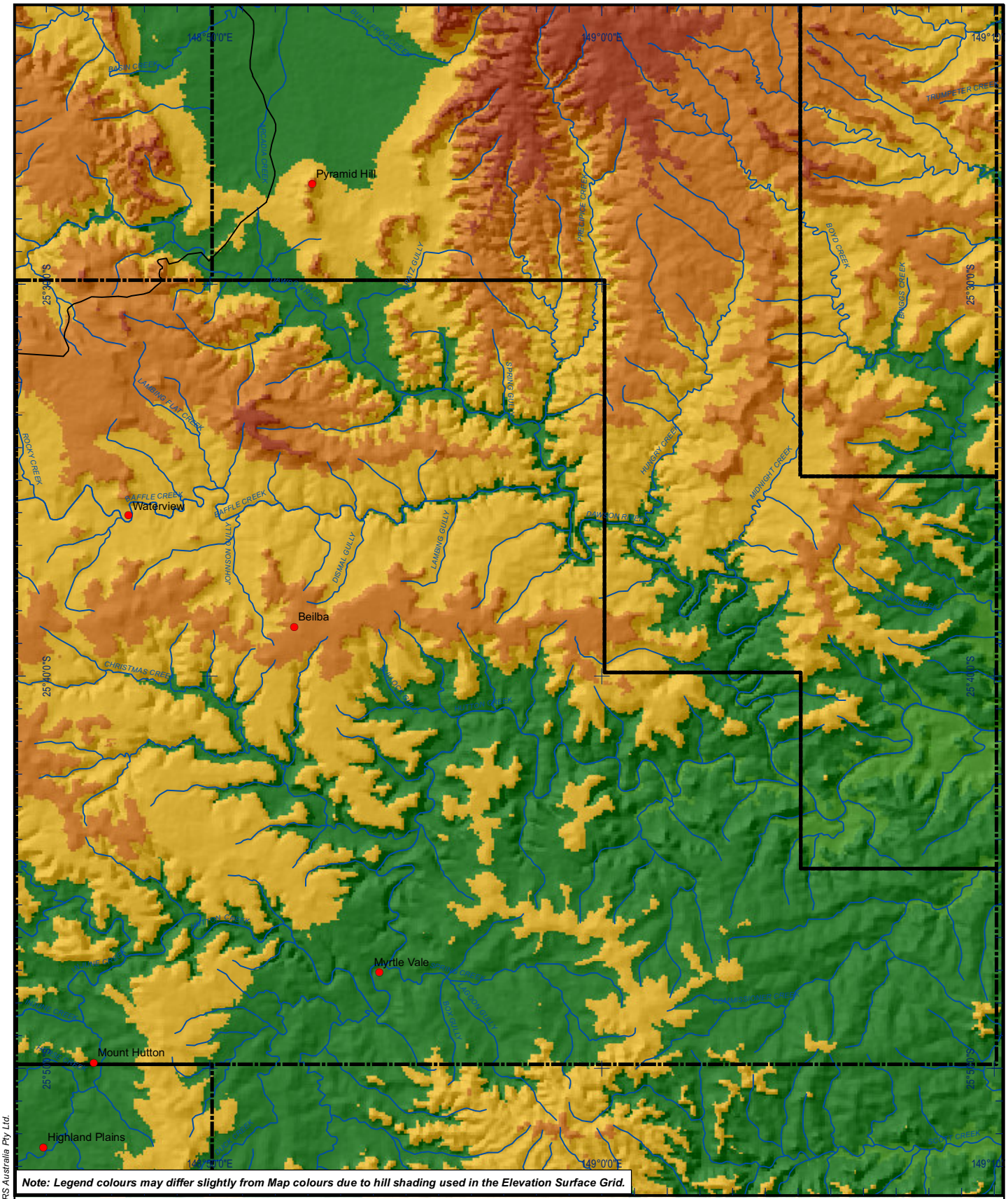



**Elevation (m)**

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

Towns / Localities
Major Roads
Rivers, Creeks and Tributary Streams
CSG Field

N
W E
S

Kilometers
0 0.5 1 2 3 4 5

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





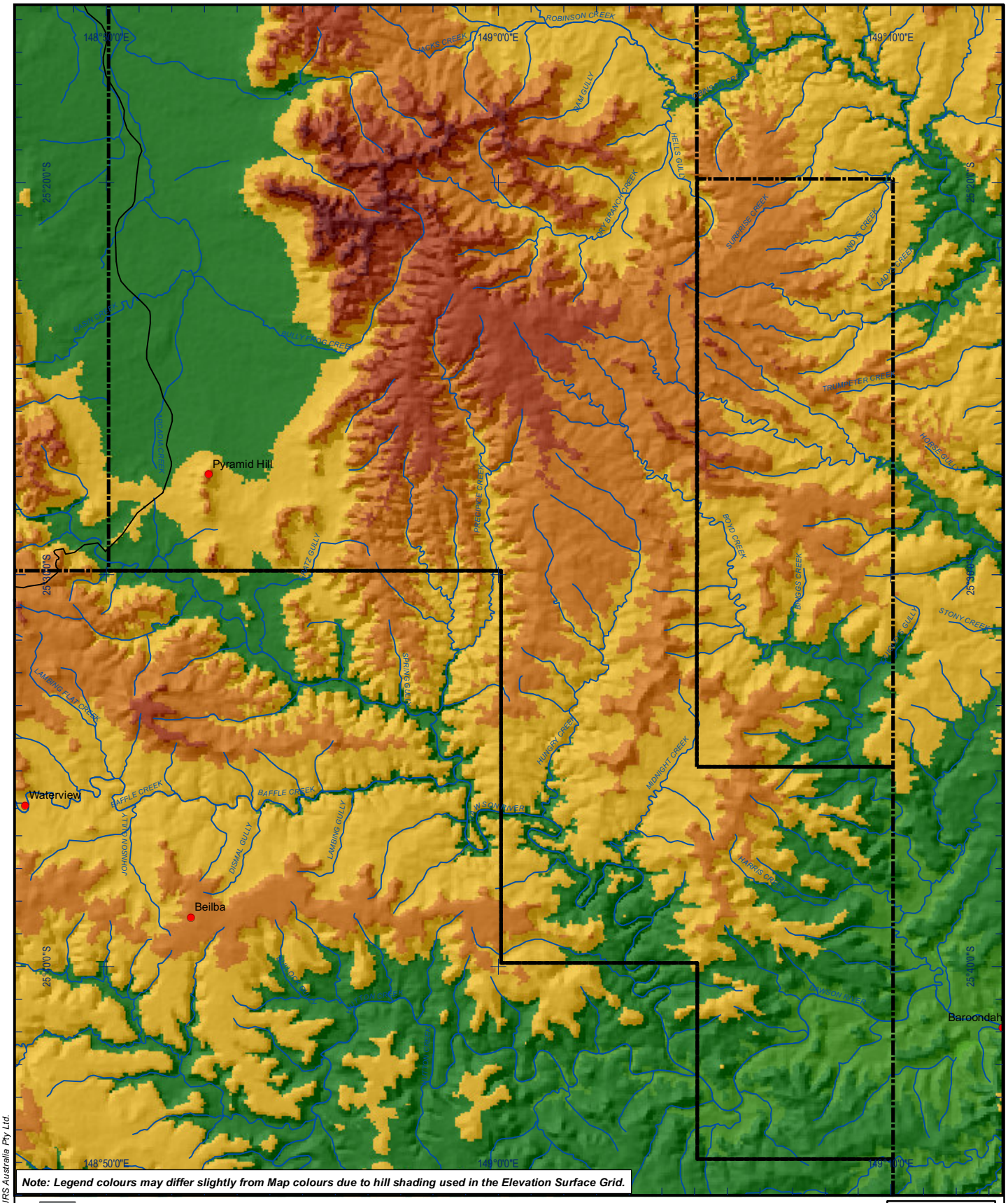
Client: LNG

URS

Project: GLADSTONE LNG PROJECT
TERRAIN, SOILS AND LAND CAPABILITY REPORT
CSG FIELD

Title: **ELEVATION**
**CSG FIELDS**
**FAIRVIEW**

| | | | |
|---|---|---|---|
| Drawn: LL | Approved: GR | Date: 11-02-2009 | Figure: **1-14** |
| Job No.: **4262 6220** | File No.: 42626220-g-700.mxd | | Rev. A<br>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 / Localities
- Major Roads
- Rivers, Creeks and Tributary Streams
- CSG Field

N W E S

Kilometers
0 0.5 1 2 3 4 5

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





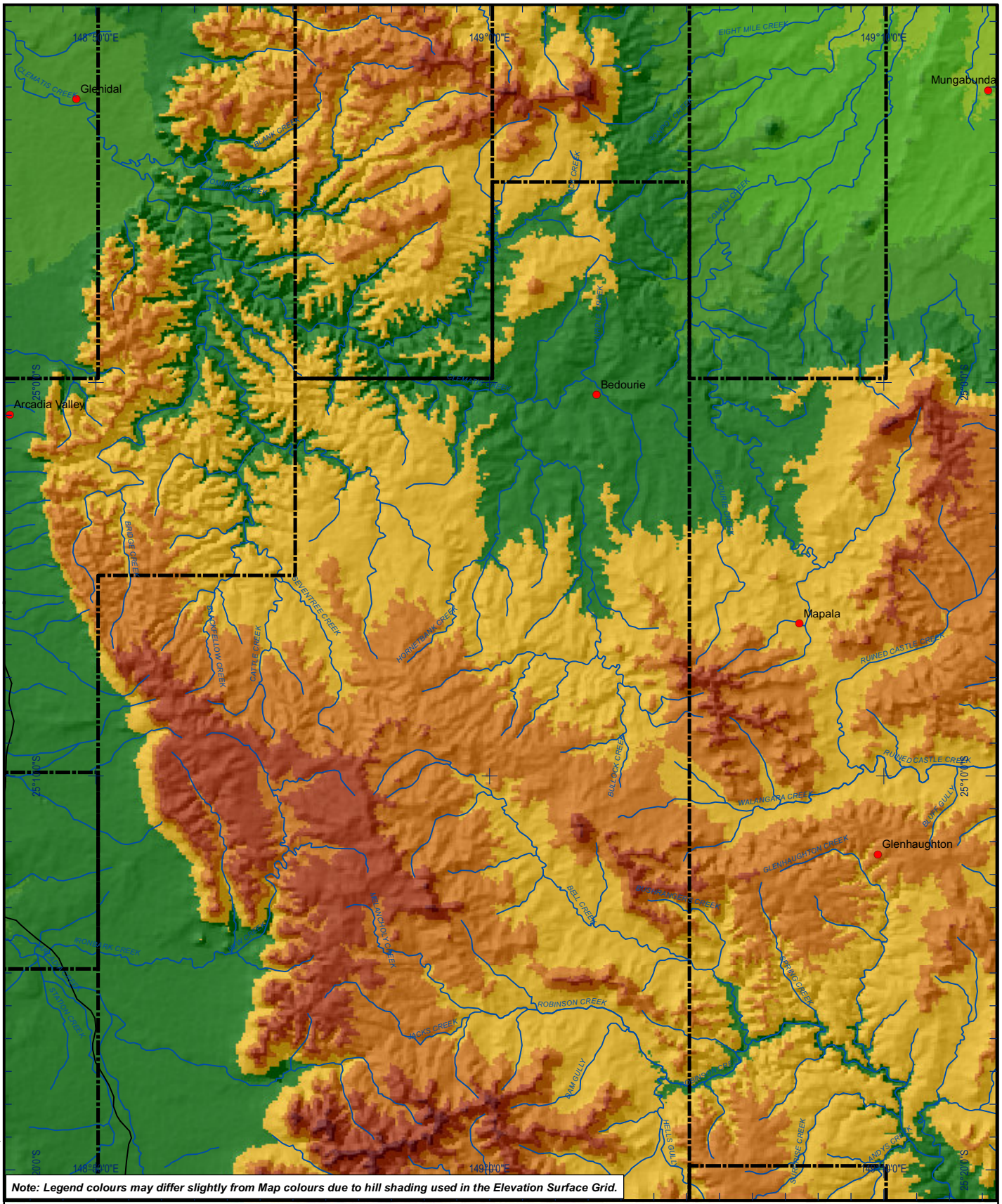
Client: LNG

URS

Project: GLADSTONE LNG PROJECT
TERRAIN, SOILS AND LAND CAPABILITY REPORT
CSG FIELD

Title: **ELEVATION**
**CSG FIELDS**
**ARCADIA VALLEY**
**(1 of 2)**

| Drawn: LL | Approved: GR | Date: 11-02-2009 | Figure: **1-15** | Rev. A |
|---|---|---|---|---|
| Job No.: **4262 6220** | File No.: 42626220-g-700.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 | >250 - 300 | >600 - 700 |
| >50 - 100 | >300 - 400 | >700 - 800 |
| >100 - 150 | >400 - 500 | >800 - 900 |
| >150 - 200 | >500 - 600 | >900 |
| >200 - 250 | | |

- Towns / Localities
- Major Roads
- Rivers, Creeks and Tributary Streams
- CSG Field

N W E S

Kilometers
0 0.5 1 2 3 4 5

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





Client: LNG

URS

Project: GLADSTONE LNG PROJECT
TERRAIN, SOILS AND LAND CAPABILITY REPORT
CSG FIELD

Title: **ELEVATION**
**CSG FIELDS**
**ARCADIA VALLEY**
**( 2 of 2)**

| | | | |
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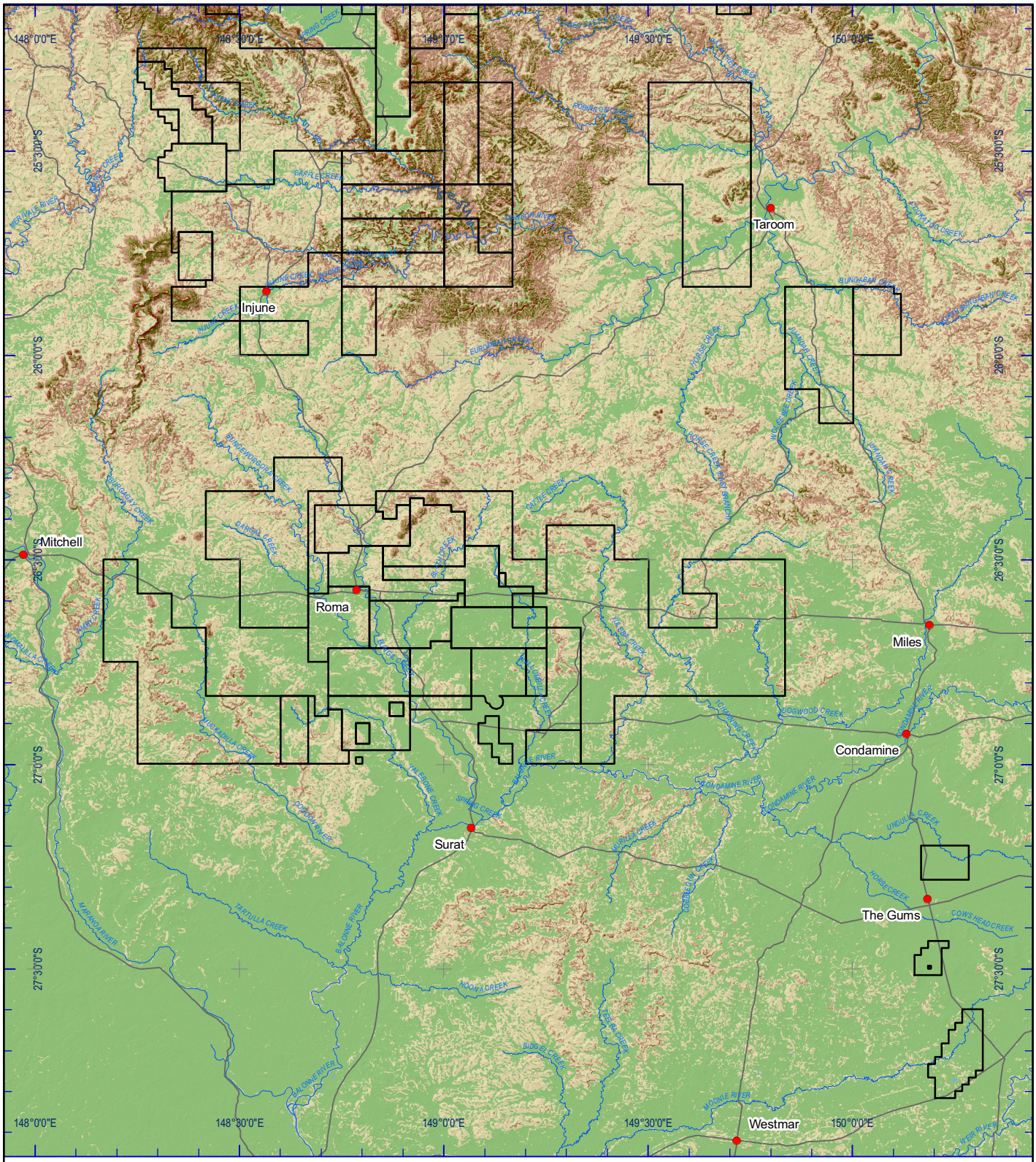
| Drawn: LL | Approved: GR | Date: 11-02-2009 | Figure: **1-16** |
| Job No.: **4262 6220** | File No.: 42626220-g-700.mxd | | Rev. A<br>A4 |




**Slope Class and 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





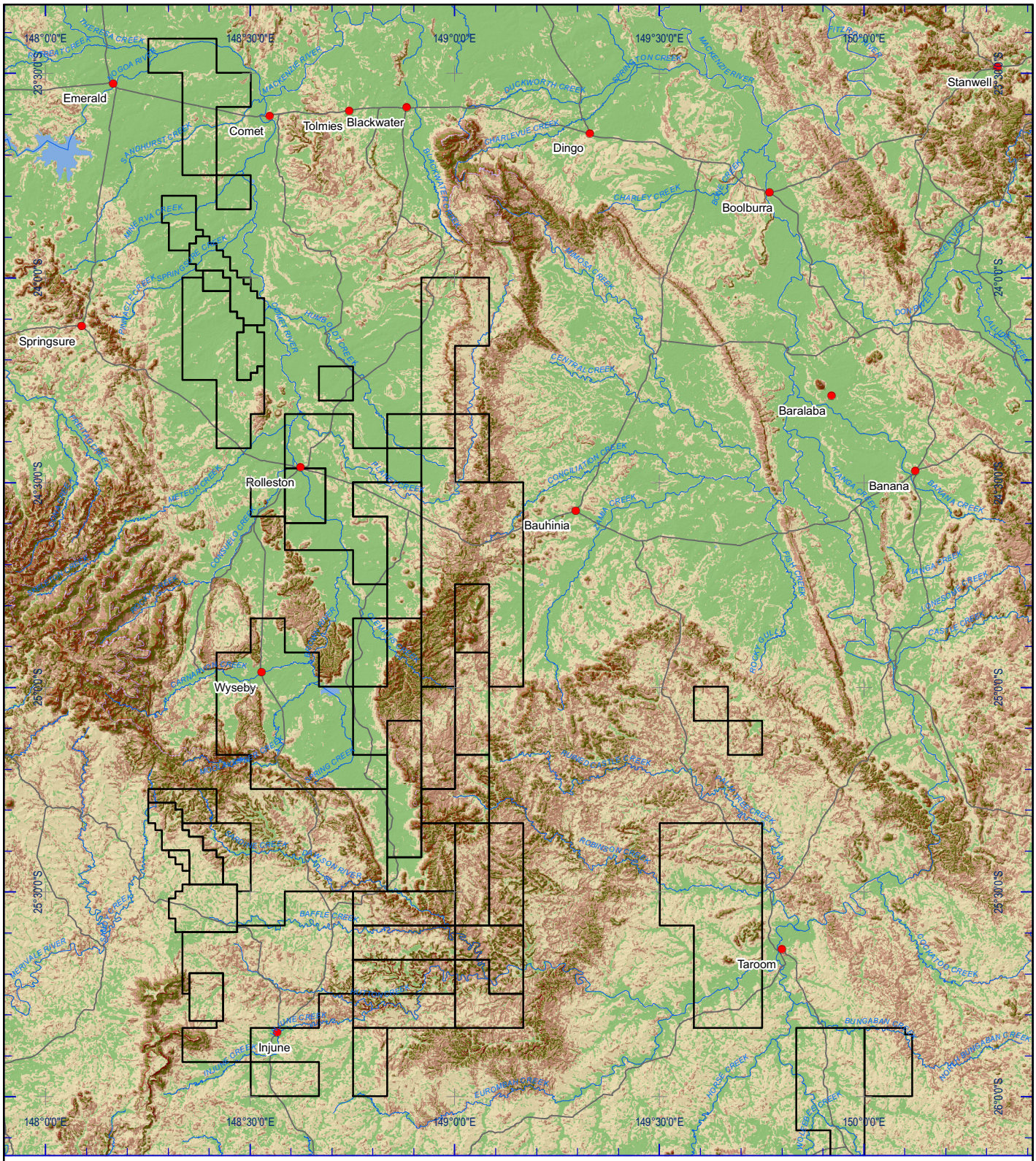
Client: LNG

URS

Project: GLADSTONE LNG PROJECT
TERRAIN, SOILS AND LAND CAPABILITY REPORT
CSG FIELD

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

| | | | |
|---|---|---|---|
| Drawn: MG | Approved: GR | Date: 11-02-2009 | Figure: **1-17** |
| Job No.: **4262 6220** | File No.: 42626220-g-688.mxd | | Rev. A<br>A4 |




**Slope Class and Slope Range %**

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

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





Client: LNG

URS

Project: GLADSTONE LNG PROJECT
TERRAIN, SOILS AND LAND CAPABILITY REPORT
CSG FIELD

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

| | | | |
|---|---|---|---|
| Drawn: MG | Approved: GR | Date: 11-02-2009 | Figure: **1-18** |
| Job No.: **4262 6220** | File No.: 42626220-g-689.mxd | | Rev. A<br>A4 |

## 1.4 Regional Geology

### 1.4.1 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.

### 1.4.2 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 field study area the predominant outcropping rocks of the Surat Basin are Cretaceous mudrocks (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 mudrocks (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.

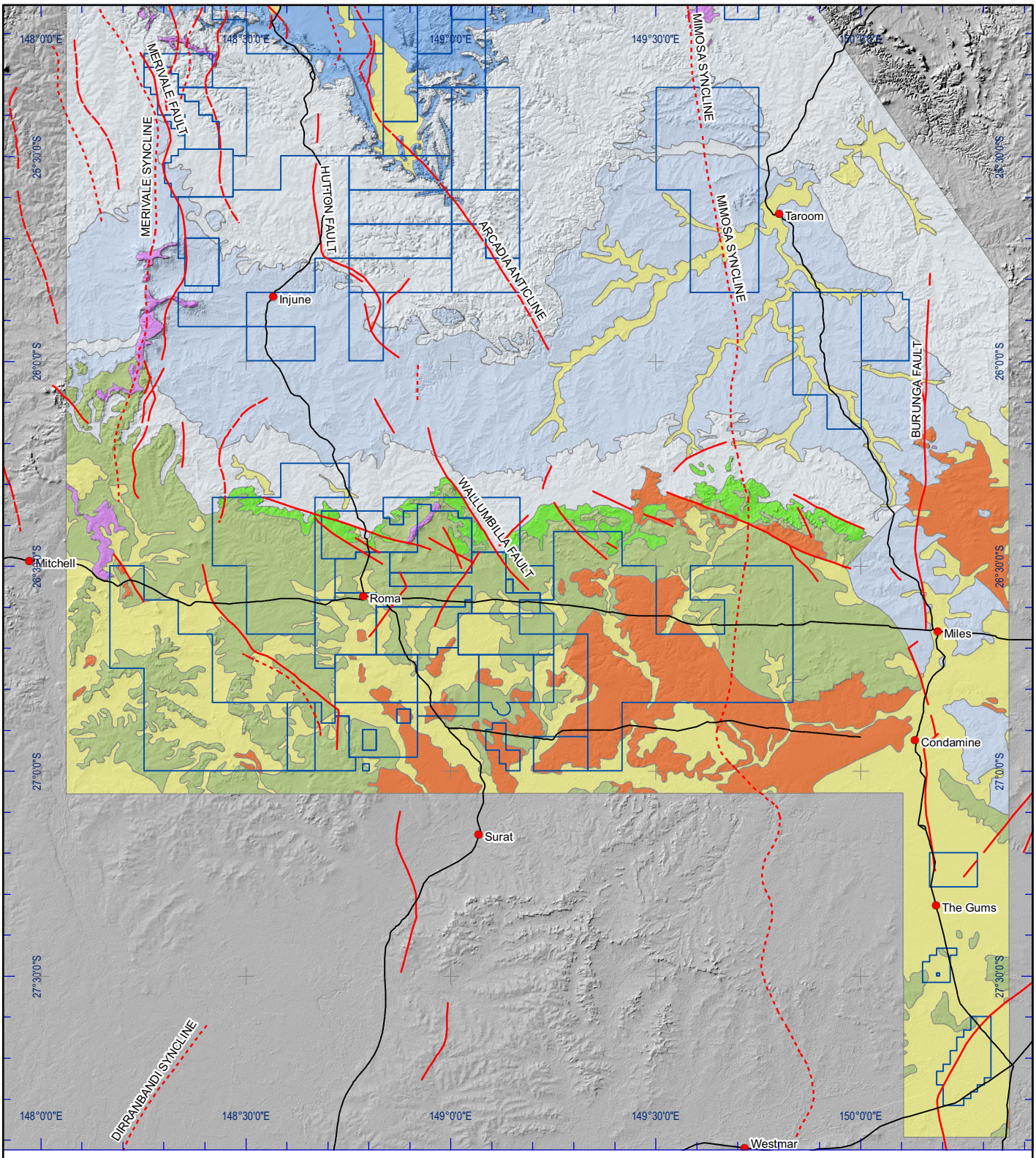
The geology of the CSG field study area has been mapped by the Geological Survey of Queensland (GSQ) in the Geoscience Datasets (2004 and 2008), the GSQ Regional Mapping of the Bowen Basin and the Surat Basin.

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 as follows:

- 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;
- 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; and
- Permian sediments and volcanics (P): includes Blackwater Group, Back Creek Group, Reid Dome Beds;

The occurrences and distribution of the geological regimes as mapped within the CSG fields are shown in **Figures 1-19 and 1-20.** Note that the EIS groundwater report for the CSG field study area also contains regional geology maps and a schematic geological cross section of the Fairview gas field**.**




**Geology**

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

N
W E
S

Kilometers
0 5 10 20 30 40 50

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





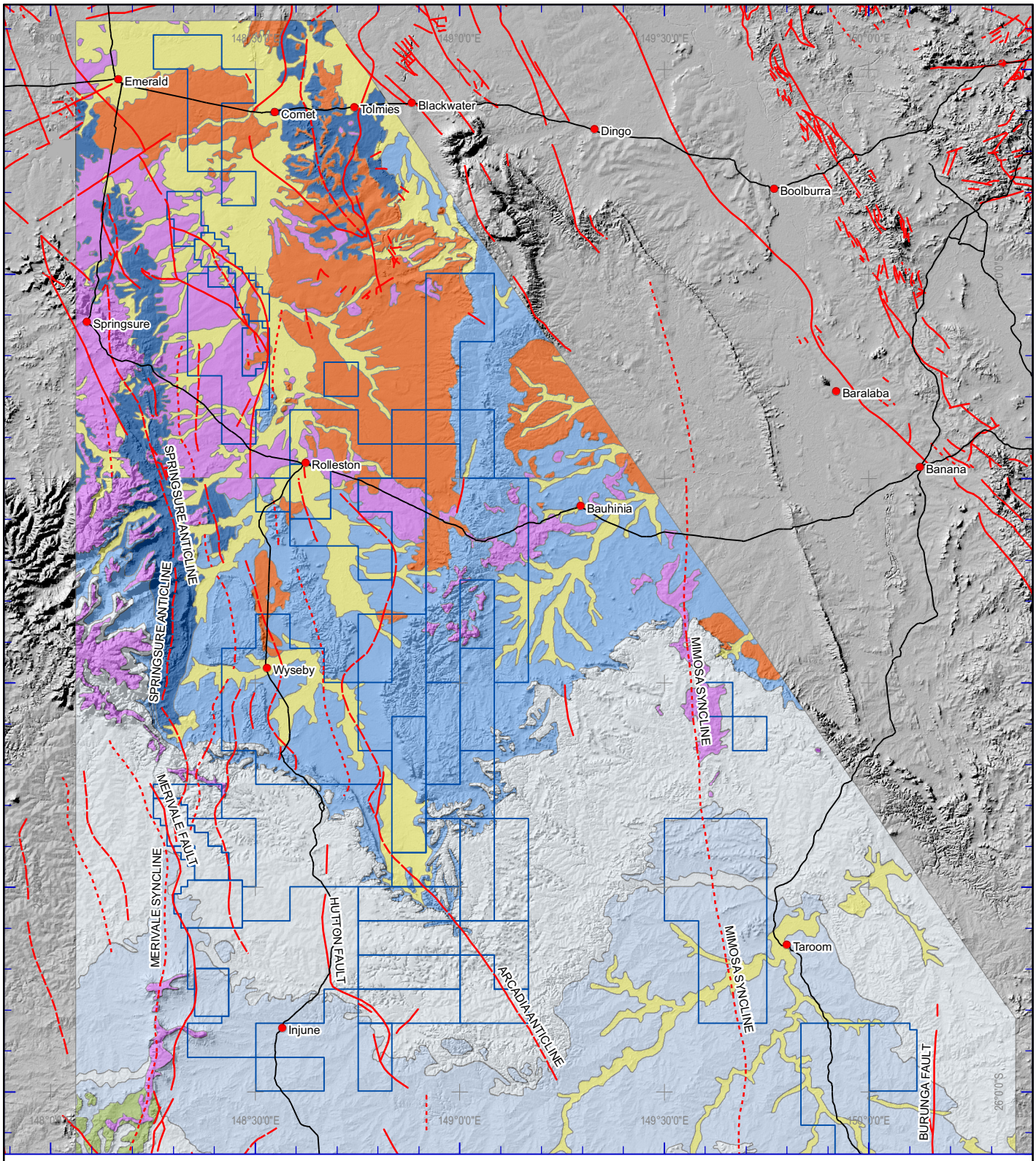
Client: LNG

URS

Project: GLADSTONE LNG PROJECT
TERRAIN, SOILS AND LAND CAPABILITY REPORT
CSG FIELD

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

| | | | |
|---|---|---|---|
| Drawn: MG | Approved: GR | Date: 11-02-2009 | Figure: **1-19** |
| Job No.: **4262 6220** | File No.: 42626220-g-690.mxd | | Rev. A<br>A4 |




**Geology**

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

N
W E
S

Kilometers
0 5 10 20 30 40 50

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



Client: LNG

URS

Project: GLADSTONE LNG PROJECT
TERRAIN, SOILS AND LAND CAPABILITY REPORT
CSG FIELD

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

| | | | |
|---|---|---|---|
| Drawn: MG | Approved: GR | Date: 11-02-2009 | Figure: **1-20** |
| Job No.: **4262 6220** | File No.: 42626220-g-691.mxd | | Rev. A |
| | | | A4 |

### 1.4.3 Economic Geology

The Bowen and Surat Basins are of enormous economic importance, due primarily to their extensive deposits of coal and significant volumes of coal seam gas 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 coal seam gas is located in the underlying Permian sediments with their extensive coal deposits.

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

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

The most recent, moderate sized earthquake within the broader region of the project 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 as defined in 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).

### 1.4.4 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 **Figures 1-19 and 1-20**. 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.

## 1.5 Landscape Units

As discussed in **Section 1.1** above, the identification of landscape units provides the basis for the description of the physical environment and as mapped, show the occurrence and distribution of geological regimes, landscape units and associated soil types which occur in the CSG fields. Descriptions of the landscape units identified, together with an assessment of some engineering and environmental attributes relevant to infrastructure development are included in **Appendix A** of this report.

The landscape units were identified from a combination of geological regimes and slope classes. The geological regime represents the simplified geology according to the existing GSQ mapping. Slope classes were derived from NASA Shuttle Radar Topography Mission 90 m 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

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 study area. Consideration was given to maintaining a single slope class as much as possible within a mapped area, but because of the presence of many very small areas of other (usually adjacent) slope classes all mapped areas 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 GIS. Notation of each landscape unit consists of alphabetic characters that identify the geological regime followed by a numeral identifying the indicative slope class number. For example, the landscape unit Jm3 consists of indicative slope class 3 occurring within geological regime Jm.

The occurrence of landscape units in the Roma, Fairview and Arcadia Valley CSG fields is summarised in **Table 1-1** below.

# Section 1 Description and Assessment of Environmental Values

**Table 1-1 Occurrence of Landscape Units - Roma, Fairview and Arcadia Valley CSG Fields**

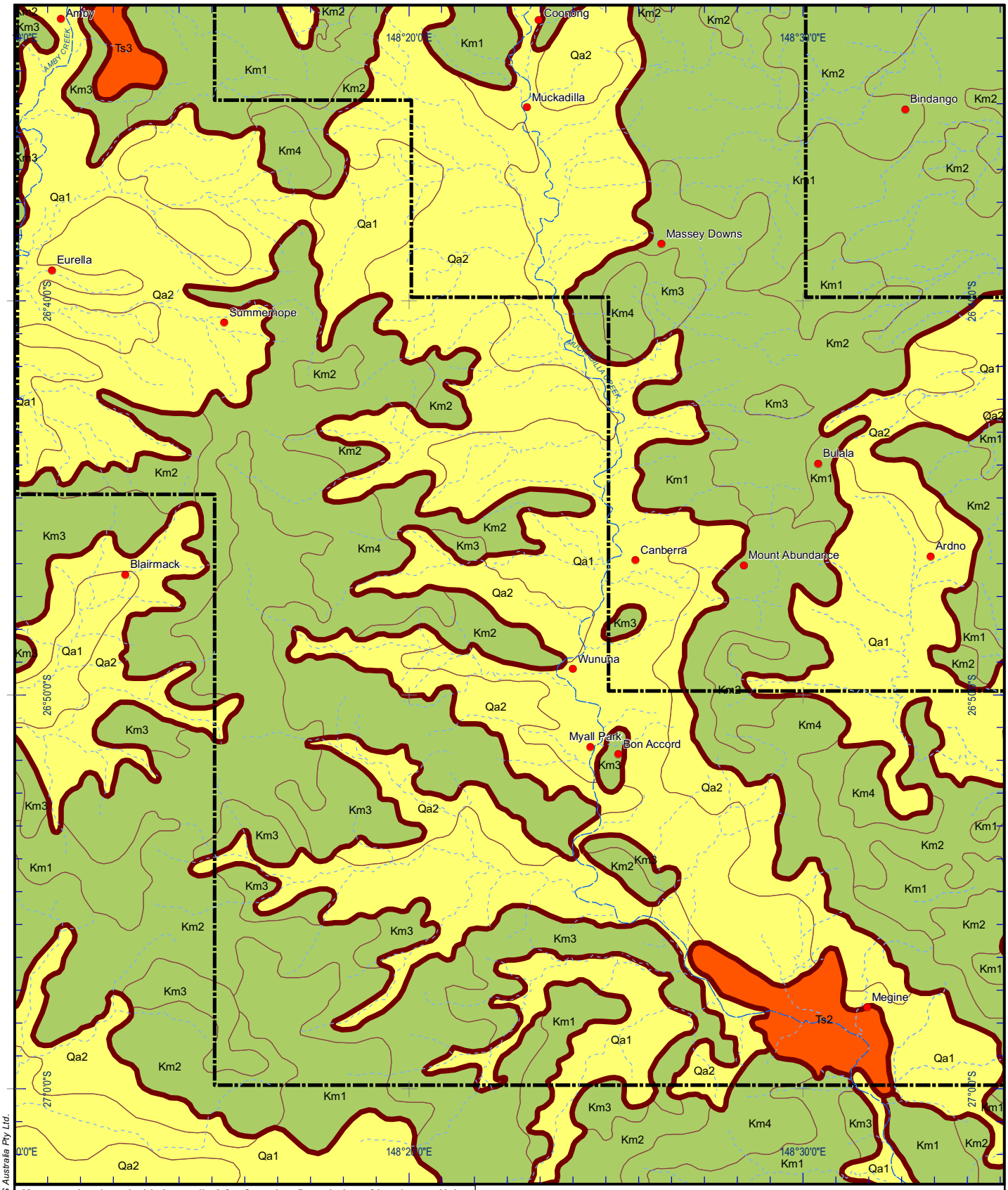
| Landscape Unit | Roma Field | | Fairview Field | | Arcadia Valley Field | |
|---|---|---|---|---|---|---|
| | Area (ha) | Area % | Area (ha) | Area % | Area (ha) | Area % |
| Qa1 139,6 | 33.5 | 17.0 | | | 15,196.3 | 7.8 |
| Qa2 31,89 | 2.9 | 3.9 | 1,485.7 1.3 | | 6,328.6 | 3.3 |
| Ts1 76,70 | 1.1 | 9.4 | | | | |
| Ts2 57,46 | 6.2 | 7.0 | | | | |
| Ts3 11,29 | 4.8 | 1.4 | | | | |
| Tv2 65.3 | | 0.01 | | | | |
| Tv3 199.0 | | 0.02 | | | | |
| Tv4 3,937.6 | | 0.5 | | | | |
| Tv5 211.1 | | 0.03 | | | | |
| Ka1 1,185.0 | | 0.1 | | | | |
| Ka2 15,24 | 2.2 | 1.9 | | | | |
| Ka3 9,940.0 | | 1.2 | | | | |
| Km1 170,6 | 30.1 | 20.8 | | | | |
| Km2 167,6 | 62.5 | 20.4 | | | | |
| Km3 41,33 | 8.1 | 5.0 | | | | |
| Km4 21,98 | 6.4 | 2.7 | | | | |
| Ja1 4,817.7 | | 0.6 | 534.7 0.5 | | 124.6 | 0.1 |
| Ja2 32,29 | 0.9 | 3.9 | 39,186.5 33.9 10,63 | | 7.2 | 5.5 |
| Ja3 5,729.9 | | 0.7 | 36,453.7 31.5 33,73 | | 2.8 | 17.4 |
| Ja4 949.2 | | 0.1 | 1,517.4 1.3 | | 550.7 | 0.3 |
| Ja5 | | | 27,451.1 | 23.8 27,21 | 6.9 | 14.0 |
| Ja6 | | | | | 11,209.2 | 5.8 |
| Jm1 6,855.9 | | 0.8 | | | | |
| Jm2 17,86 | 1.3 | 2.2 27.1 | | 0.02 | | |
| Jm3 2,684.7 | | 0.3 | 575.7 0.5 | | | |
| Rm1 | | | | | 1,554.8 | 0.8 |
| Rm2 | | | 165.5 | 0.1 20,94 | 8.1 | 10.8 |
| Rm3 | | | | | 45,717.6 | 23.5 |
| Rm4 | | | | | 1,470.4 | 0.8 |
| Rm5 | | | 1,420.6 | 1.2 10,94 | 0.4 | 5.6 |
| Rm6 | | | 6,838.3 | 5.9 8,385.7 | | 4.3 |
| **Total** | **820,575.5** | **100** | **115,656.3** | **100** | **194,013.3** | **100** |

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

Roma field: **Figures 1-21 to 1-28**

Fairview field: **Figure 1-29**

Arcadia Valley field: **Figures 1-30 to 1-31.**




*Map must be viewed with Appendix A 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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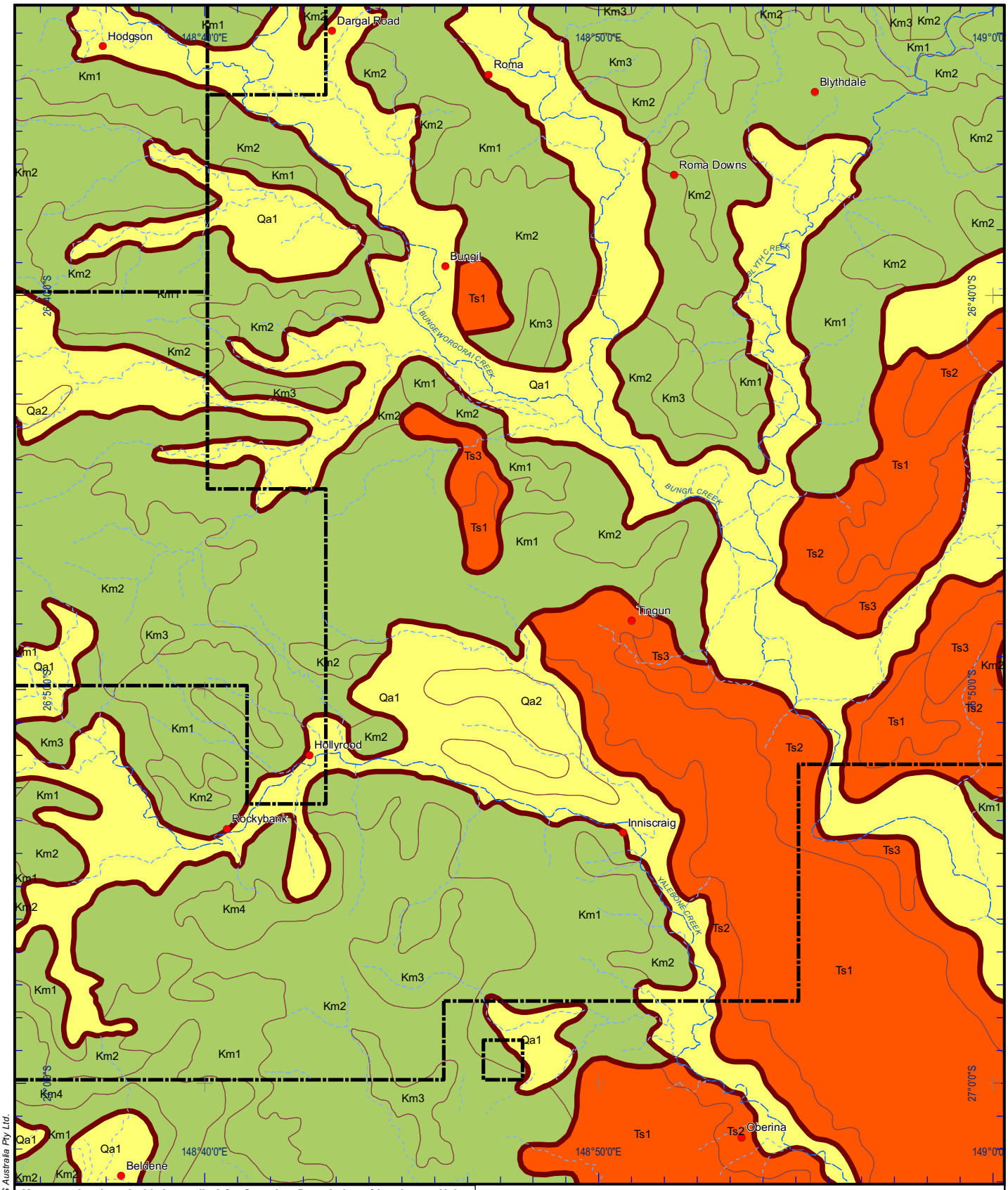
TERRAIN, SOILS AND LAND CAPABILITY REPORT
CSG FIELD

Title: **LANDSCAPE UNITS**
**CSG FIELD**
**ROMA**
**(1 of 8)**

| | | | |
|---|---|---|---|
| Drawn: CA | Approved: GR | Date: 11-02-2009 | Figure: **1-21** |
| Job No.: **4262 6220** | File No.: 42626220-g-698.mxd | | Rev. A<br>A4 |




*Map must be viewed with Appendix A 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





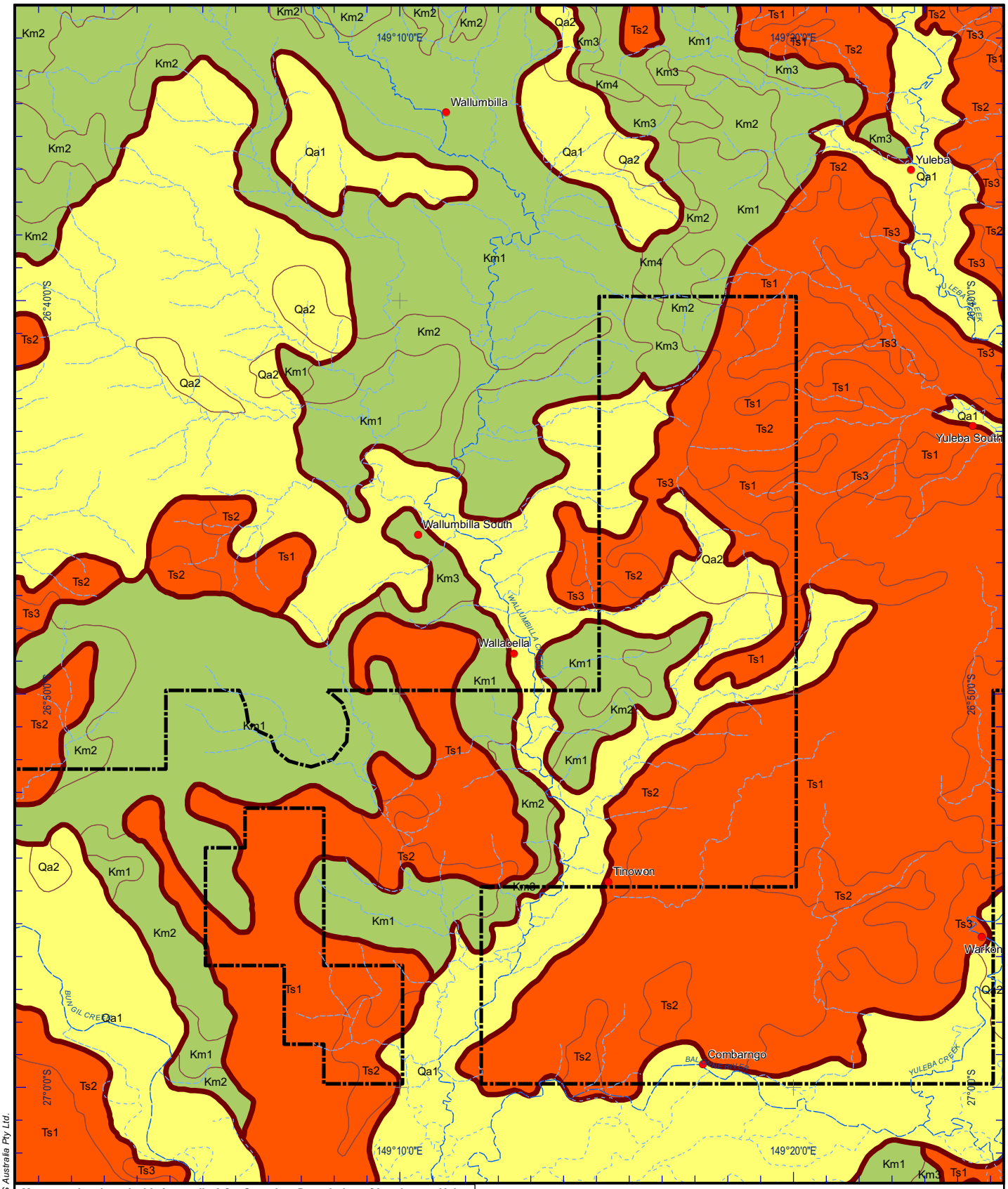
Client: LNG

URS

Project: GLADSTONE LNG PROJECT
TERRAIN, SOILS AND LAND CAPABILITY REPORT
CSG FIELD

Title: **LANDSCAPE UNITS**
**CSG FIELD**
**ROMA**
**(2 of 8)**

| | | | |
|---|---|---|---|
| Drawn: CA | Approved: GR | Date: 11-02-2009 | Figure: **1-22** |
| Job No.: **4262 6220** | File No.: 42626220-g-698.mxd | | Rev. A<br>A4 |




*Map must be viewed with Appendix A 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: LNG

URS

Project: GLADSTONE LNG PROJECT
TERRAIN, SOILS AND LAND CAPABILITY REPORT
CSG FIELD

Title: **LANDSCAPE UNITS**
**CSG FIELD**
**ROMA**
**(3 of 8)**

| | | | |
|---|---|---|---|
| Drawn: CA | Approved: GR | Date: 11-02-2009 | Figure: **1-23** |
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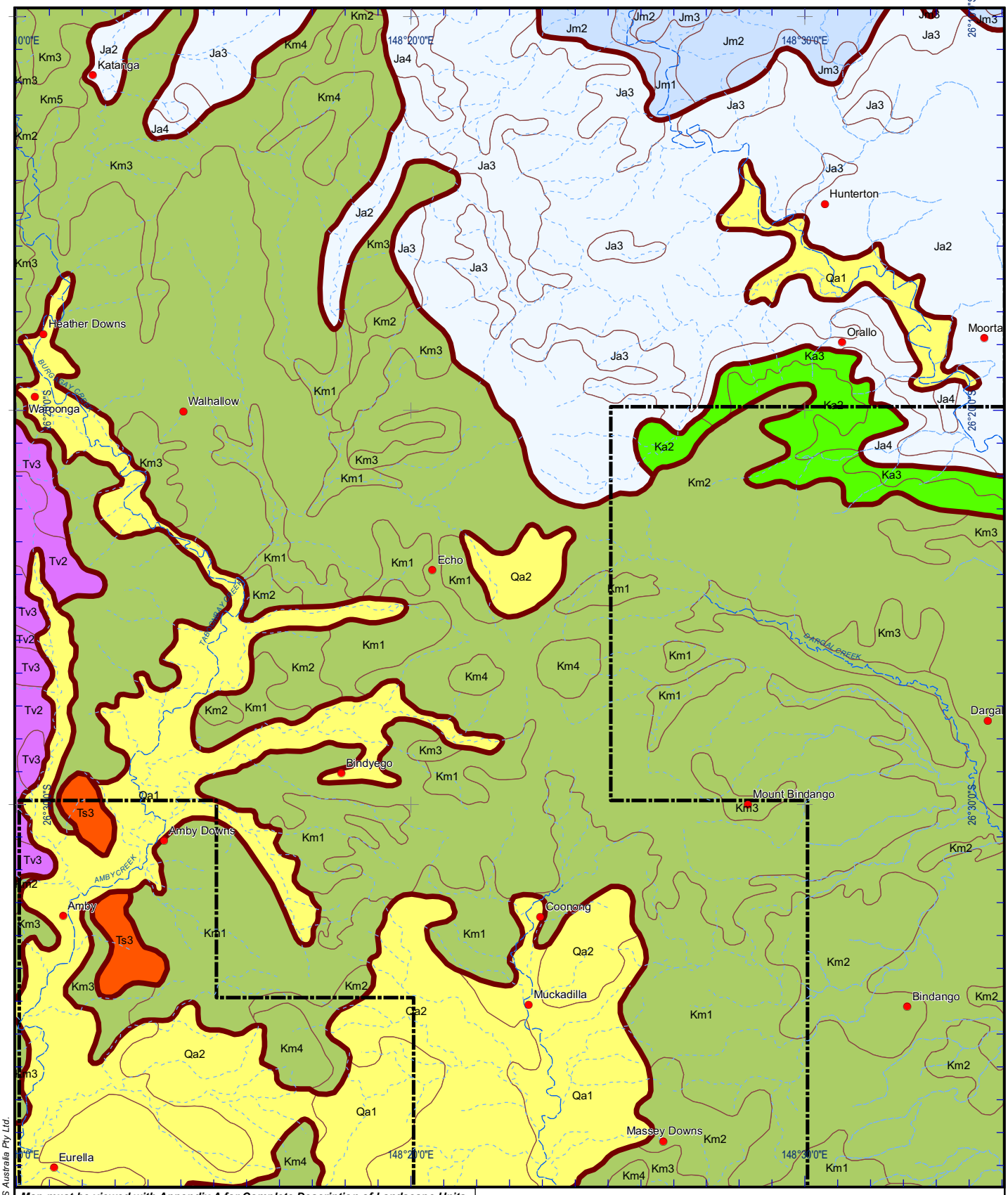


*Map must be viewed with Appendix A for Complete Description of Landscape Units.*

**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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**CSG FIELD**
**ROMA**
**(4 of 8)**

| | | | |
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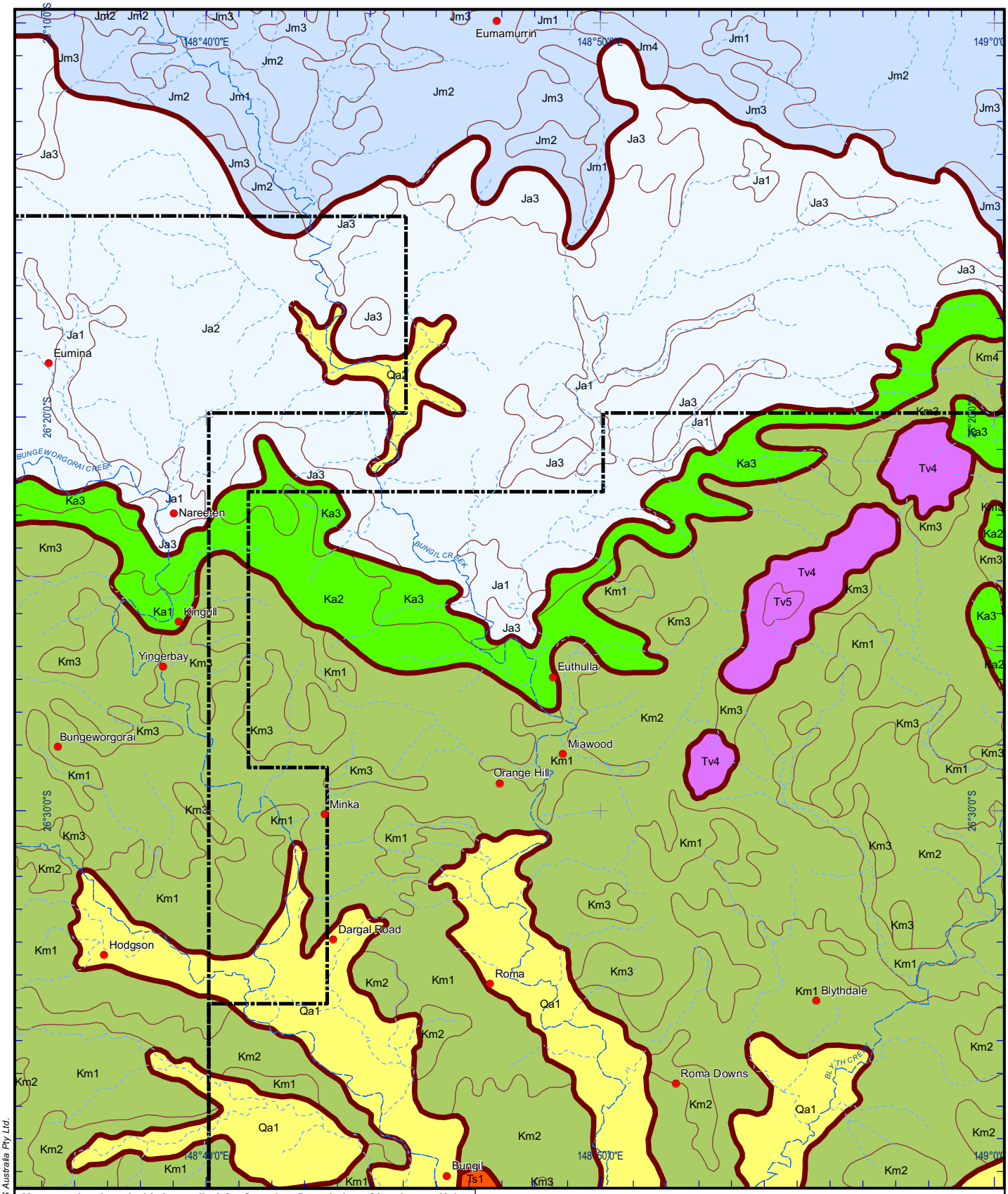


*Map must be viewed with Appendix A for Complete Description of Landscape Units.*

**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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Title: **LANDSCAPE UNITS**
**CSG FIELD**
**ROMA**
**(5 of 8)**

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Figure: **1-25**

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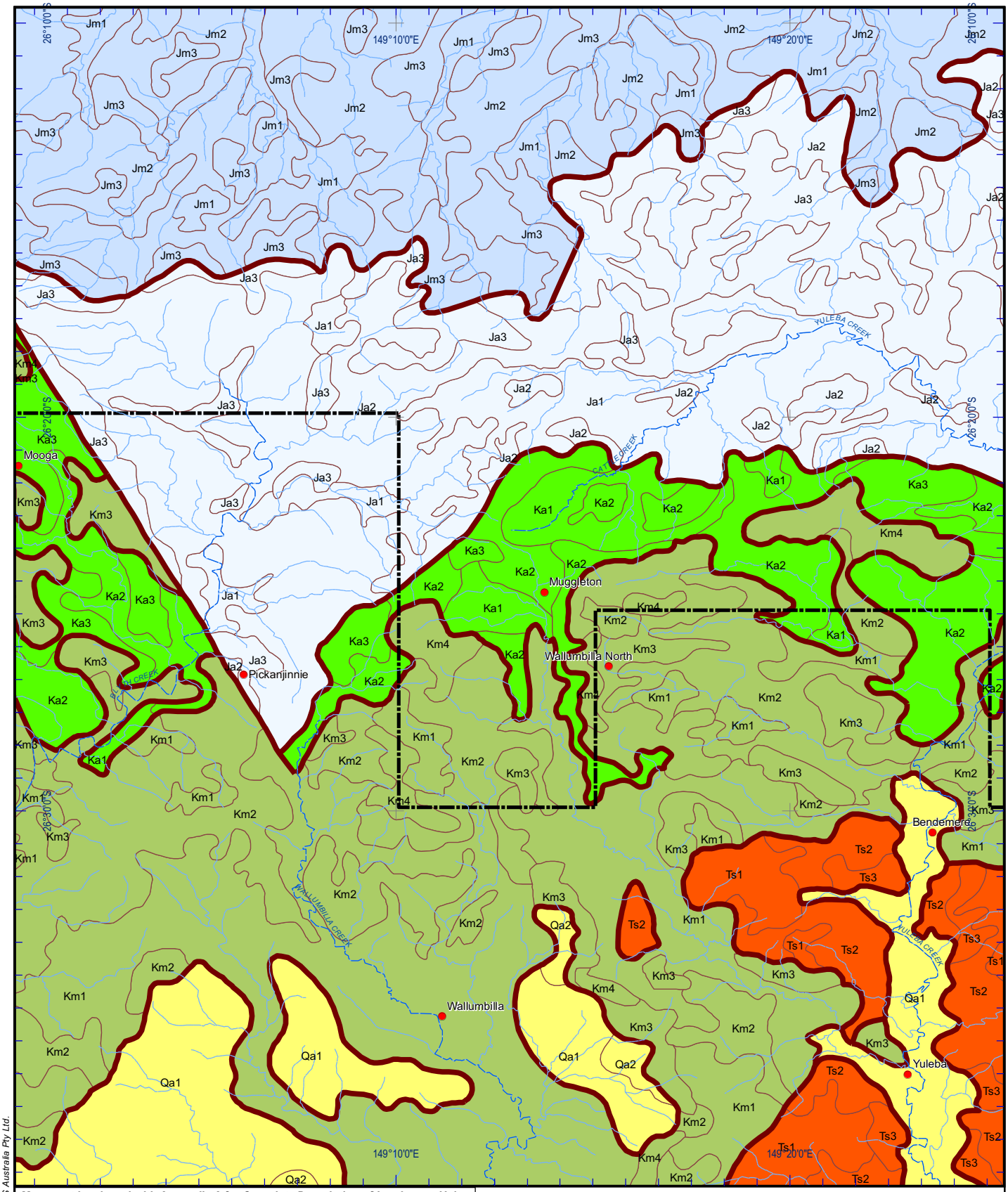


*Map must be viewed with Appendix A for Complete Description of Landscape Units.*

**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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CSG FIELD

Title: **LANDSCAPE UNITS**
**CSG FIELD**
**ROMA**
**(6 of 8)**

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Figure: **1-26**

Rev. A
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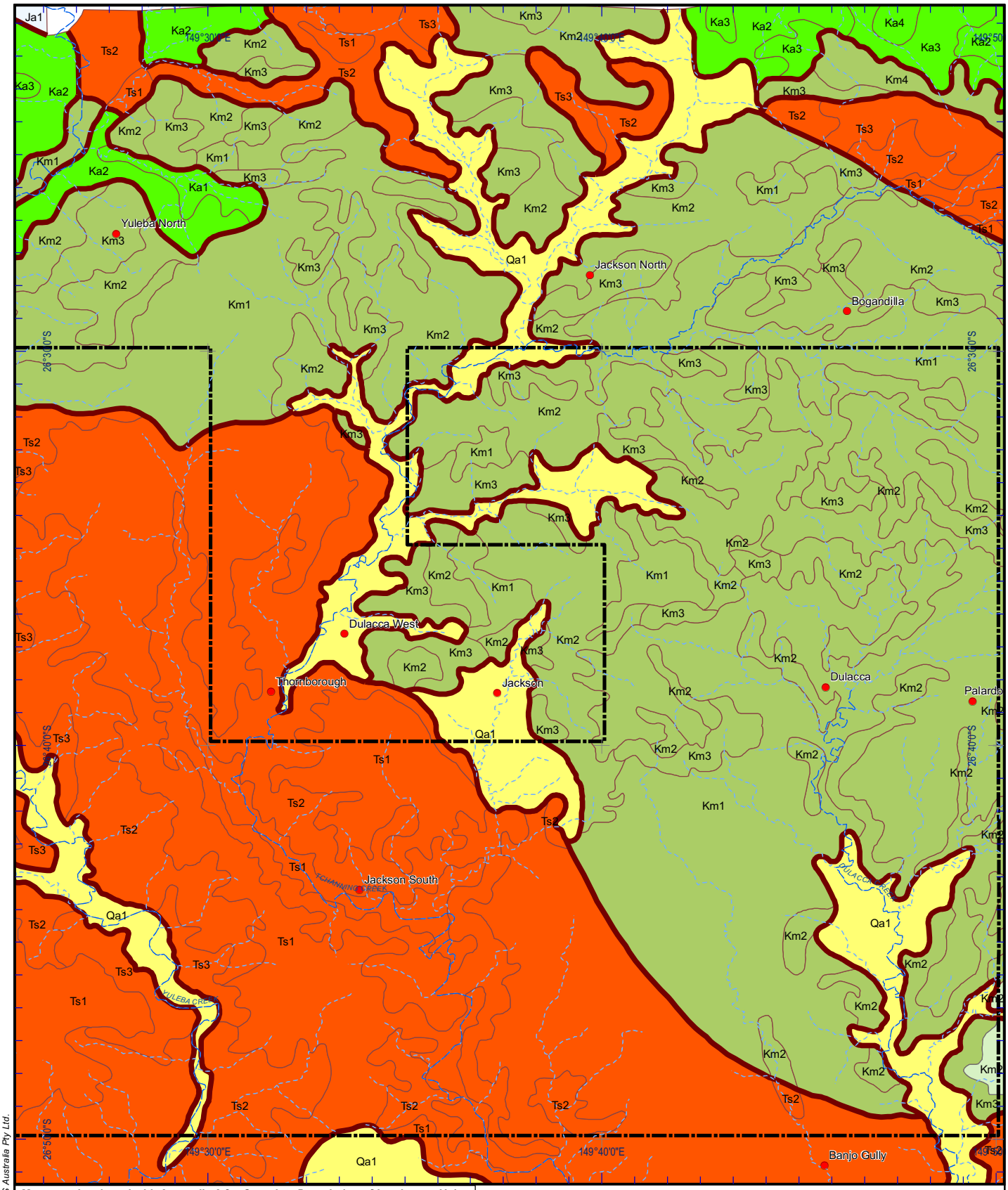


*Map must be viewed with Appendix A for Complete Description of Landscape Units.*

**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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CSG FIELD

Title: **LANDSCAPE UNITS**
**CSG FIELD**
**ROMA**
**(7 of 8)**

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Figure: **1-27**

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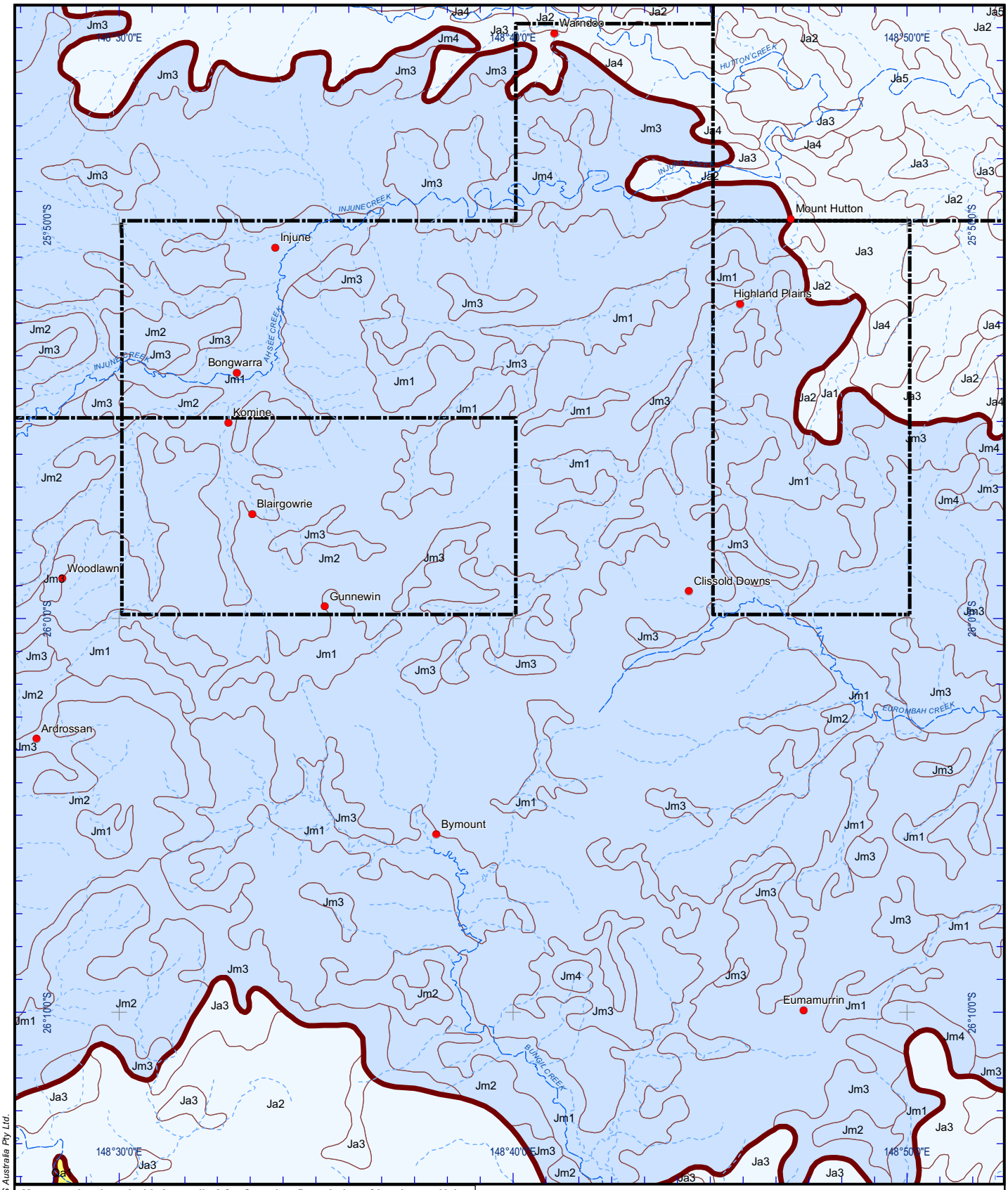
A4




*Map must be viewed with Appendix A 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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CSG FIELD

Title: **LANDSCAPE UNITS**
**CSG FIELD**
**ROMA**
**(8 of 8)**

| | | | |
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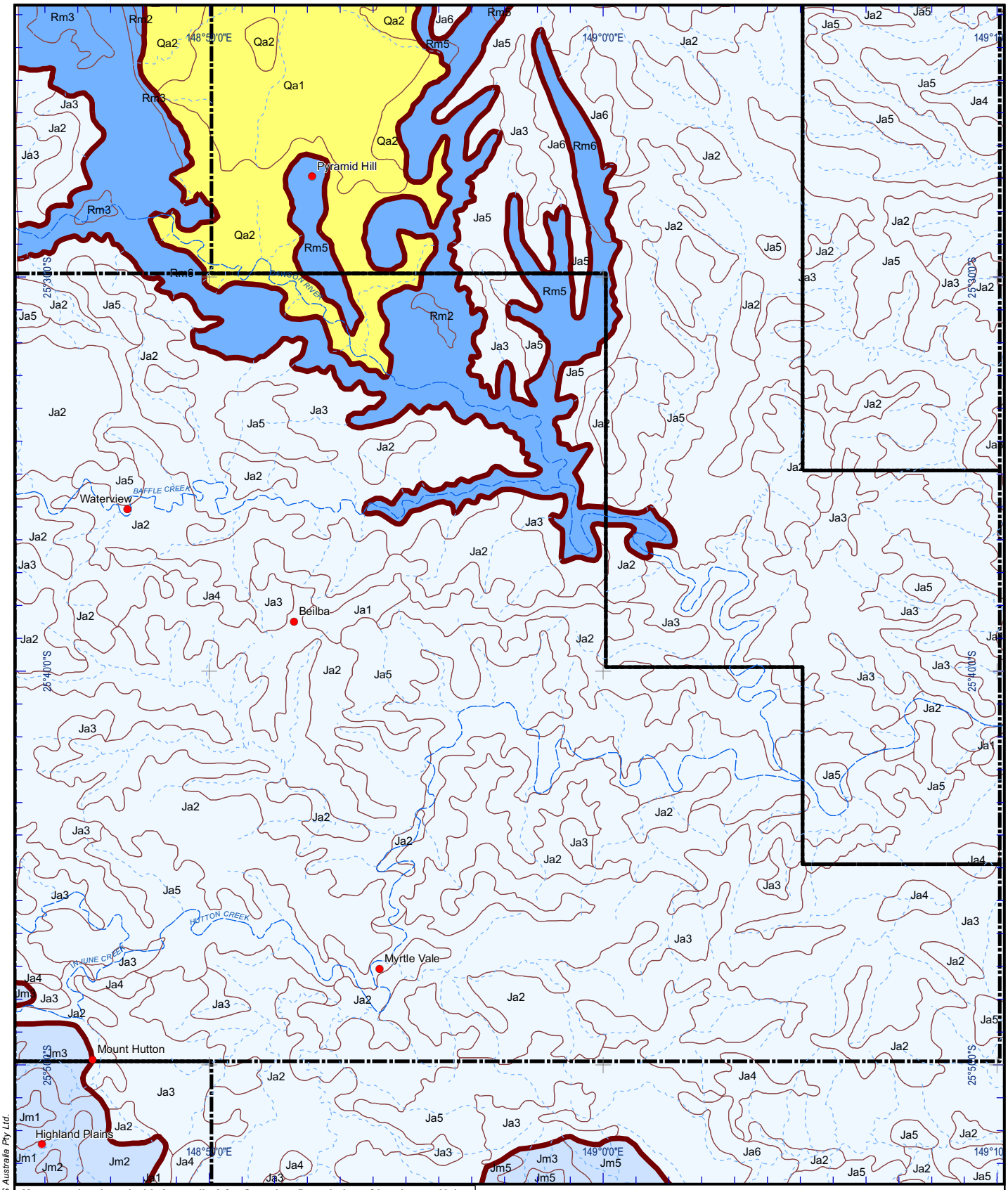


*Map must be viewed with Appendix A for Complete Description of Landscape Units.*

## 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: LNG

URS

Project: GLADSTONE LNG PROJECT
TERRAIN, SOILS AND LAND CAPABILITY REPORT
CSG FIELD

Title: **LANDSCAPE UNITS**
**CSG FIELD**
**FAIRVIEW**

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Figure: **1-29**

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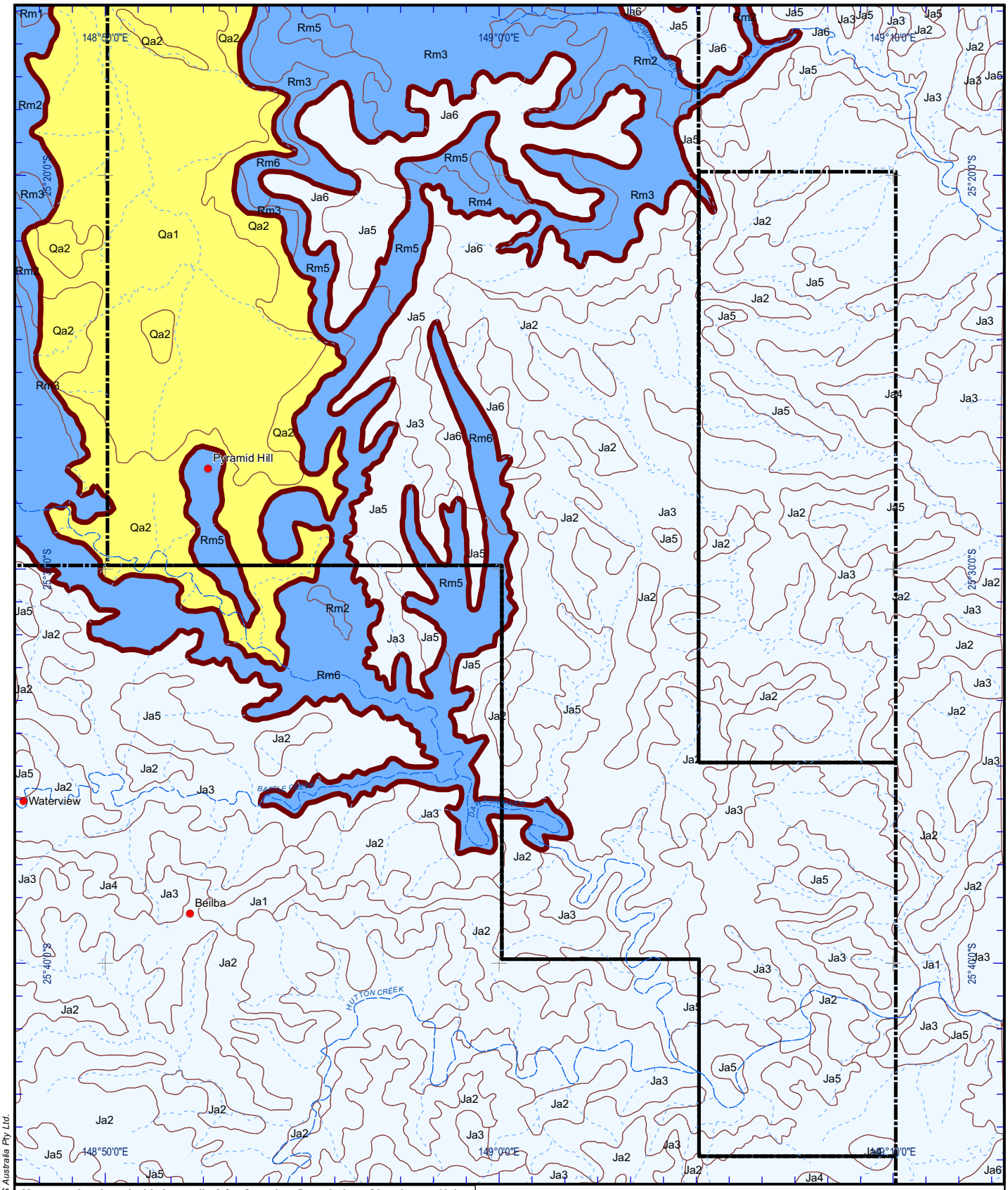
A4




*Map must be viewed with Appendix A 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: LNG

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Project: GLADSTONE LNG PROJECT
TERRAIN, SOILS AND LAND CAPABILITY REPORT
CSG FIELD

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

| | | | |
|---|---|---|---|
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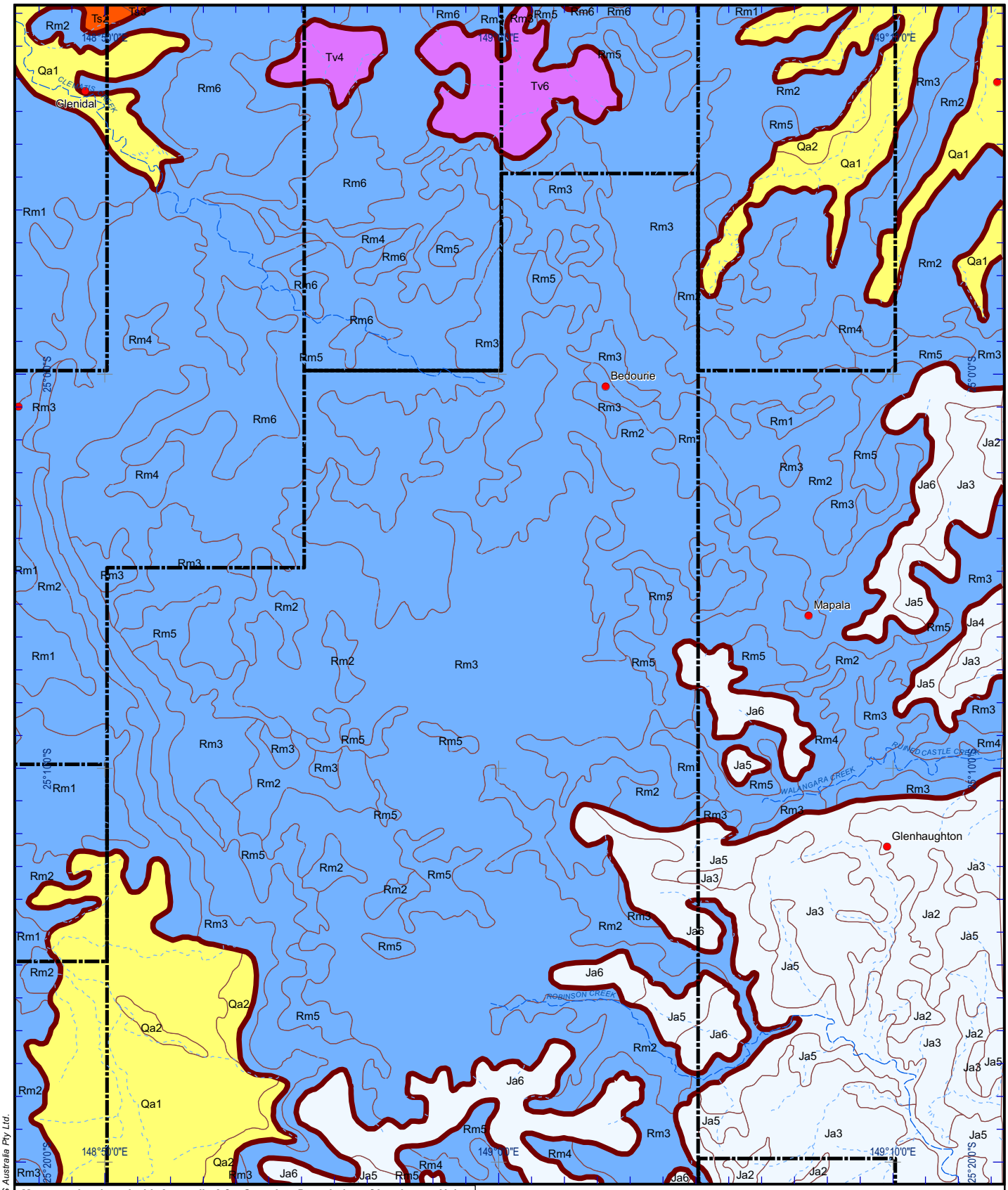
| Job No.: **4262 6220** | File No.: 42626220-g-698.mxd | | Rev. A<br>A4 |




*Map must be viewed with Appendix A 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: LNG

URS

Project: GLADSTONE LNG PROJECT
TERRAIN, SOILS AND LAND CAPABILITY REPORT
CSG FIELD

Title: **LANDSCAPE UNITS**
**CSG FIELD**
**ARCADIA VALLEY**
**( 2 of 2)**

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|---|---|---|
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Figure: **1-31**

Rev. A
A4

Section 1

# Description and Assessment of Environmental Values

## 1.6 Soils

### 1.6.1 Soils in the Coal Seam Gas Field

The occurrence and distribution of the major soil groups as mapped within the CSG fields is shown in **Figures 1-32 and 1-33** and the descriptions of the soils associated with the landscape units are provided in **Appendix A.** Typical soil profile characteristics of the main soil groups mapped 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).

### 1.6.2 The Major Soil Groups

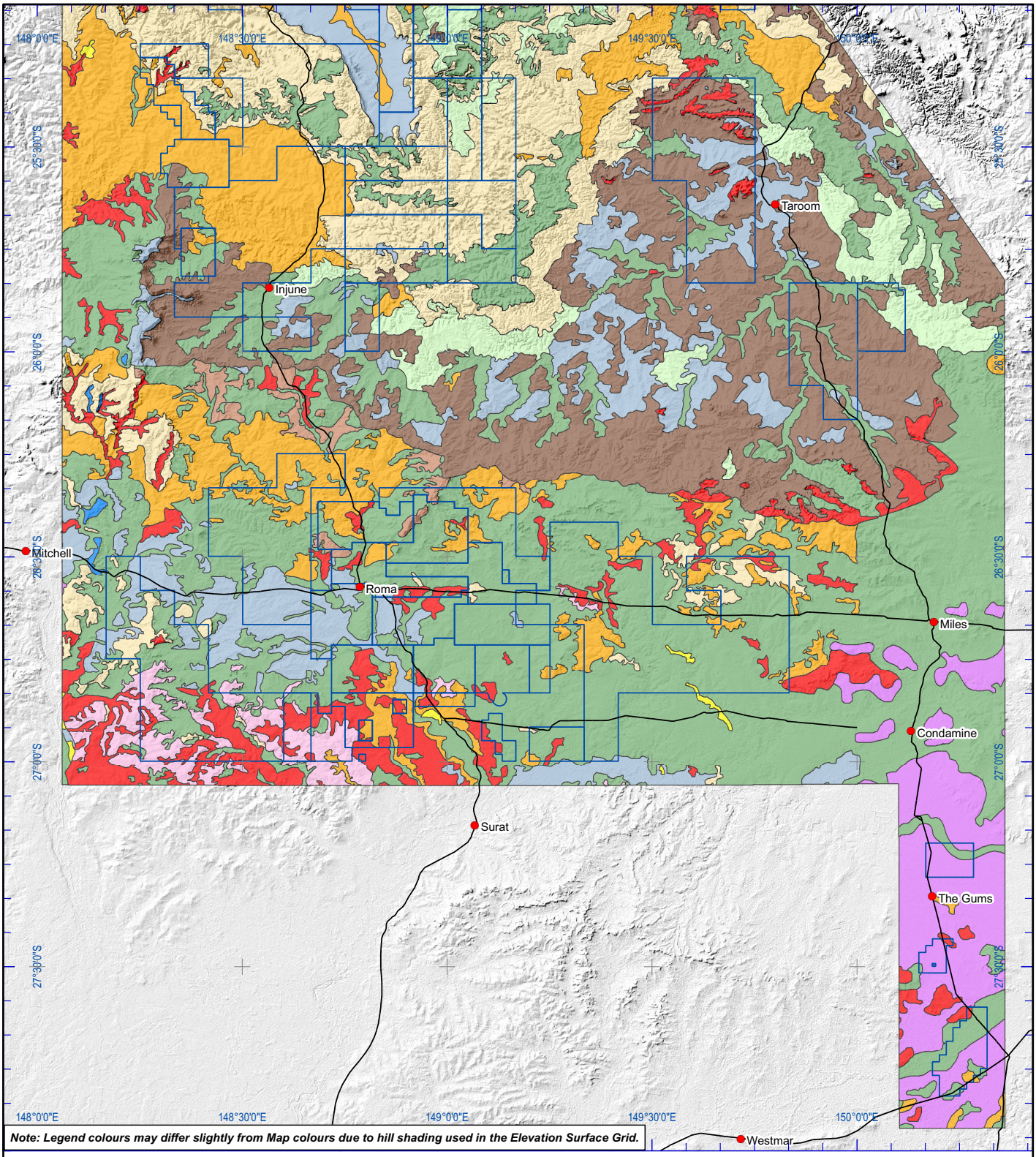
The major soil groups that occur are essentially very similar to those described for the gas transmission pipeline corridor study. The soil groups identified in **Table 1-2** cover a broad range of Australian Soil Groups (Stace *et al,* 1968) and include uniform coarse-textured (sandy) soils, uniform and gradational medium-textured (loamy) soils (in particular uniform loams), gravelly loams, red and yellow earths and lateritic red earths. Also included are sandy and loamy surface texture contrast (duplex) soils, uniform or gradational fine-textured grey and brown non-cracking clays and black, dark grey and brown cracking clay soils. The soil groups are generally characterised by increasingly finer (more clayey) texture and higher plasticity in the subsoil layers with increasing soil group number. Wherever possible, soils have been characterised in terms of the following soil classification schemes:

- Handbook of Australian Soils (Stace *et al,* 1968);
- Principal Profile Form (PPF) of Northcote (1974);
- Australian Soil Classification (ASC) (Isbell, 2002); and
- Australian Standard for Engineering Soil Classification (AS 1726-1993).

## Table 1-2 Description and Classification of Major Soil Groups

| Soil Group | Summary Soil Description | Soil Classification | | | |
|---|---|---|---|---|---|
| | | Aust. Soil Group (1) | P.P.F. (2) | U.S.C. (3) | A.S.S. (4) |
| 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<br>Earthy sands<br>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<br>Sandy Red-Yellow Earths | (Uc4-5, Uml-3);<br>Gn2.11, Gn2.12 | SP-SC/SC-CL /CL<br>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<br>Gravelly Loams<br>Red and Yellow Massive Earths<br>Lateritic Red-Yellow Earths | Um2.12<br>K-Um2.12<br>Um4.11<br>Gn2.12<br>Gn2.22 | CL/GC-CL/GC<br>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 ;<br>Grey & Brown Soloths | Dr2.12, 2.22<br>Dy3.42, 3.22<br>Dy3.12, 3.32<br>Db1.41 | SP-SC/CL or CL-CH | Ferric Red-Brown Chromosols;<br>Sodic Yellow & Brown Kurosols |
| 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<br>Dr2.13,<br>Dy2.23,<br>Dd1.13 | ML-CL/CL-CH or CH<br>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 fin e-textured (non-crackin g) clay soils or gradational often stony or gravelly clay loam or light clay surface soils over alka line medium to heavy clay subsoils, locally sodic an d sa line in the deeper subsoils – som e deep incipient cracking clays; | Alluvial Soils<br>Dark brown Grey-brown or Dark Reddish-brown (Non-Cracking) Clay Soils, some Solonchaks | Uf6.31, 6.32<br>Uf6.61, 6.63<br>Uf6.32, 6.21<br>Gn3.22, 3.42<br>Gn3.93, 3.13<br>Gn3.12 | CL/CL,<br>SC-CL/CL-CH<br>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<br>Grey, Brown and | Ug5.12, 5.21<br>Ug5.24, 5.25<br>Ug5.38,<br>Ug5.15, 5.16 | CL-CH/CH,<br>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).*




*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 1-34 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





Client: LNG

URS

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TERRAIN, SOILS AND LAND CAPABILITY REPORT
CSG FIELD

Title: **SOILS MAPPING UNITS**
**CSG FIELDS**
**(SOUTHERN SECTION)**

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Figure: **1-32**

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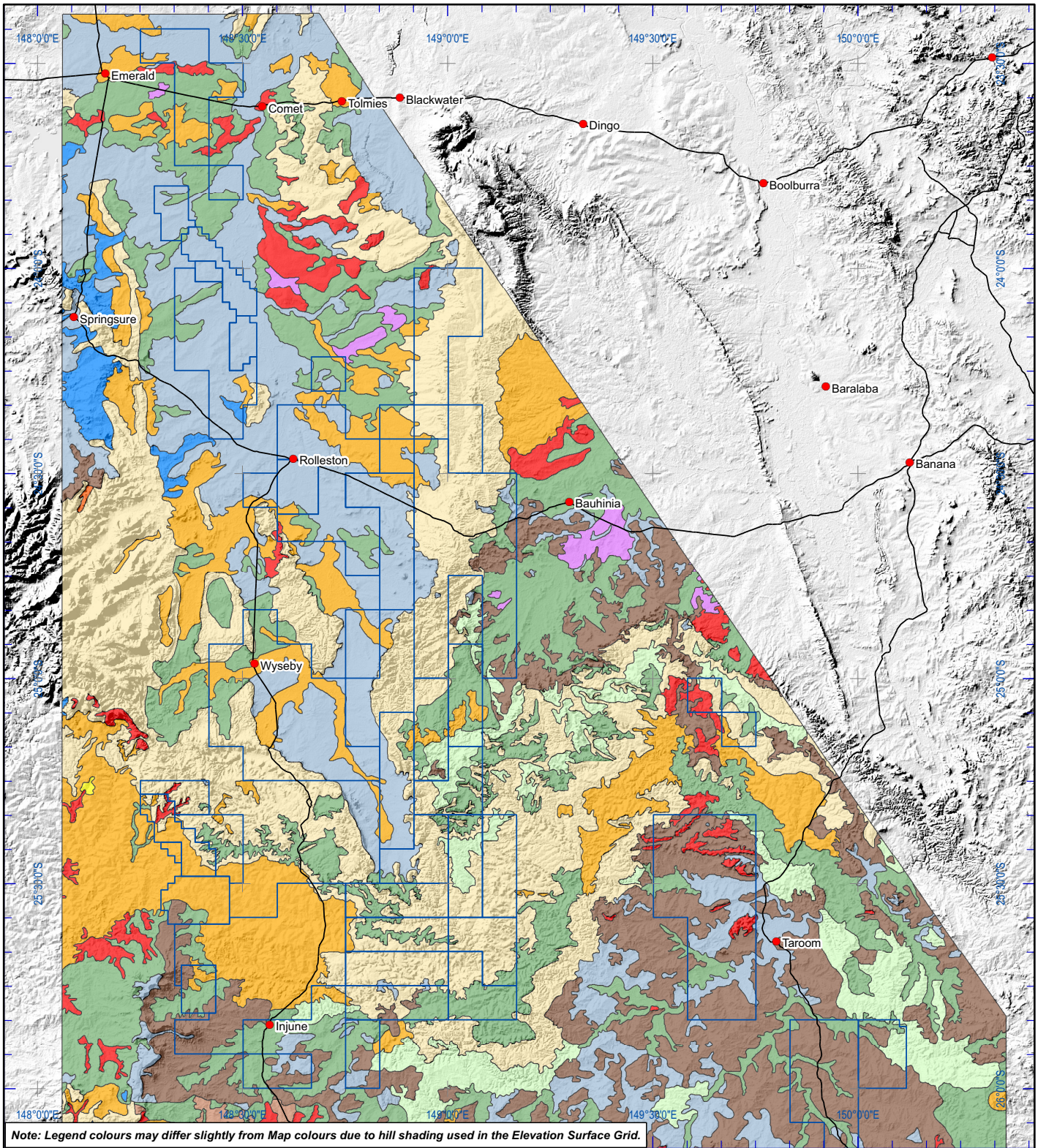


*Note: Legend colours may differ slightly from Map colours due to hill shading used in the Elevation Surface Grid.*

## Soils Mapping Units - Refer to Figure 1-34 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

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TERRAIN, SOILS AND LAND CAPABILITY REPORT
CSG FIELD

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

| Drawn: LL/CA | Approved: GR | Date: 11-02-2009 |
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| Job No.: **4262 6220** | File No.: 42626220-g-693.mxd | |

Figure: **1-33**

Rev. A
A4

### 1.6.3 Soil Types

With respect to the major soil groups identified in **Table 1-1**, the 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 1-3**.

**Table 1-3 Soil Groups and Associated Soil Types**

| | |
|---|---|
| Soil Group 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 |
| Soil Group 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<br>*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 |
| Soil Group 3 | *Soil Type 3.1:* Shallow (<0.6 m) mainly uniform coarse to medium textured sandy earths, sandy loam soils, often stony or gravelly<br>*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<br>*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 |
| Soil Group 4 | *Soil Type 4.1:* Shallow (<0.6 m) gradational or uniform medium-textured gravelly loamy soils<br>*Soil Type 4.2:* Medium to deep (0.6->1.0 m) massive red-yellow earths in places with lateritic gravelly lenses<br>*Soil Type 4.3:* Medium to deep (0.6->1.0 m) structured red or brown earths |
| Soil Group 5 | *Soil Type 5.1:* Shallow (<0.6 m) mostly sandy surface neutral to acidic duplex soils<br>*Soil Type 5.2:* Medium to deep (0.6->1.0 m) often bleached thick (>0.3) sandy surface yellow-brown and red-brown duplex soils with acidic locally strongly acidic clay subsoils<br>*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 |
| Soil Group 6 | *Soil Type 6.1:* Shallow (<0.5 m) fine sandy to loamy surface often gravelly or stony neutral to alkaline duplex soils<br>*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<br>*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 |
| Soil Group 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<br>*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<br>*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 |
| Soil Group 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<br>*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<br>*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. |

More detailed descriptions of each of the main soil types together with analytical data is included in **Section 1.5.2 of the Gas Transmission Pipeline Corridor Report.**

### 1.6.4 Soils in the Roma Field

The Roma field encompasses a land area of 820,664 ha. Based on the Soil Mapping Units (SMU) described in **Figure 1-34**, the occurrence and distribution of soils in the Roma field is shown in **Figures 1-35 to 1-42.** The collective extent of occurrence of the respective SMU's identified is as follows:

- SMU 8 is widespread throughout the Roma field and encompasses an area of approximately 495 339 ha (60.4%) of the area. 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 field in the central eastern, central southern, central northern and in the north western and far north western sectors of the area. 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 field mainly on undulating rises in the south western sector, with smaller occurrences scattered throughout the Roma 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 field, mainly in the central western and in the far north western sectors of the area. 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 field mainly on undulating rises and low hilly lands in the south western sector of the area. 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 field on rises and low hilly lands mainly along the far western and north eastern margins of the area. 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 field on undulating plains with local low hills and rises in the far north western sector of the area. 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 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 depressional areas.
- Minor isolated occurrences of SMU 2 encompassing a combined area of 1 166 ha (<0.1%) 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).

## 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 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.

**NOTE: Soil Mapping Unit Reference for Figures 1-32 to 1-33 and Figures 1-35 to 1-45**

Client: LNG

URS

Project: GLADSTONE LNG PROJECT
TERRAIN, SOILS AND LAND CAPABILITY REPORT
CSG FIELD

Title: **SOIL MAPPING UNITS**
**CSG FIELDS**

| Drawn: CA | Approved:GR | Date: 16-01-2009 | Figure: **1-34** | Rev. A |
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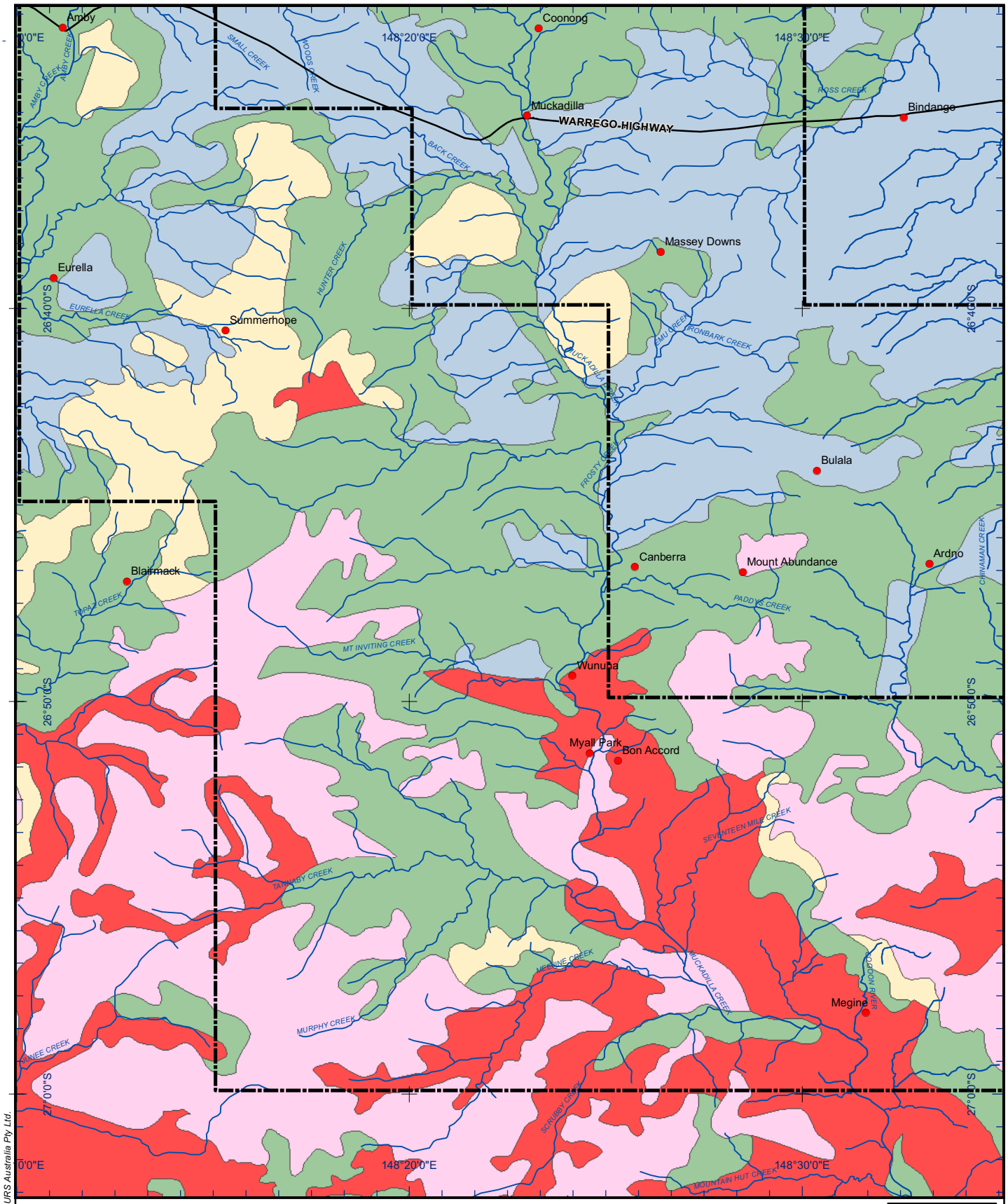
| Job No.: 4262 6220 | File No.: 42626220-g-697.mxd | | | A4 |




**Note: This Map must be viewed with Figure 1-34 for Soils Mapping Units**

Towns / Localities
Major Roads
Rivers, Creeks and Tributary Streams
CSG Field

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





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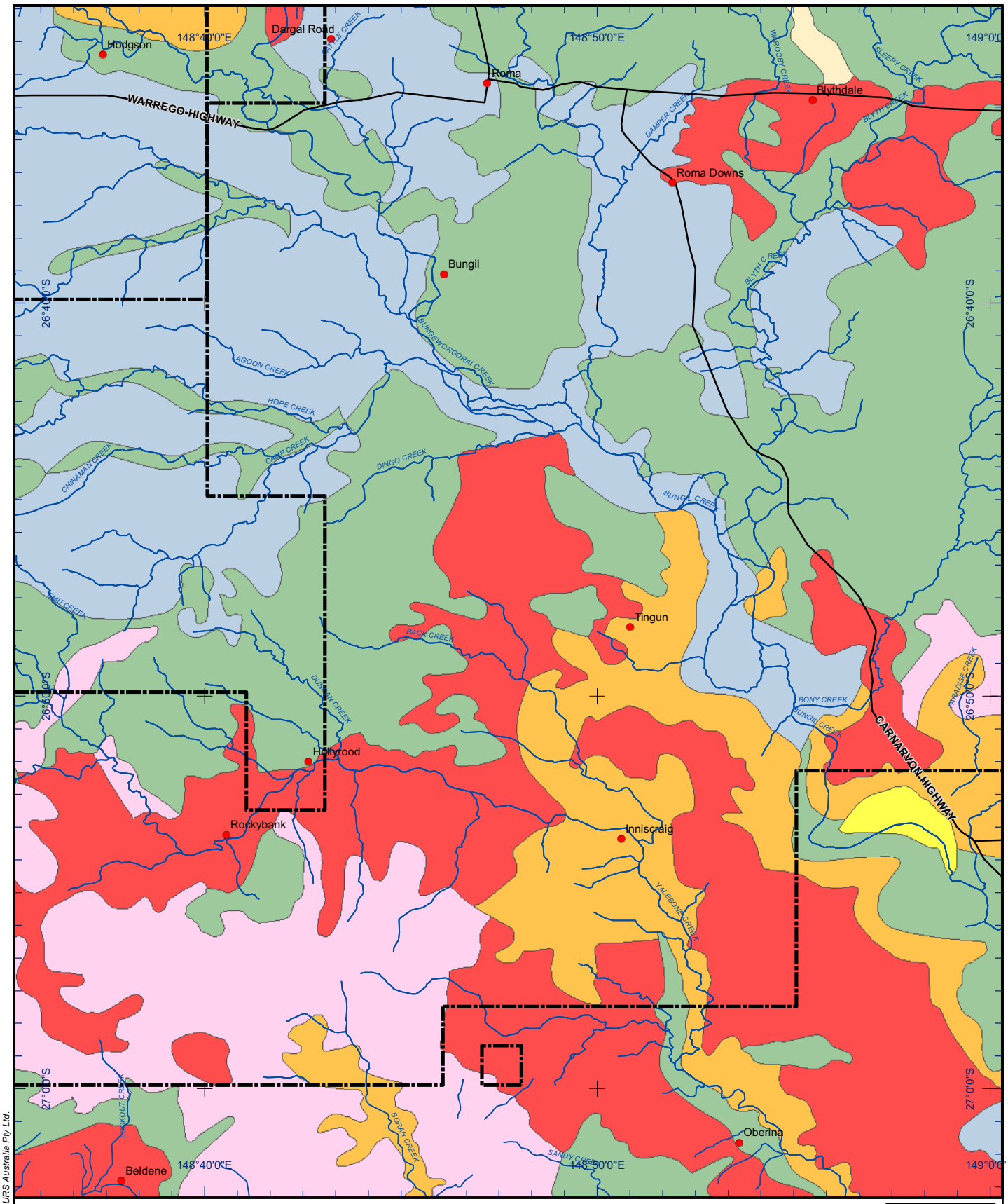
| URS | Drawn: LL / Approved: GR / Date: 11-02-2009<br>Job No.: **4262 6220** / File No.: 42626220-g-699.mxd | Figure: **1-35** | Rev. A<br>A4 |




**Note: This Map must be viewed with Figure 1-34 for Soils Mapping Units**

Towns / Localities
Major Roads
Rivers, Creeks and Tributary Streams
CSG Field

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Datum : GDA 94





Client: LNG

URS

Project: GLADSTONE LNG PROJECT
TERRAIN, SOILS AND LAND CAPABILITY REPORT
CSG FIELD

Title: **SOILS**
**CSG FIELDS**
**ROMA**
**(2 of 8)**

| Drawn: LL | Approved: GR | Date: 11-02-2009 |
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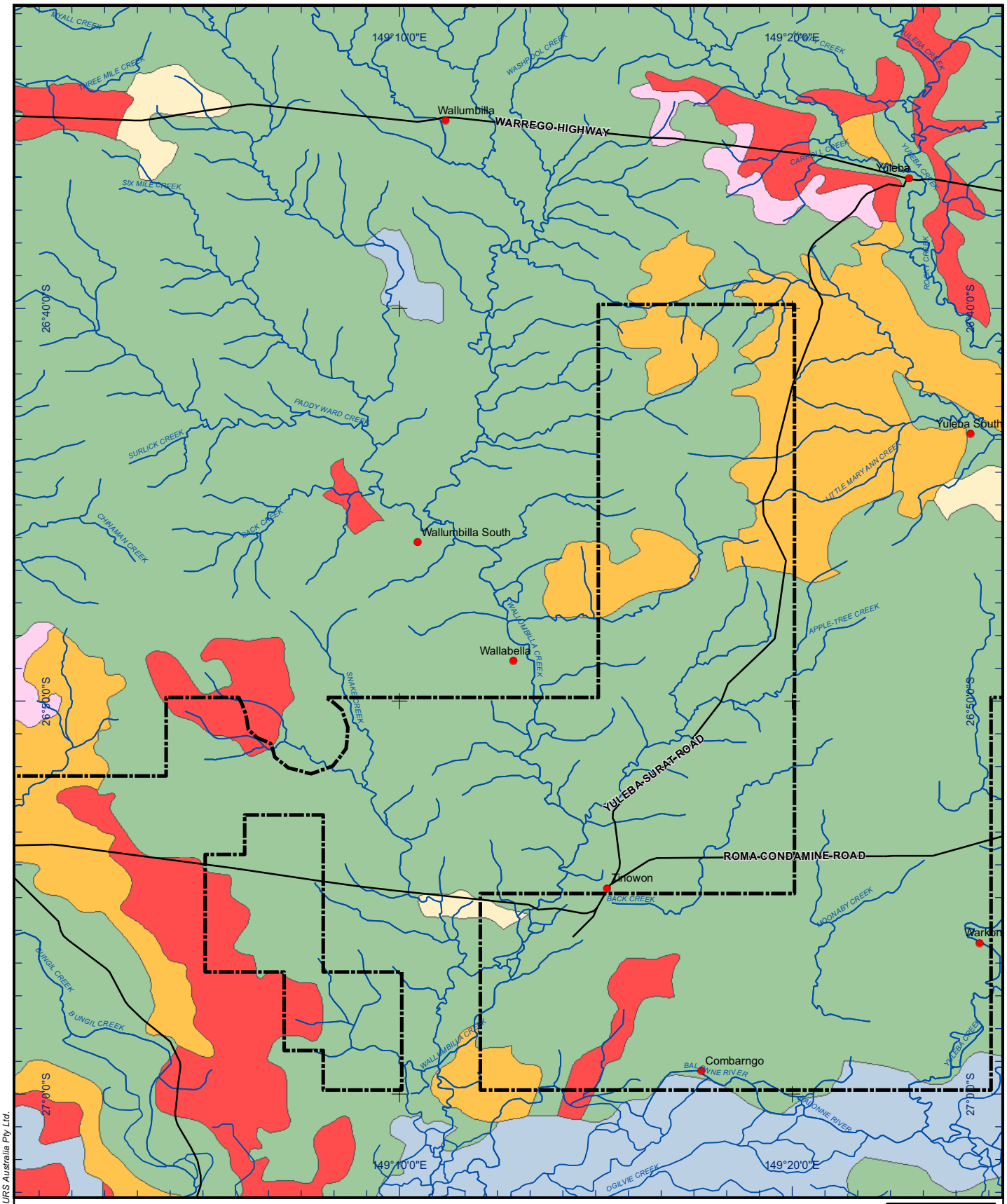
| Job No.: 4262 6220 | File No.: 42626220-g-699.mxd | |

Figure: **1-36**

Rev. A
A4




**Note: This Map must be viewed with Figure 1-34 for Soils Mapping Units**





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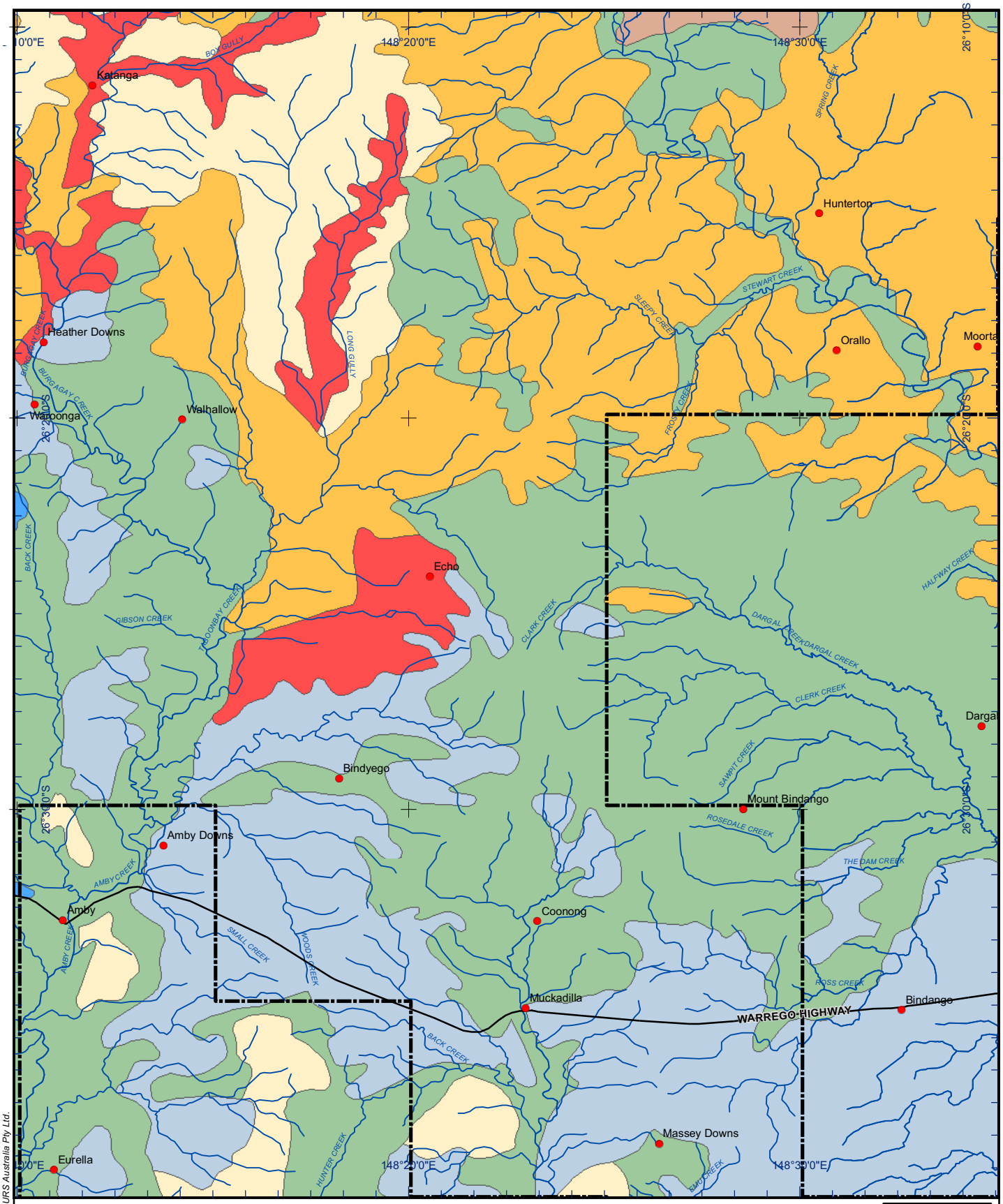
| | Drawn: LL | Approved: GR | Date: 11-02-2009 |
| | Job No.: **4262 6220** | File No.: 42626220-g-699.mxd | Figure: **1-37** |
| | | | Rev. A<br>A4 |




**Note: This Map must be viewed with Figure 1-34 for Soils Mapping Units**

Towns / Localities
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Rivers, Creeks and Tributary Streams
CSG Field

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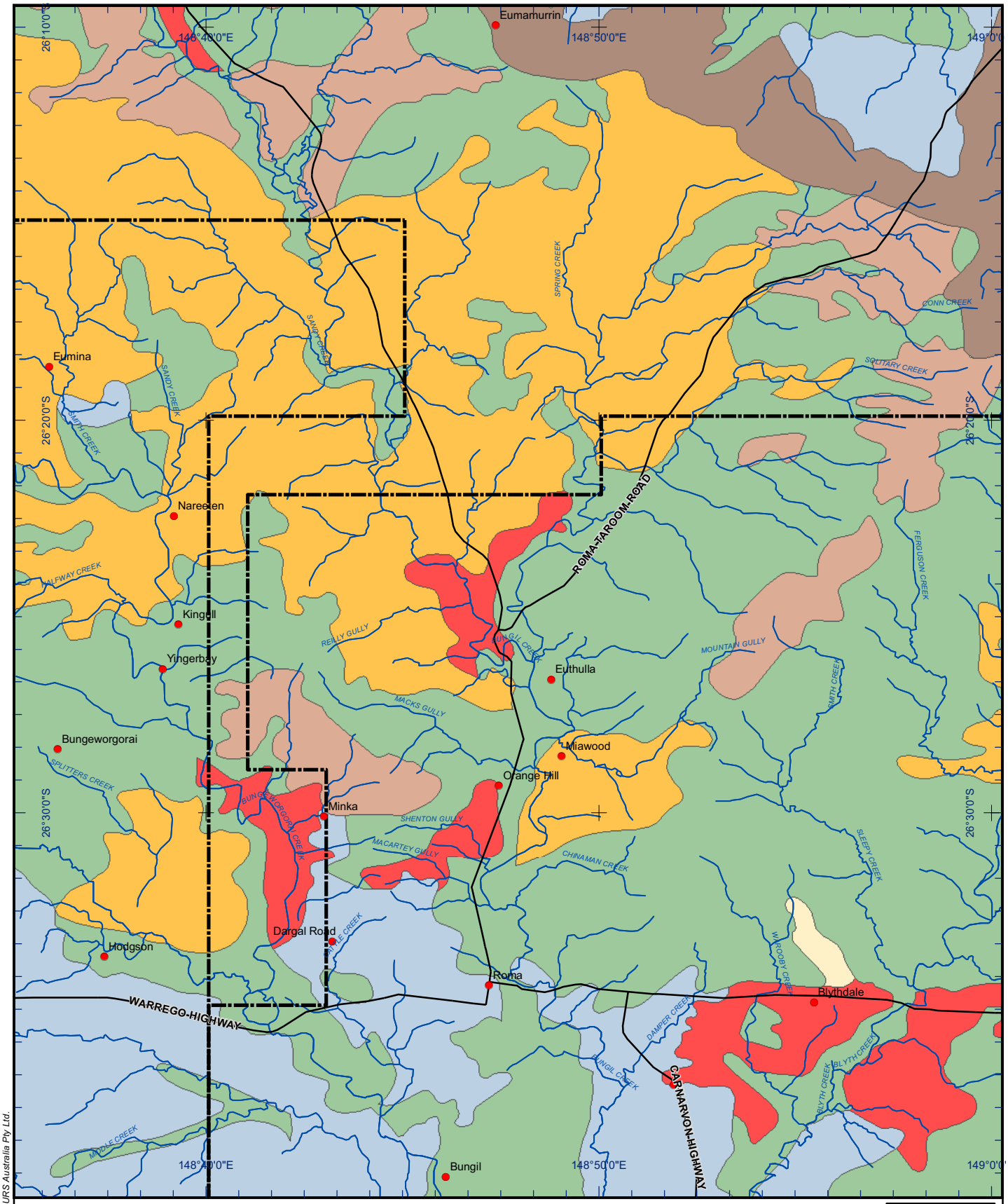
| Client: LNG / URS | Project: GLADSTONE LNG PROJECT<br>TERRAIN, SOILS AND LAND CAPABILITY REPORT<br>CSG FIELD | | Title: **SOILS**<br>**CSG FIELDS**<br>**ROMA**<br>**(4 of 8)** |
| | Drawn: LL | Approved: GR | Date: 11-02-2009 |
| | Job No.: **4262 6220** | File No.: 42626220-g-699.mxd | Figure: **1-38** |
| | | | Rev. A<br>A4 |




**Note: This Map must be viewed with Figure 1-34 for Soils Mapping Units**





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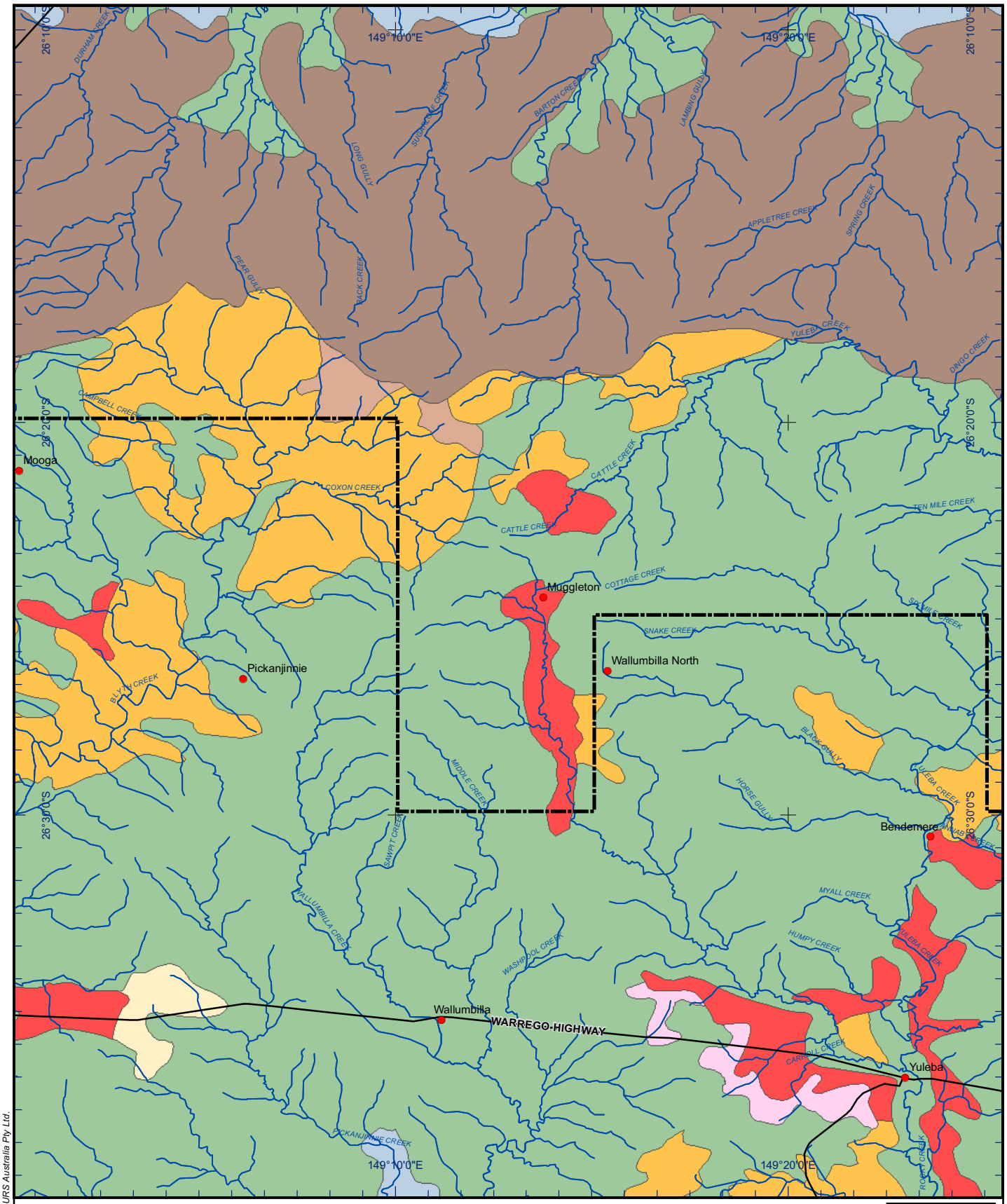
| Client: LNG | Project: GLADSTONE LNG PROJECT<br>TERRAIN, SOILS AND LAND CAPABILITY REPORT<br>CSG FIELD | Title: **SOILS**<br>**CSG FIELDS**<br>**ROMA**<br>**(5 of 8)** | |
| URS | Drawn: LL / Approved: GR / Date: 11-02-2009<br>Job No.: **4262 6220** / File No.: 42626220-g-699.mxd | Figure: **1-39** | Rev. A<br>A4 |




**Note: This Map must be viewed with Figure 1-34 for Soils Mapping Units**

- Towns / Localities
- Major Roads
- Rivers, Creeks and Tributary Streams
- CSG Field

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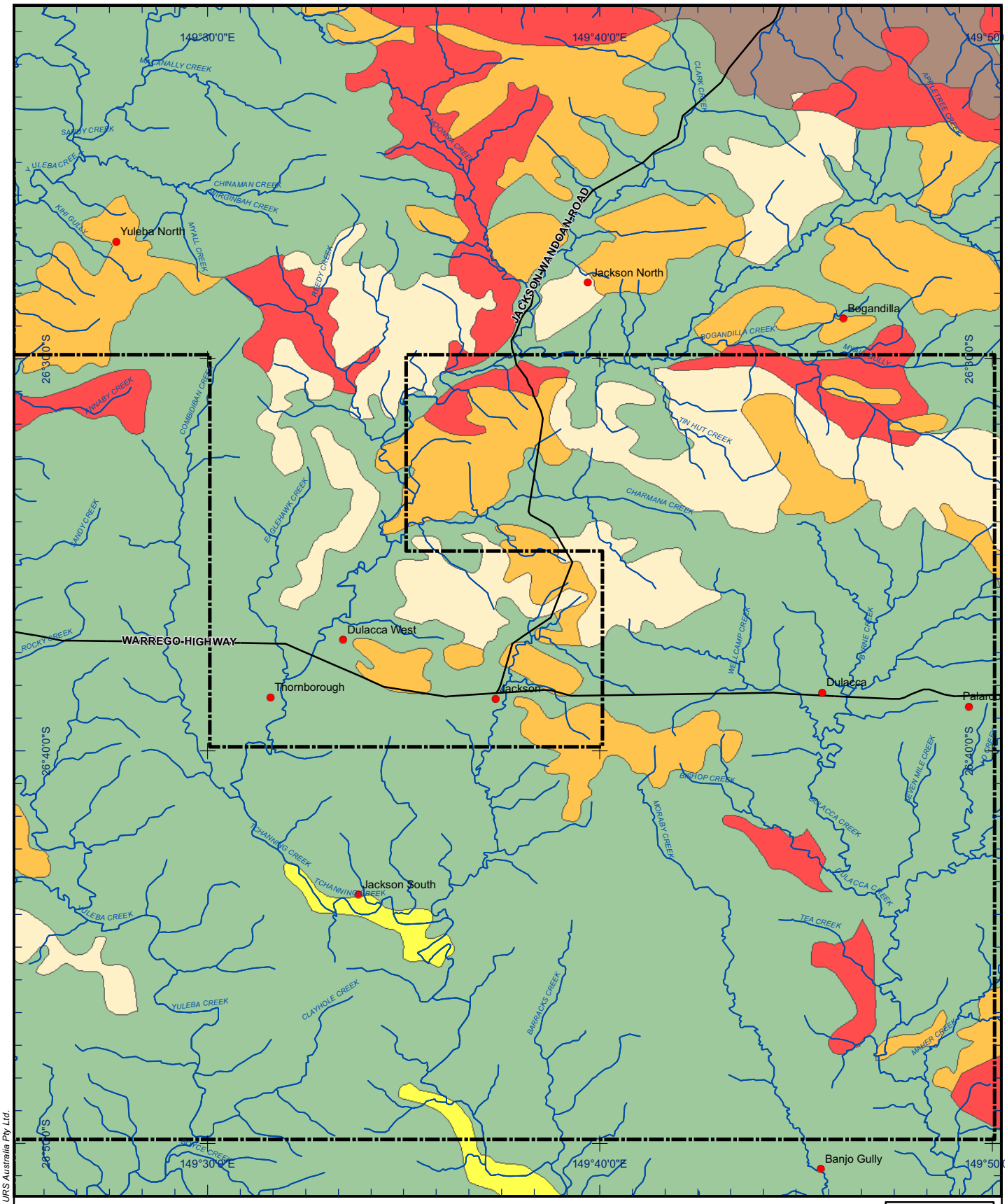
| Client: LNG / URS | Project: GLADSTONE LNG PROJECT<br>TERRAIN, SOILS AND LAND CAPABILITY REPORT<br>CSG FIELD | Title: **SOILS**<br>**CSG FIELDS**<br>**ROMA**<br>**(6 of 8)** | |
| | Drawn: LL / Approved: GR / Date: 11-02-2009 | Figure: **1-40** | Rev. A |
| | Job No.: **4262 6220** / File No.: 42626220-g-699.mxd | | A4 |




**Note: This Map must be viewed with Figure 1-34 for Soils Mapping Units**

- Towns / Localities
- Major Roads
- Rivers, Creeks and Tributary Streams
- CSG Field

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





| Client | Project | Title |
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| LNG / URS | GLADSTONE LNG PROJECT<br>TERRAIN, SOILS AND LAND CAPABILITY REPORT<br>CSG FIELD | **SOILS**<br>**CSG FIELDS**<br>**ROMA**<br>**(7 of 8)** |

| Drawn: LL | Approved: GR | Date: 11-02-2009 | Figure: **1-41** | Rev. A |
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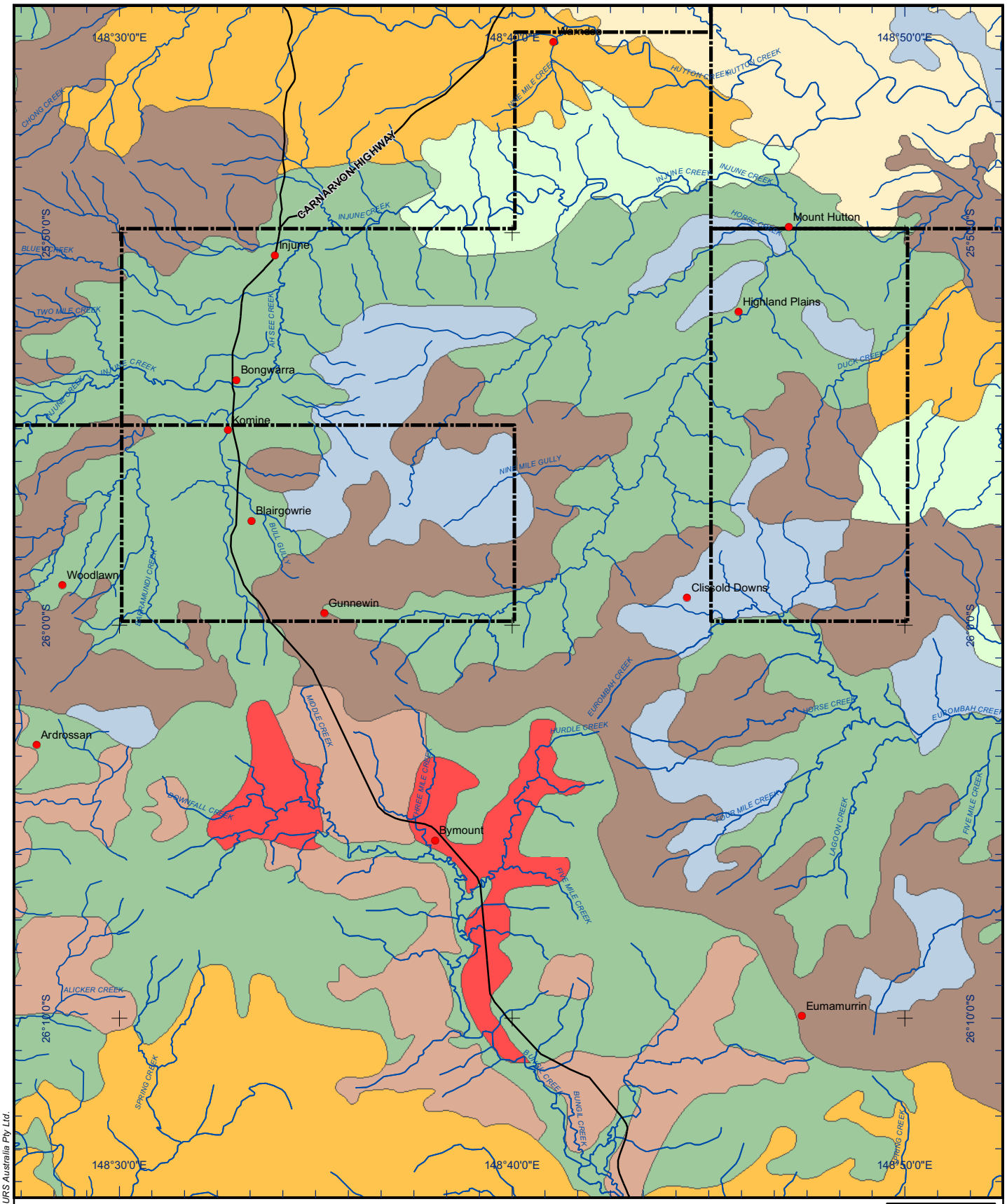
| Job No.: **4262 6220** | File No.: 42626220-g-699.mxd | | | A4 |




**Note: This Map must be viewed with Figure 1-34 for Soils Mapping Units**

Towns / Localities
Major Roads
Rivers, Creeks and Tributary Streams
CSG Field

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





Client: LNG

URS

Project: GLADSTONE LNG PROJECT
TERRAIN, SOILS AND LAND CAPABILITY REPORT
CSG FIELD

Title: **SOILS**
**CSG FIELDS**
**ROMA**
**(8 of 8)**

| Drawn: LL | Approved: GR | Date: 11-02-2009 |
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| Job No.: 4262 6220 | File No.: 42626220-g-699.mxd | |

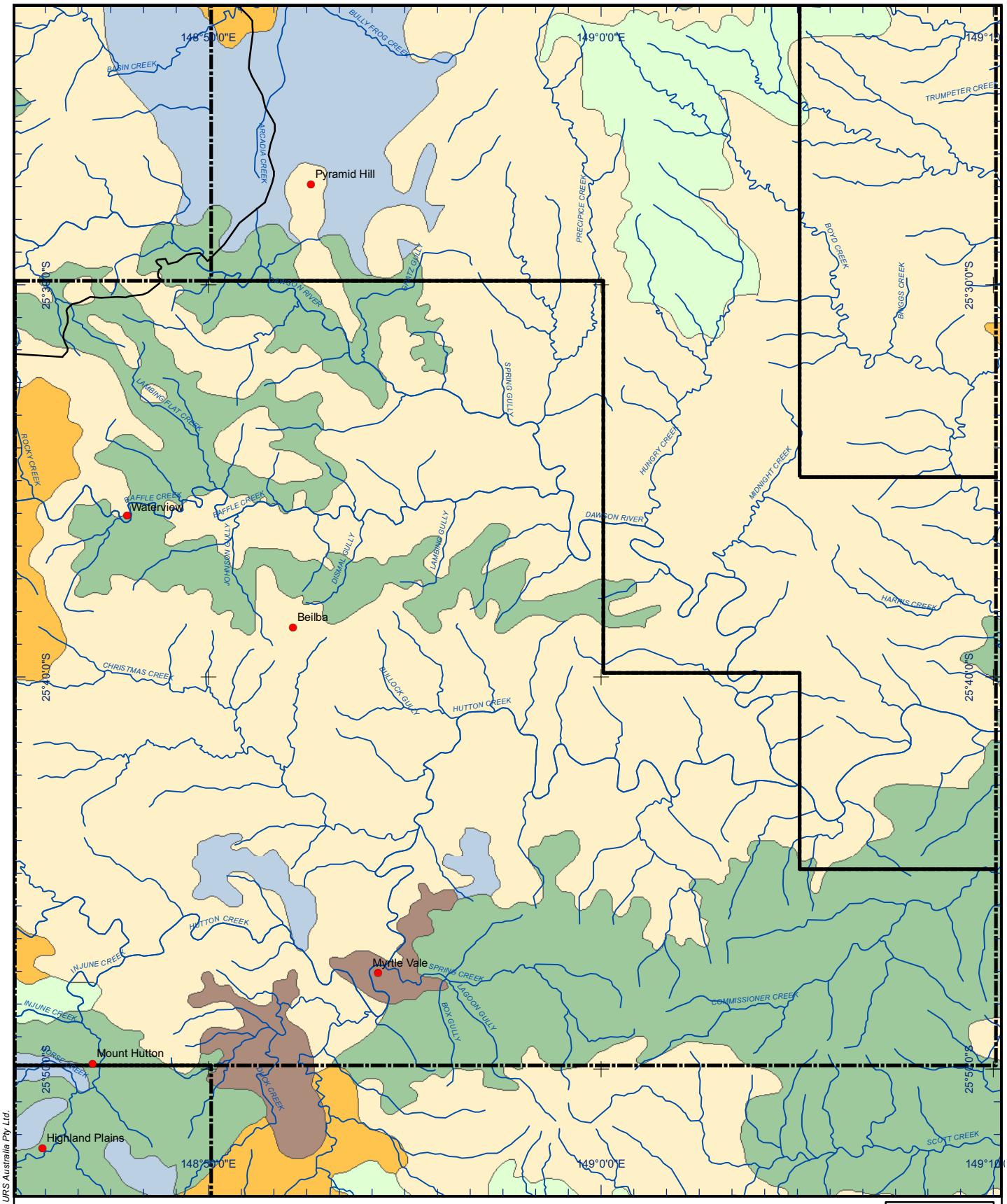
Figure: **1-42**

Rev. A
A4

### 1.6.5 Soils in the Fairview Field

The Fairview field encompasses a land area of 116,097 ha. The occurrence and distribution of soils in the Fairview field is shown in **Figure 1-43**. The collective extent of occurrence of the respective SMU's identified is as follows:

- SMU 1 encompasses approximately 72,686 ha (62.6%) of the Fairview 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 area. 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 field mainly on hilly lands in the south eastern and on undulating fluvial plains in the central northern and north western sectors of the area. 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 outcrop, 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 field and comprises an area of undulating plain along the western boundary in the north western sector of the field area. 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 field and occurs as undulating to locally near flat to depressional fluvial plains in the central southern sector of the area. 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 field occur in the same general vicinity as SMU 10 near the central southern boundary of the area. 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 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.




**Note: This Map must be viewed with Figure 1-34 for Soils Mapping Units**





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| Client: LNG / URS | Project: GLADSTONE LNG PROJECT<br>TERRAIN, SOILS AND LAND CAPABILITY REPORT<br>CSG FIELD | | Title: **SOILS**<br>**CSG FIELDS**<br>**FAIRVIEW** |
| | Drawn: LL | Approved: GR | Date: 11-02-2009 |
| | Job No.: **4262 6220** | File No.: 42626220-g-699.mxd | Figure: **1-43** |
| | | | Rev. A<br>A4 |

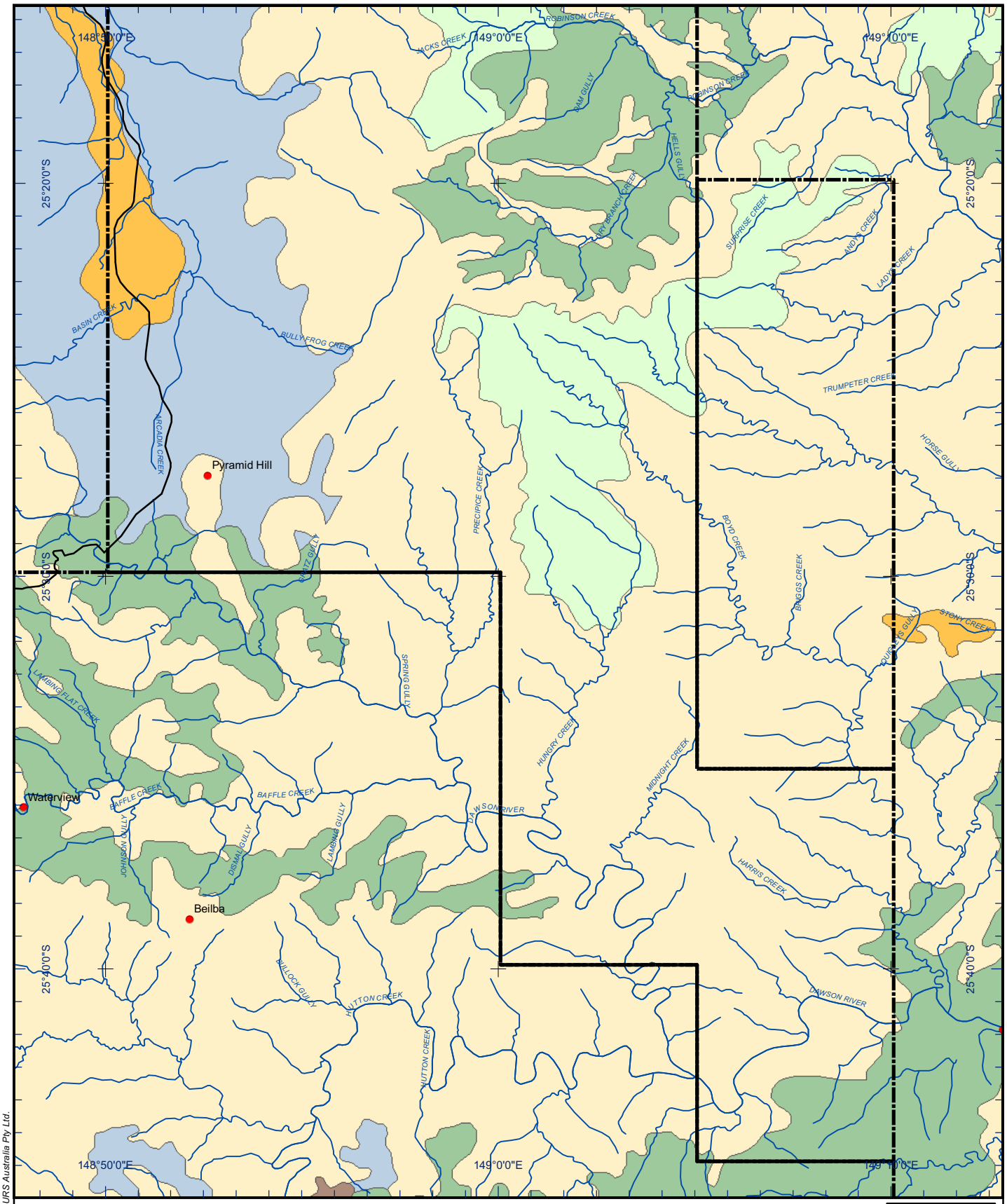
### 1.6.6 Soils in the Arcadia Valley Field

The Arcadia Valley field encompasses a land area of 194,016 ha. The occurrence and distribution of soils in the Arcadia Valley field is shown in **Figures 1-44 and 1-45**. The collective extent of occurrence and order of dominance of the respective SMU's identified is as follows:

- SMU 1 encompasses an area of approximately 93,817 ha (48.3%) of the Arcadia Valley 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 area. 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 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 area. 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 field in the central and northern sectors of the area and comprises hilly lands with extensive mid to lower footslopes. 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 field in the central western sector of the area 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 field where formed on tributary drainage flats along the central western boundary of the area and in hilly upland areas in the central northern sector of the area. 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 field occur in the central and north eastern sectors of the area 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.




**Note: This Map must be viewed with Figure 1-34 for Soils Mapping Units**

Towns / Localities
Major Roads
Rivers, Creeks and Tributary Streams
CSG Field

N
W E
S

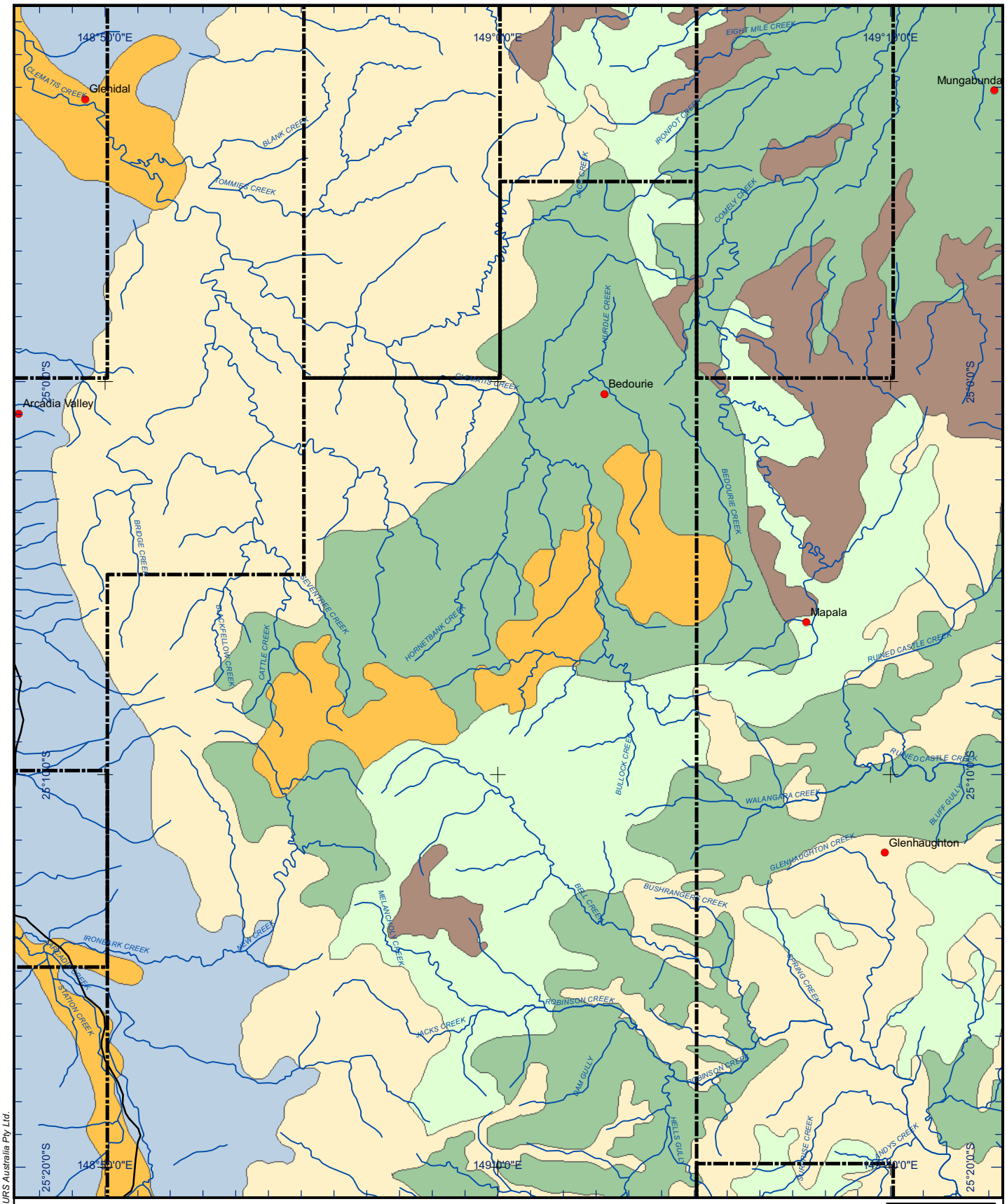
Kilometers
0 0.5 1 2 3 4 5

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





| | | | |
|---|---|---|---|
| Client: LNG / URS | Project: GLADSTONE LNG PROJECT<br>TERRAIN, SOILS AND LAND CAPABILITY REPORT<br>CSG FIELD | | Title: **SOILS**<br>**CSG FIELDS**<br>**ARCADIA VALLEY**<br>**(1 of 2)** |
| | Drawn: LL | Approved: GR | Date: 11-02-2009 |
| | Job No.: **4262 6220** | File No.: 42626220-g-699.mxd | Figure: **1-44** |
| | | | Rev. A<br>A4 |




**Note: This Map must be viewed with Figure 1-34 for Soils Mapping Units**

Towns / Localities
Major Roads
Rivers, Creeks and Tributary Streams
CSG Field

N
W E
S

Kilometers
0 0.5 1 2 3 4 5

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





| | | | |
|---|---|---|---|
| Client: LNG / URS | Project: GLADSTONE LNG PROJECT<br>TERRAIN, SOILS AND LAND CAPABILITY REPORT<br>CSG FIELD | | Title: **SOILS**<br>**CSG FIELDS**<br>**ARCADIA VALLEY**<br>**( 2 of 2)** |
| | Drawn: LL | Approved: GR | Date: 11-02-2009 |
| | Job No.: **4262 6220** | File No.: 42626220-g-699.mxd | Figure: **1-45** |
| | | | Rev. A<br>A4 |

## 1.7 Topsoil Resources

### 1.7.1 Method of Assessment

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 field 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 1-4.**

## Table 1-4 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, sily, loamy or clayey soil matrix | 1 | 0 | Skeletal to shall ow rock y soils (>60% co arse fragments); r ock 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<br>2.2<br>2.3 | 0.1<br>0<br>0.25 | Utilise seedstock and organics<br>Potential source of bedding sand<br>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<br>3.2<br>3.3 | 0.2<br>0.3<br>0.3 | Strongly acidic subsoils (>0.2 m)<br>Texturally suitable (0.3-0.6) but low levels of soil nutrients<br>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 profiles with clay loam, light clay or medium clay subsoils, in places with siliceous stone and/or ferruginous gravelly lenses included | 4.1<br>4.2<br>4.3 | 0.2<br>0.3<br>0.3 | Excess gravel/stone below 0.2 m<br>Texturally suitable (0.3-0.6) but high gravel content may occur<br>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<br>5.2<br>5.3 | 0.2<br>0.3<br>0.2 | Strongly acidic in deeper subsoils<br>Bleached (A2) horizon (>0.3 m), source of bedding sand (0-0.6 m)<br>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<br>6.2<br>6.3 | 0.15<br>0.15<br>0.25 | Shallow soils, bleached (A2) horizon, strongly alkaline subsoils<br>Thin pale or bleached layer over hard clay subsoils<br>Thick sandy A horizon, bleached A2 horizon (>0.25 m) |
| 7 | Shallow uniform often grave lly fi ne-textured soils, med ium to de ep un iform fi ne-textured (non-cracking) cla y so ils or gradational often stony or grav elly cla y l oam or light cl ay surface s oils o ver alk aline m edium to heavy clay s ubsoils, locally s odic a nd s aline in th e deeper s ubsoils – som e de ep incipient cracking clays; | 7.1<br>7.2<br>7.3 | 0.2<br>0.3<br>0.2 | Excess gravel/stone below 0.2 m<br>Texturally suitable (0.3-0.6 m), highly alkaline/calcareous below<br>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<br>8.2<br>8.3 | 0.2<br>0.25<br>0.2 (rises)<br>0.3 m (in depressions) | Medium to coarse blocky structure (>0.15-0.2 m); some rock cobbles and gravel included<br>Medium to coarse hard blocky structure below 0.2-0.3 m<br>Medium to coarse hard blocky structure and mod. saline below 0.2 m on gilgai mounds |

### 1.7.2 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 exploration activities and 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.

### 1.7.3 Topsoil Stripping

Prior to the commencement of topsoil stripping, areas will be cleared of vegetation. Earthmoving plant operators will be trained and/or supervised to ensure that stripping operations are conducted in accordance with stripping plans and anticipated *in situ* soil conditions. This will ensure that suitable topsoil material resources are salvaged 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 that 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.

### 1.7.4 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 6 months, the stockpile will be deep ripped and sown with local grass seed-stock, legumes and where appropriate the use of any suitable potentially threatened (local) plant species will be considered in order to keep the soil healthy and maintain biological activity. Topsoil stockpiles will be clearly sign-posted for easy identification and to avoid any inadvertent losses. Establishment of weeds on the stockpiles will also be monitored and controlled.

## 1.8 Soil Erosion

The development of well sites will involve clearing and earthworks within a defined footprint. Associated infrastructure areas as well as in areas will also have a defined footprint for areas where temporary and permanent access tracks are proposed. Potential environmental impacts that may result from the establishment of production well sites primarily relate to the erosion potential of the land in areas that are cleared or disturbed.

### 1.8.1 Existing and Potential Soil Erosion

From examination of imagery acquired covering the general vicinity of the study area, substantial areas are currently subject to accelerated soil erosion, in particular extensive surface sheet and rill erosion. Areas of gully erosion mainly exist on the approaches or adjacent to the more major stream lines. 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 runon/runoff potential and the effects of wind erosion over time. Accordingly, a qualitative assessment of erosion potential has been made on a Landscape Unit basis in **Appendix A**, with erosion potential rated simply as low (L), medium (M) or high (H). The basis of the assessment of erosion potential is included in **Appendix B-1** of this report. Erosion control measures also outlined in **Appendix B-2** will be incorporated in a generic environmental management plan (EMP) which will be developed and implemented to minimise the effects of erosion that may result from development of the CSG field facilities and associated infrastructure. These erosion control measures are based on the Engineering Guidelines for Queensland for Soil Erosion and Sediment Control (Institute of Engineers Australia *et al* 1996), as well as from the NSW Department of Conservation and Land Management (CALM - 1992).

## 1.9 Agricultural Land Capability

### 1.9.1 Agricultural Land Classes

An assessment of the agricultural land capability has been carried out to provide a benchmark of existing/potential agricultural land use. As required in the EIS Terms of Reference and in accordance with, State Planning Policy 1/92: *Development and the Conservation of Agricultural Land*, the assessment is 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.

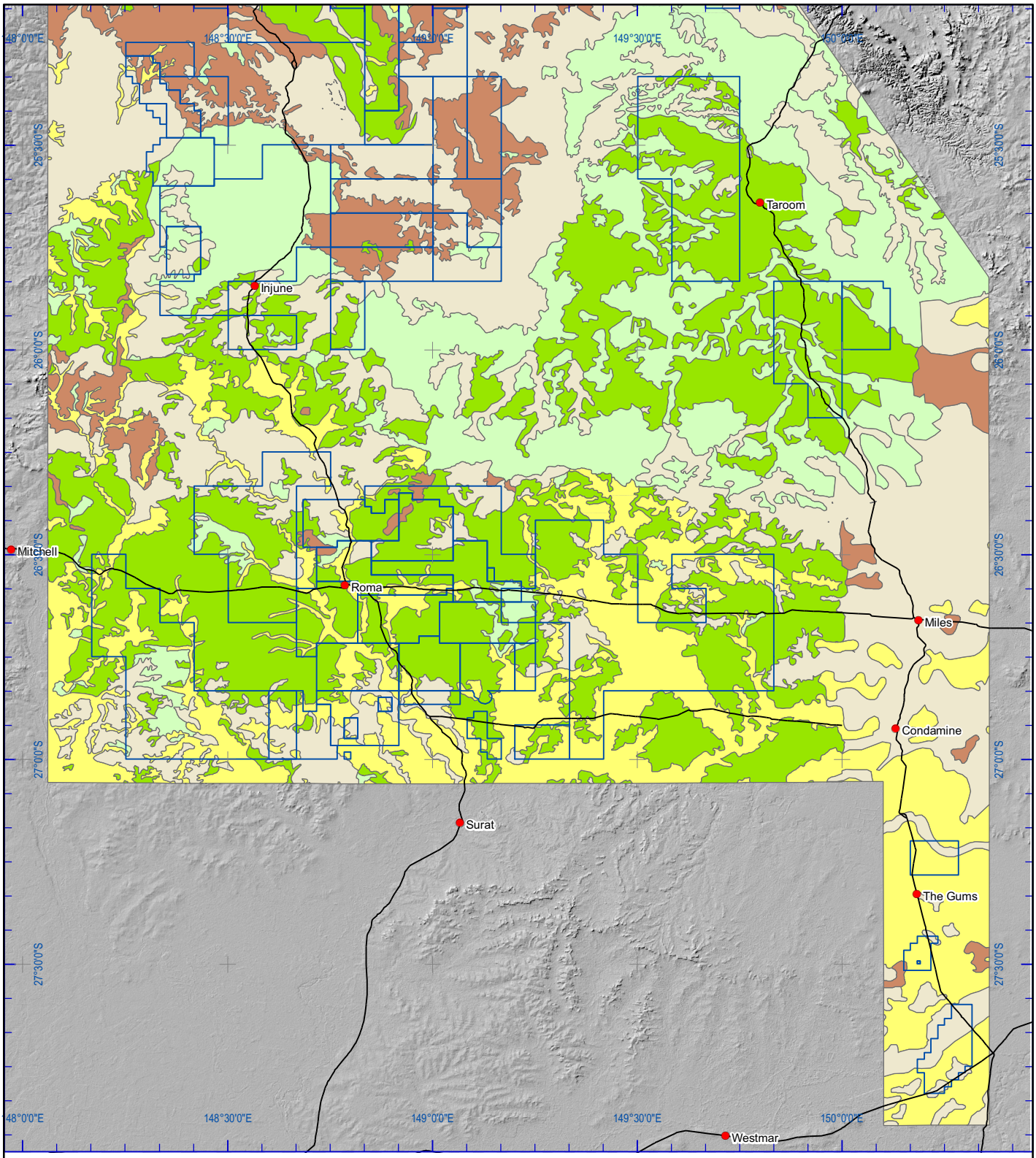
C3) - Land that is suited to restricted light grazing of native pastures in accessible areas, otherwise steep to very steep hilly lands more suited for forestry, conservation or catchment protection.

***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.

Agricultural land classes for the CGS Field as a whole are shown in **Figures 1-46 and 1-47**. The land classes identified are based primarily on the regional compilation and mapping (1:250,000) of Good Quality Agricultural Lands (GQAL) in the Central West Region of Queensland – NRW (2004). Areas of the CSG field 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. The agricultural land classes assessed for the landscape units identified within the CSG field are included in landscape unit descriptions and assessment of engineering and environmental attributes in **Appendix A** of this report.

## 1.10 Acid Sulfate Soils

The EIS Terms of Reference (ToR) require 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. Given that the ground surface level within the CSG field is typically in excess of RL 50 m AHD, the presence of ASS is not likely to be an issue.




**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) |

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





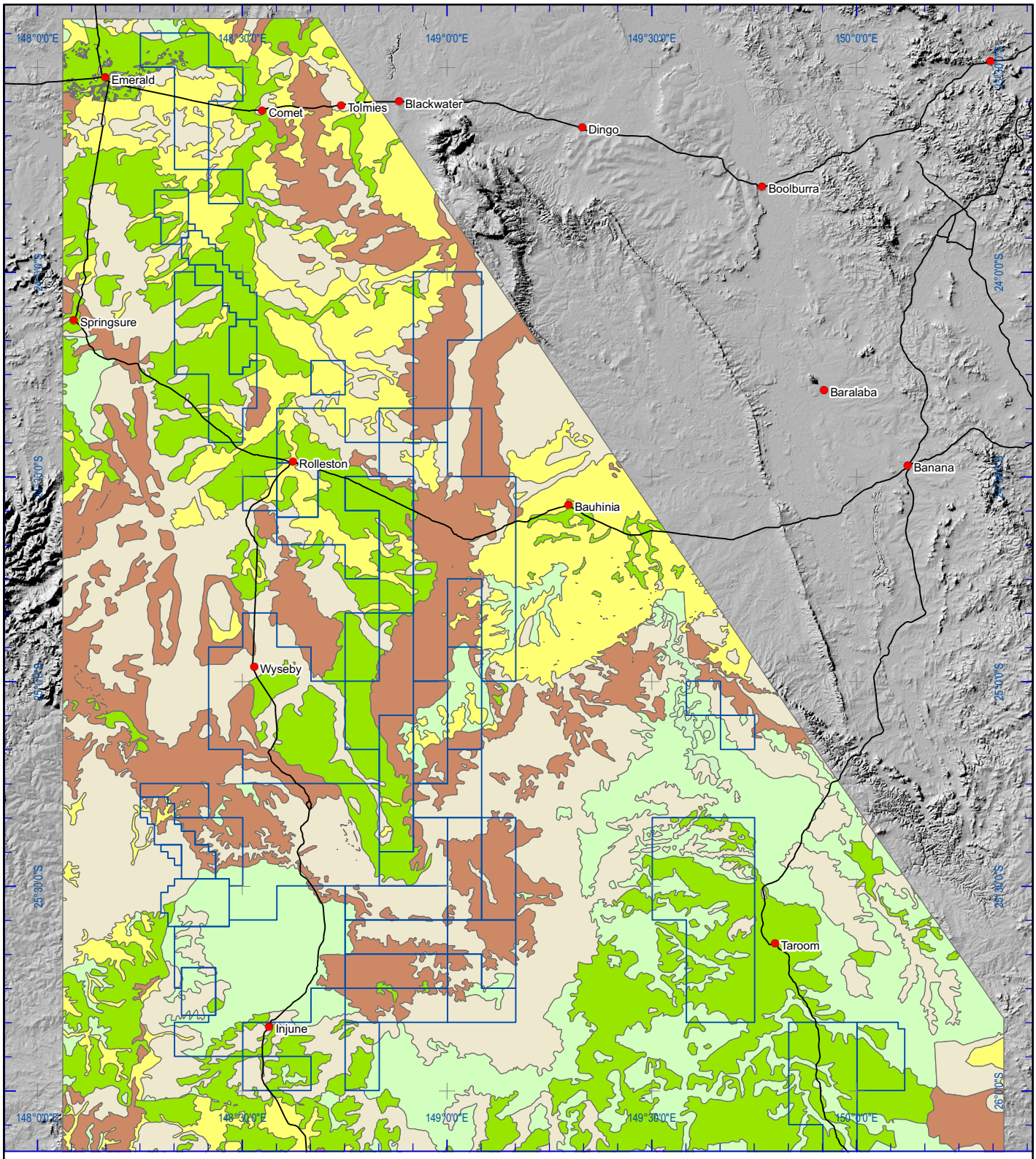
Client: LNG

URS

Project: GLADSTONE LNG PROJECT
TERRAIN, SOILS AND LAND CAPABILITY REPORT
CSG FIELD

Title: **AGRICULTURAL LAND CLASSES**
**CSG FIELDS**
**(SOUTHERN SECTION)**

| | | | |
|---|---|---|---|
| Drawn: LL | Approved: GR | Date: 11-02-2009 | Figure: **1-46** |
| Job No.: **4262 6220** | File No.: 42626220-g-694.mxd | | Rev. A<br>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) |

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: LNG

URS

Project: GLADSTONE LNG PROJECT
TERRAIN, SOILS AND LAND CAPABILITY REPORT
CSG FIELD

Title: **AGRICULTURAL LAND CLASSES CSG FIELDS (NORTHERN SECTION)**

| | | | |
|---|---|---|---|
| Drawn: LL | Approved: GR | Date: 11-02-2009 | Figure: **1-47** |
| Job No.: **4262 6220** | File No.: 42626220-g-695.mxd | | Rev. A<br>A4 |

A broad scale terrain analysis was carried out to assess the engineering and/or environmental constraints with respect to the future development of the CSG Fields, the location and extent of which is shown in **Figure 1-1 and 1-2**. 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. The occurrences of the landscape units as mapped for the Roma, Fairview and Arcadia Valley fields are shown in **Figure 1-21 to 1-28, Figure 1-29 and Figure 1-30 to 1-31** respectively. Descriptions of the landscape units, together with an assessment of some of the more important engineering and/or environmental constraints and by association, potential environmental impacts for development of the CSG fields, are provided in **Appendix A** of this report. The terrain attributes assessed include:

- 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 sulphate soils;
- Excavation conditions - relates to the assessed ease or difficulty of excavation within the upper 1.5 m for construction of the pipeline network; and
- Terrain suitability for construction of water storage facilities.

A summary of findings and comments with respect to mitigation of potential environmental impacts are described below:

## 2.1 Agricultural Land Capability

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 fields. The results of the assessment are included in **Appendix A** of this report. The basis for the assessment of agricultural land capability is provided in **Section 1.8** above. A summary of the findings of the assessment for each field is as follows.

***Roma Field***

**Table 2-1 Roma CSG Field Land Area**

| Land Class | % of Roma Field | Area (ha) |
|---|---|---|
| A 52.2 | | 428,174 |
| A-B 27.4 | | 225,129 |
| B 3.9 | | 31,893 |
| C1 1.6 | | 12,824 |
| C2 12.1 | | 99,409 |
| C3 2.8 | | 23,147 |
| **Total** | **100** | **820,576** |

# Section 2 Potential Impacts and Mitigation Measures

***Fairview Field***

**Table 2-2 Fairview CSG Field Land Area**

| Land Class | % of Fairview Field | Area (ha) |
|---|---|---|
| A < | 0.1 | 27 |
| B 1.3 1,486 | | |
| C1 0.6 | | 741 |
| C2 65.7 | | 76,175 |
| C3 26.3 | | 30,389 |
| D 6.0 | | 6,838 |
| **Total** | **100** | **116,097** |

***Arcadia Valley Field***

**Table 2-3 Arcadia Valley CSG Field Land Area**

| Land Class | % of Arcadia Valley Field | Area (ha) |
|---|---|---|
| A 7.8 | | 15,196 |
| B 4.1 7,883 | | |
| C1 10.8 | | 20,948 |
| C2 46.5 | | 90,212 |
| C3 20.7 | | 40,178 |
| D 10.1 | | 19,595 |
| **Total:** | **100** | **194,012** |

## 2.1.1 Agricultural Land Capability Impacts and Mitigation Measures

Areas identified as Land Class A and B and C1 may be subject to short term disruption of existing land use during the development of the gas 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 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 possible 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 Land Class C2 are essentially good quality grazing land suitable for native or improved pastures, but cultivation is not normally undertaken. When construction is 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 Land Class C3 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 is complete in these areas, land management and erosion control measures described in Section 2.3.1 for sloping lands and drainage lines should be implemented. In general these areas will be revegetated as soon as practicable after construction has been completed.

## 2.2 Erosion Potential

Appendix A includes an indicative assessment of erosion potential carried out on a landscape unit basis which is applicable to each of the Roma, Fairview and Arcadia Valley fields. The basis for the assessment of erosion potential is provided in Appendix B of this report. A summary of the findings of the assessment for each of the fields is as follows.

### *Roma Field*

**Table 2-4 Roma Field Erosion Potential**

| Erosion Potential | Potential Environmental Impact | % of Roma Field | Area (ha) | Applicable Landscape Units |
|---|---|---|---|---|
| Low-Moderate Lo | w | 48.1 | 395,071 | Qa1, Km1, Ka1, Ts1, Tv2 and Jm1 |
| Moderate Moder | ate 41.5 | | 340,412 | Ja1, Jm2, Ka2, Km2, Km3, Qa2, Ts2, Tv3 and Tv4 |
| Moderate to High | Moderate to High | 10.4 | 85,093 | Ja2, Ja3, Ja4, Jm3, Ka3, Km4, Ts3 and Tv5 |
| **Total** | **-** | **100** | **820,576** | **-** |

### *Fairview Field*

**Table 2-5 Fairview Field Erosion Potential**

| Erosion potential | Potential Environmental Impact | % of Fairview Field | Area (ha) | Applicable Landscape Units |
|---|---|---|---|---|
| Low-Moderate | Low | Nil Nil Nil | | |
| Moderate Moder | ate | 32.6 | 37 758 | Ja1, Ja5, Jm2, Qa2, Rm5 and Rm6. |
| Moderate to High | Moderate to High | 67.4 | 77 899 | Ja2, Ja3, Ja4, Jm3, and Rm2 |

# Section 2 Potential Impacts and Mitigation Measures

| Erosion potential | Potential Environmental Impact | % of Fairview Field | Area (ha) | Applicable Landscape Units |
|---|---|---|---|---|
| **Total** | **-** | **100** | **115 657** | **-** |

***Arcadia Valley Field***

**Table 2-6 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 Moder | ate 33.9 | | 65,676 | Ja1, Ja5, Ja6, Rm4, Rm5 and Rm6 |
| Moderate to High | Moderate to High | 57.5 | 111,586 | Ja2, Ja3, Ja4, Rm2, and Rm3 |
| **Total** | **-** | **100** | **194,013** | **-** |

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

## 2.2.1 Erosion Control Measures

Erosion on field development construction and operational sites (i.e. well leases, compressor stations, accommodation facilities, in field pipeline networks etc) cannot be eliminated completely. With the implementation of the following general erosion control measures, the minimisation of erosion and the reduction of sediment loss from disturbed areas will result.

- 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;
- Control 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;
- 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.

***Drainage Line Management:***

- Where pipelines or other buried services are required to cross water courses, where practicable these will be directional drilled to reduce area disturbance and minimise environmental impact in these areas;
- In other drainage lines, if required a 20 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 10 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 may be assisted by pushing disturbed riparian vegetation back over the re-instated area to provide seedstock and to help stabilise the area. This will also help restrict cattle from accessing the area; otherwise it may be necessary to install temporary fencing.

***Dust Mitigation:***

- The construction 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;

# Section 2 Potential Impacts and Mitigation Measures

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

The strategy outlined above provides a summary of general erosion control measures that will be adopted. Some additional erosion control measures relevant to infrastructure structure development, linear facilities and permanent and temporary access roads and tracks are outlined in **Appendix B – 2**. 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 as part of phase 2 impact assessment (refer section 6.1).

## 2.3 Problem Soil Areas

In relation to the development of the CSG well sites and associated infrastructure development, problem soil areas relate to the occurrence of soils that may give rise to adverse engineering and/or environmental impacts if exposed and untreated as a result of development /construction activities. Potential problem soils have been assessed in **Appendix A** of this report as having low (L), low to moderate (L-M), moderate (M), moderate to high (M-H) or high (H) levels of limitations and by association low to high levels of potential impact. The soil attributes assessed have included the likely occurrence of reactive soils (R), sodic soils (So), dispersive soils (D) and soil salinity (Sa). The properties may occur throughout the profile but more commonly occur in the deeper subsoil (B) horizons and/or in the soil substrate. The basis for the assessment of these soil attributes is included in **Appendix B-3**. A summary of the findings of the problem soil assessments within each of the Roma, Fairview and Arcadia Valley fields is as follows (note that Appendix A identifies the nature of the problem soil limitations).

***Roma Field***

**Table 2-7 Roma Field Problem Soil Areas**

| Problem Soil Area Content | Potential Environmental Impact | % of Roma Field | Area (ha) | Applicable Landscape Units |
|---|---|---|---|---|
| Low Lo | w | 0.1 | 1,160 | - |
| Low-Moderate Moder | ate | 13.3 | 108,892 | Ja1, Ka1, Km4, Ts1, Tv2, Tv3 and Tv4 |
| Moderate Moder | ate 84.2 | | 690,683 | 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 |

| Problem Soil Area Content | Potential Environmental Impact | % of Roma Field | Area (ha) | Applicable Landscape Units |
|---|---|---|---|---|
| **Total** | **-** | **100** | **820,216** | **-** |

# Section 2 Potential Impacts and Mitigation Measures

***Fairview Field***

**Table 2-8 Fairview Field Problem Soil Areas**

| Problem Soil Area Content | Potential Environmental Impact | % of Fairview Field | Area (ha) | Applicable Landscape Units |
|---|---|---|---|---|
| Low | Low | 31.0 | 35,807 | Ja4, Ja5 and Rm6 |
| Low-Moderate Moder | ate | 1.7 | 1,955 | Ja1 and Rm5 |
| Moderate Moder | ate 66.7 | | 77,153 | Ja2, Ja3, Jm2 and Qa2 |
| Moderate to High and High | High | 0.6 | 741 | Jm3 and Rm2 |
| **Total** | **-** | **100** | **115,656** | **-** |

***Arcadia Valley Field***

**Table 2-9 Arcadia Valley Problem Soil Areas**

| Problem Soil Area Content | Potential Environmental Impact | % of Arcadia Valley Field | Area (ha) | Applicable Landscape Units |
|---|---|---|---|---|
| Low Lo | w | 24.5 | 47,363 | Ja4, Ja5, Ja6 and Rm6 |
| Low-Moderate Moder | ate | 6.5 | 12,535 | Ja1, Rm4 and Rm5 |
| Moderate Moder | ate 45.4 | | 88,098 | Ja2, Ja3,Qa1, Qa2, Rm1 and Rm2 |
| Moderate to High and High | High | 23.6 | 45,718 | Jm1, Jm3 and Ka3 |
| **Total** | **-** | **100** | **193,714** | **-** |

## 2.3.1 Problem Soils and Mitigation Measures

***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). General ratings for sodicity established by Northcote and Skene (1972) are provided in **Appendix B-3**. 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. 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.

Where sodic and dispersive soils do occur, adopting the relevant erosion control measures outlined in **Section 2.2.1** and in **Appendix B-2** 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 in the soils. 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. 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. The soil reactivity ratings and basis for the assessment of reactive soils is included in **Appendix B-3**.

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

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 addition to deleterious effects on plant growth, soils with high levels of soluble salts increase the potential for corrosion of buried steel and/or concrete products. The criteria used to assess low, medium and high levels of soil salinity are included in **Appendix B-3**.

# Section 2 Potential Impacts and Mitigation Measures

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.

In areas with saline soils, a common salinity management recommendation is to avoid clearing of trees and other woody vegetation, or revegetate cleared areas as soon as practicable following disturbance. This helps to maintain groundwater at a lower level and reduces the risk of secondary salinisation that may result from a general rise in groundwater level as a result of clearing. However much of the existing high risk salinity areas have already previously been cleared for cropping and/or grazing and deep drainage vegetation is required to lower the water table below the root zone is necessary to combat secondary salinity effects in these areas. Application of excess water on occasions to leach the build-up of soluble salts in the plant root zone is one means of combating salt build-up in the surficial soils.

Further geotechnical and soils investigations including soil resistivity surveys in the proposed CSG fields 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.

## 2.4 Area Excavation Conditions

An assessment has been made on a landscape unit basis of the likely ease or difficulty and the associated impacts with respect to the excavation of the materials that occur nominally within the upper 1.5 m below natural ground level. The basis for 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 moderately weathered (MW) to fresh (F) medium strength rock or closely fractured stronger rock.

**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.

### 2.4.1 Results of Assessment

Based on the excavation ratings outlined above, reference to the descriptions and assessment of landscape units provided in **Appendix A** of this report, 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 fields, are as follows:

### *Roma Field*

**Table 2-10 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 | 74,843 | Qa1; Qa2; Ts1; Ts2; Tv2; Ka1; Km1; Km2; Km3; Ja1;Ja2; Jm1;Jm2;Rm1; Rm2 and Rm3 |
| Rating 2; Rating 2-3 | More Difficult | Moderate | 7.4 | 61 ,075 | 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** | **820 606** | **-** |

### *Fairview Field*

**Table 2-11 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 | 35.6 | 41,234 | - |
| Rating 2; Rating 2-3 | More Difficult | Moderate | 32.2 | 37,195 | Ja3, Jm3 and Rm2. |
| Rating 3 Rating 3-4 Rating 4 | Difficult | Moderately High to High | 32.2 37,22 | 7 | Ja4, Ja5, Rm5 and Rm6. |
| **Total** | | | **100** | **115,656** | **-** |

# Section 2 Potential Impacts and Mitigation Measures

***Arcadia Valley Field***

**Table 2-12 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 | - |
| Rating 2; Rating 2-3 | More Difficult | Moderate | 17.4 | 33,733 | Ja3 |
| Rating 3 Rating 3-4 Rating 4 | Difficult | Moderately High to High | 30.8 59,73 | 3 | Ja4, Ja5, Ja6, Rm4, Rm5, Rm6 |
| **Total** | **-** | **-** | **100** | **193,973** | **-** |

## 2.4.2 Impacts and Mitigation Measures

Low, moderate and high levels of constraint with respect to excavation conditions relate to corresponding increasing levels of potential environmental impacts including the likely extent of clearing, 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.

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. Blasting will be carried out in accordance with relevant local authority guidelines and AS:2885.

## 2.5 Land Suitability for the Location of Water Storage Facilities

Groundwater produced from individual well sites will be collected and stored temporarily at local transfer sites. The approximate area required for transfer sites will typically range between about 5 and 7ha. Each site will require a pumping station and lined storage pond (up to 6ha). Water from the various transfer sites will subsequently be transported via a water pipeline to a water treatment facility for processing and treatment. The water treatment facility sites may include a water storage pond of up to 200ha in area. It is expected that the water from the treatment process will be utilised for beneficial use or discharged to local major water courses (refer to the separate 'Associated Water Strategy' report in the EIS for a full discussion on water management options).

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 **Appendix A** of this report. 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 fields is as follows:

### *Roma Field*

**Table 2-13 Roma Field Potential Impacts and Mitigation Measures**

| Land Rating for Siting Water Storage Facility | % of Roma Field | Area (ha) | Applicable Landscape Units |
|---|---|---|---|
| Suitable (S) | 65.3 | 535,721 | Jm1, Jm2, Ka1, Km1, Km2, Qa1 and Qa2 |
| Suitable to Marginal (S-M) and Marginal (M) | 29.5 241,9 | 01 | Ka2, Tv2, Ja1, Ja2, Jm3, Km3, Ts1, Ts2 and Ts3 |
| Unsuitable (U) | 5.2 | 42,953 | Tv3; Tv4; Tv5; Ja3; Ka3; Km4 |
| Total 100 | | 820,575 | - |

### *Fairview Field*

**Table 2-14 Fairview Field Potential Impacts and Mitigation Measures**

| Land Rating for Siting Water Storage Facility | % of Fairview Field | Area (ha) | Applicable Landscape Units |
|---|---|---|---|
| Suitable (S) | 1.3 | 1,513 | Jm2; Qa2 and Rm2 |
| Marginal (M) | 35.0 | 40,462 | Ja1, Ja2, and Jm3 |
| Unsuitable (U) | 63.7 | 73,681 | Ja3; Ja4; Ja5; Rm5 and Rm6 |

# Section 2 Potential Impacts and Mitigation Measures

| Land Rating for Siting Water Storage Facility | % of Fairview Field | Area (ha) | Applicable Landscape Units |
|---|---|---|---|
| Total 100 | | 115,656 | - |

***Arcadia Valley Field***

**Table 2-15 Arcadia Valley Field Potential Impacts and Mitigation Measures**

| 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 | 93,506 | Ja3; Ja4; Ja5; Ja6 and Rm5 |
| Total 100 | | 194,013 | - |

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. Accordingly more detailed area specific site investigations, soil sampling and soil testing will be carried out as part of phase 2 (post EIS) impact assessment studies (refer section 6.1, main of EIS report) at the outset of any proposed future CSG field development areas being commissioned.

## 2.6 Seismic Activity and Ground Stability

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 1.3 above.

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.
- 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 pipeline facilities will be designed in accordance with this standard.

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# Landscape Units

# Appendix A

**Geological Regime: Qa - Quaternary alluvium: stream and floodplain alluvium, clay, silt, sand, gravel; minor colluvium and residual soil overlying Tertiary or Mesozoic sedimentary rocks**

| Landscape Unit | Characteristic Topography | Characteristic Soils | Indicative Ag. Land Class | Erosion Potential | Problem Soil Areas | Excavation Rating (Upper 1.5 m) | Water Storage Suitability |
|---|---|---|---|---|---|---|---|
| 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 | Class A; Class C1 in lower lying more floodprone areas | L-M | M (R3, So/Sa) | 1 | S |
| 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 | Class A; Class C1 in lower lying floodprone areas | M | M (R3, So) | 1 | S |

**Geological Regime: Ts - Tertiary sediments: quartzose sandstone, conglomerate, siltstone**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 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 eaths 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 | Land Class C1-central southern sector; Class A in the south east with C1 on slopes to drainage | L-M | L-M (So/D) in the duplex soil areas | 1 | M |
| 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 | Mostly land Class C1; some Class A and Class B land on higher areas with gentler slopes | M | M (So/D) | 1-2 | M |
| Ts 3 | Moderately inclined surfaces and slopes of rises and low hills; mainly slope Class 3 (5-12%) | Medium deep red earths and lateritic red earth soils (Type 4.2 ) on rises; some shallow rocky soils and lateritic gravelly loam soils (Type 1-3.1) on some steeper rises; sandy duplex soils (Type 5.2 and 6.2) on marginal slopes; | Land Class C2; some Class C1 on gentler lower slopes | M-H | M (So/D) in duplex soil areas on lower slopes | 2 | M |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Ts 4 | Moderately steep hill slopes, jump-ups and low scarps; mainly slope Class 4 (12-25%) | Shallow to medium deep lateritic red earth soils (Type 4.1) on rises; some shallow rocky soils and lateritic gravelly loam soils (Type 1-3.1) on some steeper parts of slopes; shallow gravelly sandy duplex soils (Type 5.1 or 6.1) on lower slopes; | C2 | M | L-M (So/D) in duplex soil areas on lower slopes | 2-3 | U |

**Geological Regime: Tv - Tertiary volcanics: volcanic rocks, predominantly mafic; basalt, trachyte, minor rhyolite**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Tv 2 | Gentle dissection slope interfluves 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 | Class A | L-M | L-M (R2) | 1-2 | S-M |
| 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) | Class C1 | M | L-M (R2) | 2 | U |
| 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 | Class C2 | M | L-M (R1) | 2-3 | U |
| 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 | Class C3 | M-H | L | 3-4 | U |
| 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 | Class D | M-H | L | 4 | U |

**Geological Regime: Ka - Cretaceous arenite: predominantly quartzose rocks (sandstone, siltstone, minor mudstone)**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 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) | Class A | L-M | L-M (So/D) | 1-2 | S |
| 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 trib-utary drainage lines, some sandy duplex soils (Type 5.2 and 5.3) on dissection slope interfluves | Class A, C1 adjacent to larger tributary drainage lines | M | M (So/D) | 2 | S-M |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 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 | Class C1 | M-H | M-H (So/D) | 3 | U |
| 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) | Class C2 | M | L | 3 | U |

**Geological Regime: Km - Cretaceous mudrock: predominantly non-quartzose rocks (carbonaceous mudstone, siltstone - some glauconitic and calcareous, minor sandstone; shelly fossils)**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Km 1 | Near-level plains, very gently rising broad low interfluves and local drainage floors; characteristic 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 some low rises and on slopes to drainage | Class A | L-M | M (R3, So/D/Sa) | 1 | S |
| Km 2 | Plateau remnants, plain areas, broad low rises and strongly undulating areas and local narrow drainage floors; characteristic 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 | Class A in flatter areas, Class B in more steeply sloping lands | M | M (R3, So/D) | 1 | S |
| Km 3 | Inclined surfaces and slopes of rises and low hills; characteristic slope Class 3 (5-12%) | Loamy surface duplex soils (Type 6.2) together with areas of red-yellow massive earth soils (Type 4.2) and shallow to medium deep lateritic gravelly loams (Type 3.1) on low rises and on slopes to drainage | Class C1 | M | M (So/D) | 1-2 | M |
| Km 4 | Moderately steep slopes of hills and ridges; characteristic slope Class 4 (12-25%) | Medium deep loamy surface duplex soils (Type 6.2) on broader crestal areas, shallow to medium deep red-yellow massive earth soils (Type 4.2) and shallow to medium deep lateritic gravelly loams (Type 3.1) and skeletal to shallow rocky soils (Type 1-3.1) on narrower hill and ridge crests and mid to upper hill slopes | Class C2 | M-H | L-M (So/D) | 2-3 | U |
| Km 5 | Steep to very steep hill and ridge slopes and escarpment slopes; characteristic 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 | Class C3 | M | L | 3-4 | U |

**Geological Regime: Ja - Jurassic arenite: predominantly quartzose rocks (medium-grained, feldspathic sublabile sandstone, fine-grained, well-sorted quartzose sandstone, minor dark grey carbonaceous siltstone, mudstone and rare pebble conglomerate)**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 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 | Class C2 | M | L-M (So/D) | 1-2 | M |
| 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, | Class C2 | M-H | M (So/D) | 1-2 | M |
| Ja 3 | Moderately steep slopes of hills, ridges, spurs and escarpment footslopes; 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 | Class C2 | M-H | M (So/D) | 2-3 | U |
| 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 | Class C3 | M-H | L | 3 | U |
| 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 | Class C3 | M | L | 3-4 | U |
| Ja 6 | Very steep to precipitous escarpment and ravine slopes; commonly 25 to 50% with some parts >50% | Skeletal to shallow rocky soils and shallow gravelly sandy soils (Type 1-2.1) in association with areas of sandstone rock outcrop | Class D | M | L | 4 | U |

**Geological Regime: Jm - Jurassic mudrock: predominantly non-quartzose rocks (micaceous siltstone, mudstone, minor labile to quartzose sandstone)**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 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 | Class A | L-M | M-H (R3, So/D/Sa) | 1 | S |
| 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) | Class A | M | M (R3, So/D) | 1-2 | S |
| 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) | Class C1 | M-H | M-H (So/D) | 2 | M |
| 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 | Class C2 | M | M (So/D) | 2-3 | U |
| 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 | Class C3 | M | L | 3 | U |

**Geological Regime: Rm - Triassic mudrock: predominantly non-quartzose rocks (micaceous lithic sandstone, micaceous siltstone)**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 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) | Class B | L-M | M (R3, So/D/Sa) | 1 | S |
| 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) | Class C1 | M-H | M (So/D) | 1 | S |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 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 | Class C2 | M-H | M-H (So/D) | 1-2 | M |
| 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 (Type6.2) | Class C3 | M | L-M (So/D) | 3 | U |
| 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 | Class C3 | M | L-M (So/D) | 3 | U |
| 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 | Class D | M | L | 4 | U |

# Erosion

# Appendix B

# APPENDIX B

## Appendix B-1
## Basis of the Assessment for Erosion Potential

The susceptibility of different soil types to erosion (soil erodibility) is a function of soil texture, and physical and chemical properties. The extent to which an area may be subject to erosion (erosion potential) is a function of soil erodibility and other factors such as surface slope and form, topographic position in the landscape (runon/runoff), rainfall intensity, surface condition and surface/plant cover.

Soil erodibility classes identified by Mills and Murphy, (1977) are summarised as follows:

- *Low Erodibility* – soils with high amounts of organic matter (OM), with surficial soils comprising sand or loamy sand (permitting high infiltration), or aggregated non-dispersive clay surface and/or subsoils;
- *Moderate Erodibility*:- soils with medium levels of OM, with surface soils comprising medium amounts of sand, silt and clay i.e. medium-textured (loamy) surface soils, with slightly dispersive (Dispersion Class Nos. 3 or 5) or aggregated slightly dispersive clay surface and/or subsoils;
- *High Erodibility*:- soils with low levels of OM, soils with bleached (A2) subsoil horizons with high amounts of fine sand and/or silt, soils with a fine strongly structured (self-mulching) clayey surface horizon, or moderately to highly dispersive clayey surface and/or subsoils (Dispersion Class Nos. 1 or 2)

The potential for accelerated erosion to occur (erosion potential) due to construction activities in the project area as a result of clearing and/or surface disturbance, has been assessed as follows:

- Low (L) - The combination of surface slope, run-on/run-off and soil erodibility is such that no appreciable erosion damage is anticipated.

- Moderate (M) - Significant short term erosion is likely to occur due to the combination of slope, soil erodibility factors and extent of run-on/run-off. Erosion control can be achieved using structural works, topsoiling and re-vegetation techniques and other site specific intensive soil conservation works. Some slightly dispersive soil layers may be present in the profile.

- High (H) - High to very high erosion/sediment losses are likely, due to steepness of slopes, surface condition, soil texture and erodibility factors and surface runoff conditions. Intensive soil conservation works will be required to minimise the effects of erosion. Moderately high to highly dispersive soil layers are usually present within the soil profile.

## Appendix B-2

## Erosion Control Measures

The following erosion control measures and topsoil management strategies are based on the Engineering Guidelines for Queensland for Soil Erosion and Sediment Control (Institute of Engineers Australia et al. 1996), The Department of Conservation and Land Management (1992). Where appropriate, these strategies will be undertaken to reduce erosion and sediment loss from disturbed areas during the construction period and ongoing site operations.

**Infrastructure and Development Areas**

Erosion on construction areas cannot be eliminated completely, but measures can be taken to minimise the impact by:

- Limiting the area disturbed, and clearing progressively, immediately prior to construction activities commencing;
- Safeguarding and 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 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 environmental management plan 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 facility. 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 do not remain untreated or unprotected

**Pipelines, and Power Transmission Line Routes**

The following erosion control measures are typically used to minimise the potential impact of erosion and to control sediment loss from the right-of-way:

- Disturbance of topsoil and vegetation along easements will be limited to the minimum practicable. The use of selective clearing techniques which cause a minimum of disturbance to surface conditions will be employed wherever practicable. Millable timber resources will be identified and salvaged where practicable and economically feasible.
- Where trenches are required for pipelines or buried services, useable topsoil material will be stripped and stockpiled separately adjacent to and along the trench. Subsurface materials will be excavated stockpiled separately along the opposite side of the trench. Backfilling of the trench will be done in reverse order.
- In sloping ground and in particular on slopes to drainage lines where surface runoff or sub-surface drainage along the trench may erode the backfill material, trench-breakers (vertical

barriers to flow) will be installed to reduce flow along the trench and promote seepage outflow to the groundwater. This will apply in particular where sodic and/or dispersive soils occur, .

- Where significant disturbance of the ground surface is necessary, topsoil will be removed from the area to be disturbed and stockpiled as work commences. Upon completion of work, the topsoil will be re-spread over any exposed subsoil areas, and the areas of disturbance stabilized by establishing suitable species of vegetation.

- In areas where diversion channels and culverts are proposed to divert flow and control runoff, the outlets may be prone to erosion and require scour protection. This can be achieved by establishing vegetation growth at these outlets. The outlets will be formed to a broad dish shape before seeding, to minimise the concentration of run-off. Rock armouring may be required at some outlets to dissipate the force of water and so reduce erosion.

- Along the alignment right-of-way of line-of route facilities such as transmission lines or pipelines, where vegetation is required to be cleared for construction purposes, the cleared vegetation will be windrowed along the edge of the working area to help control runoff and to allow for efficient re-spreading of vegetation if appropriate, following the completion of construction.

**Access Roads, Service Roads and Temporary Access Tracks**

- Major access roads will normally be sealed and constructed to appropriate local engineering design standards

- Unsealed or graveled 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 armoring, 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 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 construction is completed. Stockpiled topsoil will be re-spread before sowing. On steeper slopes the seeded areas will be protected if necessary.

**Vegetation Clearing – General**

- Disturbance of vegetation in construction areas will be limited to the minimum practicable.

- Selective clearing techniques will be used where practicable which will cause a minimum of disturbance to surface conditions.

- Chipping 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 seed/root stock is left in the ground and surface soils are disturbed as little as possible.

## Appendix B-3

## Basis for the Assessment of Soil Attributes

### Soil Reactivity

L – Nil or low soil reactivity, predominantly sandy coarse-textured soils with Kaolin clay minerals where present
R1 – Moderately reactive soils, ie soils which have medium to heavy clay subsoils, but are not subject to substantial soil swelling or shrinkage; mainly Illite clay minerals present
R2 – Shallow or medium deep, highly reactive (cracking) clay soils, underlain by low or non-reactive substrate soils or weathered rock;
R3 – Deep, highly reactive(cracking) clay soils subject to substantial swelling and shrinkage on wetting and drying; mainly smectite clay minerals present.

### Soil Salinity: (E.C. – 1:5 $H_20$)

Rating L – E.C (mS/cm) <0.25 (sand), <0.4 (loam), <0.55 (clay) – Nil to Low Salinity
Rating M – E.C (mS/cm) 0.25-0.47 (sand), 0.4-0.8 (loam), 0.55-1.15 (clay) – Medium Salinity
Rating H – E.C (mS/cm) >0.47 (sand), >0.8 (loam),>1.15 (clay) – High to Very High Salinity

**Sodicity (ESP):** [Northcote & Skene (1972)]

N – very low or non Sodic, ESP <6%
Rating 1 – Sodic, ESP 6-14%
Rating 2 – Strongly sodic, ESP >14-25%
Rating 3 - Very strongly sodic, ESP >25%

### Dispersion Class:

Rating N – Non-dispersive [Dispersion Classes 4, 6, 7 and 8]
Rating Sl – Slightly Dispersive [Dispersion Classes 5, 3(!) & 3(2)]
Rating M – Moderately Dispersive [Dispersion Classes 3(3) to 2(2)]
Rating H – Strongly dispersive [Dispersion Classes 2(3) to 1]
* *Dispersion Sub Classes (Charman, 1978)*
*(1) - Slight milkiness adjacent to the aggregates*
*(2) - Obvious milkiness < 50% of the aggregates affected*
*(3) - Obvious milkiness, >50% of the aggregate affected*
*(4) - Total dispersion leaving only sand grains.*