FINAL REPORT

GLNG Environmental Impact Statement - Gas Transmission Pipeline Terrain Soils and Land Capability

Prepared for

Santos Ltd

Santos House
Level 14
60 Edward Street
Brisbane QLD 4000

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42626220

Project Manager:

……………………………
Jim Barker
Associate Environmental Scientist

URS Australia Pty Ltd

Level 16, 240 Queen Street
Brisbane, QLD 4000
GPO Box 302, QLD 4001
Australia
T: 61 7 3243 2111
F: 61 7 3243 2199

Project Director:

……………………………
Chris Pigott
Senior Principal

Author:

……………………………
Gavan Renfrey

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Executive Summary

As part of the EIS being undertaken for the Santos GLNG Project, a terrain evaluation study was carried out for the proposed gas transmission pipeline corridor that links the Santos coal seam gas fields in inland Central Queensland with a proposed LNG facility to be constructed in the south western sector of Curtis Island.

Methodology

The terrain analysis has essentially involved a detailed desktop assessment of terrain conditions along the route as a basis for the identification and description of geological, landform and soil conditions, including areas of high engineering geological constraints and/or any potential environmental impacts that may result from construction of the gas transmission pipeline.

Terrain mapping has been carried out with reference to existing regional (1:250,000 scale) and more detailed (1:100,000 scale) GSQ geological data. Topographic information (5 m contour interval) and regional CSIRO land systems and soils information was also utilised, using SPOT geo-referenced satellite imagery as a base for the identification and mapping of *Terrain Units* that occur within the gas transmission pipeline corridor.

The identification of terrain units provides a basis for the description of the physical environment and as mapped, show the occurrence and distribution of geological regimes, landform units and associated soil types which occur along the gas transmission pipeline corridor. Detailed descriptions of the terrain units identified together with an assessment of engineering/environmental attributes and constraints for construction and on-going operations of the gas transmission pipeline and associated infrastructure are included in **Appendix A** of the report.

Fieldwork involving excavation of test pits and soil sampling was undertaken within the LNG plant site area and along the final sector of the gas transmission pipeline corridor that terminates at the LNG facility site on Curtis Island. Fieldwork involving drilling and soil sampling operations were also undertaken as part of an acid sufate soils investigation within the coastal and estuarine areas in the vicinity of and to the south of the proposed bridge crossing in the vicinity of Laird Point on Curtis Island and on the estuarine flats to the south-west of Friend Point on the mainland (refer to **Appendix L4**). A drive-through reconnaissance survey of parts of the western and southern sectors of the gas transmission pipeline corridor, including parts of the southern CSG fields, was also carried out to gain an overall general appreciation of terrain and soil types in the general area.

More detailed field investigations including drilling and soil sampling operations are proposed to be undertaken prior to the commencement of construction of the pipeline, in particular in those areas identified in this study as potential “high constraint” areas, to determine appropriate construction and potential environmental impact management strategies.

Topography and Regional Geology

A comprehensive description of the main topographic features along the gas transmission pipeline corridor is provided in Section 1.2. In summary, the corridor commences in the dissected sandstone plateau lands to the south of the Fairview area and heads to the north via the Arcadia Valley to the vicinity of the Dawson Highway. The alignment then heads in an easterly direction, crossing the Expedition, Dawson, Cooper, Callide, Calliope, Mt. Alma and Mt. Larcom Ranges en route to the proposed LNG plant site on Curtis Island via a proposed bridge crossing of Port Curtis between Friend Point and Laird Point. Townships, roads, rivers and mojor tributary streams are identified along the route.

The geology within the corridor as mapped by the Geological Survey of Queensland (GSQ) in the Geoscience Datasets (2005) for the 1:100,000 Gladstone map sheet covers the eastern sector of the alignment, including

Executive Summary

Curtis Island. GSQ Regional Mapping of the Bowen Basin covers the central and western sectors of the alignment and the southern sector of the route corridor is covered by the mapping of 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 occurrence and distribution of geological regimes and associated terrain units as mapped within the gas transmission pipeline corridor are shown in **Figure 2a, 2b and 2–1 to 2-24.**

Soils and Land Capability

A suite of 9 broad soil groups and associated soil types have been identified and used as a basis for mapping of soils and/or soil associations along the gas transmission pipeline corridor. A description of these soils is included in Section 1.5 below. The description and assessment of terrain units and associated soil groups and soil types included in Appendix A of this report provide the basis for the identification of problem soil area occurrences within the corridor. They also provide the basis to assess the suitability and availability of topsoil resources and to characterise and map the land in terms of its pre-construction agricultural land capability. This in turn will provide a means for establishing land rehabilitation targets upon decommissioning of the gas transmission pipeline and associated facilities.

Soil Erosion Potential

Construction of the gas transmission pipeline will involve clearing and earthworks in the general vicinity of the pipeline trench, in areas where temporary and permanent access roads are proposed and in associated infrastructure areas. Potential environmental impacts that may result from construction activities primarily relate to the erosion potential of the land in areas that are subject to clearing or are disturbed during the development process. The occurrence, distribution and cumulative distance of terrain units intersected along the gas transmission pipeline alignment and the associated erosion potential ratings have been determined on a route sector by sector basis and for the alignment as a whole. General erosion control measures outlined in Section 2.3.1 and in **Appendix B** are recommended and will be implemented where appropriate to minimise the potential effects of erosion during the construction and the on-going operational life of the of the gas transmission pipeline and associated facilities.

Environmental Impacts and Mitigation Measures

Descriptions of the terrain units, together with an assessment of engineering and environmental constraints and by association, potential environmental impacts for pipeline construction relate primarily to the following: includes:

- Topographic constraints;
- Excavation conditions - relates to the ease or difficulty of excavation within the typical trench depth;
- Erosion potential – where the land is subject to clearing or disturbance associated with construction;
- Drainage status – relating to surface drainage conditions and susceptibility to flooding or tidal inundation;
- Problem soils - the occurrence of reactive soils, sodic, dispersive and/or saline soils, acid sulfate soils; and
- Agricultural land classes – changes to agricultural land capability.

Where identified, these potential impacts have been addressed in Section 2.0 and management strategies have been recommended to mitigate the potential environmental impacts.

1.0 Introduction

As part of the Environmental Impact Statement (EIS) being conducted for the proposed Gladstone Liquefied Natural Gas (GLNG) project, a terrain, soils and land capability analysis was undertaken along the 429 km length of the proposed gas transmission pipeline corridor. This pipeline corridor links Santos' coal seam gas fields in Central Queensland with its LNG facility on Curtis Island. The gas transmission pipeline corridor commences in the vicinity of Santos' Fairview CSG field, and runs north through the Arcadia Valley to the western footslopes of the Expedition Range just south of the Dawson Highway. The corridor then heads in an east-north-easterly direction towards Gladstone, closely paralleling the alignment of the existing Queensland Gas Pipeline (QGP), to a proposed bridge crossing of the waterway of Port Curtis between Friend Point on the mainland and Laird Point on Curtis Island, approximately 13 km to the north-west of Gladstone. On Curtis Island the corridor continues in an easterly direction for approximately 3 km, then heads in a southerly direction (traversing the south western section of Curtis Island) to link with the LNG facility site in the vicinity of Hamilton Point.

The Terms of Reference for this study require that a terrain analysis of the proposed gas transmission pipeline corridor be carried out as a basis for the description of the physical environment in terms of geological regimes, landform and associated soil conditions. Additionally, the study is to serve as a means of identifying potential engineering and environmental impacts that may result from the construction activities and on-going operational issues associated with the development. 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 along the gas transmission pipeline corridor including any significant features of the landscape and areas of high conservation values;
- Describe the geological regimes that occur along the pipeline corridor and identify any geological hazards or features that may impact on construction or be impacted by construction;
- 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 along the pipeline corridor 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 construction of the pipeline and associated infrastructure facilities;
- 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.

Section 1 Introduction

1.1 Method of Assessment

1.1.1 Desktop Assessment

The terrain within the gas transmission pipeline corridor has been assessed in terms of geological regimes, landform types and associated soils. The area assessed initially comprised a 5 km wide corridor (2.5 km each side of the designated centreline) and included various potential alternative routes. This was subsequently reduced to a 2km wide corridor (1 km each side of the centreline) as shown for the route finally adopted for the EIS. 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 below which have provided the basis for identifying *Terrain Units* that occur within the gas transmission pipeline corridor.

As mapped, a terrain 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.

The features along the gas transmission pipeline corridor are described in this report in relation to kilometre points (Kp's), where the start point (Kp 0) is approximate 2 km to the south of Hutton Creek in the Fairview area and the end point (Kp 429) is at the proposed LNG facility site on Curtis Island.

1.1.2 Data Sources

The following data were reviewed and/or used for the mapping, description and assessment of the physical environment along the gas transmission pipeline corridor:

- Colour aerial photography – The State of Queensland (NRM&E) Series QAP 5719 flown 02/05/99 at a nominal scale of 1:40,000 for the Curtis Island segment of the gas transmission pipeline corridor; colour 06.ECW (SPOT) imagery provided by Santos Ltd. for the mainland sectors of the pipeline corridor.
- Route corridor topographic data with 5 m Lidar Contours provided by Santos Ltd. covering the majority of the main route corridor; with Geoscience Australia (100k) 20 m Contours, supplemented by reference to Google Earth 3D imagery, in the southern sector of the corridor and in various route alternative corridor sectors considered.
- Geological mapping derived from Regional Geological Map Sheets of the Surat Basin and the Bowen Basin and the Gladstone 1:100,000 Series Geological Mapping, included in the Geoscience Data Set compiled by the Geological Survey of Queensland (July 2004).
- 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.
- Land Resources and Evaluation of the Capricornia Coastal Lands (CCL) – Sheet 3 Calliope area, NRW Data (1995).
- Queensland Department of Natural Resources and Water (NRW – 2004)) regional compilation of and mapping (1:250,000) Central West Region - Good Quality Agricultural Lands (GQAL).
- Denison Trough Gas Project – Gladstone Option. Results of Terrain Analysis and Field Investigations, prepared by Terrain Analysis QLD Pty Ltd on behalf of CSR Oil and Gas Division (1984).

1.1.3 Field Investigations

The terrain analysis undertaken for the gas transmission pipeline corridor has essentially involved an in depth desktop assessment of terrain conditions along the route as a means of identifying geological, landform and soil conditions, as well as areas of potential high engineering/geological constraints for pipeline construction, including areas of potentially high environmental impact that may result from construction of the gas transmission pipeline in particular locations. Fieldwork including soil sampling was undertaken within the LNG plant site area and along the final sector of the gas transmission pipeline corridor that terminates at the LNG facility site on Curtis Island. Fieldwork involving drilling and soil sampling operations were undertaken as part of an acid sufate soils investigation within the coastal and estuarine areas on the south-west coast of Curtis Island and on the estuarine flats to the south-west of Friend Point on the mainland (see Appendix L4). A drive-through reconnaissance survey of parts of the western and southern sectors of the gas transmission pipeline corridor, including parts of the southern CSG fields, was also carried out to gain an overall general appreciation of terrain and soil types in the general area.

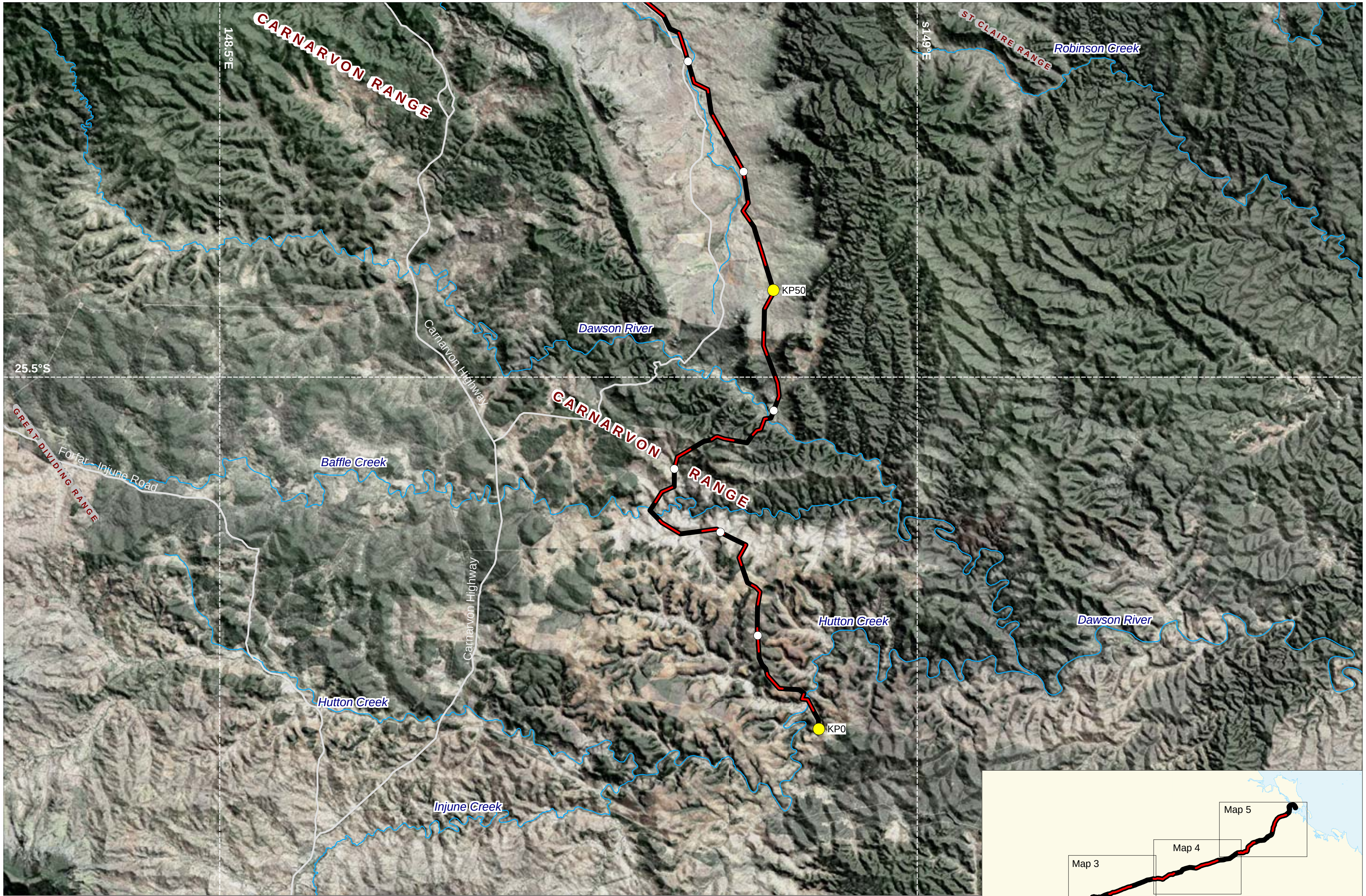
More detailed field investigations including drilling and soil sampling operations are proposed to be undertaken prior to the commencement of construction of the pipeline, in particular in those areas identified in this study as potential “high constraint” areas, to determine appropriate construction and potential environmental impact management strategies.

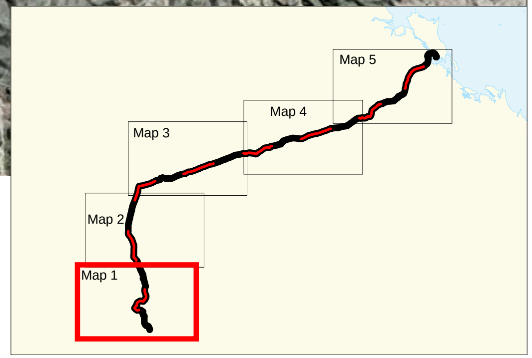
1.2 Topography and Geomorphology

1.2.1 Major Topographic Features and Drainage in the Pipeline Corridor

The gas transmission pipeline corridor shown on Figure’s 1-1 to 1-5 represents the proposed corridor current at the time of completion of the route corridor mapping in November 2008. The corridor commences at Kp 0 km in the dissected plateau country of the Great Dividing Range to the south of Hutton Creek, located approximately 38 km east-north-east of Injune. The topography on the plateau of the Jurassic sandstone rock types comprises locally near flat to undulating, in places strongly undulating to low hilly uplands. The plateau is cut in many places by steep-sided scarps and ravines within which the soils are mostly sandy surface duplex soils or uniform loamy soils or gradational red and yellow earth soils. These soils often very shallow and stony, with areas of sandstone rock outcrop on the upper margins of the plateau and on the steeper bounding scarp slopes. Drainage of these dissected plateau uplands is generally in an easterly direction via Hutton Creek and Baffle Creek and by the upper reaches of the Dawson River, each of which are intersected by the pipeline corridor in the vicinity of Kp 3 km, Kp 26 km and Kp 39 km respectively. The pipeline corridor descends from the upland plateau area via the northern bounding escarpment of the Carnarvon Range, which features near-vertical sandstone precipices with very steep to steep mid to lower slopes in sandstone, siltstone and mudstone rock types.

At the foot of the escarpment (Kp 39 km), the corridor crosses the narrow sandy floodplain of the upper reaches of the Dawson River and proceeds northward through the Arcadia Valley. The Arcadia Valley comprises locally near flat to gently undulating alluvial plains and drainage flats in the vicinity of the crossing of Arcadia Creek near Kp 76 km, on the alluvial plains associated with Brown River and approaching the pipeline crossing of Clematis Creek near Kp 120 km. Along the eastern margin of the valley, Cainozoic colluvial fan deposits containing some sandy-surfaced duplex soils (Chromosols, Sodosols and Kurosols) and areas of medium to heavy clays (Dermosols) form a discontinuous gently to moderately sloping transition to the dissected footslopes of the Expedition Range. The broad alluvial plains of the Brown River and other streams within the Arcadia Valley are dominated by cracking and non-cracking uniform clay soils (Vertosols and Dermosols).





Gas Transmission Pipeline
Major Drainage
Major Road
KP50 Kilometre Post Distance Markers (in Km)
Kilometre Post Distance Markers (10Km Intervals)

0 5 10 15Km
Scale: 1:400,000 (A4)
Datum: GDA94

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

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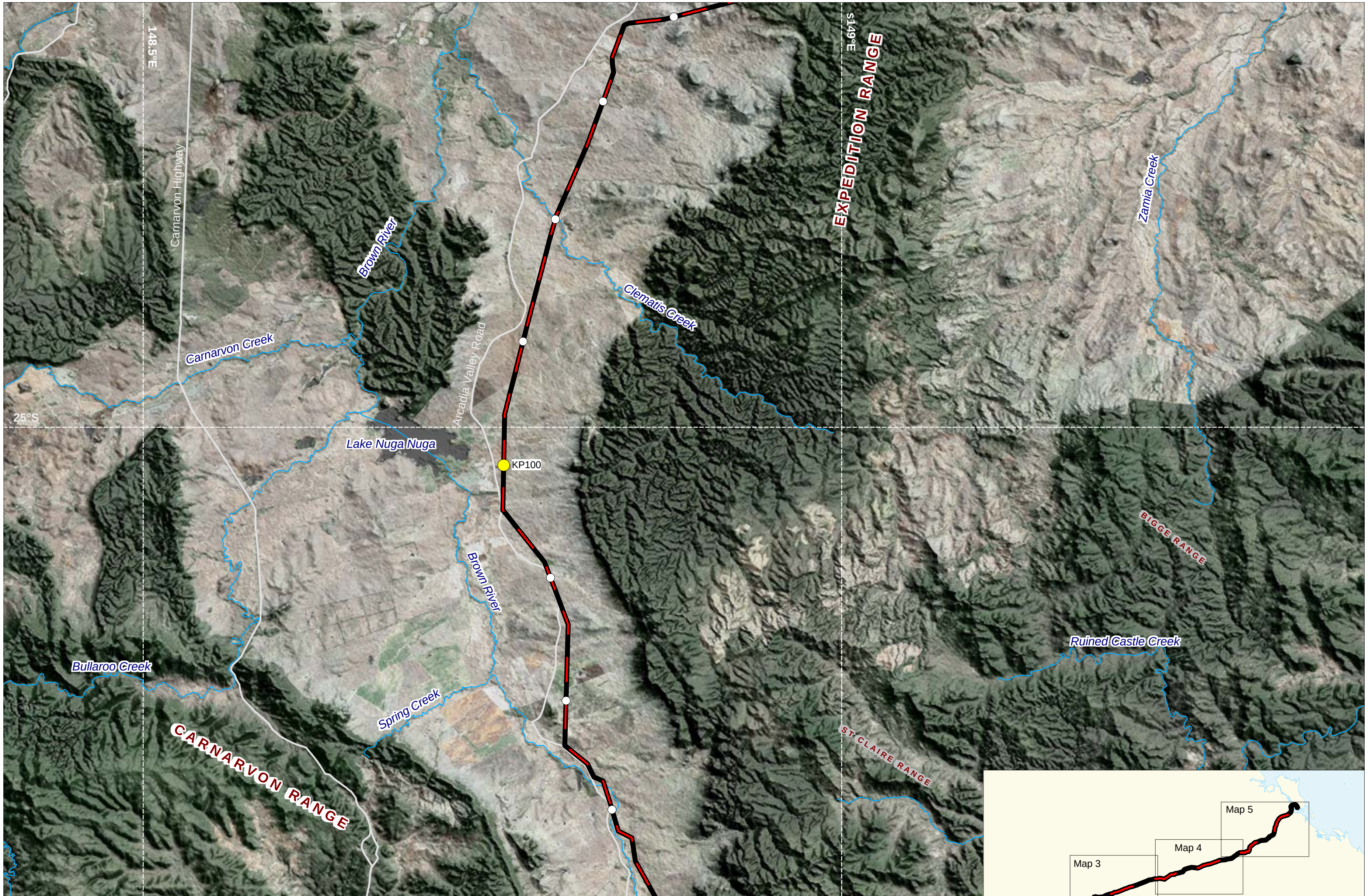
Project
GLADSTONE LNG PROJECT
TERRAIN, SOILS AND
LAND CAPABILITY REPORT
GAS TRANSMISSION PIPELINE

Drawn: CA | Approved: JB | Date: 01-02-2009
Job No: 4262 6220 | File No: 42626220-g-702.wor

Title
GAS TRANSMISSION
PIPELINE ALIGNMENT
TOPOGRAPHY

Figure: 1-1
Rev:A
A4



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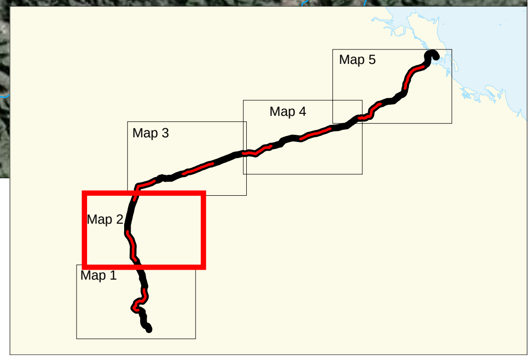
Gas Transmission Pipeline
Major Drainage
Major Road
KP100 Kilometre Post Distance Markers (in Km)
Kilometre Post Distance Markers (10Km Intervals)

0 5 10 15Km
Scale: 1:400,000 (A4)
Datum: GDA94



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TERRAIN, SOILS AND
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GAS TRANSMISSION PIPELINE

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Job No: 4262 6220 | File No: 42626220-g-703.wor

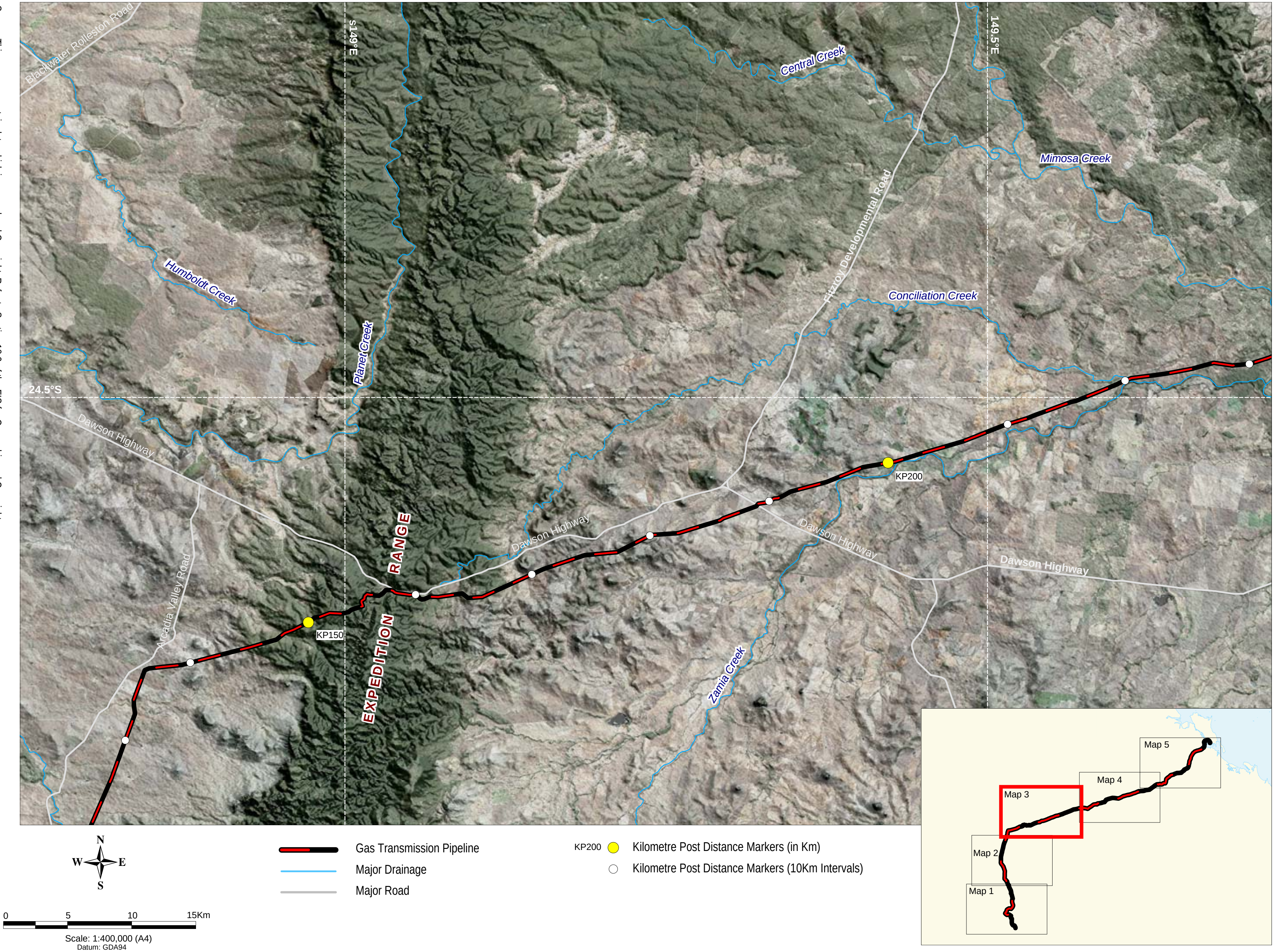
Title

GAS TRANSMISSION
PIPELINE ALIGNMENT
TOPOGRAPHY

Figure: 1-2

Rev: A

A4



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GAS TRANSMISSION PIPELINE

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GAS TRANSMISSION PIPELINE ALIGNMENT TOPOGRAPHY

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Job No: **4262 6220**	File No: 42626220-g-704.wor	

Figure: **1-3**

Rev: A

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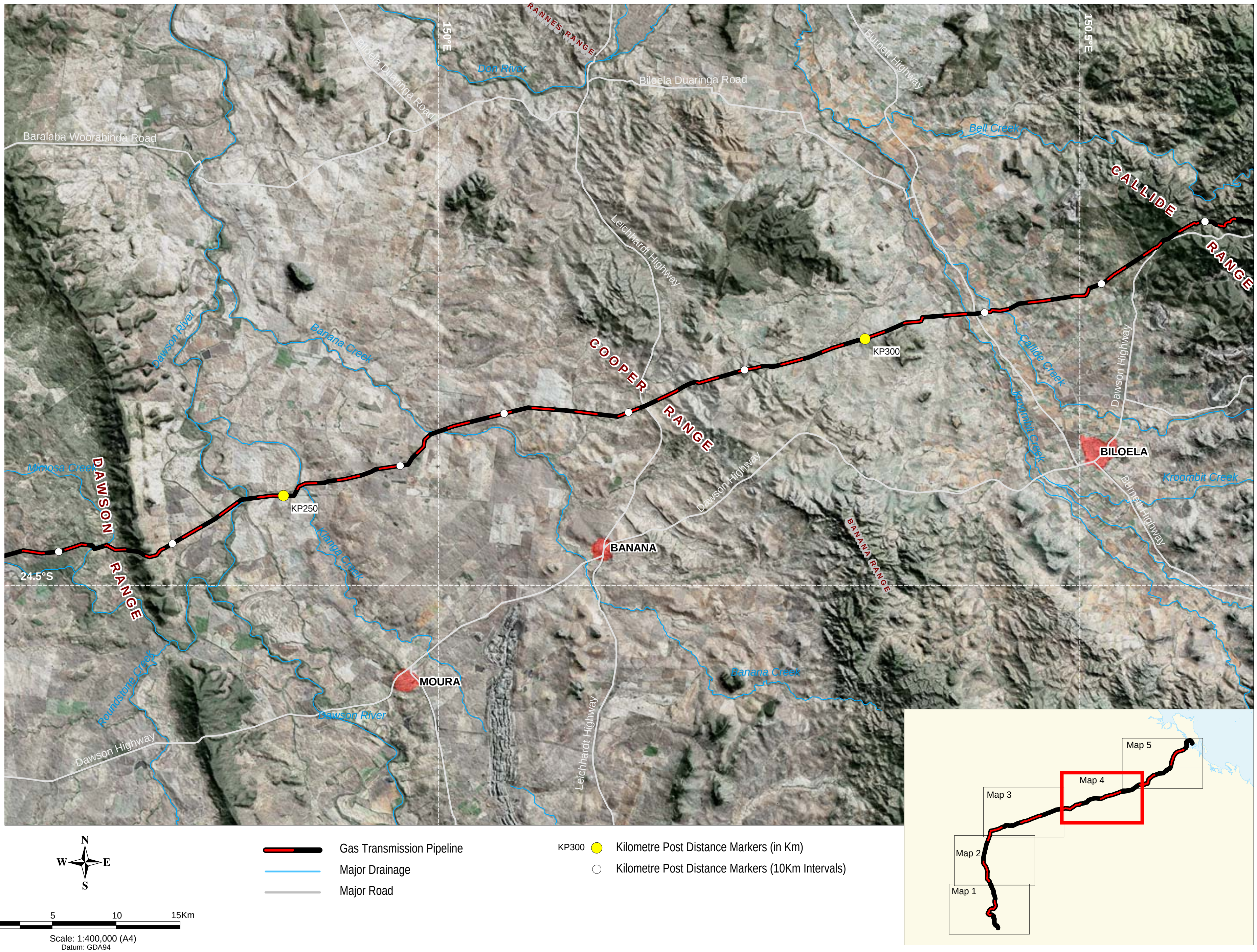

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Title

GAS TRANSMISSION
PIPELINE ALIGNMENT
TOPOGRAPHY

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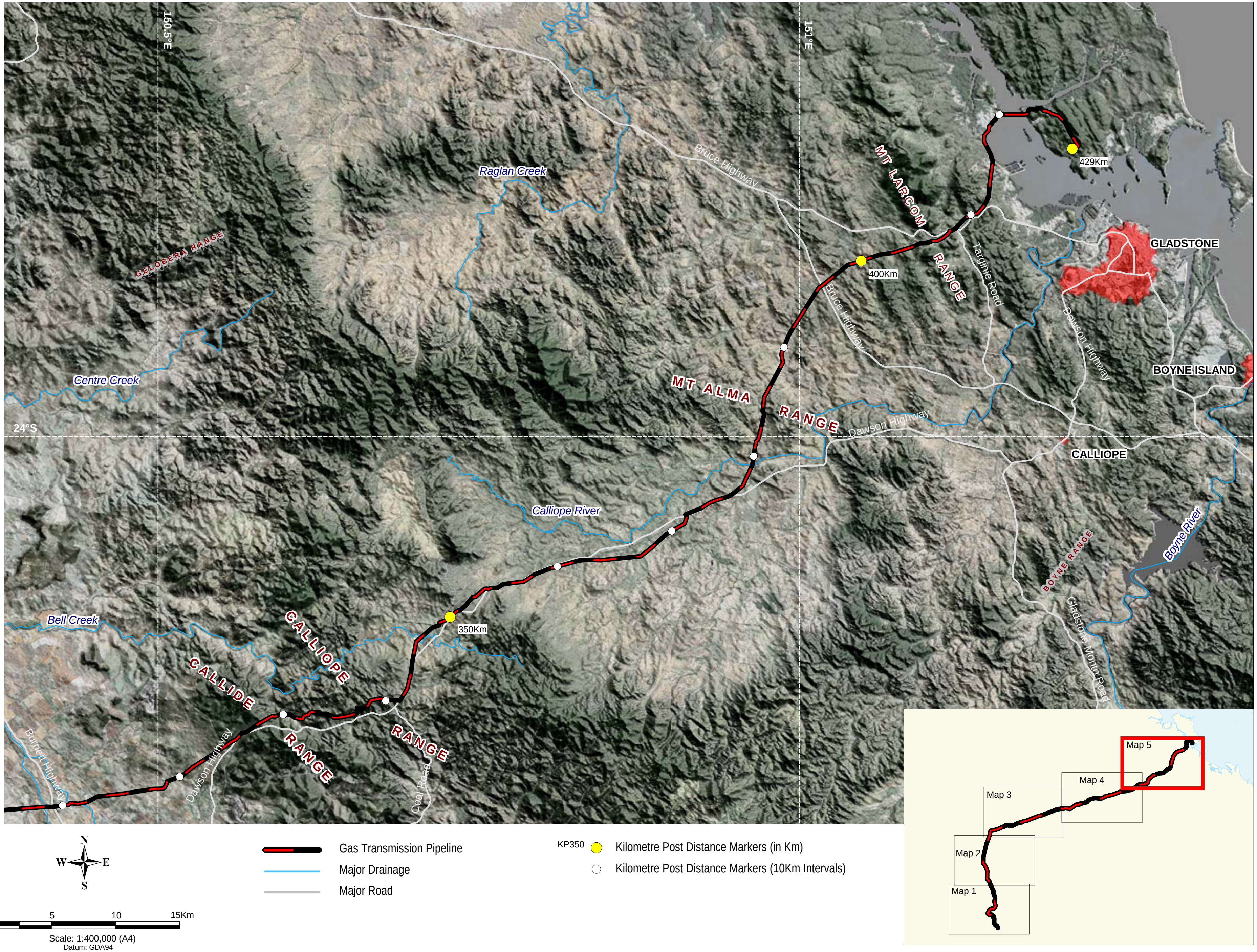
Job No: 4262 6220	File No: 42626220-g-705.wor	

Figure: 1-4

Rev.A

A4



N
W E
S

Gas Transmission Pipeline
Major Drainage
Major Road

KP350 Kilometre Post Distance Markers (in Km)
Kilometre Post Distance Markers (10Km Intervals)

0 5 10 15Km

Scale: 1:400,000 (A4)
Datum: GDA94

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TERRAIN, SOILS AND
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GAS TRANSMISSION PIPELINE

Drawn: CA | Approved: JB | Date: 01-02-2009

Job No: 4262 6220 | File No: 42626220-g-706.wor

Title

GAS TRANSMISSION
PIPELINE ALIGNMENT
TOPOGRAPHY

Figure: 1-5

Rev: A

A4

Introduction

At approximately Kp 136 km, the pipeline corridor changes direction to the east and commences a gradual assent to a crossing of the Expedition Range between Kp 155 km to Kp 160 km approximately. The main rock types in the Expedition Range include heavily fractured quartz-rich sandstone, conglomerate, siltstone and mudstone of the Triassic Clematis Group and the terrain types comprise steep high hilly to mountainous lands with ridge crest heights in the general area varying between RL 480 m to 560 m AHD. The pipeline corridor through the higher section of the range crossing is located in close proximity to the Dawson Highway. The terrain through this sector comprises steep to very steep dissected hilly lands including narrow sharp-crested rocky ridges and spurs with intervening sharply incised steep-sided gullies. Hill and ridge slopes also are present, typically in the range 30-50%, locally with sub-vertical scarps and rock benches. The steep and difficult descent of the Expedition Range contains many bare rocky areas and the steeper slopes often contain shallow stony soils underlain by weathered rock. The more gently sloping lower slopes are mostly underlain by siltstone and mudstone rock types and typically have shallow texture-contrast (duplex) soils with medium to heavy clay subsoils (Sodosols and Chromosols).

East of the Expedition Range from Kp 175 to Kp 283 km approximately, with the exception of a crossing of the Dawson Range between Kp 236 km to Kp 238 km, comprises a narrow low range of hills developed on Triassic Clematis sandstone rock types, the corridor traverses mainly undulating plains and lowlands developed on a variety of rock types including, Triassic sandstone, Tertiary volcanics, Tertiary sediments, Cainozoic sediments and Permian sediments. Extensive areas of Quaternary alluvial deposits also occur in the crossings of the floodplains and stream channels of Conciliation Creek, Zamia Creek, Mimosa Creek, the Dawson River, Kianga Creek and Banana Creek. In general, all of these areas contain large areas of mainly cracking clay soils and non-cracking clays (Vertosols and Dermosols), with sandy surface texture-contrast soils (Sodosols) also occurring.

Continuing east from Kp 283 km to approximately Kp 289 km, the corridor crosses Coopers Range which comprises strongly undulating to low rounded hilly lands with slopes mostly in the range 5-12%, locally up to 25%, developed on Permian volcanic rocks. From Kp 289 km to Kp 292 km, more deeply dissected steeper hilly lands occur, with broadly rounded crestal areas and hill and ridge slopes between 20-35% which are underlain by volcaniclastic rocks of the Carboniferous Torsdale Volcanics geological regime. These areas mostly have shallow to medium deep red and brown duplex soils (Chromosols and Sodosols) and shallow gravelly gradational and uniform clay soils (Rudosols and Dermosols) on the steeper and upper parts of slopes and medium deep cracking clays and loamy surface alkaline duplex soils on the lower slopes and valley floors. From Kp 292 km to Kp 328 km, the corridor traverses undulating plains underlain by Tertiary sediments and gently to moderately inclined footslopes of local low flat-topped hills of the Tertiary land surface and the lower slopes of low benched hills developed on Jurassic Precipice Sandstone. Within this sector, the corridor crosses undulating alluvial plains and the floodplains of Kroombit Creek and Callide Creek between Kp 307 km and Kp 313 km approximately. The dominant soils within this sector comprise mainly cracking and non-cracking clays (Vertosols and Dermosols) on the lowlands, with sandy surface duplex soils and shallow uniform sandy soils on the lower slopes of the low hilly rises.

Continuing in an easterly direction from Kp 328 km, apart from a moderately steeply incised crossing of Bell Creek in the vicinity of Kp 331 km, the corridor traverses steep dissected high hilly lands of the Callide Range with slopes mostly in the range 25-50% developed on Permian volcanic rocks and Devonian sedimentary rock sequences. These areas have mainly shallow gravelly clays and loams (Dermosols and Kandosols) and rock outcrop is common. From Kp 341 km to kp 380 km, the terrain comprises mainly strongly undulating lands with areas of low rounded hills and rises developed on a range of Permian intrusive (granitic) rocks, which give rise to a range of medium deep sandy soils (Rudosols and Tenosols) and mainly yellow-brown sandy surface duplex soils (Chromosols and Kurosols) . Within this sector, the corridor descends through the steep rocky eastern fault-line escarpment of the Callide Range between Kp 350 to Kp 351 km. Further to the east, between Kp 366 km to Kp 367 km, the corridor crosses a broad tributary stream floodplain of the Calliope River, prior to a crossing the Calliope River in the vicinity of Kp 379 km. Cracking clay soils (Vertosols) and thin loamy surface duplex soils (Chromosols and Sodosols) occur on the floodplains of the Calliope River and its major tributaries throughout this sector.

Heading north from the Calliope River crossing to approximately Kp 406 km, the corridor traverses mostly along the foot-slopes of low hilly, hilly and higher hilly lands of the Mt. Alma Range, which are underlain mainly by Silurian and Devonian volcaniclastic sedimentary rock types and some Permian volcanic rock types between Kp 404 to 406 km. The associated soil types in these areas consist mainly of shallow gravelly sandy loams and loams (Rudosols) with areas of rock outcrop and gradational or uniform shallow gravelly clay soils (Dermosols) on hill slopes and medium deep thin loamy surface duplex soils (Sodosols) on some gently inclined lower slopes. Some cracking clay soils and thin silt loamy surface duplex soils occur in intervening lower-lying areas of Quaternary alluvium in the valley flats.

From Kp 406 km, to the proposed bridge site crossing of Port Curtis at Friend Point near Kp 420 km, the corridor traverses undulating to near flat Quaternary alluvial plains, local gently inclined footslopes and outwash fan deposits with overall slopes (3-7%), mostly with sandy and loamy surface duplex soils (Sodosols), before descending onto the coastal estuarine tidal marine flats, which consist mainly of deep soft saline clay, silt and muddy sand soils (Inter-tidal and Extra-tidal Hydrosols).

Between Kp 420 to 422 km, the gas transmission pipeline crossing of the Port Curtis waterway between Friend Point and Laird Point, as presently proposed, will be in a trench to be constructed adjacent to the proposed bridge crossing to Curtis Island. From Kp 422 km, the gas transmission pipeline, powerline and proposed access road share a common infrastructure access corridor terminating at the LNG facility site at Kp 429 km. Along this sector, the pipeline corridor traverses gently to moderately inclined mid to lower slopes and foot-slopes (mostly <12%) of low rounded hilly and steep to very steep higher hilly lands developed on lithic sandstone and other sedimentary rocks sequences, including greywacke and in places meta-sediments associated with the Carboniferous Wandilla Formation. These hilly lands have intervening narrow valley floors and undulating valley plains, locally with alluvial drainage-ways included. In places in the northern part of this sector, the pipeline corridor crosses short sections of the supra-tidal estuarine/marine flats and tidal mangrove flats fringing the northern coastline. The soils in these areas comprise deep soft saline clays, silt and muddy sand soils on the estuarine flats (Inter-tidal and Extra-tidal Hydrosols), with deep uniform clay soils and silt loamy surface duplex soils (Dermosols and Sodosols) on the alluvial flats and drainage-ways. Medium to deep gravelly loamy surface duplex soils (Chromosols and Sodosols) and uniform or gradational gravelly clay soils (Dermosols) occur on the lower hill slopes and the valley plains.

1.3 Regional Geology

The geology of the general area of interest has been mapped by the Geological Survey of Queensland (GSQ) in the Geoscience Datasets (2005) as shown on the 1:100,000 Gladstone (9150) map sheet which covers the eastern sector of the pipeline alignment, including Curtis Island. The geology of the central and western sectors of the pipeline alignment have been identified based on the GSQ Regional Mapping of the Bowen Basin. The southern sector of the route corridor is covered by the mapping of 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:

Table 1-1 Geological Regimes

Geological Regime	Map Symbol	Description
Quaternary (Holocene) Estuarine Sediments	Qe	Delta and coastal marine deposits comprising saline silty clays, clays, saline muds and sands;
Quaternary alluvium	Qa	Comprising clay, silt, sand and gravel deposits;
Cainozoic Sediments	Czs	Sand plain, residual soils and older alluvial deposits, mainly sandy sediments, some gravel and clay;
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	Tb	Volcanic rocks, predominantly mafic; basalt, trachyte, rhyolite;
Early Jurassic Hutton Sandstone, Bundamba Group	Jh	Sub-labile to quartzose sandstone, siltstone, mudstone; minor conglomerate and coal;
Early-Middle Jurassic Evergreen Formation, Bundamba Group	Je	Labile and sub-labile sandstone, carbonaceous mudstone, siltstone and minor coal; local oolitic ironstone;
Jurassic Precipice Sandstone, Bundamba Group	Jp	Thick bedded, cross bedded pebbly quartzose sandstone, minor lithic sublabile sandstone, siltstone, mudstone;
Triassic Moolayember Formation, Mimosa Group	Rm	Micaceous lithic sandstone, micaceous siltstone;
Early-Middle Triassic Clematis Group	Rc	Quartz-rich sandstone, conglomerate, siltstone, mudstone;
Triassic Arcadia Formation, Rewan Group	Ra	Lithic sandstone and green to reddish brown mudstone and minor conglomerate;
Permian Sediments	Ps	Clastic sediments: - As mapped includes: - the Blackwater Group and Back Creek Group - comprising sandstone, siltstone, shale, mudstone, tuff and conglomerate. As mapped includes Lakes Creek Formation - siltstone and lithic sandstone and Berserker Beds - siltstone and litho-feldspathic sandstone;
Permian Volcanics	Pv	Intermediate extrusive/intrusive rocks; - As mapped includes:- Inverness Volcanics - trachyte to dacite , volcanic breccia; - Chalmers Formation (Berserker Group) - rhyolitic to andesitic volcaniclastic breccia, siltstone and lithic sandstone; - Camboon Volcanics (Back Creek Group) - andesite, basalt, dacite, rhyolitic flows; - Smoky Beds - andesitic conglomerate, sandstone; Youlambie Conglomerate - polymictic conglomerate, volcaniclastic sandstone, dacitic to rhyolitic ignimbrite
Late Permian-Early Triassic Felsic Intrusives	Pfi	As mapped includes - Voewood Granite, Granodiorite, Bocoolima Granodiorite (part of) Galloway Plains Igneous Complex, Rocky Point Granodiorite, Redshirt Granite - Littlemore Suite, Targinie Quartz Monzonite -collectively comprising granite, granodiorite & quartz monzonite rock facies;
Late Permian-Early Triassic Intermediate Intrusive Rock-types	Pii	As mapped includes - Hornblende Diorite, Galloway Plains Igneous Complex, Zig-zag Granodiorite, Craiglands Quartz Monzodiorite, (Pgdu) Dumgree Tonolite, Gabbro, (Pgma) Manersley Granodiorite - collectively comprising quartz diorite, tonolite, monzodiorite, gabbro rock facies;
Carboniferous Torsdale Volcanics	Ct	Dacitic to rhyolitic ignimbrite, volcaniclastic rocks and lava, subordinate andesitic rocks and volcanilithic conglomerate and sandstone;

Geological Regime	Map Symbol	Description
Carboniferous Rockhampton Group	Cr	Mudstone, siltstone, volcaniclastic sandstone, polymictic conglomerate, oolitic limestone;
Carboniferous Wandilla Formation	Cw	Mudstone, lithic sandstone, siltstone jasper, chert, slate and schist;
Late Devonian - Early Carboniferous Intermediate Extrusives and Volcaniclastic Sediments	Dcs	As mapped includes - Mount Alma Formation; - Three Moon Conglomerate; - Yarwun Beds; - Doonside Formation, Curtis Island Group; - Balnagowan Volcanic Member; collectively comprising andesitic to basaltic volcaniclastic rocks, altered basalt, sandstone, siltstone and conglomerate, chert, mudstone and limestone;
Silurian-Devonian Volcaniclastic Rocks	Sf	As mapped includes - Erebus Beds and - Mount Holly Beds; collectively comprising dacitic to rhyolitic and basaltic to andesitic volcaniclastic sandstone and conglomerate, with minor siltstone and fossiliferous limestone.

The occurrences and distribution of the geological regimes as mapped within the gas transmission pipeline corridor are shown in **Figure's 2a, 2b, 2–1 to 2-24.**

1.3.1 Seismic Activity and Ground Stability

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

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

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

As shown in Plate 1-1, the GLNG Project area extends over a considerable distance, with some areas of the project falling within different expected earthquake intensities. The area with the highest earthquake risk is near Gladstone due to its close proximity to an earthquake source zone as defined in Gaull *et al*., 1990. From the coast, approximately 200 km inland to the west along the pipeline corridor, including the area to the south through the Roma and Scotia CSG field tenements, the intensity is V on the Modified Mercalli Scale. The portions west of these areas containing the western and southern sectors of the gas transmission pipeline and all of the other CSG fields are categorised as IV (Gaull *et al*., 1990).

1.3.2 Geological Structural Features and Faults

As mapped by the GSQ (2005) on the Regional Surat and Bowen Basin Map Sheets, the 100,000 Bajool Sheet (9050) and the Gladstone Sheet (9150), major fault lines and other geological structural features that occur in close proximity to, or that intersect the gas transmission pipeline corridor are shown in **Figure 2a, 2b and 2-1 to 2-24**. These structural features may potentially comprise a zone of weakness in the earth's crust that may be subject to differential movement if subjected to the impact of a significant seismic event in the general area. The approximate locations of major structural features and inferred faults that intersect or occur in the vicinity of the proposed pipeline corridor are described below.

The Arcadia Anticline which is in the vicinity of the corridor runs along the western margin of the Arcadia Valley at the base of the escarpment of the Carnarvon Range, intersecting the corridor near Kp 45 km. A major fault line (the Hutton Fault) runs parallel to the pipeline corridor approximately 20 km to the west in this same general vicinity. A fault line intersects the corridor in the vicinity of Kp 75 km and the Arcadia Anticline again intersects and closely parallels the corridor between Kp 75 to Kp 80 km. This feature again intersects the corridor at Kp 111 km. and at Kp136 km, where the corridor changes direction to the east.

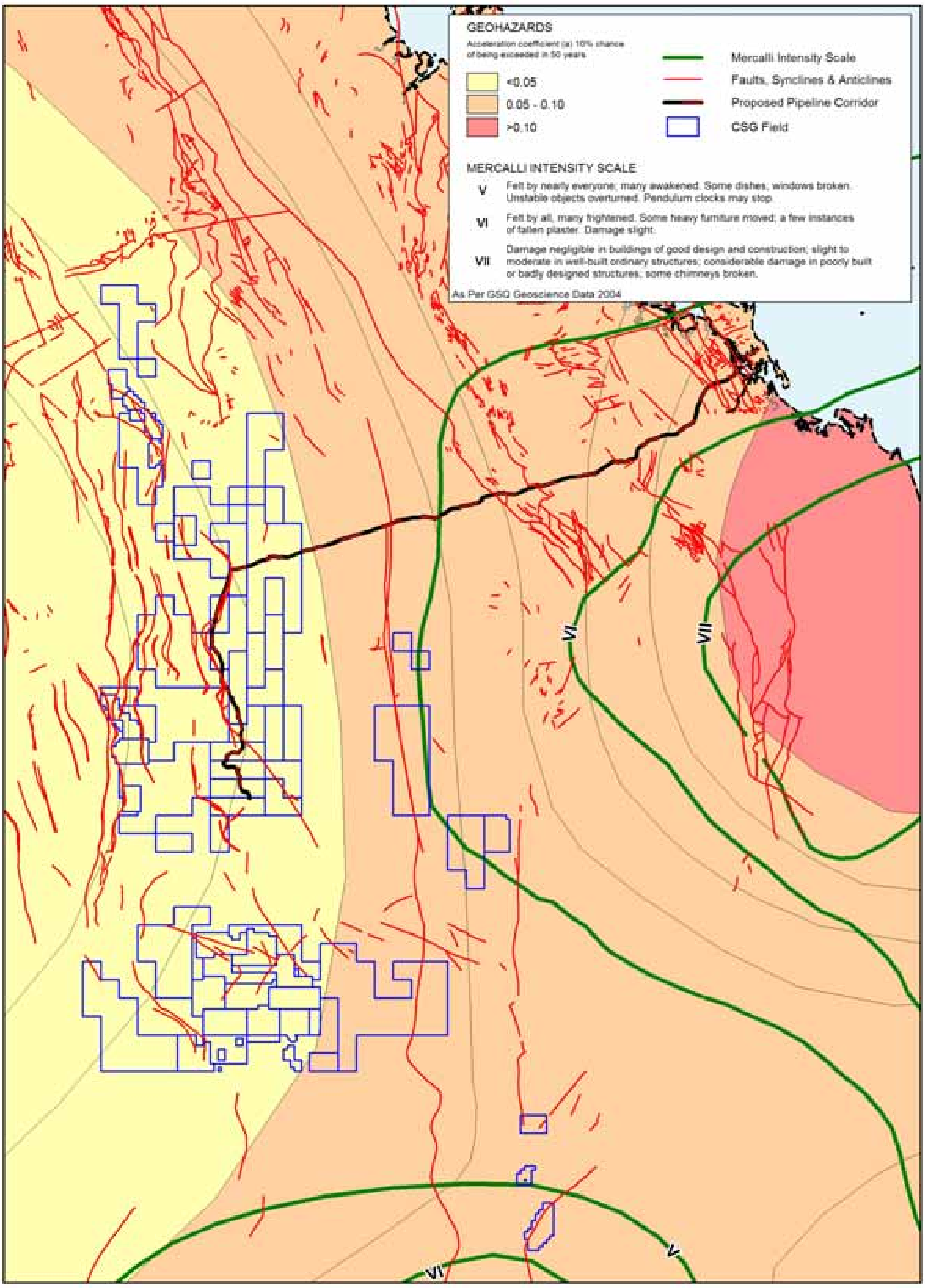
A feature identified as the Mimosa Syncline crosses the corridor in the vicinity of Kp 214 to Kp216 km. An inferred fault line along the valley of Bell Creek intersects the corridor in the vicinity of Kp 330 km. A group of inferred fault lines have also been identified to occur mainly associated with internal scarps within the Callide Range to the south-east of the corridor between Kp 330 to Kp 341 km. Further to the east, the corridor crosses an inferred fault line which corresponds with the eastern escarpment of the Callide Range in the vicinity of Kp 353 km. A further inferred fault line is shown to intersect the corridor in the vicinity of Kp 390 approximately.

A series of inferred sub-parallel faults have been identified in the Mt Alma Range area that intersect the corridor in the vicinity of Kp 398 km, 399 km, 402 km and 403 km approximately. Further to the east the corridor crosses two north-north-west trending major fault lines at Kp 403 km, identified as the Boyne River Fault and in the vicinity of Kp 413 km along the eastern footslope of the Mount Larcom Range.

A major north south trending inferred fault line runs parallel to the western coastline of "The Narrows" waterway, which crosses the pipeline corridor in the vicinity of Friend Point at Kp 420 km. Approximately 3 km east of Laird Point on Curtis Island, the gas transmission pipeline corridor follows a north-north-west trending narrow, (possibly fault controlled) valley, en-route to the LNG facility site. A series of six east west trending fault lines have been identified along this sector which trend towards or intersects the pipeline corridor between Kp 422 to Kp428 km.

Section 1 Introduction

Plate 1-1 Seismic Activity over the project area



1.4 Terrain Units

As discussed in **Section 1.1**, the identification of terrain units provides a basis for the description of the physical environment and as mapped, terrain units serve to show the occurrence and distribution of geological regimes, landform units and associated soil types which occur along the gas transmission pipeline corridor.

Terrain units were identified along the gas transmission pipeline corridor initially within a 5 km wide corridor which included various potential alternative routes. Accordingly not all of the terrain units identified occur within the 1km wide corridor for the route finally adopted for the EIS. The terrain units that occur within the adopted pipeline corridor are shown in **Figure 2–1 to 2-24** where they are coloured on the basis of the geological regime in which they occur. The map sheet layout is shown in **Figure 2a** and a key to the identification of terrain units is provided in **Figure 2b**. Detailed descriptions of the terrain units together with an assessment of some more important engineering/environmental attributes and constraints for construction and on-going operations of the gas transmission pipeline and associated infrastructure are included in **Appendix A** of this report.

1.5 Soils

1.5.1 Major Soil Groups

The Key to the Identification of Terrain Units (**Figure 2b)** is to be read in conjunction with **Figures 2–1 to 2-24**. This key includes a generic suite of 9 broad Soil Groups that occur within the project area (as also described in Table 1-1 below). The soil groups identified cover a broad range of Australian soils including:

- Uniform and gradational coarse-textured (sandy);
- Medium-textured (loamy) soils,
- Texture contrast (duplex) soils and
- Gradational or uniform fine-textured (non-cracking and cracking clay) soil profile forms.

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 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.C. [4]
1	Skeletal, rocky or gravelly soils (>60% coarse fragments) with sandy, silty, loamy or clayey soil matrix	Shallow rocky soils	K- Uc1, Um1, Gn1, Uf1	GW, GM, GP, GC	Lithosolic/Colluvic Rudosols
2	Sand soils; shallow to deep uniform or weakly gradational profiles; includes stratified alluvial soils, residual sand soils, earthy sands;	Siliceous sands Earthy sands	(Ucl-Uc6)[2]	SP, SM,SW	Rudosol, Tenosol Podosol Soil Orders [3]
3	Coarse to medium-textured soils; uniform or gradational profiles; predominantly sandy earths with sand, silty or clayey sand over clayey sand-sandy clay soil profiles	Sandy Earths Sandy Red-Yellow Earths	(Uc4-5, Uml-3) Gn2.11, Gn2.12	SP-SC/SC-CL /CL SC/SC-CL	Tenosols or Podosol Soil Orders.
4	Medium-textured sandy, sandy loam or silt to clay loamy surface uniform or gradational profiles with clay loam, light clay or medium clay subsoils, in places with siliceous stone and/or ferruginous gravelly lenses included	Shallow Loams Gravelly Loams Red and Yellow Massive Earths Lateritic Red-Yellow Earths	Um2.12 K-Um2.12 Um4.11 Gn2.12 Gn2.22	CL/GC-CL/GC GC-CL/GC	Tenosols, Kandosols or Ferrosol Soil Orders.
5	Sand, loamy sand, sandy loam or loamy surface duplex soils over acidic to locally strongly acidic, in places neutral or slightly alkaline sandy clay to medium to heavy clay subsoils;	Red, Yellow & Brown Podzolic Soils ; Grey & Brown Soloths	Dr2.12, 2.22 Dy3.42, 3.22 Dy3.12, 3.32 Db1.41	SP-SC/CL or CL-CH	Ferric Red-Brown Chromosols; Sodic Yellow & Brown Kurosols
6	Fine sandy, silty or clay loamy surface duplex soils with neutral to alkaline often calcareous, sodic and locally saline medium to heavy clay or heavy clay subsoils;	Yellow, Brown, Red-brown Solodic Soils; Solodized Solonetz	Db1.33, 1.13 Dr2.13, Dy2.23, Dd1.13	ML-CL/CL-CH or CH SM-ML/CL-CH or CH	Subnatric Brown Sodosols, Chrom-osols, Sodosols or Calcarosols Soil Orders
7	Shallow uniform often gravelly fine-textured soils, medium to deep uniform fine-textured (non-cracking) clay soils or gradational often stony or gravelly clay loam or light clay surface soils over alkaline medium to heavy clay subsoils, locally sodic and saline in the deeper subsoils – some deep incipient cracking clays;	Alluvial Soils Dark brown Grey-brown or Dark Reddish-brown (Non-Cracking) Clay Soils, some Solonchaks	Uf6.31, 6.32 Uf6.61, 6.63 Uf6.32, 6.21 Gn3.22, 3.42 Gn3.93, 3.13 Gn3.12	CL/CL, SC-CL/CL-CH CL/CL-CH/CH	Dermosol or Hydrosol Soil Orders.
8	Shallow to medium to deep uniform fine-textured (cracking) clay soils, locally with thin self-mulching surficial soils with dark grey, brown or black mostly alkaline or alkaline over acidic heavy clay subsoils in areas with Gilgai micro-relief;	Black Earths Grey, Brown and	Ug5.12, 5.21 Ug5.24, 5.25 Ug5.38, Ug5.15, 5.16	CL-CH/CH, CH/CH	Vertosols Soil Order

Soil Group	Summary Soil Description	Soil Classification			
		Aust. Soil Group (1)	P.P.F. (2)	U.S.C. (3)	A.S.C. (4)
9	Deep to very deep, very soft, uniform gradational or weak duplex soil profiles, with organic silty clay to silty clay loam surface soils and seasonally or permanently saturated sub-soils, typically gleyed saline clays, clayey silt, silty sand or sandy mud	Humic Gley Soils Solonchaks	Uf6.41 Dg2.11 Uf6.61	CL-ML/OL-OH	Intertidal and Supratidal Hydrosols; Redoxic Hydrosols
Notes: - (1) - Common Soil Group Name (Stace et.al. 1968); (2) - Principal Profile Form (Northcote 1974); (3) - Australian Engineering Soil Classification (AS 1726-1993); (4) - Australian Soil Classification (Isbell, 2002).					

Descriptions of terrain units and associated soils that occur along the gas transmission pipeline corridor are included in **Appendix A.** Soil profile characteristics have been identified from various sources including the findings from the Acid Sulfate Soils Investigation **(see Appendix L4)** and from the results of the test pits excavated as part of the field investigation program for the LNG facility development area included in **Appendix L3**. Additional soils data was obtained from reference to and interpretation of the Land Systems and Soils mapping by CSIRO (1967, 1968 & 1967) and NRW (1995), which collectively cover the general project 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).

1.5.2 Soil Types

With respect to the major soil groups identified in **Figure 2b** and described in **Section 1.5.1** above, the scheme allows for one or more soil profile variants (soil types) to be described within a particular soil group in order to differentiate between similar soils which have somewhat differing soil profile characteristics. A general description of the soil types identified in the terrain unit descriptions in **Appendix A** of this report is as follows:

Soil Types in Soil Group 1 – Group 1 soils comprise mainly shallow to medium deep stony, gravelly and rocky soils, typically with >60% coarse fragments in a sandy, silty, loamy or clayey soil matrix. Only the one general soil type was identified within this group.

Soil Types in Soil Group 2 – Group 2 soils comprise uniform or weakly gradational coarse-textured sandy soil profiles. Three soil types identified within the group areas follows:

Soil Type 2.1 - These soils occur mainly on the eroded plateau margins, on steep dissected scarps and hilly lands mainly in the sandstone plateau areas and comprise mainly shallow (<0.5 m) acidic sands and gravelly sands underlain by weathered sandstone or colluvium derived there-from. In terms of Australian Soil Taxonomy (Great Soil Groups), these soils are classified as – Lithosols; Principal Profile Form (PPF –Northcote 1974) - Uc1.21; Australian Soil Classification (ASC Isbell 1996) – *Acidic Paralithic Rudosols*.

Soil Type 2.2 - These soils comprise mainly alluvial, in places stratified alluvial or colluvial deposits comprising medium deep (>0.5 m) uniform slightly acidic brown single-grain loose sand soils. These soils are classified as - Alluvial soils; (Uc1.22); *Stratic Rudosols.*

Soil Type 2.3 - These soils occur mainly on the mid to lower slopes in hilly sandstone lands and comprise medium to deep (0.5->1.0 m) sands and loamy sand soils with organic humic surface soils over red-brown or yellowish red slightly to moderately acidic sandy subsoils underlain by weathered rock. These soils may be classified as - Deep Leached Sands; (Uc1.23, Uc1.41); *Leptic Rudosols*.

Soil Types in Soil Group 3 – Group 3 soils comprise uniform or gradational coarse to medium-textured uniform or gradational predominantly sandy earth soil profiles. Two soil type variants identified within this group are as follows:

Soil Type 3.1 - These soils occur on upper slopes and crests in hilly lands and comprise shallow uniform or weakly gradational bleached massive earthy sands and ferruginous gravelly sandy loam soils with neutral to acidic subsoils transitional to the weathered rock substrate. These soils are classified as – Earthy Sands-Sandy Red and Yellow Earths; (Gn2.12, Gn2.22); *Bleached Orthic Tenosols.*

Soil Type 3.2 - As mapped these soils occur on banks and levees along alluvial drainage-ways and comprise medium to deep (0.5->1.0 m) gradational massive earthy sand soils with neutral to slightly acidic brown sandy light clay or clayey sand subsoils. These soils are classified as – Alluvial Earthy Sands-Sandy Earth Soils; (Gn2.22); *Stratic Rudosol-Tenosol*.

Soil Types in Soil Group 4 – Group 4 soils include medium-textured frequently stony or gravelly uniform or gradational loam to clay loam soil profiles with massive to weakly to moderately structured clay loam, light clay or medium clay subsoils. Three soil type variants have been identified within this soil group, details of which are as follows:

Soil Type 4.1 - These soils occur on the higher parts of strongly undulating to low hilly lands and on the crestal areas and upper marginal slopes of hilly and high hilly lands where they comprise mainly shallow (<0.5 m) stony and/or ferruginous gravelly uniform or weakly gradational brownish black, brown, red-brown or red massive loams and clay loam soil profiles underlain by weathered rock. These soils are classified as Lithosols – Shallow Gravelly Loams; (Um5.41, Um1.23, Gn2.12); *Leptic Rudosols, Red-Brown Kandosols.*

Soil Type 4 2 - As mapped these soils occur on the mid slopes of low rises in strongly undulating plains underlain by Permian sediments. They comprise medium to deep (0.5->1.0 m) gradational loamy surface red earth soils with clay loam to light clayey subsoils often with lateritic gravel included. These soils are classified as Loamy Red Earths – Lateritic Red Earths; (Gn2.12); *Red Kandosols, Ferric Red Kandosols*

Soil Type 4.3 - As mapped these soils occur on low rises and on levees and alluvial terraces in the upper parts of narrow valley floors. They comprise medium to deep (0.5->1.0 m) gradational sandy loam to loamy surface soils over red and brown weak to moderately well-structured neutral to moderately alkaline clay loam to light clayey subsoils. These soils are classified as Loamy Red Earths; (Gn3.13, 4.12); *Red Kandosols*.

Only very limited analytical data is available for these Group 4 soils; however calcium and magnesium are reported by R. H. Gunn – CSIRO (1967) to be the dominant cations; cation exchange capacity (CEC) is low (<8 m-equiv./100g soil), plant available water capacity (PAWC) is low. Soil salinity levels are low and indicative testing of the fines content of the soils indicates non to very low dispersion characteristics.

Soil Types in Soil Group 5 – Group 5 soils comprise sand, loamy sand and loamy surface duplex soils with mostly acidic to neutral or slightly alkaline sandy clay to medium to heavy clay subsoils. Three soil type variants have been identified within this soil group, details of which are as follows:

Soil Type 5.1 - These soils occur mainly in hilly lands underlain by sandstone bedrock and in particular on the eroded margins of dissected sandstone plateau areas. They comprise shallow (<0.5 m) sandy, sandy loam or loamy surface duplex soils with yellow-brown, grey-brown or red-brown often gravelly, weak to moderately strongly structured acidic to neutral, in parts strongly acidic sandy clay or medium to heavy clay subsoils with hard dry consistence. These soils are classified as Soloths; (Dr2.11, 2.12, Dy2.21, 2.22, Db1.12); *Red-Brown Chromosols, Red-Brown Kurosols.*

Soil Type 5.2 - These soils occur in undulating and gently to moderately sloping lands underlain by sandstone bedrock and in parts by intrusive (granitic) bedrock. They comprise medium to deep (0.5->1.0 m) duplex soils with thick (>0.3 m) sand or loamy sand surface (A) horizon, often with a pale or bleached sub-surface (A2) horizon with an abrupt change to yellowish-brown, grey-brown or reddish-brown, locally prominently mottled sandy clay to medium clay sub-soils. The subsoils are poorly drained, mostly moderately to strongly acidic with massive tending to coarse blocky or columnar structure with depth. These soils are classified as Soloths or Podzolic Soils; (Dr2.21, Dy3.41, 4.61, Db1.32); *Red-Yellow-Brown Chromosols and Sodic Kurosols.*

Soil Type 5.3 - These soils occur on slopes of up to 5% and are similar to Soil Type 5.2 except that they have thinner (<0.3 m) sandy, sandy loam or loamy surface soils that tend to be hard-setting, usually with a pale or bleached (A2) sub-surface horizon underlain by brown or yellowish brown sandy clay or medium clay neutral to moderately acidic hard, medium to coarse blocky structured subsoils. These soils are classified as Red-brown Earths, Soloths or Podzolic Soils; (Dr2.21, 2.22, Db1.32, Dy3.41, 3.42); *Red-Brown Chromosols*, Red-Brown Sodosols.

Analytical data available for these soils is limited, except for one site sampled in the foot-slopes of terrain unit Cw5/5-7 on the pipeline corridor on Curtis Island and from data reported by R. H. Gunn – CSIRO (1967). The available data included in **(Appendix L3)** indicates these soils are acidic in the surface soil horizons, tending to neutral in the deeper subsoils. Cation exchange capacity (CEC) is low in the surface soils (<5 m-equiv./100 g soil) and <20 m-equiv./100 g soil in the subsoil horizons. Magnesium is the dominant metal cation throughout the profile. Total soluble salts and salinity levels were low in the surface soils but tend to increase to moderate levels in the deeper subsoils. The less gravelly (more clayey) soil variants tend to be non-sodic to slightly sodic in the surficial soil layers, becoming strongly sodic in the subsoils below a depth of about 0.6 m. The high levels of sodium and magnesium indicate potential soil structural instability and potential for dispersion of the deeper clay materials. Total nitrogen and available phosphorus are mostly deficient in the surface soil horizons.

Soil Types in Soil Group 6 – Group 6 soils comprise mostly thin fine sandy loam, silt loam or clay loamy surface duplex soils with neutral to alkaline, often strongly alkaline, usually with carbonate present in the medium to heavy clay or heavy clay subsoils. Two soil type variants were identified within this soil group, details of which are as follows:

Soil Type 6.1 - These soils occur mainly on undulating plains, rolling rises and low hilly lands underlain by siltstone or mudstone bedrock. They comprise shallow (<0.5 m), gravelly, sandy or loamy surface duplex soils with yellow-brown, grey-brown or red-brown often gravelly, strongly alkaline sandy clay, light clay or medium to heavy clay subsoils with hard dry consistence and weak to moderate blocky to columnar soil structure. These soils are classified as Solodic Soils; (Dr2.23, Dy2.43, 2.23, Db1.23); *Red-Yellow-Brown Calcic Mesonatric Sodosols.*

Soil Type 6.2 – These soils occur on gently to moderately inclined foot-slopes, on undulating plains and lowlands and on alluvial plains, stream terraces and floodplains associated with major streams and rivers, where they often occur in association with non-cracking clays and cracking clay soils of Group 7 and Group 8 respectively. The Type 6.2 soils comprise medium to deep (0.5->1.0 m) mainly thin (<0.3 m) hard-setting slightly acidic, fine sandy to silt loamy or clay loamy surface duplex soils in places with a pale or bleached sub-surface (A2) horizon. There is a sharp transition to the subsoil (B) horizon which comprises brown, yellow-brown or red-brown alkaline to strongly alkaline medium to heavy clay subsoils which have moderates amounts of soft carbonate inclusions and weak to moderate blocky to columnar soil structure with hard dry consistence. The deeper subsoils tend to become more massive, apedal and strongly cohesive heavy clays with low to moderate levels of sodicity and salinity usually present. These soils may be classified as either Solodic Soils or Solodized Solonetz; (Dr2.23, Dy2.43, 2.23, Db1.23); *Red-Yellow-Brown Calcic Mesonatric Sodosols.*

Analytical data from one profile of Soil Type 6.2 in terrain unit Qa2/6-7 on Curtis Island – (refer to **Appendix L3)**, indicates medium to high levels of CEC and PAWC. The soils are non-saline and non-sodic in the surficial soil layers becoming sodic, moderately dispersive and moderately saline in the deeper subsoils. The ratio of calcium to magnesium is low (<1.0) throughout the profile. Reference to R. H. Gunn – CSIRO (1967) with respect to these soils, further indicates that calcium is the dominant metal cation in the surface soils whilst magnesium is dominant in the subsoils. Exchangeable sodium is high in the subsoils and the preponderance of sodium and magnesium accounts for the poor physical properties and dispersive characteristics of the subsoil layers.

Soil Types in Soil Group 7 – As a group these soils comprise shallow and deep uniform fine-textured (non-cracking) clay soils and gradational clay loam or light clayey surface soils with either acidic or alkaline, often sodic and in places saline medium to heavy clay or heavy clay subsoils. Locally the soils tend to exhibit characteristics of (incipient) cracking clay soils. Three soil variants have been identified, details of which are as follows:

Soil Type 7.1 – These soil profiles occur mainly on low hilly, hilly and higher hilly lands where mainly developed on argillaceous sedimentary rock types and intermediate to basic volcanic rock lithologies. They comprise mainly shallow to medium deep (0.5-0.7 m) uniform light to medium acidic clays, or gradational clay loam, gravelly clay loam or gravelly clay surface soils with 30-50% fine gravel and coarse stone over gravelly acidic or alkaline dark brown, grey-brown clays or medium to heavy clay subsoils underlain by weathered rock generally below about 0.6-0.8 m. These soils are classified as Dark Brown and Grey-brown (Non-cracking) Clays: (Uf6.31, 6.32); *Gravelly Grey-brown and Red-Brown Dermosols.*

Analytical data from two sites tested, refer **(Appendix L3)**, indicates the clayey subsoils contain slightly to moderately sodic and dispersive soil layers. The ratio of calcium to magnesium in samples tested was very low, indicating potential soil structural stability problems.

Soil Type 7.2 – These soils occur mainly on undulating alluvial plains and on undulating lowlands and gently inclined slopes adjacent to and along drainage lines. They comprise medium to deep uniform clay soil profiles with light to medium clay texture throughout, or grade from clay loam at the surface to light to medium clay subsoils below about 0.3- 0.5 m. The surface soils have granular structure becoming sub-angular blocky in the subsoils, tending to massive in the deeper subsoils. The surface soils are mostly dark brown and neutral to moderately acidic, with a gradual change to brown, yellowish or reddish-brown moderately to strongly alkaline clay subsoils. These soils are classified as Dark Brown and Grey-brown (Non-cracking) Clay Soils: (Uf6.31, 6.21); *Grey, Brown or Red Dermosols*.

Limited available analytical data from two sites, refer **(Appendix L3)**, indicates these soils tend to be slightly sodic and dispersive in the upper soil layers and strongly sodic and dispersive in the deeper subsoils. Soil salinity levels are low near the surface and in places become moderately high in the deeper subsoils.

Soil Type 7.3 – These soil profiles occur locally in association with soils of Group 5 on the lower foot-slopes in terrain unit Cw5/5-7 and on the slightly elevated estuarine flats in terrain unit Qe2/7.3 on Curtis Island. The soils comprise deep uniform clays or gradational brown to yellowish red silty clay or heavy clay surface soils with diffusely mottled reddish-brown, brown or yellow-brown neutral to acidic, in places strongly acidic, sodic and locally approaching the coast, moderately to highly saline in the medium to heavy or heavy clay subsoils. These soils may be classified as Dark Brown and Grey-brown (Non-cracking) Clay Soils: (Uf6.31, 6.21, 6.12, 6.61); *Acidic Sodic Mottled Grey, Brown and Red-brown Dermosols* or *Acidic Sodic Dermosolic Hydrosols.*

Indicative soil testing and analytical data from one site tested in terrain unit Qe2/7.3 on Curtis Island, refer to **(Appendix L3)**, indicates that these soils are sodic and tend to become increasingly sodic to very high levels in the deeper heavy clay subsoils. However the samples tested from similar depths for dispersion class were non-dispersive, possibly related to the strong levels of acidity throughout the profile. Calcium/magnesium ratios were all very low and soil salinity levels were moderate increasing to high in the deeper medium to heavy clay subsoil layer.

Soil Types in Soil Group 8 – In general, Group 8 soils include shallow, medium and deep to very deep uniform fine-textured (cracking) clay soils with dark grey, brown or black mostly alkaline medium to heavy clays throughout, or alkaline over acidic heavy clay subsoils in areas with intensive gilgai surface micro-relief. The soils are strongly reactive and prone to substantial horizontal and vertical movement and associated cracking in the upper parts of the soil profile due to seasonal wetting and drying cycles. Three soil type variants have been identified, details of which are as follows:

Soil Type 8.1 – These soils occur on slopes, mostly 2-3% locally up to 5% on gently undulating erosional plains and lowlands and undulating low plateau surfaces underlain by Tertiary volcanic rock types mainly basalt and on low rises underlain by argillaceous Permian sedimentary and volcanic rock types. They comprise shallow (<0.6 m) mainly uniform light to heavy clays formed in-situ. Surface soils when dry to just moist, have a friable, self-mulching granular structure becoming hard with medium to coarse angular blocky below (0.25 m) approximately. Soil reaction trend is neutral to slightly acidic near the surface and moderately to strongly alkaline in the subsoil where soft carbonate is usually present. Soil colour near the surface is dark grey or grey-brown, becoming lighter with depth approaching the underlying weathered rock zone. These soils are classified as Black Earths; (Ug5.12, 5.27, 5.32); *Self-mulching Black or Brown Epicalcareous Vertosols*.

Soil Type 8.2 – These soils occur on rises and mid to upper slopes (2-5%) in gently to moderately undulating plains and lowlands formed on Triassic, Permian and some Tertiary mudstone, shale and calcareous sandstones. They comprise medium to deep (0.6->1.0 m) uniform sandy medium to heavy clays, colours are dark grey or grey-brown at the surface becoming gradually lighter with depth. Soil reaction at the surface is acidic to moderately alkaline and moderately to strongly alkaline in the deeper subsoils where soft carbonate is usually present. The surface soils generally have a thin crusty to weak granular friable self-mulching surface layer grading through hard coarse blocky structure in the subsoil tending to massive soil structure in the deeper subsoils (>0.6-0.8 m). These soils may be classified as Black Earths or Grey and Brown Soils of Heavy Texture; (Ug5.12, 5.15, 5.27, 5.32); *Self-mulching Black or Brown Epicalcareous Vertosols*.

Soil Type 8.3 – These soils occur in the lower-lying older alluvial plains and river floodplain areas with near level to gently undulating relief. They are deep to very deep (typically >1.5 m), uniform medium to heavy clay soils typically with strongly developed gilgai micro-relief with vertical intervals between gilgai mounds and troughs ranging from 0.3 to 1.0 m. Surface soils are dark grey-brown, dark grey or brown, which generally become lighter in colour with depth. Black manganiferous staining is common below a depth of 1.0 m and prominent coarse red, yellow or brown mottling occurs in the deeper subsoils. When dry, there is usually a thin surface crust present on the gilgai mounds, underlain by hard coarse blocky structured subsoils. Large cracks form in the gilgai depressions and there is usually a thin self-mulching granular surface layer present. Soil reaction is variable but frequently moderately to strongly alkaline near the surface, with soft carbonate present in the subsoil layer, becoming acidic to strongly acidic in the deeper subsoil layers. Surface and internal profile drainage is poor and water may be retained in the gilgai depressions for lengthy periods. These soils may be classified as Grey and Brown Soils of Heavy Texture; (Ug5.16, 5.24); *Dark Grey, Black or Brown Epicalcareous Endoacidic-Mott;ed Vertosols* .

Analytical data on these soils from R. H. Gunn – CSIRO (1967), indicates salinity levels are low in the surficial (0.3 m) soil layers, becoming high in the lower subsoils. Soil sodicity (ESP) levels are <10% in the surficial soils but become high (15-25%) in the subsoils and extremely high (>25%) in the deeper subsoils. Calcium is the dominant metal cation in the surface soil layers, with magnesium becoming dominant in the deeper subsoils indicating potential soil structural instability and dispersion in the deeper subsoil layers. Nitrogen, phosphorus and potassium levels are variable but generally at moderately high levels and clay mineral determinations indicate that montmorillonite and kaolinite are the co-dominant clay minerals.

Soil Types in Soil Group 9 – As mapped, these soils occur on the inter-tidal mangrove flats and tidal inlets in terrain unit Qe0/9 and in the estuarine supra-tidal and extra-tidal flats in terrain unit Qe1/7-9, which occur on the mainland approaches to the bridge crossing of The Narrows and along the coastal fringe on Curtis Island.

Only the one general soil type was identified within this group as the soils vary considerably and include a wide range of deep to very deep, very soft, uniform, gradational, weak duplex soil profiles with highly organic silty clay, silty clay loam surface soils and seasonally or permanently saturated subsoils, typically gleyed and saline clays, clayey silt, silty sand or sandy mud. These soils may be classified as Humic Gley Soils and Solonchaks; (Uf6.41, 6.61, Dg2.11); *Intertidal and Supratidal Hydrosols;Redoxic Hydrosols*

No analytical data is available for the Group 9 soils, however soil chemistry data acquired for the GLNG EIS Acid Sulfate Soils (ASS) investigations indicates that the surficial silty clay soils comprise very strongly acidic Actual ASS and the deeper permanently saturated soil layers include very high levels of Potential ASS which will pre-dispose these soils to high levels of acid production if they are exposed to air and subject to the effects of oxidation.

The occurrence and distribution of soils and soil associations identified within the pipeline corridor and the terrain units in which they occur are shown in **Figure 2–1 to 2-24.**

1.6 Topsoil Resources

1.6.1 Method of Assessment

Good quality natural topsoil promotes high growth rates, absolute levels of plant production and species diversity. This occurs when coupled with a balanced pool of nutrients and organic matter, relatively high levels of infiltration and porosity and adequate water holding capacity, all of which is governed by the soil texture, structure and relatively low bulk density in the plant root zone. The suitability of materials for use as topsoil resources for rehabilitation of lands that may be disturbed during the construction and operating stages of the gas transmission pipeline has been assessed from the soil characterisation, indicative testing and the results of the analytical data obtained during the LNG facility field investigations, (refer to **Appendix L3**). Additional soils data was also obtained from reference to and interpretation of the Land Systems and Soils mapping by CSIRO (1967, 1968 & 1967) and NRW (1995) which collectively cover the general project 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 identified and summarised in **Table 1-2**. Some comments on topsoil suitability are also included in the descriptions of terrain units in **Appendix A** of this report.

1.6.2 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, which contain seed-stock, micro-organisms, organic matter and nutrients necessary for plant growth. Soil microbial activity, organic matter content and other parameters affecting soil productivity and fertility, tend to decrease with depth.

In general, topsoil resources that occur along the gas transmission pipeline right-of-way (ROW) will be salvaged from areas likely to be subject to disturbance as a result of clearing and the provision of temporary construction or permanent access tracks. Where possible, the pre-stripped topsoil material will be temporarily stockpiled within the ROW for subsequent rehabilitation of areas disturbed by construction activities. Topsoil resources along the immediate gas transmission pipeline centreline will be stripped and placed in stockpiles separate from the underlying trench spoil for subsequent replacement during the final stages of the construction period.

Table 1-3 Indicative Topsoil Resources & Stripping Depths

Soil Group	Summary Soil Description	Soil Type	Indicative Stripping Depth (m)	Remarks
1	Skeletal, rocky or gravelly soils (>60% coarse fragments) with sandy, silty, loamy or clayey soil matrix	1	0	Skeletal to shallow rocky soils and rock outcrop
2	Sand soils; shallow to deep uniform or weakly gradational profiles; includes stratified alluvial soils, residual sand soils, earthy sands;	2.1	0.1	Utilise seed stock and organics
		2.2	0	Potential source of bedding sand
		2.3	0.25	Humic surface soil, strongly acidic subsoils
3	Coarse to medium-textured soils; uniform or gradational profiles; predominantly sandy earths with sand, silty or clayey sand over clayey sand-sandy clay soil profiles	3.1	0.2	Strongly acidic subsoils (>0.2 m)
		3.2	0.3	Texturally suitable (0.3-0.6) but low levels of soil nutrients
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	0.2	Excess gravel/stone below 0.2 m
		4.2	0.3	Texturally suitable (0.3-0.6) but high gravel content may occur
		4.3	0.3	Texturally suitable (0.3-0.6), but low soil nutrients
5	Sand, loamy sand, sandy loam or loamy surface duplex soils over acidic to locally strongly acidic, in places neutral or slightly alkaline sandy clay to medium to heavy clay subsoils;	5.1	0.2	Strongly acidic, locally sodic in the deeper subsoils
		5.2	0.3	Bleached erodible (A2) horizon (>0.3 m), possible source of bedding sand (0-0.6 m)
		5.3	0.2	Bleached (A2) horizon (>0.2 m), sodic/dispersive subsoils
6	Fine sandy, silty or clay loamy surface duplex soils with neutral to alkaline often calcareous, sodic and locally saline medium to heavy clay	6.1	0.15	Shallow soils, bleached (A2) horizon, strongly alkaline, sodic/dispersive subsoils

Soil Group	Summary Soil Description	Soil Type	Indicative Stripping Depth (m)	Remarks
	or heavy clay subsoils;	6.2	0.15	Thin pale or bleached layer over hard clay subsoils
7	Shallow uniform often gravelly fine-textured soils, medium to deep uniform fine-textured (non-cracking) clay soils or gradational often stony or gravelly clay loam or light clay surface soils over alkaline medium to heavy clay subsoils, locally sodic and saline in the deeper subsoils – some deep incipient cracking clays;	7.1	0.2	Excess gravel/stone below 0.2 m approximately
		7.2	0.3	Texturally suitable (0.3-0.6 m), highly alkaline/calcareous below
		7.3	0.2	Locally strongly acidic, sodic and moderately highly saline in the subsoil below about 0.2 m
8	Shallow to medium to deep uniform fine-textured (cracking) clay soils, locally with thin self-mulching surficial soils with dark grey, brown or black mostly alkaline or alkaline over acidic heavy clay subsoils in areas with gilgai micro-relief;	8.1	0.2	Medium to coarse blocky structure (>0.15-0.2 m); some rock cobbles and gravel included
		8.2	0.25 0.2 (rises)	Medium to coarse hard blocky structure below 0.2-0.3 m
		8.3	0.2 (rises) 0.3 (depressions)	Medium to coarse hard blocky structure and mod. saline and sodic below 0.2 m on gilgai mounds
9	Deep to very deep, very soft, uniform gradational or weak duplex soil profiles, with organic silty clay to silty clay loam surface soils and season-ally or permanently saturated sub-soils, typically gleyed saline clays, clayey silt, silty sand or sandy mud	9	0	Mostly saline and in places strongly acidic in the surficial soil layers; Potential ASS may occur locally.

Some variability will occur with respect to the available topsoil resources within the soil groups and soil types identified within the gas transmission pipeline corridor. Accordingly, monitoring of soil type variability will be undertaken by approved personnel with soils expertise 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.

1.6.3 Topsoil Stripping

Prior to the commencement of topsoil stripping, areas will be cleared of vegetation. Details of the topsoil stripping and management process will be included in the gas transmission pipeline construction EMP. Earthmoving plant operators will be trained and/or supervised to ensure that stripping operations are conducted in accordance with the construction EMP 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.

1.6.4 Stockpiling

Where possible, topsoil material will be respread directly from stripped areas on to other areas being rehabilitated. Where this is not possible, topsoil shall be stored in stockpiles within the gas transmission pipeline easement. Apart from the immediate pipeline trench corridor, topsoil material stockpiles will be 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 3 metres maximum) and maximum surface area, consistent with the storage area available. If the stockpile is to be retained for a period of more than three 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.

1.7 Soil Erosion

Construction of the gas transmission pipeline will involve clearing and earthworks along the easement in the immediate vicinity of the trench, in areas where temporary and permanent access roads are proposed and in associated infrastructure areas. Potential environmental impacts that may result from pipeline construction activities primarily relate to the erosion potential of the land in areas that are cleared or disturbed for development.

1.7.1 Existing and Potential Soil Erosion

From examination of the SPOT imagery acquired along the gas transmission pipeline corridor, substantial areas are currently subject to accelerated soil erosion, in particular extensive surface sheet and rill erosion, with areas of gully erosion mainly on the approaches or adjacent to the more major stream lines. The areas most affected include those with terrain units assessed to have high (H) erosion potential **(see Appendix A)**. These include a range of terrain types associated with the Jurassic sandstone geological regimes (terrain units Jh4/2-5, Jh 5/5.2; Je4/2-5, Je 5/2-5, Je6/1-5 and Jp5/2-5, Jp6/0-2); Triassic rock units (Rm4/5-7, Rm5/5-7 and Rc6/1-5, Rc7/1-5); the Permian intrusive rock types (Pfi4/5.1, Pfi 5/2-5); the Silurian volcanics (Sf4/4.3, Sf6/4-7) and Cainozoic sediments geological regime (Czs5/6.2). All of these terrain units tend to have sand soils or sandy surface duplex soils often with sodic and/or dispersive clay subsoils. In many parts these areas may have been subject locally to extensive heavy grazing activities. In general, further clearing of vegetation and stripping of topsoil resources along the gas transmission pipeline easement will expose the land to varying levels of erosion due to the combined effects of surface slope and form, soil type, surface run-on/run-off potential and wind erosion over time. Accordingly, a qualitative assessment of erosion potential has been made on a terrain 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 but not restricted to those included in **Appendix B-2** may be incorporated in a construction pipeline-specific site-based environmental management plan (EMP) which will be implemented to minimise the effects of erosion from disturbed land areas. 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).

1.8 Agricultural Land Capability

1.8.1 Agricultural Land Classes

An assessment of the agricultural land capability of the area has been carried out to provide a benchmark of existing/potential agricultural land use. As required in the project EIS Terms of Reference, in accordance with

Section 1 Introduction

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 have been determined on a terrain unit basis as shown in **Appendix A**. The land classes determined 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). The mapping has been modified in parts by the more detailed terrain unit mapping undertaken for the pipeline route corridor assessment. The occurrence and distribution of agricultural land classes within the gas transmission pipeline corridor is shown in **Figure 2-1 to 2-24.** The cumulative distance of terrain units and associated agricultural land class areas intersected along the pipeline centreline are shown on a sector by sector basis in **Figure 2–1 to 2-24**.

1.9 Acid Sulfate Soils

The EIS Terms of Reference (ToR) for the project require that an investigation and mapping of the occurrence and distribution of acid sulfate soils (ASS) is undertaken, together with an assessment of any potential environmental impacts associated with the proposed gas transmission pipeline construction. To address the requirements of the ToR, a separate investigation of ASS has been carried out, the results of which, together with an assessment of potential impacts and mitigation measures are included **Appendix L4** and in **Section 8.3.3** of the EIS.

The above report indicates that ASS, both Actual ASS (AASS) and Potential ASS (PASS) were found to occur within the upper levels of the estuarine sediments within the proposed gas transmission pipeline trench depth. These estuarine sediments occur along the coastal fringes of “The Narrows”, both on the mainland eastern coastline and along the western coastline of Curtis Island to the south of Graham Creek. As mapped, the ASS occurs in terrain units Qe0/9, Qe1/7-9 and possibly in slightly elevated extra-tidal areas in terrain unit Qe2/7.3.

1.10 Load Bearing Capacity of Marine Plains

Variable shallow to deep and in parts very deep occurrences of saturated soft sediments have been found to occur on the marine/estuarine plains in terrain units Qe0/9 and Qe1/7-9. Depending on site-specific locations and their proximity to the landward margins of the terrain units, these areas may be prone to substantial settlement under load – e.g. fill emplacement. The load bearing capacity of marine plain soils has been addressed as part of site acid sulphate soil investigation in **Appendix L4.**

Section 2 Potential Impact and Mitigation Measures

2.0 Pipeline Construction - Constraints and Impacts

A terrain analysis of a 5 km wide gas transmission pipeline corridor was initially carried out, to assess the engineering and/or environmental constraints with respect to the location and construction of a pipeline and various possible alternatives being considered. A series of terrain units were identified for each of the main geological regimes identified within the gas transmission pipeline corridor based on landform characteristics (surface form and slope) and associated soils. Subsequently, a 2 km wide corridor was adopted for the EIS of the proposed pipeline route. The occurrences of terrain units within that corridor are shown in **Figures 2–1 to 2-24**. Descriptions of the terrain units, together with an assessment of the more important engineering/environmental constraints and by association, potential environmental impacts for pipeline construction, are provided in **Appendix A** of this report. The assessment includes:

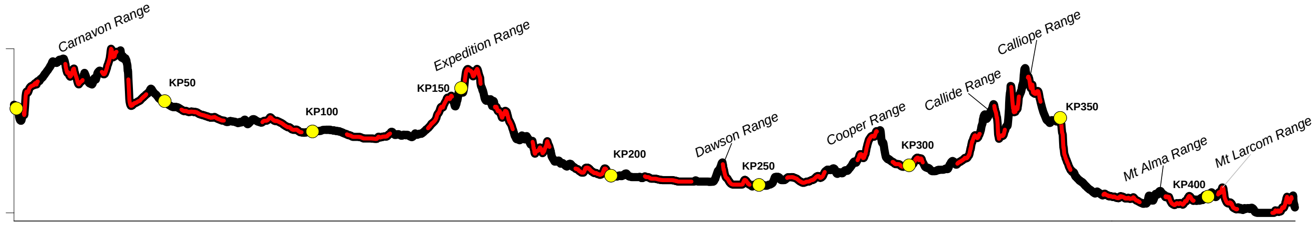
- Topographic constraints;
- Excavation rating - relates to the ease or difficulty of excavation within the typical trench depth;
- Erosion potential - if the land is subject to clearing or disturbance associated with construction;
- Drainage status - assessment of area drainage conditions and susceptibility to flooding/tidal inundation;
- Problem soils - the occurrence of reactive soils, sodic, dispersive and/or saline soils, acid sulphate soils; and
- Agricultural land classes – changes to agricultural land capability.

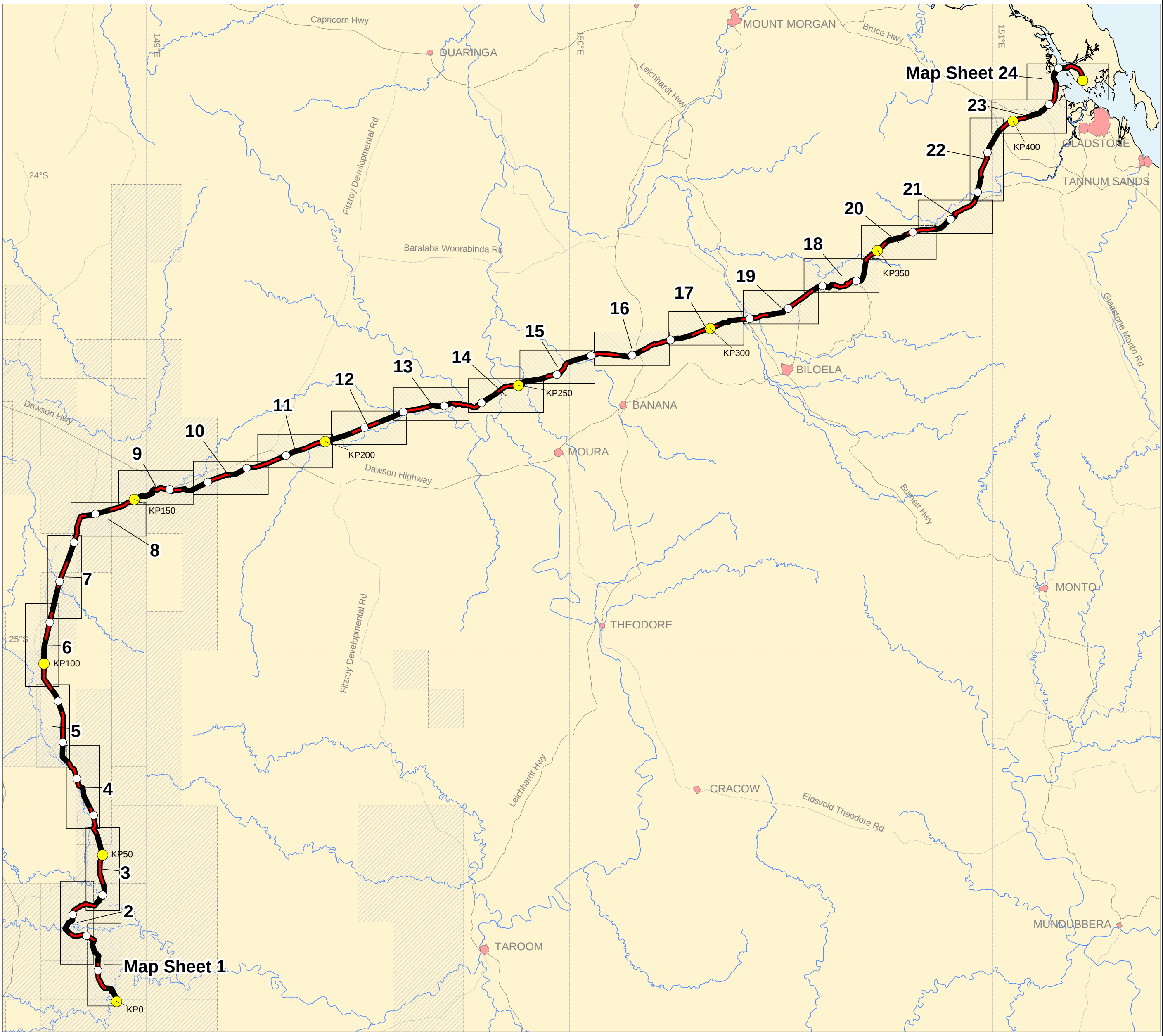
Discussion relating to the above engineering/environmental constraints together with a summary of findings and comments with respect to mitigation of potential environmental impacts is provided as follows:

2.1 Topographic Constraints

Topographic constraints and their impact on the level of difficulty with respect to the construction of the pipeline, relate primarily to the steepness of slopes, in particular the steepness of cross slopes and the degree of dissection along the pipeline centreline. In general, terrain units that have overall surface slopes up to 3% have been rated as presenting a low (L) level of constraint. Terrain units with surface slopes between 3-5% and locally between 5-12%, depending on the local internal relief and degree of dissection, have been rated as presenting a low to moderate (L-M) level of constraint. Strongly undulating to low hilly lands with surface slopes up to 25% and including some of the larger tributary stream crossings, have been rated as presenting a moderate (M) level of constraint. The steeper hilly and high hilly lands and steep escarpment slope areas, with slopes 25-50% or steeper, together with the major stream and river crossings along the pipeline route, have been rated as presenting a high (H) level of topographic constraint for pipeline construction.

PIPELINE ELEVATION PROFILE





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0 25 50km

Scale: 1:1,500,000 (A4)
Datum: GDA94

	Gas Transmission Pipeline
KP100	Kilometre Post Distance Markers (in Km)
	Kilometre Post Distance Markers (10Km Intervals)
	CSG Fields

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

Client: LNG / URS

Project: GLADSTONE LNG PROJECT
TERRAIN, SOILS AND
LAND CAPABILITY REPORT
GAS TRANSMISSION PIPELINE

Title: **GAS TRANSMISSION PIPELINE CORRIDOR ELEVATION PROFILE AND MAP SHEETS LAYOUT ALONG GAS TRANSMISSION PIPELINE CORRIDOR**

Drawn: CA	Approved: JB	Date: 01-02-2009	Figure: **2a**
Job No: **4262 6220**	File No: 42626220-g-681.wor		Rev:A / A4

Generic Key to the Identification of Terrain Units

GEOLOGICAL REGIME

Symbol	Description
Qe	Quaternary (Holocene) Estuarine Sediments
Qa	Quaternary Alluvium
Czs	Cainozoic Sediments
Ts	Tertiary Sediments
Tb	Tertiary Volcanic Rocks mostly basalt
Jp	Jurassic Precipice Sandstone
Je	Early-Middle Jurassic Evergreen Formation
Jh	Early Jurassic Hutton Sandstone
Rc	Early-Middle Triassic Clematis Group
Rm	Triassic Moolayember Formation
Ra	Triassic Arcadia Formation, Rewan Group
Ps	Permian Sediments
Pv	Permian Volcanics
Pfi	Late Permian-Early Triassic Felsic Intrusives
Pii	Late Permian Intermediate Intrusive Rocks
Ct	Carboniferous Torsdale Volcanics
Cr	Carboniferous Rockhampton Group
Cw	Carboniferous Wandilla Formation
Dcs	Late Devonian Intermediate Extrusive Rocks
Sf	Silurian-Devonian Volcaniclastic Rocks
W	Water Body
D	Disturbed Area – not mapped
Note:	Refer to EIS Report Section 1.3 for more detailed descriptions of Geological Regimes.

LANDFORM – TERRAIN TYPE

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

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

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

SOILS

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

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

Note: This Figure 2b must be viewed with Figure 2-1 to 2-24.

Client

URS

Project

GLADSTONE LNG PROJECT
TERRAIN, SOILS AND
LAND CAPABILITY REPORT
GAS TRANSMISSION PIPELINE

Drawn: CA | Approved: JB | Date: 03-02-2009

Job No: **4262 6220** | File No: 42626220-g-686.wor

Title

GENERIC KEY TO THE IDENTIFICATION OF TERRAIN UNITS

Figure: **2b**

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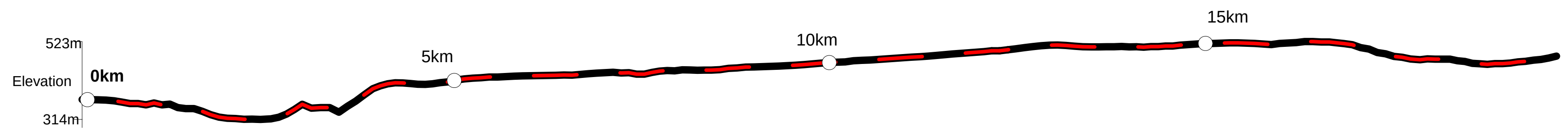
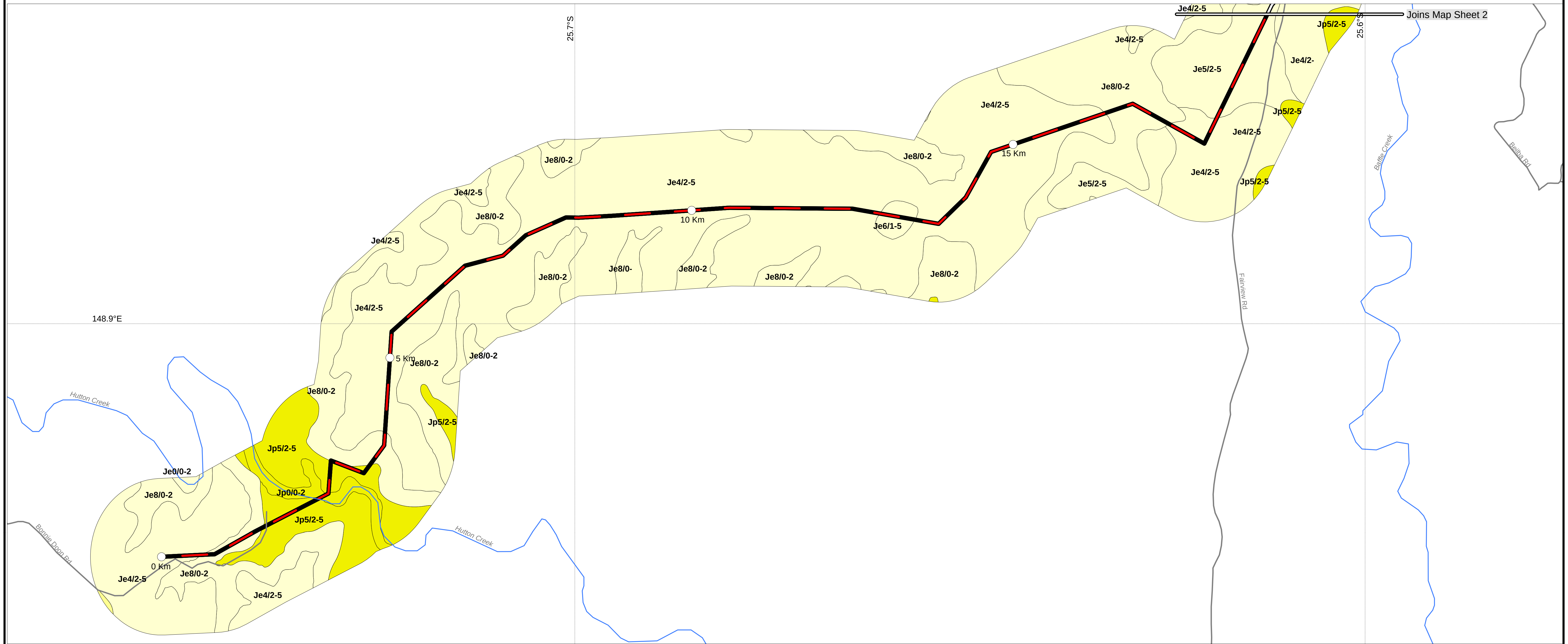
PIPELINE ELEVATION PROFILE





Note: Figures 2-1 to 2-24 must be viewed with Figure 2b.

0 1 2km
Scale 1:50 000 (A3)
Datum: GDA94

- 5km Distance Markers from Start of Pipeline
- Gas Transmission Pipeline
- Fault
- Anticline
- Syncline
- River / Creek
- Road

Terrain Units & Constraints Intersecting Pipeline:

Terrain Unit	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Pipeline Length (m)
Jp0/0-2	H	3-4	H	F4	L	D	144
Je6/1-5	M	2-3	H	W	M (So/D)	C3	499
Je5/2-5	M	2-3	H	W	M (So/D)	C2	1,454
Jp5/2-5	L-M	2	H	W	L	C2	1,757
Je8/0-2	H	3-4	H	X	L	D	2,574
Je4/2-5	L-M	2-3	H	W	M (So/D)	C2	13,284

Total pipeline length in current map sheet: 19,712m (19.7km)

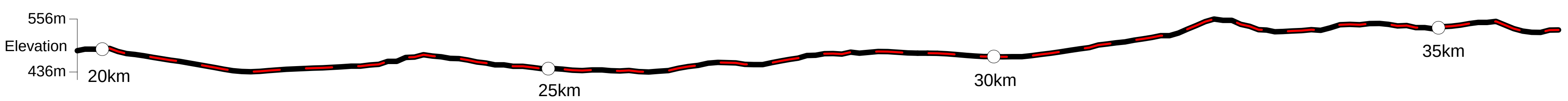
Sector Summary:

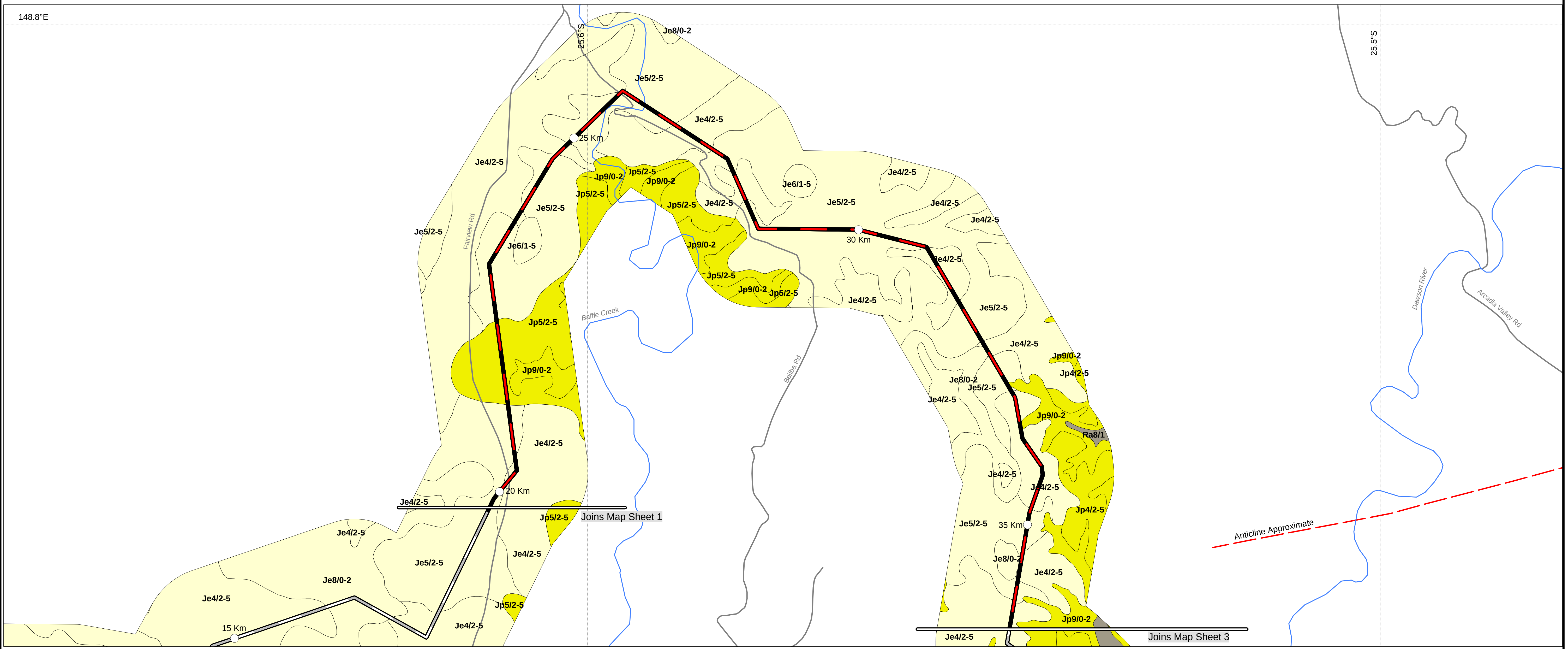
Constraints	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils
Low Constraint	15,041	-	-	16,994	4,475
Moderate Constraint	1,953	16,994	-	2,574	15,237
High Constraint	2,718	2,718	19,712	144	-

Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT TERRAIN, SOILS AND LAND CAPABILITY REPORT GAS TRANSMISSION PIPELINE	**GEOLOGICAL REGIMES AND TERRAIN UNITS**

Drawn: CA | Approved: JB | Date: 01-02-2009
Job No: 4262 6220 | File No: 42626220-g-657.wor
Figure: 2-1 | Rev:A | A3

PIPELINE ELEVATION PROFILE





Note: Figures 2-1 to 2-24 must be viewed with Figure 2b.

0 1 2km

Scale 1:50,000 (A3)
Datum: GDA94

5km Distance Markers from Start of Pipeline
Gas Transmission Pipeline
Fault
Anticline
Syncline
River / Creek
Road

Terrain Units & Constraints Intersecting Pipeline:

Terrain Unit	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Pipeline Length (m)
Je8/0-2	H	3-4	H	X	L	D	260
Jp5/2-5	L-M	2	H	W	L	C2	1,079
Je4/2-5	L-M	2-3	H	W	M (So/D)	C2	5,025
Je5/2-5	M	2-3	H	W	M (So/D)	C2	10,269

Total pipeline length in current map sheet: 16,633m (16.6km)

Sector Summary:

Constraints	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils
Low Constraint	6,104	-	-	16,373	1,339
Moderate Constraint	10,269	16,373	-	260	15,294
High Constraint	260	260	16,633	-	-

Client: LNG / URS

Project: GLADSTONE LNG PROJECT
TERRAIN, SOILS AND
LAND CAPABILITY REPORT
GAS TRANSMISSION PIPELINE

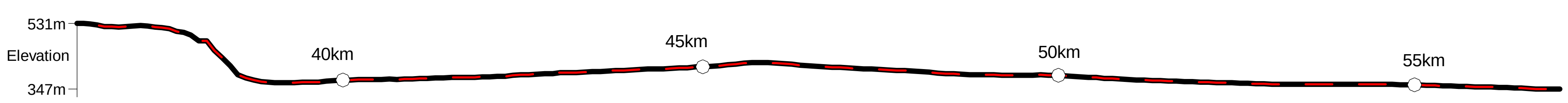
Title: **GEOLOGICAL REGIMES AND TERRAIN UNITS**

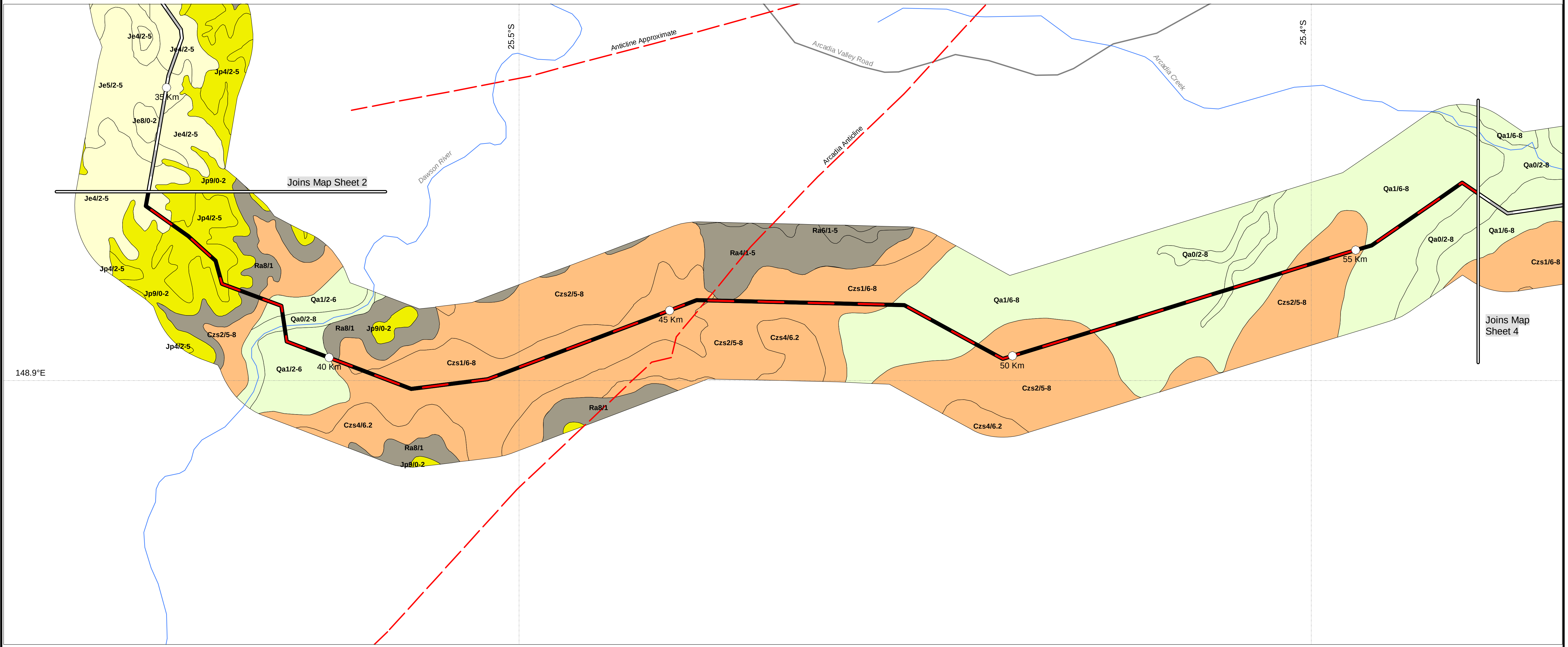
Drawn: CA | Approved: JB | Date: 01-02-2009

Job No: **4262 6220** | File No: 42626220-g-658.wor

Figure: **2-2** | Rev:A | A3

PIPELINE ELEVATION PROFILE





Terrain Units & Constraints Intersecting Pipeline:

Terrain Unit	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Pipeline Length (m)
Jp9/0-2	H	3-4	H	X	L	D	151
Qa0/2-8	H	2	M-H	F4	M (R1)	D	357
Ra8/1	H	3-4	M-H	X	L	D	418
Je4/2-5	L-M	2-3	H	W	M (So/D)	C2	593
Qa1/2-6	L	1	H	F3	M (D)	C2	1,096
Jp4/2-5	L-M	2-3	M-H	W	L-M (So/D)	C2	1,195
Czs1/6-8	L	1	M	F2	H (R3,So/D)	C1	5,058
Qa1/6-8	L	1	M	F3	H (R3,So/D)	C1	5,820
Czs2/5-8	L	1	M	I	M (R1)	B	5,937

Total pipeline length in current map sheet: 20,625m (20.6km)

Sector Summary:

Constraints	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils
Low Constraint	19,699	17,911	-	1,788	569
Moderate Constraint	-	2,145	16,815	11,564	9,178
High Constraint	926	569	3,810	7,273	10,878

0 1 2km
Scale 1:50,000 (A3)
Datum: GDA94

Note: Figures 2-1 to 2-24 must be viewed with Figure 2b.

- 5km Distance Markers from Start of Pipeline
- Gas Transmission Pipeline
- Fault
- Anticline
- Syncline
- River / Creek
- Road

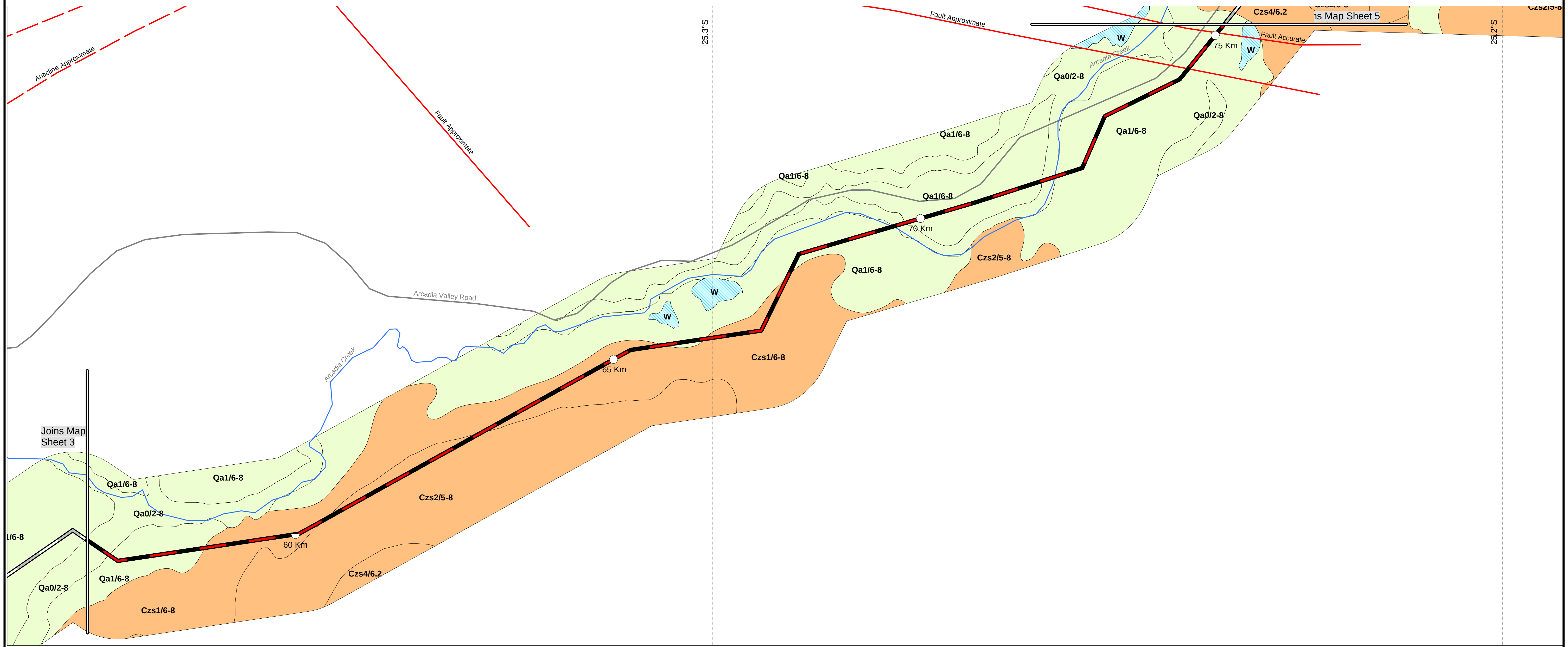
Client: LNG / URS

Project: GLADSTONE LNG PROJECT
TERRAIN, SOILS AND
LAND CAPABILITY REPORT
GAS TRANSMISSION PIPELINE

Title: **GEOLOGICAL REGIMES AND TERRAIN UNITS**

Drawn: CA	Approved: JB	Date: 01-02-2009	Figure: 2-3	Rev:A
Job No: 4262 6220	File No: 42626220-g-659.wor			A3

PIPELINE ELEVATION PROFILE



Terrain Units & Constraints Intersecting Pipeline:

Terrain Unit	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Pipeline Length (m)
Qa0/2-8	H	2	M-H	F4	M (R1)	D	714
Czs2/5-8	L	1	M	I	M (R1)	B	2,430
Czs1/6-8	L	1	M	F2	H (R3,So/D)	C1	6,205
Qa1/6-8	L	1	M	F3	H (R3,So/D)	C1	8,869

Total pipeline length in current map sheet: 18,218m (18.2km)

0 1 2km
Scale 1:50,000 (A3)
Datum: GDA94

Note: Figures 2-1 to 2-24 must be viewed with Figure 2b.

- 5km Distance Markers from Start of Pipeline
- Gas Transmission Pipeline
- Fault
- Anticline
- Syncline
- River / Creek
- Road

Sector Summary:

Constraints	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils
Low Constraint	17,504	17,504	-	-	-
Moderate Constraint	-	714	17,504	8,635	3,144
High Constraint	714	-	714	9,583	15,074

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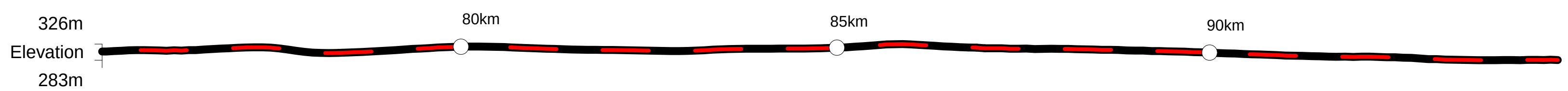
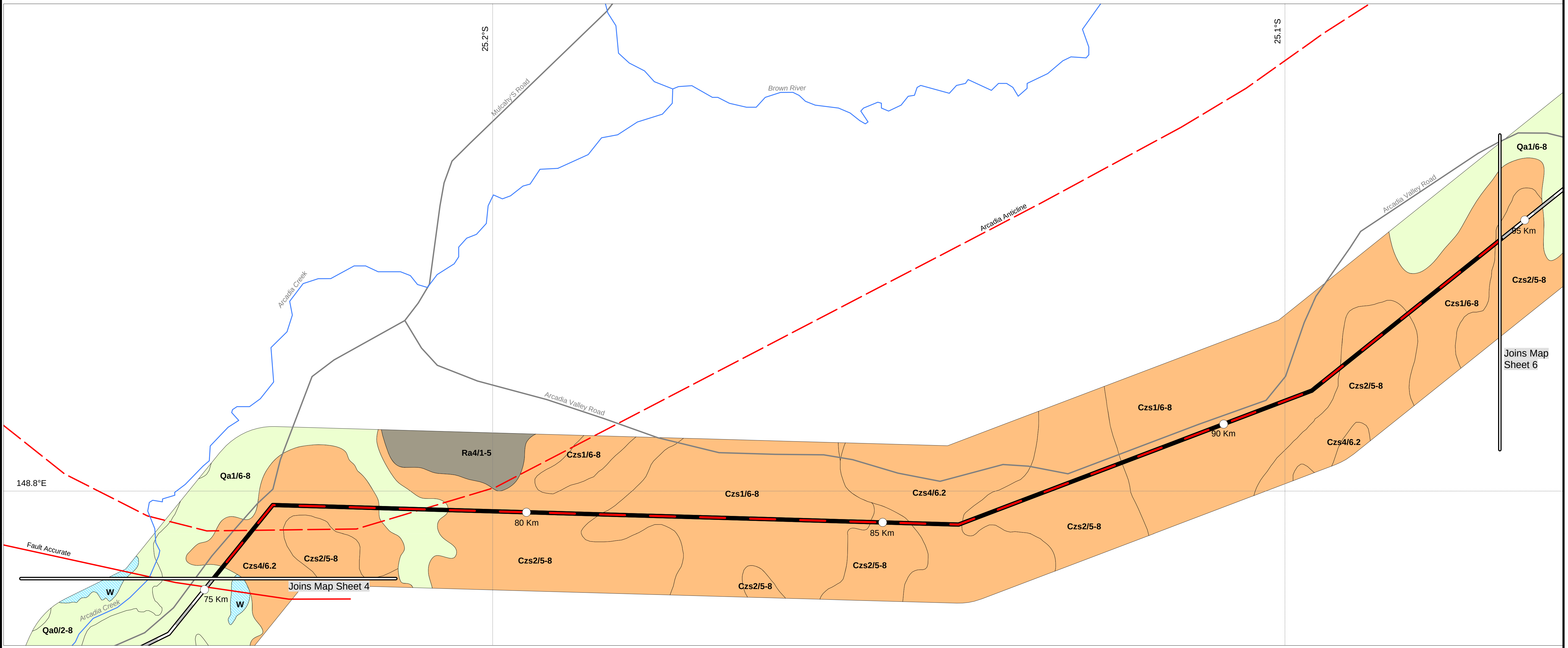
Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT TERRAIN, SOILS AND LAND CAPABILITY REPORT GAS TRANSMISSION PIPELINE	GEOLOGICAL REGIMES AND TERRAIN UNITS
	Drawn: CA Approved: JB Date: 01-02-2009	Figure: 2-4
	Job No: 4262 6220 File No: 42626220-g-660.wor	Rev:A A3

PIPELINE ELEVATION PROFILE





Note: Figures 2-1 to 2-24 must be viewed with Figure 2b.

0 1 2km

Scale 1:50,000 (A3)
Datum: GDA94

- 5km Distance Markers from Start of Pipeline
- Gas Transmission Pipeline
- Fault
- Anticline
- Syncline
- River / Creek
- Road

Terrain Units & Constraints Intersecting Pipeline:

Terrain Unit	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Pipeline Length (m)
Qa1/6-8	L	1	M	F3	H (R3,So/D)	C1	1,163
Czs4/6.2	L-M	1-2	M	W	H (So/D)	C2	3,275
Czs2/5-8	L	1	M	I	M (R1)	B	6,338
Czs1/6-8	L	1	M	F2	H (R3,So/D)	C1	8,621

Total pipeline length in current map sheet: 19,397m (19.4km)

Sector Summary:

Constraints	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils
Low Constraint	19,397	19,397	-	3,275	-
Moderate Constraint	-	-	19,397	14959	6,338
High Constraint	-	-	-	1,163	13,059

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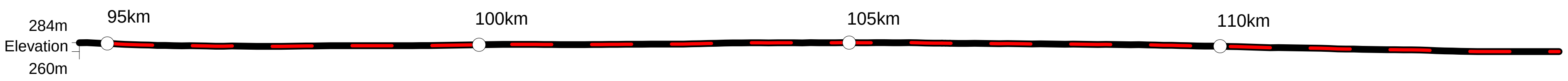
Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT TERRAIN, SOILS AND LAND CAPABILITY REPORT GAS TRANSMISSION PIPELINE	GEOLOGICAL REGIMES AND TERRAIN UNITS

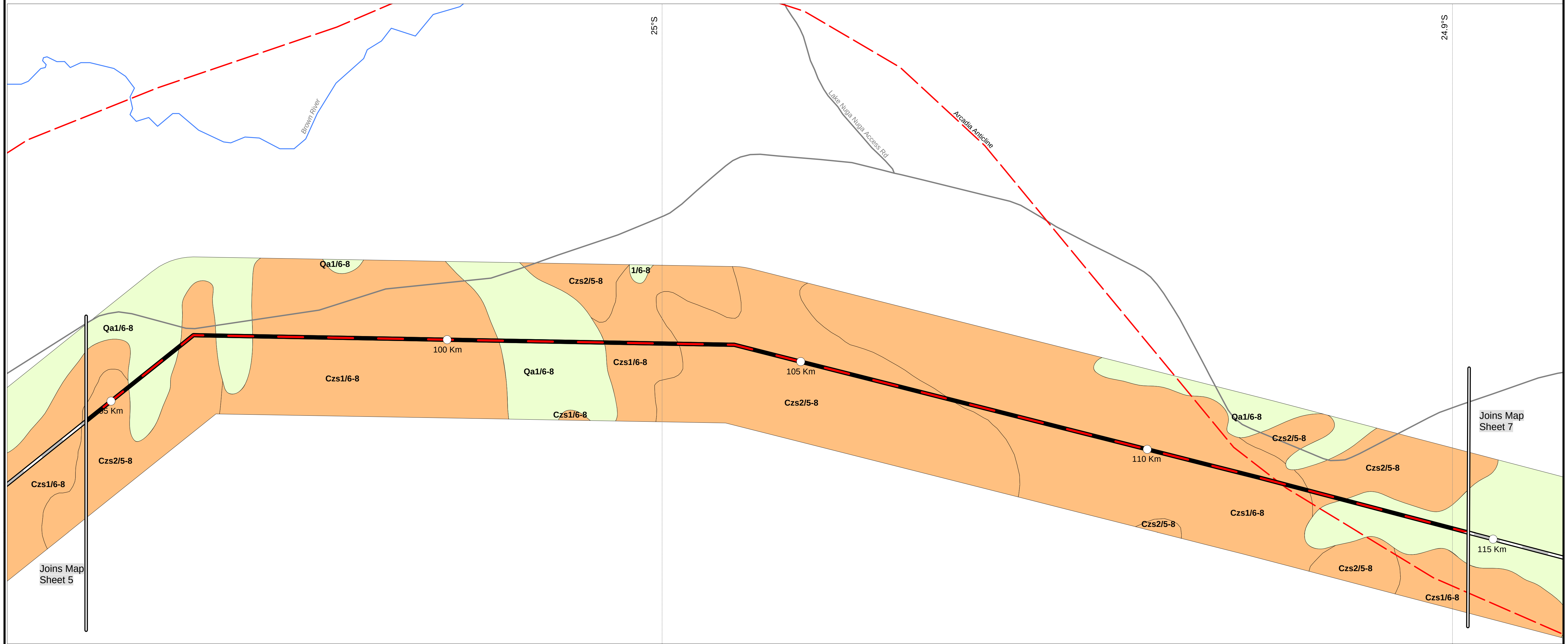
Drawn: CA | Approved: JB | Date: 01-02-2009

Job No: 4262 6220 | File No: 42626220-g-661.wor

Figure: 2-5 | Rev:A | A3

PIPELINE ELEVATION PROFILE





Terrain Units & Constraints Intersecting Pipeline:

Terrain Unit	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Pipeline Length (m)
Qa1/6-8	L	1	M	F3	H (R3,So/D)	C1	4,670
Czs2/5-8	L	1	M	I	M (R1)	B	5,679
Czs1/6-8	L	1	M	F2	H (R3,So/D)	C1	9,677

Total pipeline length in current map sheet: 20,026m (20km)

0 1 2km

Scale 1:50,000 (A3)
Datum: GDA94

Note: Figures 2-1 to 2-24 must be viewed with Figure 2b.

- 5km Distance Markers from Start of Pipeline
- Gas Transmission Pipeline
- Fault
- Anticline
- Syncline
- River / Creek
- Road

Sector Summary:

Constraints	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils
Low Constraint	20,026	20,026	-	-	-
Moderate Constraint	-	-	20,026	15,356	5,679
High Constraint	-	-	-	4,670	14,347

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Client: LNG / URS

Project: GLADSTONE LNG PROJECT
TERRAIN, SOILS AND
LAND CAPABILITY REPORT
GAS TRANSMISSION PIPELINE

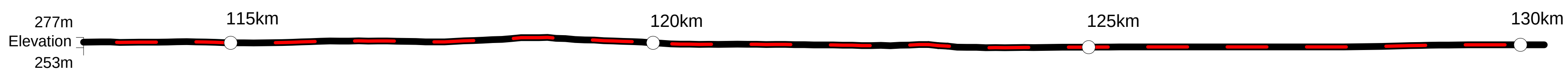
Title: **GEOLOGICAL REGIMES AND TERRAIN UNITS**

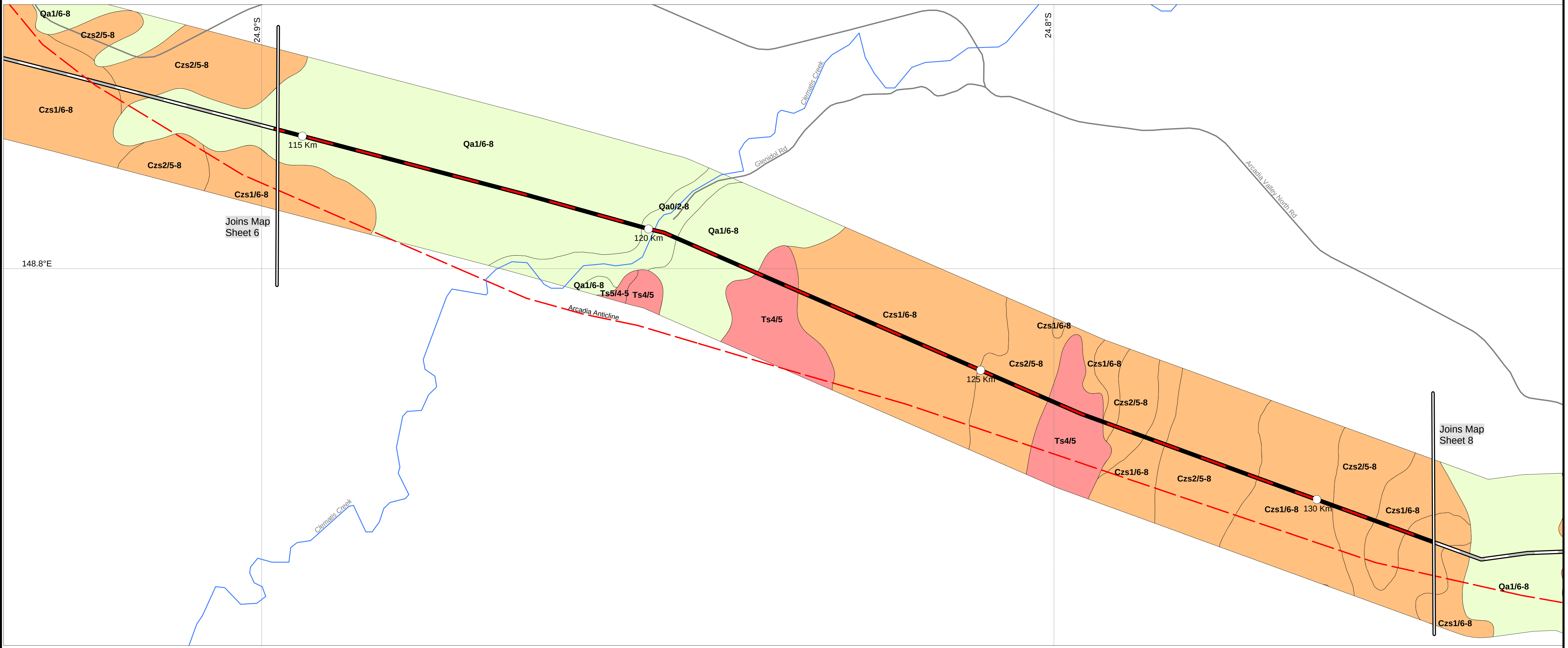
Drawn: CA | Approved: JB | Date: 01-02-2009

Job No: 4262 6220 | File No: 42626220-g-662.wor

Figure: 2-6 | Rev:A | A3

PIPELINE ELEVATION PROFILE





Terrain Units & Constraints Intersecting Pipeline:

Terrain Unit	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Pipeline Length (m)
Qa0/2-8	H	2	M-H	F4	M (R1)	D	519
Ts4/5	L-M	1-2	M-H	I	M (So/D)	C2	1,448
Czs2/5-8	L	1	M	I	M (R1)	B	3,864
Czs1/6-8	L	1	M	F2	H (R3,So/D)	C1	4,787
Qa1/6-8	L	1	M	F3	H (R3,So/D)	C1	6,487

Total pipeline length in current map sheet: 17,105m (17.1km)

0 1 2km
Scale 1:50,000 (A3)
Datum: GDA94

Note: Figures 2-1 to 2-24 must be viewed with Figure 2b.

- 5km Distance Markers from Start of Pipeline
- Gas Transmission Pipeline
- Fault
- Anticline
- Syncline
- River / Creek
- Road

Sector Summary:

Constraints	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils
Low Constraint	16586	16586	-	-	-
Moderate Constraint	-	519	15138	10099	5831
High Constraint	519	-	1967	7006	11274

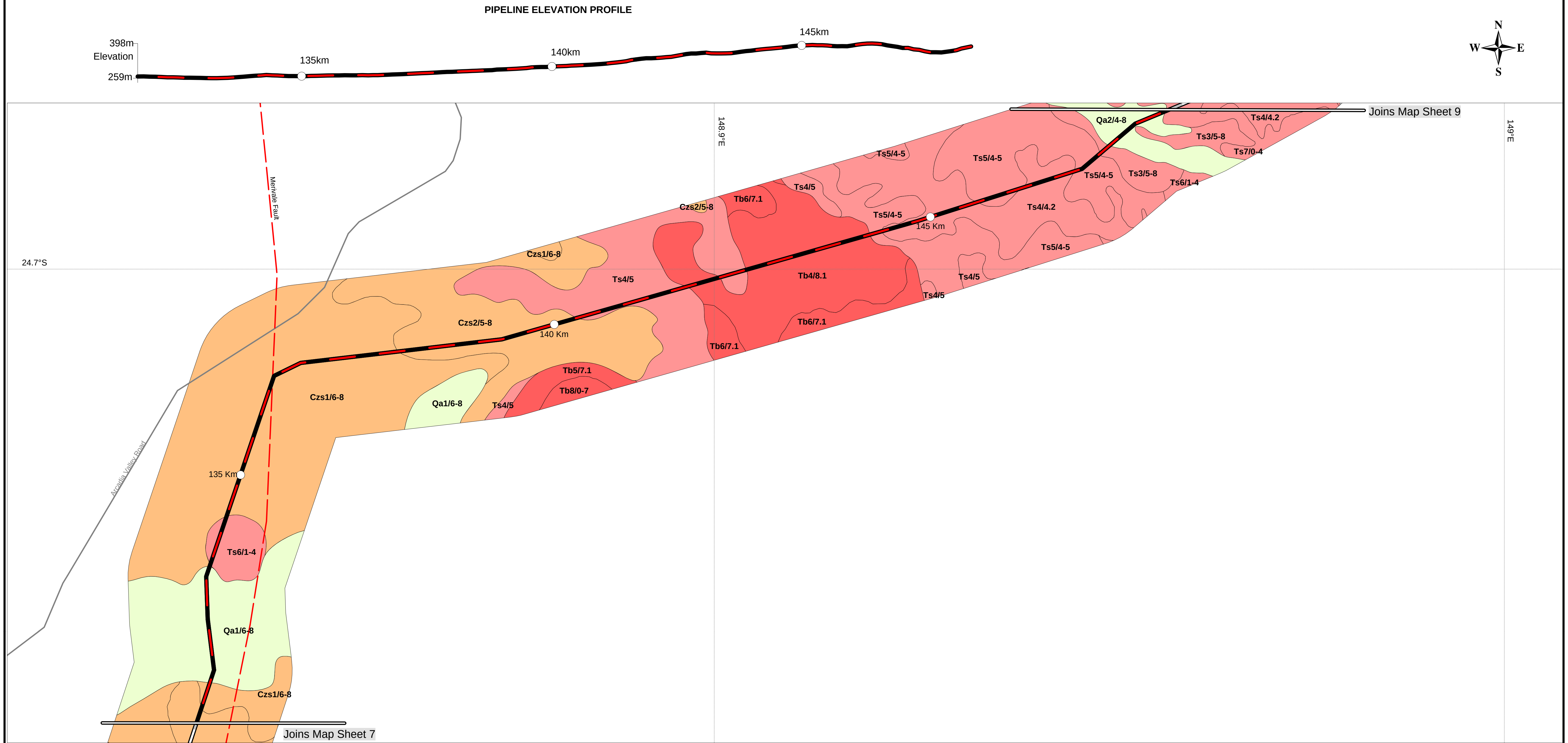
Client: LNG / URS

Project: GLADSTONE LNG PROJECT
TERRAIN, SOILS AND
LAND CAPABILITY REPORT
GAS TRANSMISSION PIPELINE

Title: **GEOLOGICAL REGIMES AND TERRAIN UNITS**

Drawn: CA | Approved: JB | Date: 01-02-2009
Job No: **4262 6220** | File No: 42626220-g-663.wor

Figure: **2-7** | Rev:A | A3



Terrain Units & Constraints Intersecting Pipeline:

Terrain Unit	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Pipeline Length (m)
Ts7/0-4	H	3-4	H	X	L	C3	59
Ts3/5-8	L	1	M	I	M (So/D)	C2	156
Ts6/1-4	M	3	M-H	X	L	C2	650
Qa2/4-8	L	1	M	F1	M (R3)	C1	853
Ts5/4-5	L-M	1-2	M	W	M (So/D)	C2	1,159
Qa1/6-8	L	1	M	F3	H (R3,So/D)	C1	1,502
Ts4/5	L-M	1-2	M-H	I	M (So/D)	C2	1,816
Ts4/4.2	L-M	1-2	L-M	W	L	C2	1,986
Tb4/8.1	L-M	2-3	M	W	L-M (R2)	C2	2,077
Czs2/5-8	L	1	M	I	M (R1)	B	2,531
Czs1/6-8	L	1	M	F2	H (R3,So/D)	C1	3,901

Total pipeline length in current map sheet: 16,690m (16.7km)

Sector Summary:

Constraints	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils
Low Constraint	15,981	13,904	1,986	5,222	2,695
Moderate Constraint	650	2,727	12,179	9,966	8,592
High Constraint	59	59	2,525	1,502	5,403

0 1 2km
Scale 1:50,000 (A3)
Datum: GDA94

Note: Figures 2-1 to 2-24 must be viewed with Figure 2b.

5km Distance Markers from Start of Pipeline
Gas Transmission Pipeline
Fault
Anticline
Syncline
River / Creek
Road

Client

URS

Project
GLADSTONE LNG PROJECT
TERRAIN, SOILS AND
LAND CAPABILITY REPORT
GAS TRANSMISSION PIPELINE

Title
GEOLOGICAL REGIMES AND TERRAIN UNITS

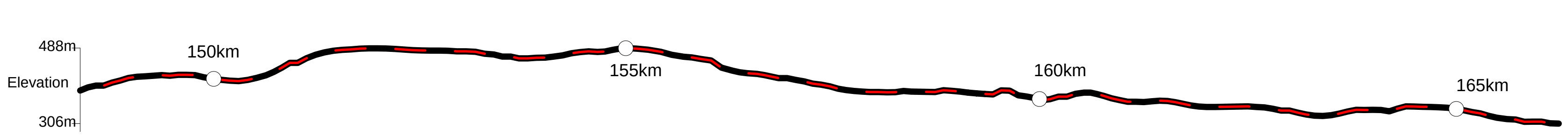
Drawn: CA	Approved: JB	Date: 01-02-2009
Job No: **4262 6220**	File No: 42626220-g-664.wor	

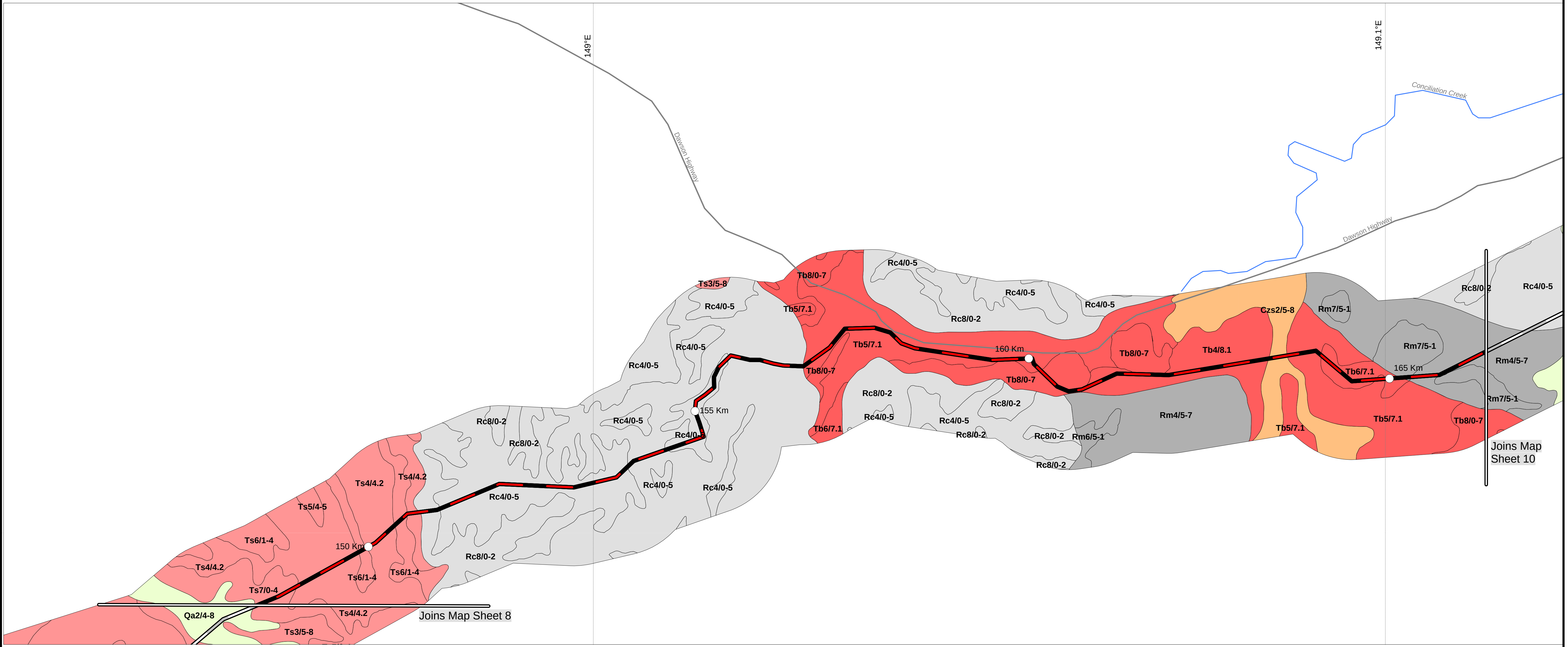
Figure: **2-8**

Rev:A

A3

PIPELINE ELEVATION PROFILE





Terrain Units & Constraints Intersecting Pipeline:

Terrain Unit	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Pipeline Length (m)
Rm7/5-1	H	3	H	X	L	D	127
Czs2/5-8	L	1	M	I	M (R1)	B	237
Ts6/1-4	M	3	M-H	X	L	C2	331
Ts7/0-4	H	3-4	H	X	L	C3	551
Tb8/0-7	H	3-4	M-H	X	L	D	790
Rm4/5-7	L-M	2	H	W	L-M (So/D)	C1	987
Tb6/7.1	M	2-3	M-H	X	L	C3	1,027
Ts4/4.2	L-M	1-2	L-M	W	L	C2	1,519
Rc8/0-2	H	3-4	M-H	X	L	D	1,779
Tb4/8.1	L-M	2-3	M	W	L-M (R2)	C2	2,283
Tb5/7.1	L-M	2-3	H	W	M (R1)	C2	3,968
Rc4/0-5	L-M	2-3	M	W-I	L-M (D)	C3	4,256

Total pipeline length in current map sheet: 17,855m (17.9km)

Sector Summary:

Constraints	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils
Low Constraint	13,250	1,756	1,519	13,013	6,124
Moderate Constraint	1,358	12,979	6,776	4,842	11,731
High Constraint	3,247	3,120	9,560	-	-

0 1 2km

Scale 1:50,000 (A3)
Datum: GDA94

Note: Figures 2-1 to 2-24 must be viewed with Figure 2b.

5km Distance Markers from Start of Pipeline
Gas Transmission Pipeline
Fault
Anticline
Syncline
River / Creek
Road

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

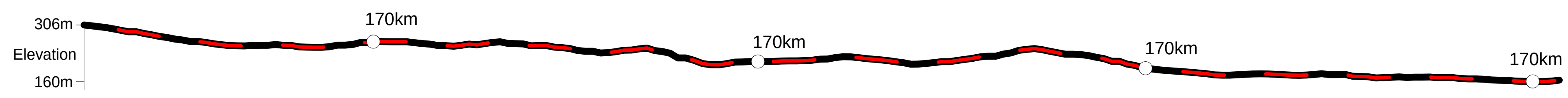
Client: LNG URS

Project: GLADSTONE LNG PROJECT
TERRAIN, SOILS AND
LAND CAPABILITY REPORT
GAS TRANSMISSION PIPELINE

Title: **GEOLOGICAL REGIMES AND TERRAIN UNITS**

Drawn: CA | Approved: JB | Date: 01-02-2009
Job No: **4262 6220** | File No: 42626220-g-665.wor
Figure: **2-9** | Rev:A | A3

PIPELINE ELEVATION PROFILE



Terrain Units & Constraints Intersecting Pipeline:

Terrain Unit	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Pipeline Length (m)
Tb8/0-7	H	3-4	M-H	X	L	D	253
Qa2/6-8	L	1	M-H	F3	H (R3,So/D)	C1	975
Rc4/0-5	L-M	2-3	M	W-I	L-M (D)	C3	1,160
Tb6/7.1	M	2-3	M-H	X	L	C3	1,243
Rm2/6-8	L	1-2	M	I	H (R3,So/D)	B	1,548
Qa1/6-8	L	1	M	F3	H (R3,So/D)	C1	1,591
Rm4/5-7	L-M	2	H	W	L-M (So/D)	C1	1,625
Rm3/6-8	L	1-2	M-H	W-I	H (R3,So/D)	B	2,111
Tb4/8.1	L-M	2-3	M	W	L-M (R2)	C2	2,580
Tb5/7.1	L-M	2-3	H	W	M (R1)	C2	5,997

Total pipeline length in current map sheet: 19,083m (19.1km)

Sector Summary:

Constraints	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils
Low Constraint	17,587	6,225	-	13,473	1,496
Moderate Constraint	1,243	12,605	6,879	3,044	11,362
High Constraint	253	253	12,204	2,566	6,225

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

0 1 2km

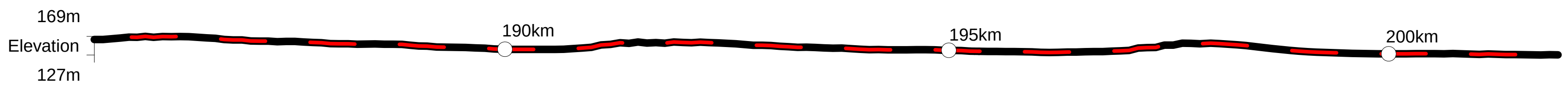
Scale 1:50,000 (A3)
Datum: GDA94

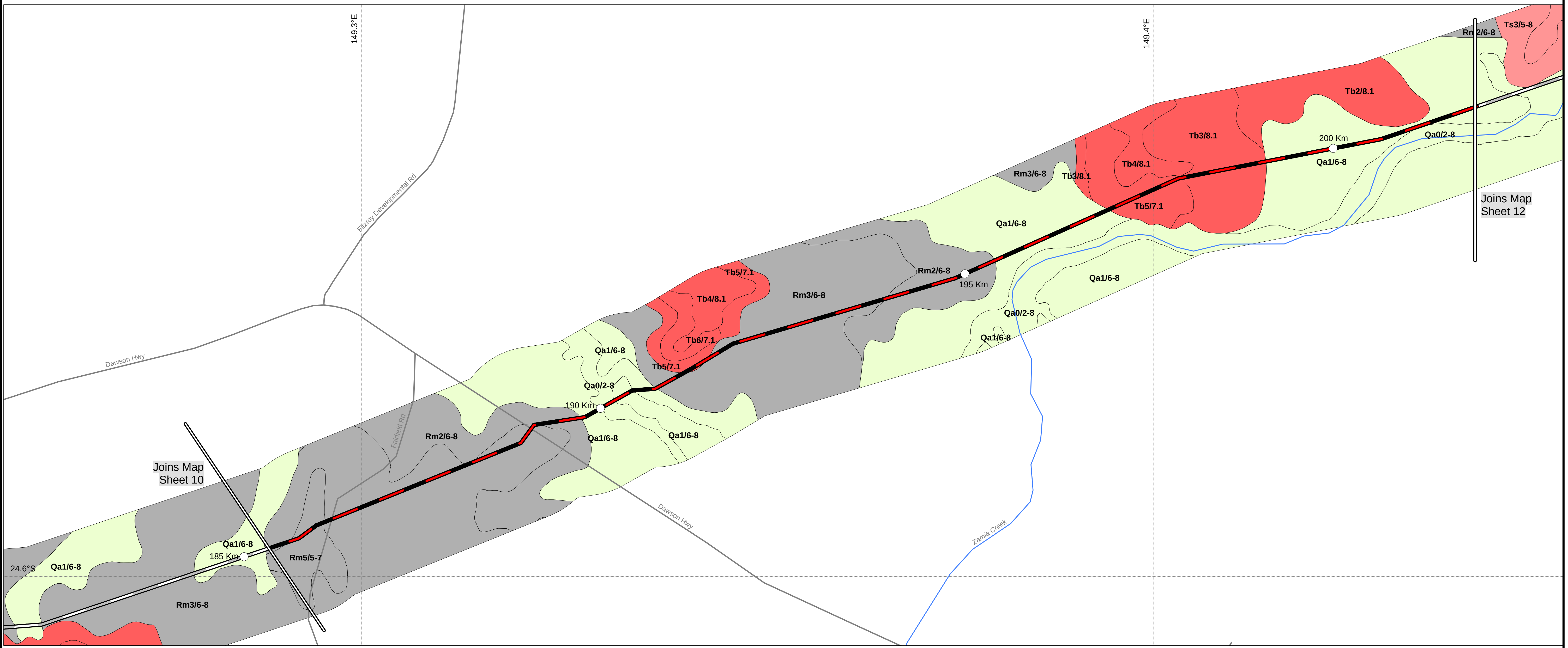
Note: Figures 2-1 to 2-24 must be viewed with Figure 2b.

- 5km Distance Markers from Start of Pipeline
- Gas Transmission Pipeline
- Fault
- Anticline
- Syncline
- River / Creek
- Road

Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT TERRAIN, SOILS AND LAND CAPABILITY REPORT GAS TRANSMISSION PIPELINE	**GEOLOGICAL REGIMES AND TERRAIN UNITS**
	Drawn: CA Approved: JB Date: 01-02-2009	Figure: 2-10 Rev:A
	Job No: **4262 6220** File No: 42626220-g-666.wor	A3

PIPELINE ELEVATION PROFILE





Terrain Units & Constraints Intersecting Pipeline:

Terrain Unit	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Pipeline Length (m)
Qa0/2-8	H	2	M-H	F4	M (R1)	D	490
Rm5/5-7	L-M	2	H	W	L-M (So/D)	C2	521
Tb3/8.1	L	2-3	M-H	W	L-M (R2)	B	1,111
Tb5/7.1	L-M	2-3	H	W	M (R1)	C2	1,351
Rm2/6-8	L	1-2	M	I	H (R3,So/D)	B	2,120
Qa1/6-8	L	1	M	F3	H (R3,So/D)	C1	4,945
Rm3/6-8	L	1-2	M-H	W-I	H (R3,So/D)	B	6,031

Total pipeline length in current map sheet: 16,569m (16.6km)

0 1 2km
Scale 1:50,000 (A3)
Datum: GDA94

Note: Figures 2-1 to 2-24 must be viewed with Figure 2b.

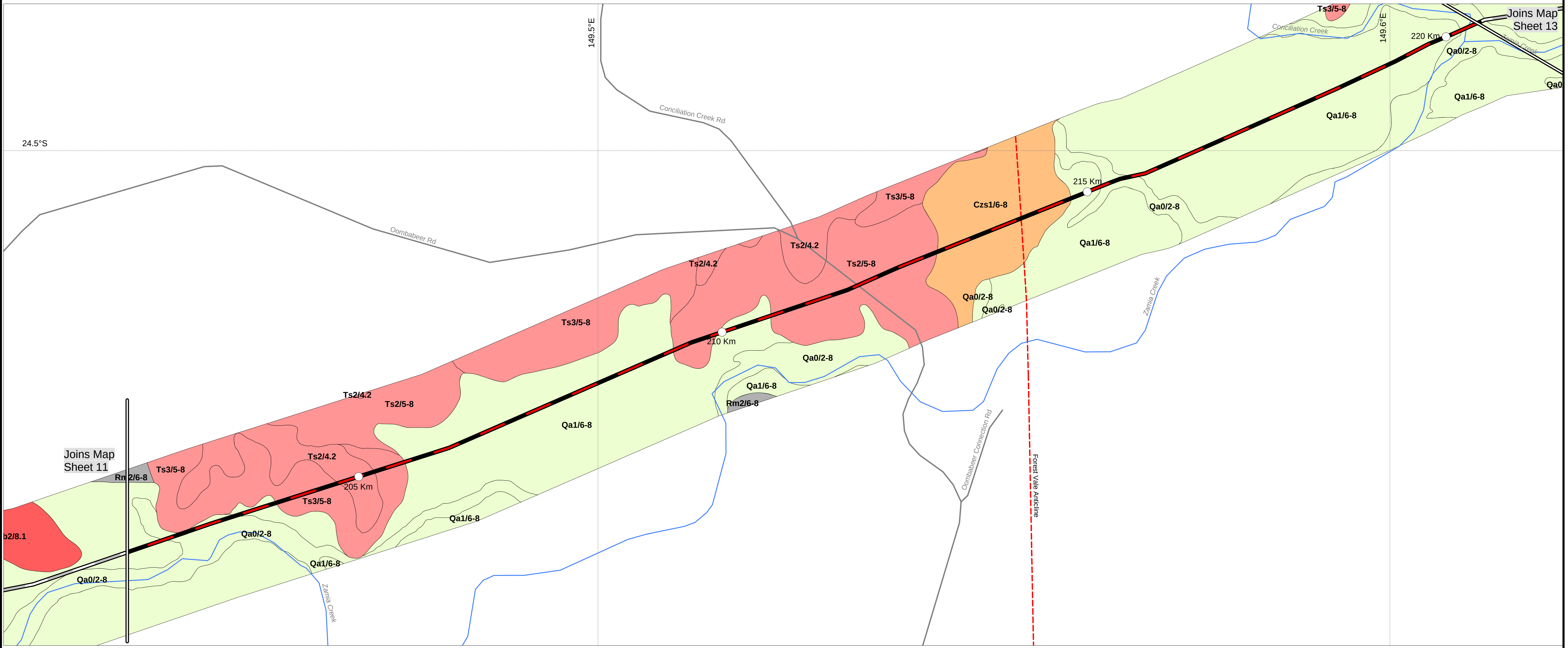
- 5km Distance Markers from Start of Pipeline
- Gas Transmission Pipeline
- Fault
- Anticline
- Syncline
- River / Creek
- Road

Sector Summary:

Constraints	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils
Low Constraint	16,079	13,096	-	9,014	-
Moderate Constraint	-	3,473	7,065	2,120	3,473
High Constraint	490	-	9,504	5,435	13,096

Client	Project: GLADSTONE LNG PROJECT TERRAIN, SOILS AND LAND CAPABILITY REPORT GAS TRANSMISSION PIPELINE	Title: GEOLOGICAL REGIMES AND TERRAIN UNITS	
	Drawn: CA / Approved: JB / Date: 01-02-2009	Figure: 2-11	Rev:A
	Job No: 4262 6220 / File No: 42626220-g-667.wor		A3

PIPELINE ELEVATION PROFILE



Terrain Units & Constraints Intersecting Pipeline:

Terrain Unit	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Pipeline Length (m)
Ts2/4.2	L	1-2	M	W-I	L	C1	481
Ts3/5-8	L	1	M	I	M (So/D)	C2	1,243
Qa0/2-8	H	2	M-H	F4	M (R1)	D	1,695
Czs1/6-8	L	1	M	F2	H (R3,So/D)	C1	1,840
Ts2/5-8	L	1	L-M	I	H (R3,D)	A	2,884
Qa1/6-8	L	1	M	F3	H (R3,So/D)	C1	10,410

Total pipeline length in current map sheet: 18,553m (18.6km)

0 1 2km
Scale 1:50,000 (A3)
Datum: GDA94

Note: Figures 2-1 to 2-24 must be viewed with Figure 2b.

5km Distance Markers from Start of Pipeline
Gas Transmission Pipeline
Fault
Anticline
Syncline
River / Creek
Road

Sector Summary:

Constraints	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils
Low Constraint	16,858	16,858	2,884	481	481
Moderate Constraint	-	1,695	13,974	5,967	2,938
High Constraint	1,695	-	1,695	12,105	15,134

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

Client

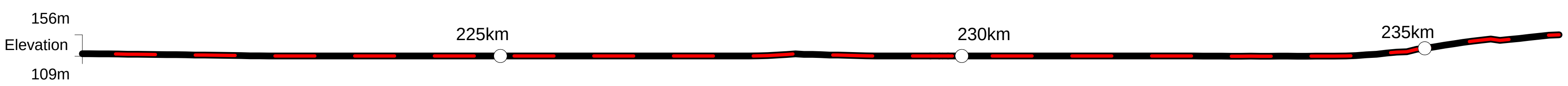
Project
GLADSTONE LNG PROJECT
TERRAIN, SOILS AND
LAND CAPABILITY REPORT
GAS TRANMISSION PIPELINECORRIDOR

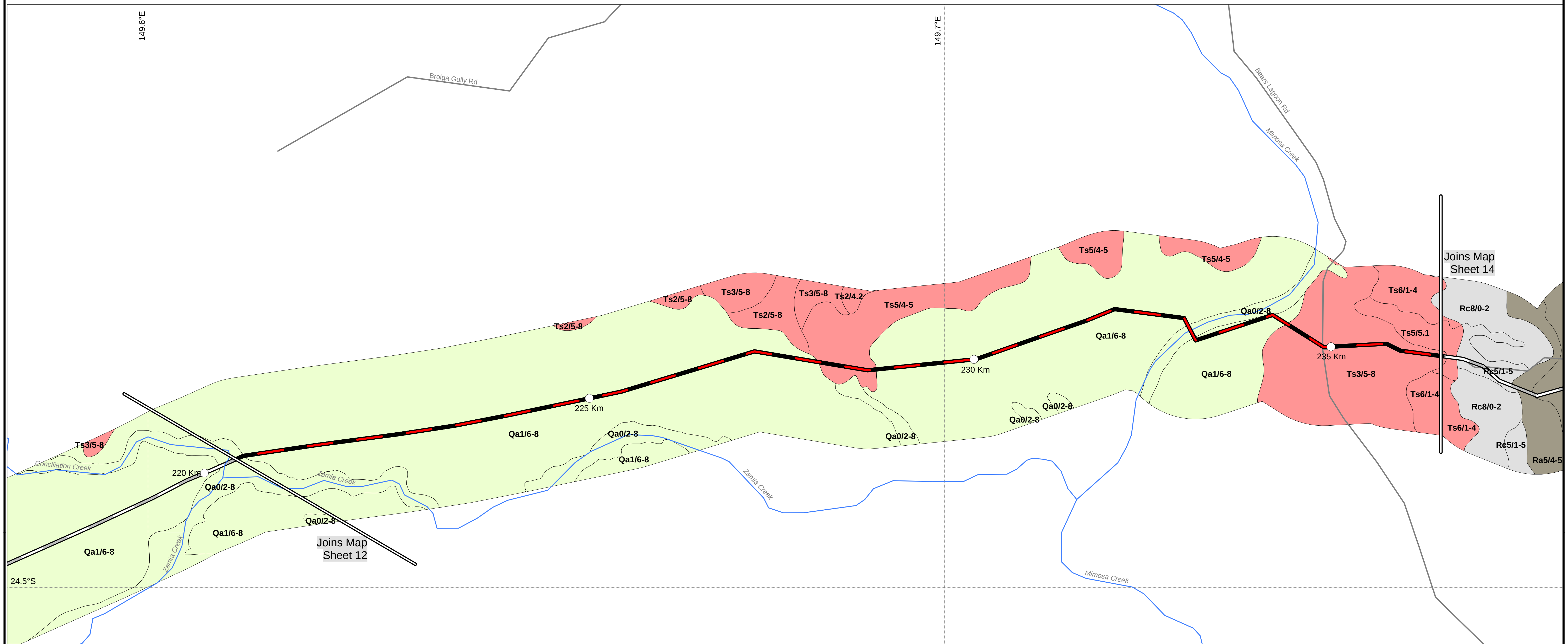
Title
GEOLOGICAL REGIMES AND TERRAIN UNITS

Drawn: CA | Approved: JB | Date: 01-02-2009
Job No: 4262 6220 | File No: 42626220-g-668.wor

Figure: 2-12
Rev:A
A3

PIPELINE ELEVATION PROFILE





Terrain Units & Constraints Intersecting Pipeline:

Terrain Unit	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Pipeline Length (m)
Qa0/2-8	H	2	M-H	F4	M (R1)	D	260
Ts5/4-5	L-M	1-2	M	W	M (So/D)	C2	749
Ts3/5-8	L	1	M	I	M (So/D)	C2	2,089
Qa1/6-8	L	1	M	F3	H (R3,So/D)	C1	12,878

Total pipeline length in current map sheet: 15,976m (16.0km)

0 1 2km
Scale 1:50,000 (A3)
Datum: GDA94

Note: Figures 2-1 to 2-24 must be viewed with Figure 2b.

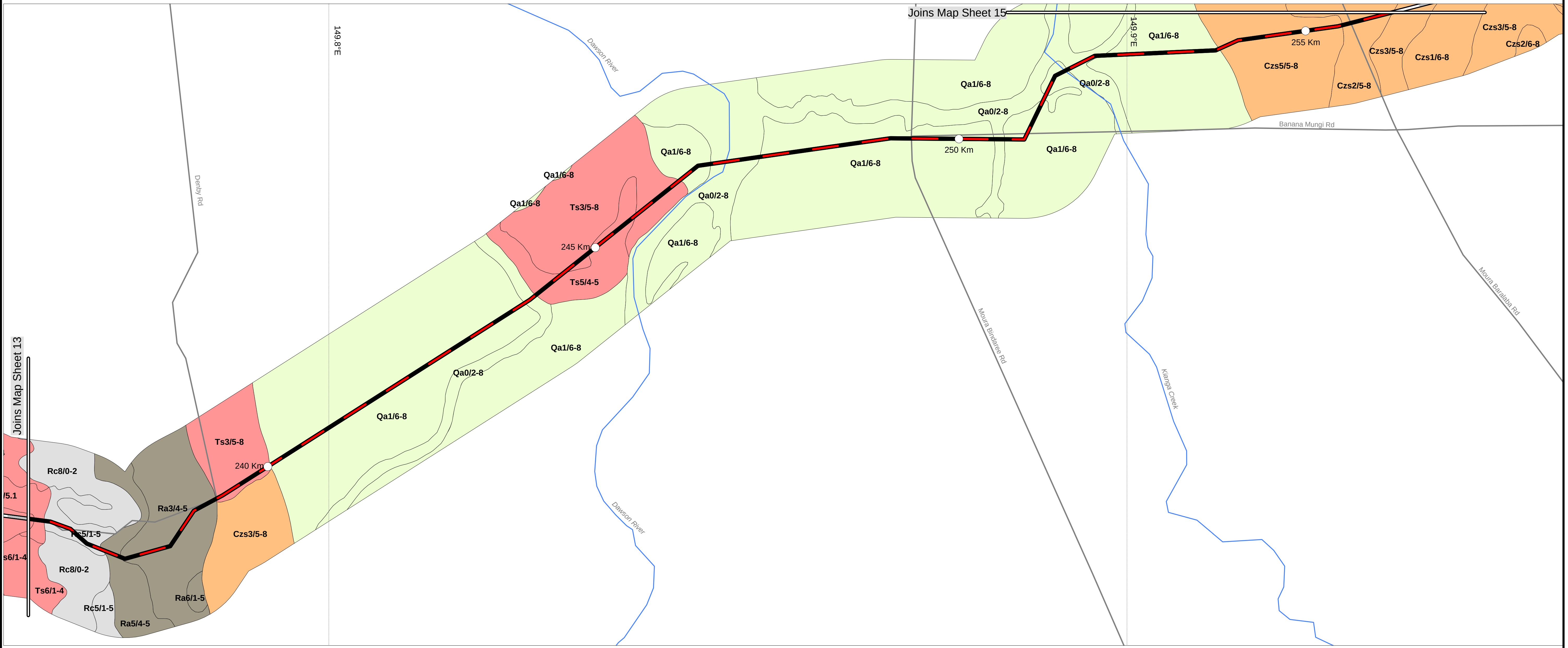
- 5km Distance Markers from Start of Pipeline
- Gas Transmission Pipeline
- Fault
- Anticline
- Syncline
- River / Creek
- Road

Sector Summary:

Constraints	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils
Low Constraint	15,716	15,716	-	749	-
Moderate Constraint	-	260	15,716	2,089	3,098
High Constraint	260	-	260	13,138	12,878

Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT TERRAIN, SOILS AND LAND CAPABILITY REPORT GAS TRANSMISSION PIPELINE	GEOLOGICAL REGIMES AND TERRAIN UNITS
	Drawn: CA · Approved: JB · Date: 01-02-2009	Figure: 2-13 · Rev:A
	Job No: 4262 6220 · File No: 42626220-g-669.wor	A3

PIPELINE ELEVATION PROFILE



Terrain Units & Constraints Intersecting Pipeline:

Terrain Unit	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Pipeline Length (m)
Czs3/5-8	L	1-2	M	W	M (So/D)	C1	12
Ts5/5.1	L-M	2-3	M-H	I	M (So/D)	C1	130
Ra5/4-5	L-M	1-2	M-H	W	L-M (So/D)	C2	270
Czs2/5-8	L	1	M	I	M (R1)	B	663
Rc5/1-5	L-M	2-3	M-H	W	L-M (D)	C2	825
Ts5/4-5	L-M	1-2	M	W	M (So/D)	C2	1,203
Qa0/2-8	H	2	M-H	F4	M (R1)	D	1,492
Ra3/4-5	L	1-2	M-H	W-I	L-M (So/D)	C1	1,507
Czs5/5-8	M	1-2	M	W	M (So/D)	C2	1,600
Ts3/5-8	L	1	M	I	M (So/D)	C2	1,988
Qa1/6-8	L	1	M	F3	H (R3,So/D)	C1	10,015

Total pipeline length in current map sheet: 19,705m (19.7km)

Sector Summary:

Constraints	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils
Low Constraint	16,613	17,258	-	5,417	-
Moderate Constraint	1,600	2,447	15,481	2,781	9,690
High Constraint	1,492	-	4,224	11,507	10,015

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

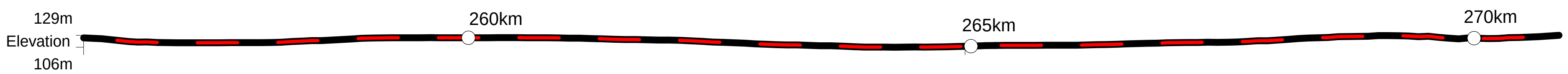
0 1 2km
Scale 1:50,000 (A3)
Datum: GDA94

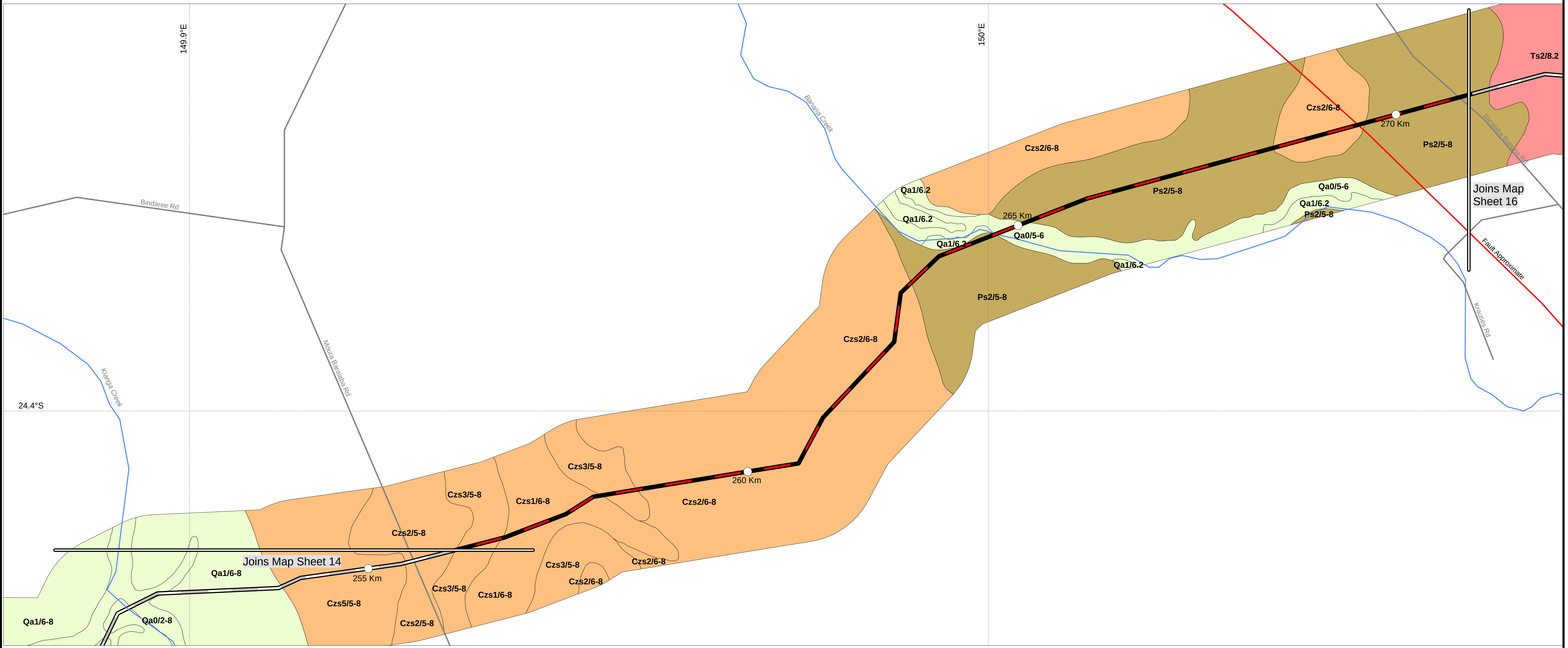
Note: Figures 2-1 to 2-24 must be viewed with Figure 2b.

- 5km Distance Markers from Start of Pipeline
- Gas Transmission Pipeline
- Fault
- Anticline
- Syncline
- River / Creek
- Road

Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT TERRAIN, SOILS AND LAND CAPABILITY REPORT GAS TRANSMISSION PIPELINE	**GEOLOGICAL REGIMES AND TERRAIN UNITS**
	Drawn: CA · Approved: JB · Date: 01-02-2009	Figure: 2-14 · Rev:A
	Job No: **4262 6220** · File No: 42626220-g-670.wor	A3

PIPELINE ELEVATION PROFILE





Terrain Units & Constraints Intersecting Pipeline:

Terrain Unit	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Pipeline Length (m)
Qa0/5-6	M-H	2	M-H	F4	M (S/D)	D	432
Czs3/5-8	L	1-2	M	W	M (So/D)	C1	1,052
Czs1/6-8	L	1	M	F2	H (R3,So/D)	C1	1,377
Ps2/5-8	L	1-2	M	I	M (R2,So/D)	C1	5,902
Czs2/6-8	L	1-2	M	I	H (R3,So/D)	C1	6,069

Total pipeline length in current map sheet: 14,832m (14.8km)

0 1 2km
Scale 1:50,000 (A3)
Datum: GDA94

Note: Figures 2-1 to 2-24 must be viewed with Figure 2b.

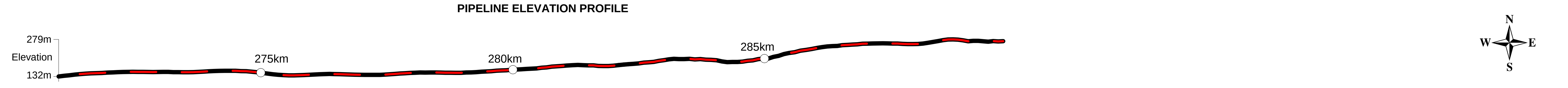
- 5km Distance Markers from Start of Pipeline
- Gas Transmission Pipeline
- Fault
- Anticline
- Syncline
- River / Creek
- Road

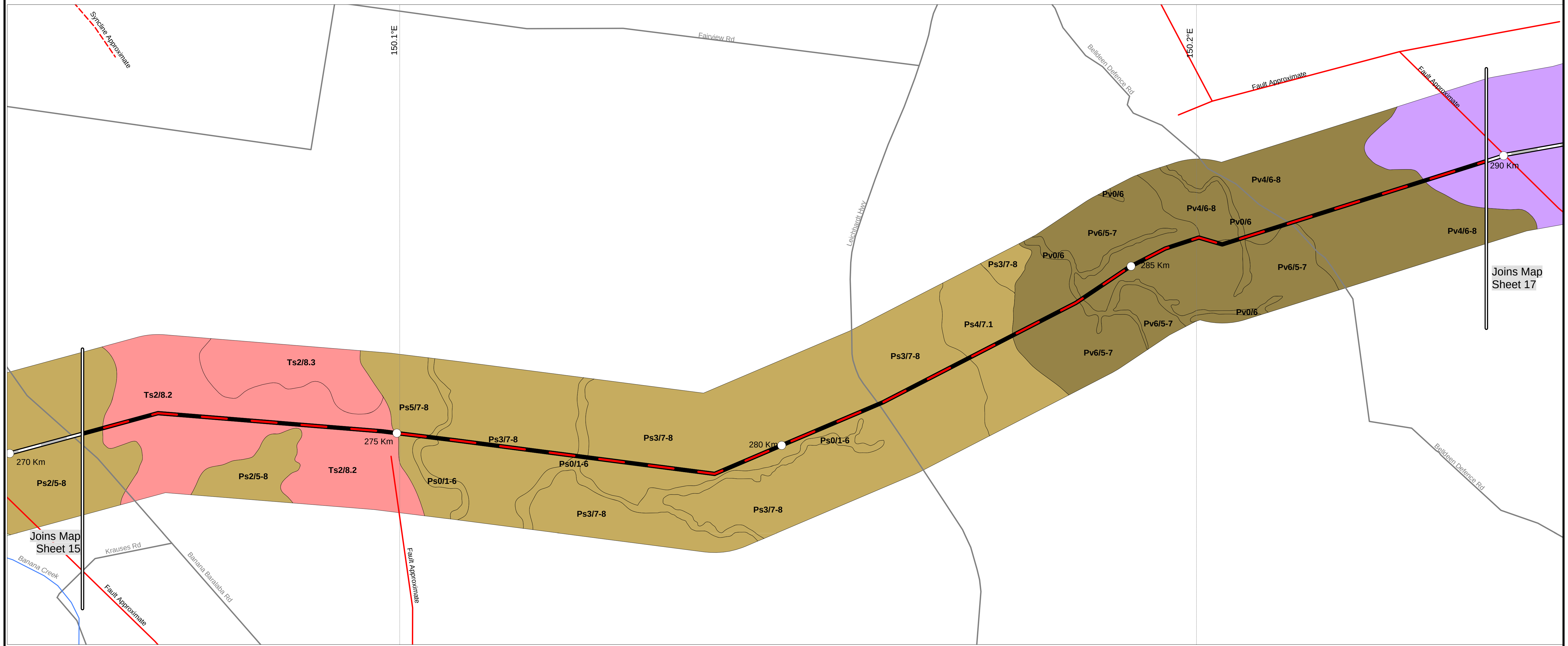
Sector Summary:

Constraints	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils
Low Constraint	14,400	14,400	-	1,052	-
Moderate Constraint	-	432	14,400	13,348	7,386
High Constraint	432	-	432	432	7,446

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 TERRAIN, SOILS AND LAND CAPABILITY REPORT GAS TRANSMISSION PIPELINE	GEOLOGICAL REGIMES AND TERRAIN UNITS
	Drawn: CA · Approved: JB · Date: 01-02-2009	Figure: 2-15 · Rev:A
	Job No: 4262 6220 · File No: 42626220-g-671.wor	A3





Terrain Units & Constraints Intersecting Pipeline:

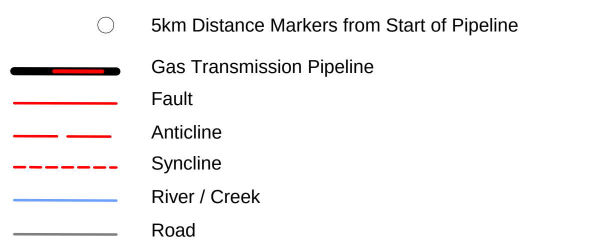
Terrain Unit	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Pipeline Length (m)
Pv0/6	M	2	H	F4	H (So/D)	D	128
Ps2/5-8	L	1-2	M	I	M (R2,So/D)	C1	246
Ps0/1-6	M	2	H	F4	M-H (So/D)	D	288
Ps5/7-8	L-M	1-2	M	W	M (R1-R2)	C1	383
Ps4/7.1	L-M	2-3	M	W	L	C2	629
Ct7/5-7	H	2-3	M-H	W	L-M (D)	C2	796
Pv4/6-8	L-M	2	M	W	M (R2,So/D)	C2	2,605
Pv6/5-7	M	2-3	M	W	L	C2	2,960
Ts2/8.2	L	1-2	M	W-I	M (R2)	A	3,772
Ps3/7-8	L	1-2	H	W	L	C1	6,955

Total pipeline length in current map sheet: 18,762m (18.8km)

0 1 2km

Scale 1:50,000 (A3)
Datum: GDA94

Note: Figures 2-1 to 2-24 must be viewed with Figure 2b.



Sector Summary:

Constraints	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils
Low Constraint	14,590	11,356	-	18,100	10,544
Moderate Constraint	3,376	7,406	10,595	246	7,802
High Constraint	796	-	8,167	416	416

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

Client: LNG / URS

Project: GLADSTONE LNG PROJECT
TERRAIN, SOILS AND
LAND CAPABILITY REPORT
GAS TRANSMISSION PIPELINE

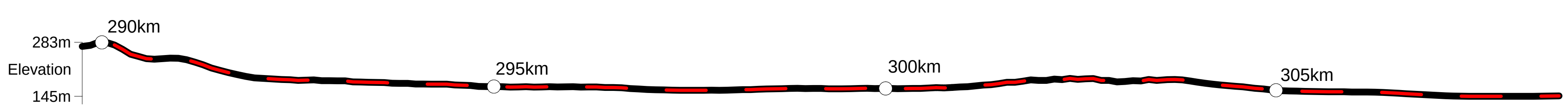
Title: **GEOLOGICAL REGIMES AND TERRAIN UNITS**

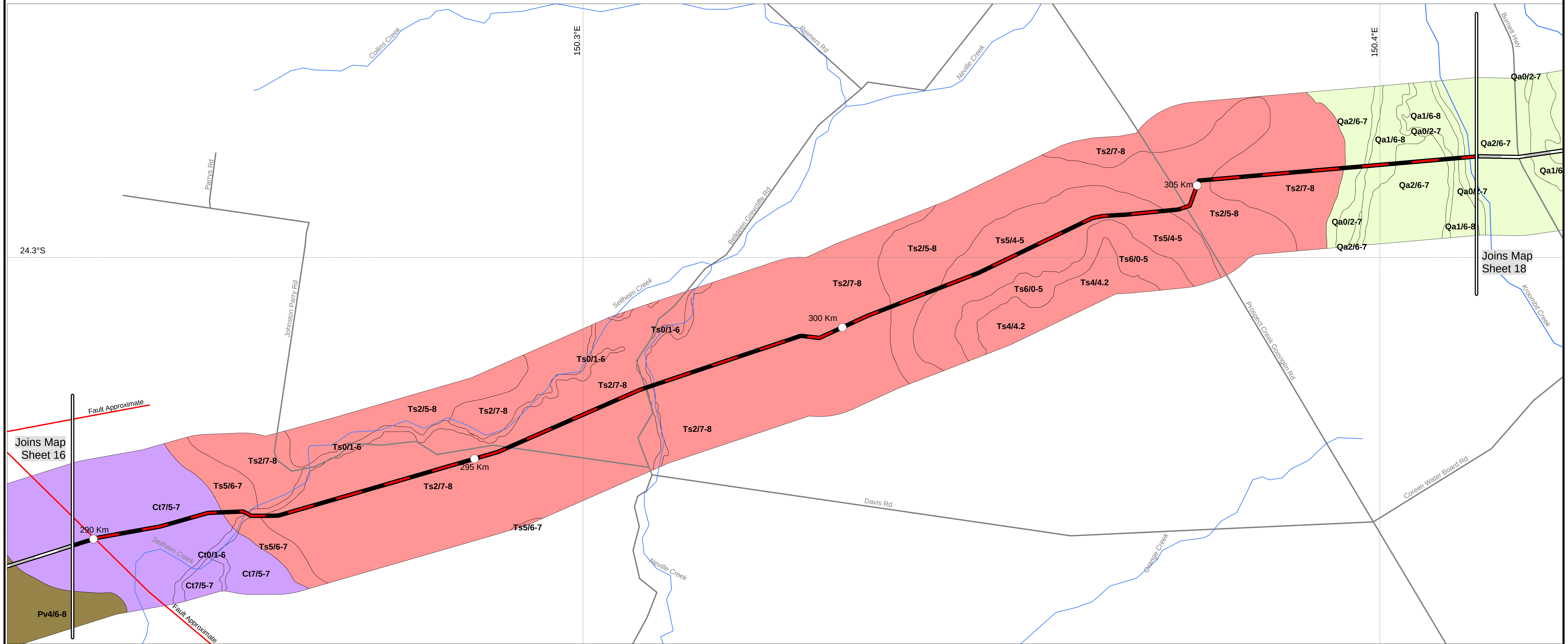
Drawn: CA | Approved: JB | Date: 01-02-2009

Job No: 4262 6220 | File No: 42626220-g-672.wor

Figure: 2-16 | Rev:A | A3

PIPELINE ELEVATION PROFILE





Terrain Units & Constraints Intersecting Pipeline:

Terrain Unit	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Pipeline Length (m)
Ts0/1-6	M	2	M	F4	M (So/D)	D	221
Qa0/2-7	H	2	M-H	F4	M (R1)	D	237
Ts5/6-7	L-M	1-2	M	W	M (So/D)	B	349
Qa1/6-8	L	1	M	F3	H (R3,So/D)	C1	415
Qa2/6-7	L	1	M-H	F1	M (So/D,R1)	A	1,038
Ts2/5-8	L	1	L-M	I	H (R3,D)	A	1,461
Ct7/5-7	H	2-3	M-H	W	L-M (D)	C2	1,937
Ts5/4-5	L-M	1-2	M	W	M (So/D)	C2	3,088
Ts2/7-8	L	1	L	W-I	H (R3)	A	10,127

Total pipeline length in current map sheet: 18,873m (18.9km)

0 1 2km

Scale 1:50,000 (A3)
Datum: GDA94

Note: Figures 2-1 to 2-24 must be viewed with Figure 2b.

- 5km Distance Markers from Start of Pipeline
- Gas Transmission Pipeline
- Fault
- Anticline
- Syncline
- River / Creek
- Road

Sector Summary:

Constraints	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils
Low Constraint	13,754	10,779	11,588	18,066	4,126
Moderate Constraint	3,658	8,094	4,073	237	14,177
High Constraint	1,461	-	3,212	570	570

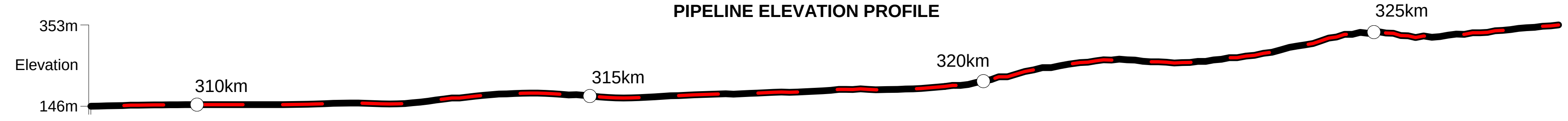
Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

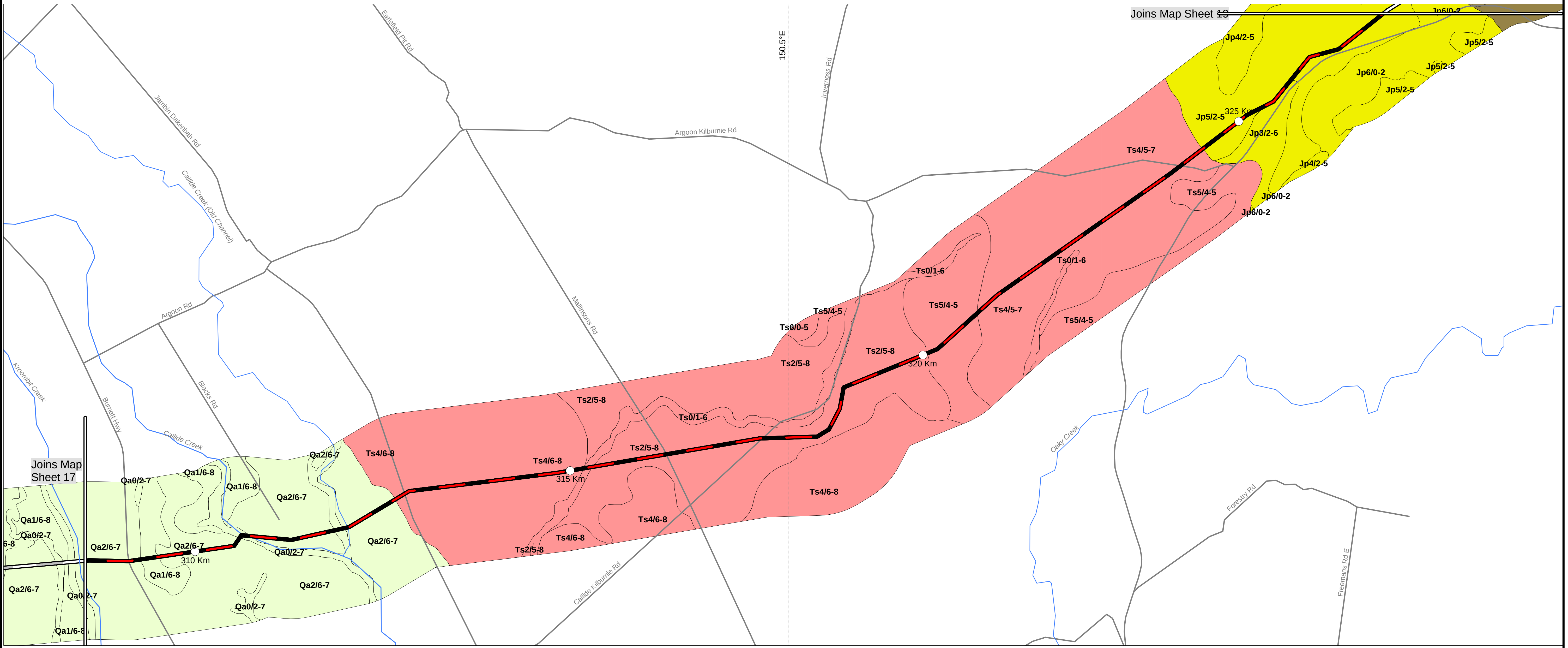
Client: LNG / URS

Project: GLADSTONE LNG PROJECT
TERRAIN, SOILS AND
LAND CAPABILITY REPORT
GAS TRANSMISSION PIPELINE

Title: **GEOLOGICAL REGIMES AND TERRAIN UNITS**

Drawn: CA	Approved: JB	Date: 01-02-2009	Figure: 2-17	Rev:A
Job No: 4262 6220	File No: 42626220-g-673.wor			A3





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Terrain Units & Constraints Intersecting Pipeline:

Terrain Unit	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Pipeline Length (m)
Ts0/1-6	M	2	M	F4	M (So/D)	D	115
Qa1/6-8	L	1	M	F3	H (R3,So/D)	C1	236
Qa0/2-7	H	2	M-H	F4	M (R1)	D	294
Ts5/4-5	L-M	1-2	M	W	M (So/D)	C2	828
Ts4/6-8	L-M	1-2	M-H	W	M (R2-So/D)	C1	2,441
Jp5/2-5	L-M	2	H	W	L	C2	2,902
Ts4/5-7	L-M	1-2	M	W	M (So/D)	A	3,539
Qa2/6-7	L	1	M-H	F1	M (So/D,R1)	A	3,588
Ts2/5-8	L	1	L-M	I	H (R3,D)	A	4,770

Total pipeline length in current map sheet: 18,713m (18.7km)

0 1 2km
Scale 1:50,000 (A3)
Datum: GDA94

Note: Figures 2-1 to 2-24 must be viewed with Figure 2b.

- 5km Distance Markers from Start of Pipeline
- Gas Transmission Pipeline
- Fault
- Anticline
- Syncline
- River / Creek
- Road

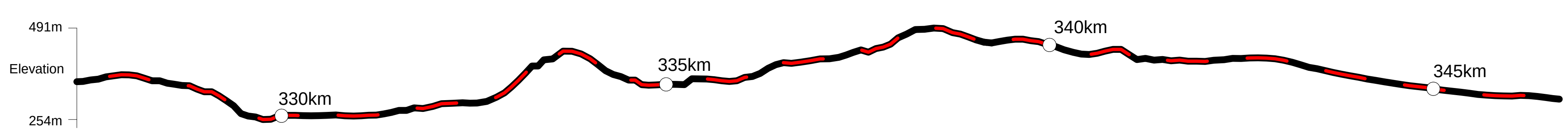
Sector Summary:

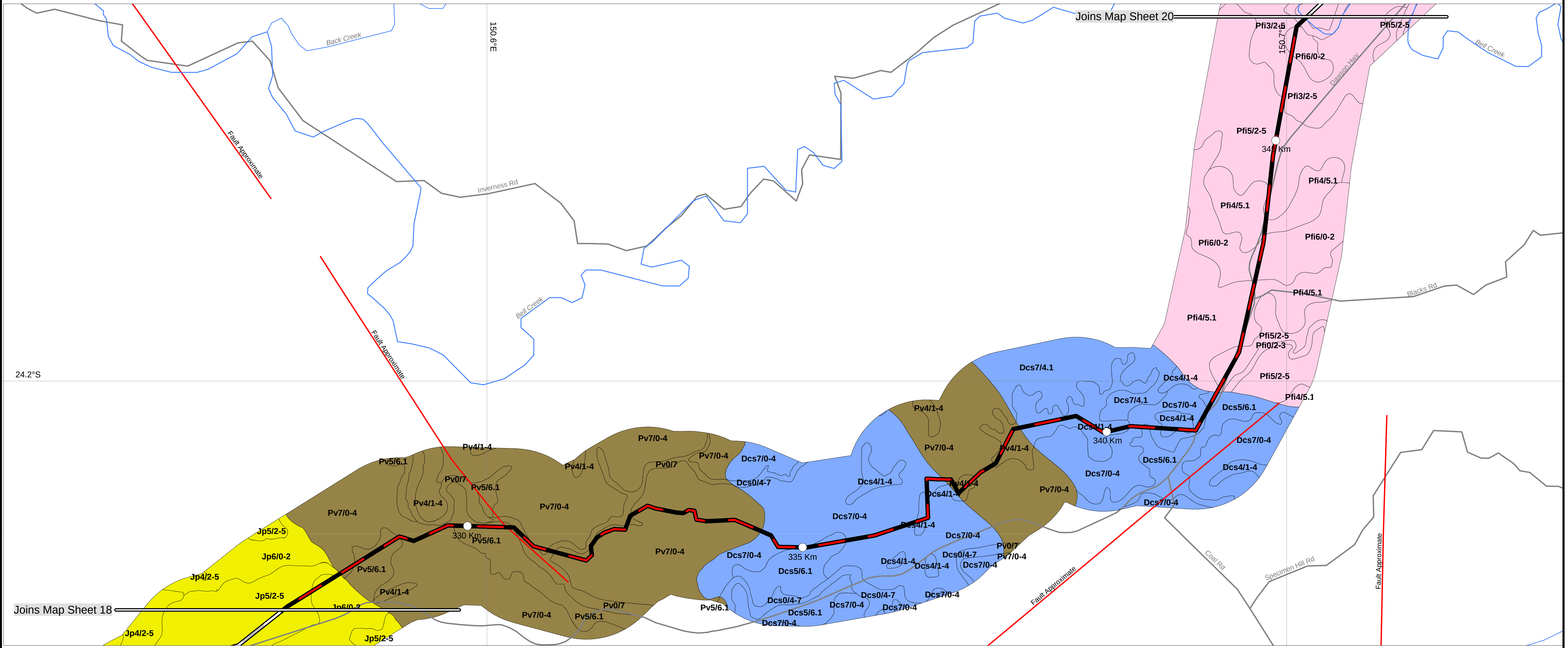
Constraints	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils
Low Constraint	18,304	15,402	4,770	9,710	2,902
Moderate Constraint	115	3,311	4,718	8,358	10,805
High Constraint	294	-	9,225	645	5,006

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 TERRAIN, SOILS AND LAND CAPABILITY REPORT GAS TRANSMISSION PIPELINE	**GEOLOGICAL REGIMES AND TERRAIN UNITS**
	Drawn: CA · Approved: JB · Date: 01-02-2009	Figure: **2-18** · Rev:A
	Job No: **4262 6220** · File No: 42626220-g-674.wor	**A3**

PIPELINE ELEVATION PROFILE





Terrain Units & Constraints Intersecting Pipeline:

Terrain Unit	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Pipeline Length (m)
Pfi0/2-3	M	2	H	F4	L	D	99
Jp6/0-2	M	3-4	M-H	W	L	C3	378
Jp5/2-5	L-M	2	H	W	L	C2	492
Pfi3/2-5	L	1	M-H	W	L	C2	617
Pv0/7	H	2-3	M	F4	L	D	753
Pfi6/0-2	M	2-3	M	W	L	C2	933
Dcs5/6.1	L-M	2-3	M-H	W-I	M-H (So/D)	C2	933
Pv4/1-4	L-M	2-3	M	W	L	C3	1,042
Pfi4/5.1	L-M	1-2	H	W	M (So/D)	C2	1,185
Pv5/6.1	L-M	2-3	M-H	W	M (So/D)	C3	1,471
Pfi5/2-5	L-M	1-2	H	W	M (So/D)	C2	2,116
Dcs4/1-4	L-M	3-4	M	W-I	L	C3	2,117
Dcs7/0-4	H	2-4	M-H	X	L	C3	2,790
Pv7/0-4	H	2-4	M-H	X	L	C3	4,386

Total pipeline length in current map sheet: 19,312m (19.3km)

Sector Summary:

Constraints	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils
Low Constraint	9,973	3,918	-	11,284	13,607
Moderate Constraint	1,410	5,723	4,845	7,176	4,772
High Constraint	7,929	9,671	14,467	852	933

0 1 2km
Scale 1:50,000 (A3)
Datum: GDA94

Note: Figures 2-1 to 2-24 must be viewed with Figure 2b.

- 5km Distance Markers from Start of Pipeline
- Gas Transmission Pipeline
- Fault
- Anticline
- Syncline
- River / Creek
- Road

Client

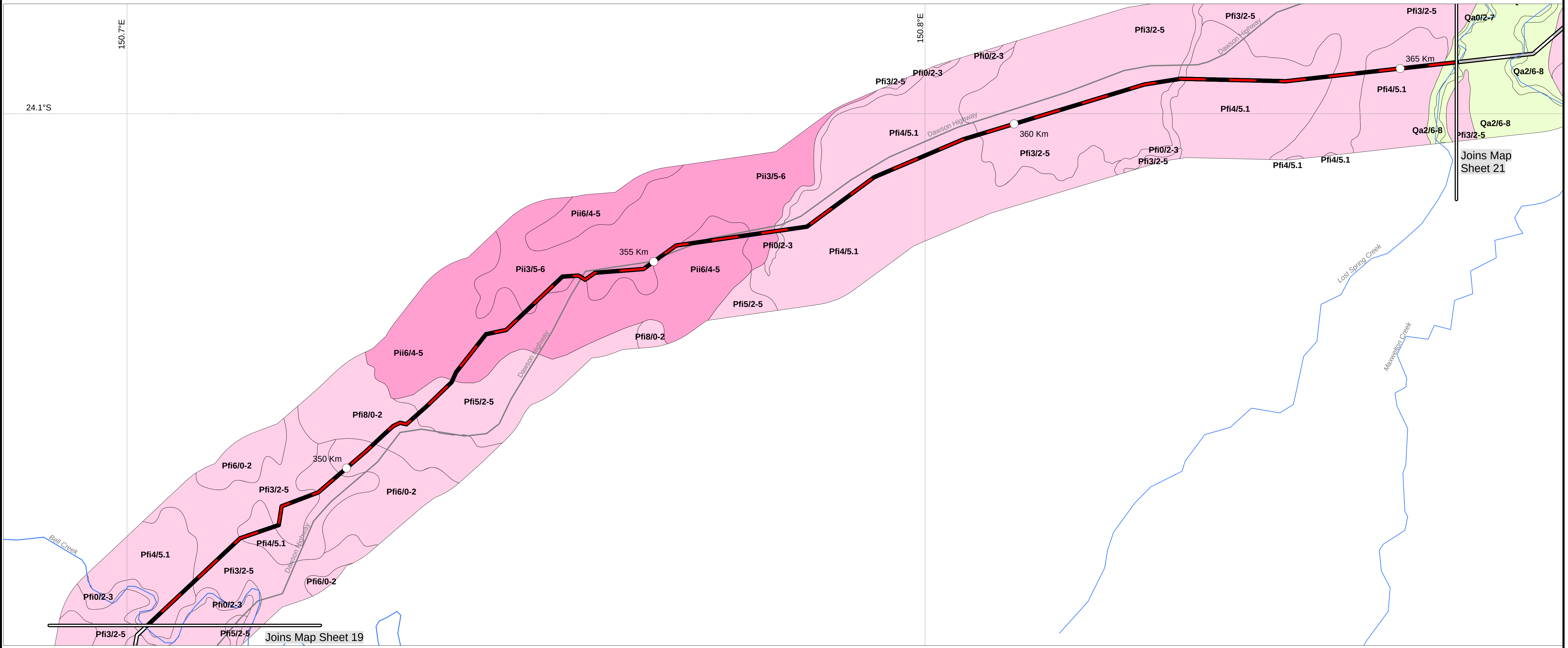
URS

Project
GLADSTONE LNG PROJECT
TERRAIN, SOILS AND
LAND CAPABILITY REPORT
GAS TRANSMISSION PIPELINE

Title
GEOLOGICAL REGIMES AND TERRAIN UNITS

Drawn: CA	Approved: JB	Date: 01-02-2009	Figure: 2-19	Rev:A
Job No: 4262 6220	File No: 42626220-g-675.wor			A3

PIPELINE ELEVATION PROFILE



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Terrain Units & Constraints Intersecting Pipeline:

Terrain Unit	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Pipeline Length (m)
Qa0/2-7	H	2	M-H	F4	M (R1)	D	39
Qa2/6-8	L	1	M-H	F3	H (R3,So/D)	C1	132
Pfi0/2-3	M	2	H	F4	L	D	181
Pfi6/0-2	M	2-3	M	W	L	C2	578
Pfi5/2-5	L-M	1-2	H	W	M (So/D)	C2	626
Pfi8/0-2	H	2-4	H	X	L	D	695
Pii3/5-6	L	1	M-H	W	M-H (So/D)	C1	2,258
Pii6/4-5	M	1-2	M	W	L	C2	2,580
Pfi3/2-5	L	1	M-H	W	L	C2	4,647
Pfi4/5.1	L-M	1-2	H	W	M (So/D)	C2	7,351

Total pipeline length in current map sheet: 19,087m (19.1km)

Sector Summary:

Constraints	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils
Low Constraint	15,014	17,594	-	18,040	8,681
Moderate Constraint	3,339	798	3,158	695	8,016
High Constraint	734	695	15,929	352	2,390

0 1 2km

Scale 1:50,000 (A3)
Datum: GDA94

Note: Figures 2-1 to 2-24 must be viewed with Figure 2b.

- 5km Distance Markers from Start of Pipeline
- Gas Transmission Pipeline
- Fault
- Anticline
- Syncline
- River / Creek
- Road

Client

LNG

URS

Project

GLADSTONE LNG PROJECT
TERRAIN, SOILS AND
LAND CAPABILITY REPORT
GAS TRANSMISSION PIPELINE

Title

GEOLOGICAL REGIMES AND TERRAIN UNITS

Drawn: CA | Approved: JB | Date: 01-02-2009

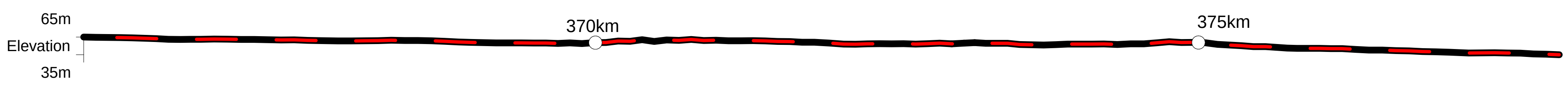
Job No: 4262 6220 | File No: 42626220-g-676.wor

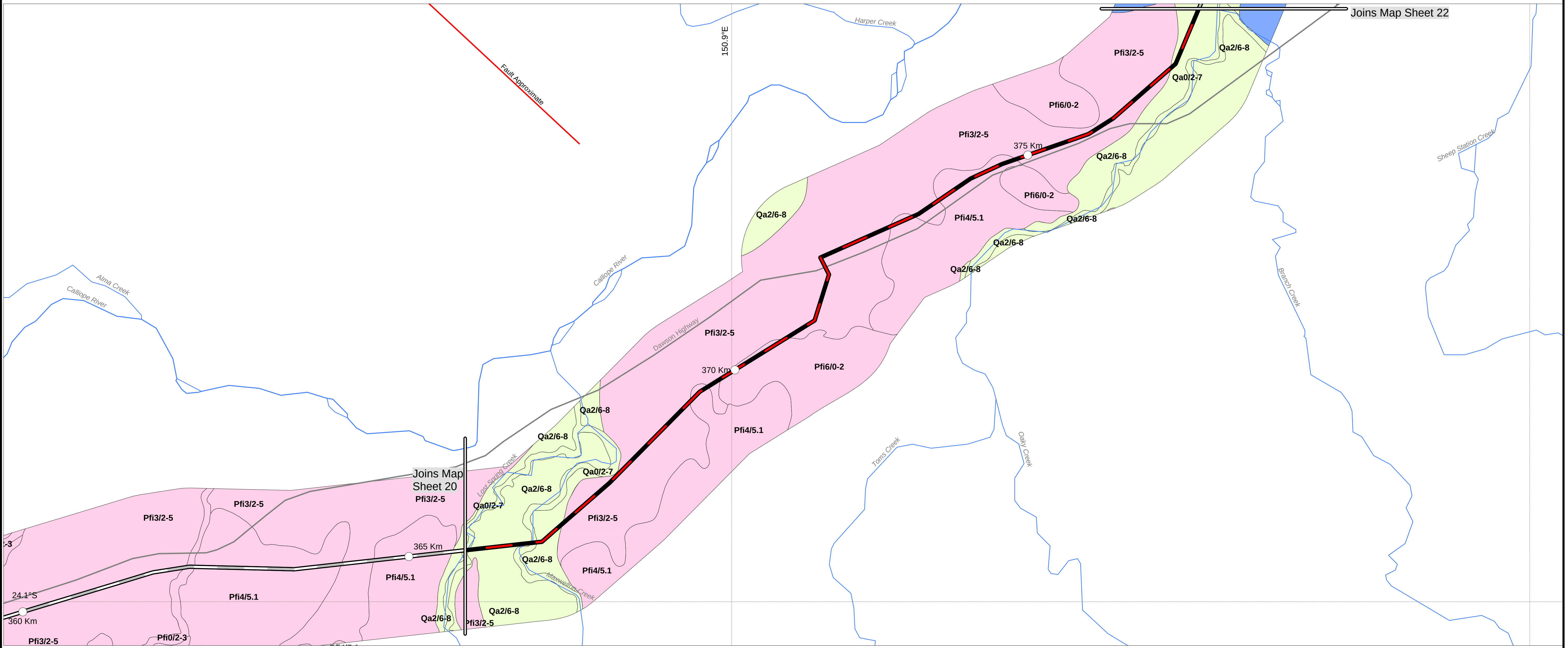
Figure: 2-20

Rev:A

A3

PIPELINE ELEVATION PROFILE





Terrain Units & Constraints Intersecting Pipeline:

Terrain Unit	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Pipeline Length (m)
Qa0/2-7	H	2	M-H	F4	M (R1)	D	113
Pfi6/0-2	M	2-3	M	W	L	C2	935
Pfi4/5.1	L-M	1-2	H	W	M (So/D)	C2	1,732
Qa2/6-8	L	1	M-H	F3	H (R3,So/D)	C1	2,046
Pfi3/2-5	L	1	M-H	W	L	C2	7,442

Total pipeline length in current map sheet: 12,268m (12.3km)

0 1 2km
Scale 1:50,000 (A3)
Datum: GDA94

Note: Figures 2-1 to 2-24 must be viewed with Figure 2b.

- 5km Distance Markers from Start of Pipeline
- Gas Transmission Pipeline
- Fault
- Anticline
- Syncline
- River / Creek
- Road

Sector Summary:

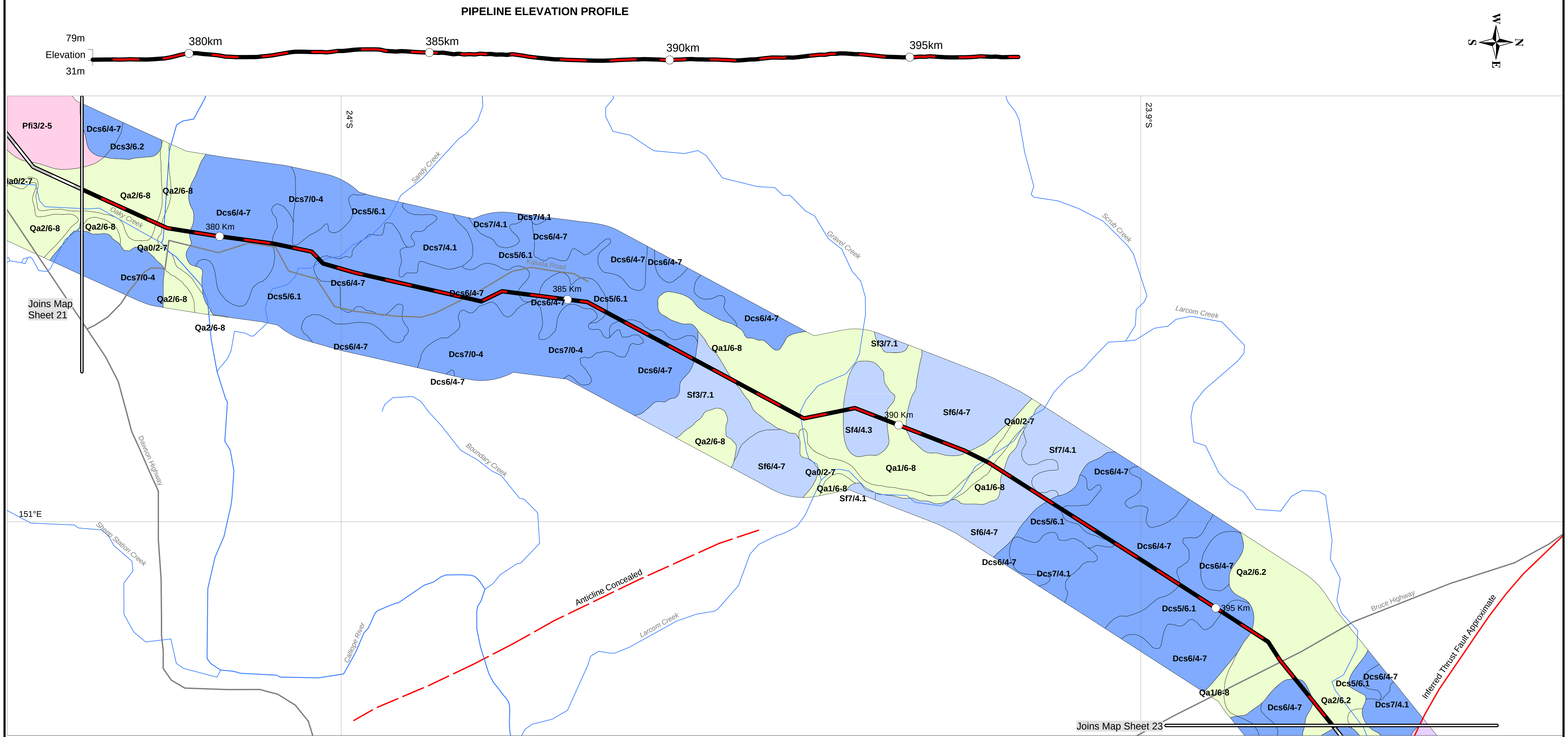
Constraints	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils
Low Constraint	11,220	11,220	-	10,109	8,377
Moderate Constraint	935	1,048	935	-	1,845
High Constraint	113	-	11,333	2,159	2,046

Client: LNG, URS

Project: GLADSTONE LNG PROJECT
TERRAIN, SOILS AND
LAND CAPABILITY REPORT
GAS TRANSMISSION PIPELINE

Title: **GEOLOGICAL REGIMES AND TERRAIN UNITS**

Drawn: CA | Approved: JB | Date: 01-02-2009
Job No: 4262 6220 | File No: 42626220-g-677.wor
Figure: 2-21 | Rev:A | A3



Note: Figures 2-1 to 2-24 must be viewed with Figure 2b.

0 1 2km
Scale 1:50,000 (A3)
Datum: GDA94

- 5km Distance Markers from Start of Pipeline
- Gas Transmission Pipeline
- Fault
- Anticline
- Syncline
- River / Creek
- Road

Terrain Units & Constraints Intersecting Pipeline:

Terrain Unit	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Pipeline Length (m)
Qa0/2-7	H	2	M-H	F4	M (R1)	D	186
Sf3/7.1	L	2	H	W-I	H (Sa)	C2	586
Sf4/4.3	L-M	2	H	W	H (Sa)	C2	643
Qa2/6.2	L	1	H	F1	H (So,D)	C2	1,313
Qa2/6-8	L	1	M-H	F3	H (R3,So/D)	C1	1,502
Sf6/4-7	M	2-3	H	W	M-H (Sa)	C2	1,631
Dcs5/6.1	L-M	2-3	M-H	W-I	M-H (So/D)	C2	2,121
Qa1/6-8	L	1	M	F3	H (R3,So/D)	C1	2,396
Dcs6/4-7	M	2-3	M-H	W-I	L	C2	8,874

Total pipeline length in current map sheet: 19,252m (19.3km)

Sector Summary:

Constraints	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils
Low Constraint	8,561	5,211	-	13,855	8,874
Moderate Constraint	10,505	14,041	2,396	1,313	186
High Constraint	186	-	16,856	4,084	10,192

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Client: URS

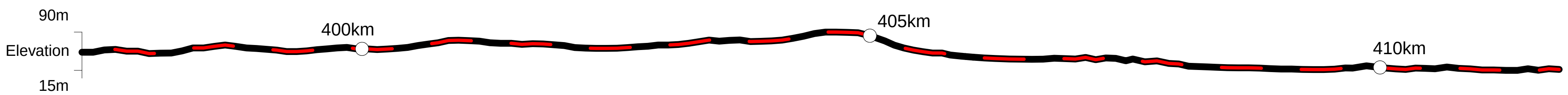
Project: GLADSTONE LNG PROJECT
TERRAIN, SOILS AND
LAND CAPABILITY REPORT
GAS TRANSMISSION PIPELINE

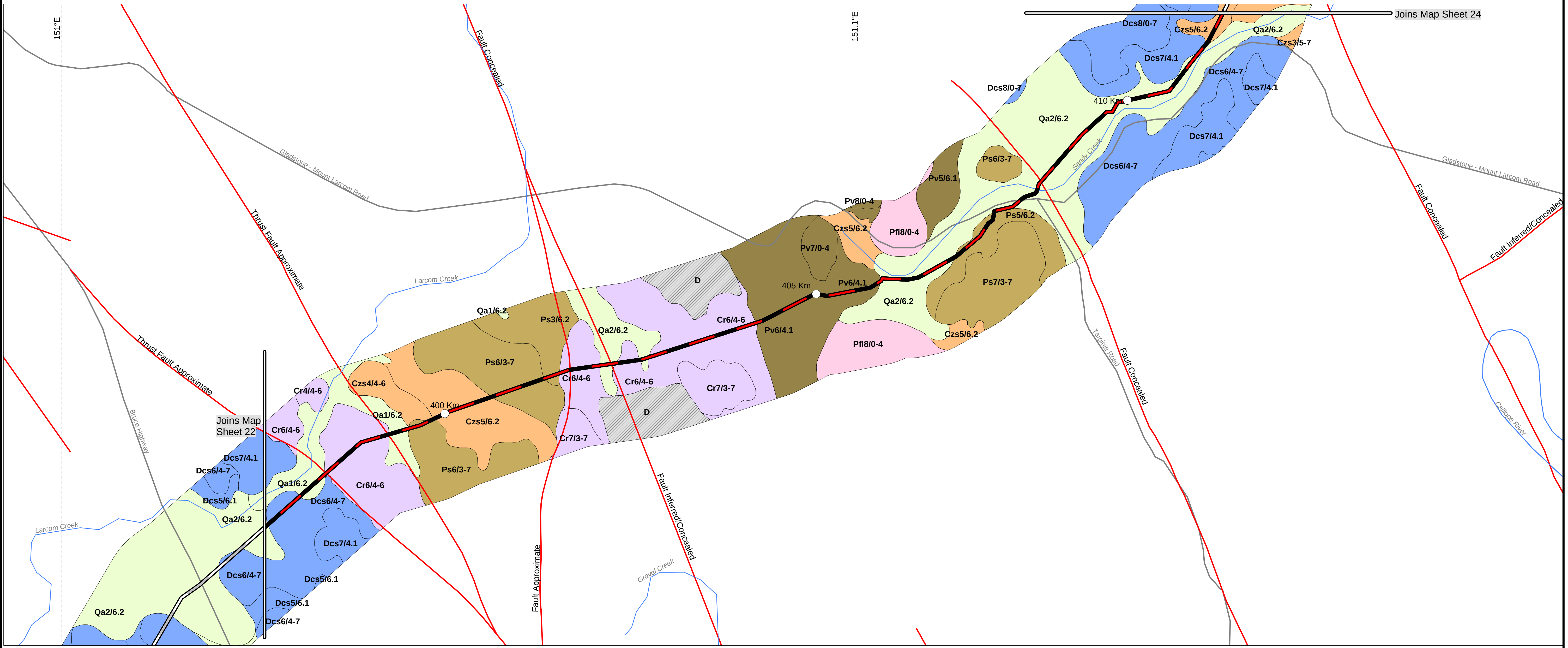
Title: **GEOLOGICAL REGIMES AND TERRAIN UNITS**

Drawn: CA	Approved: JB	Date: 01-02-2009
Job No: 4262 6220	File No: 42626220-g-678.wor	

Figure: 2-22
Rev:A
A3

PIPELINE ELEVATION PROFILE





Terrain Units & Constraints Intersecting Pipeline:

Terrain Unit	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Pipeline Length (m)
Dcs7/4.1	H	2-4	M-H	X	M-H (Sa)	C3	59
Ps3/6.2	L	1-2	M-H	W-I	M-H (So/D)	C2	200
Dcs6/4-7	M	2-3	M-H	W-I	L	C2	545
Ps6/3-7	M	2	M	W	L	C3	713
Ps5/6.2	L-M	1-2	M-H	W	M-H (So/D)	C2	904
Qa1/6.2	L	1	H	F3	H (So/D)	C2	1,028
Czs5/6.2	L-M	1-2	H	I	H (R1,So/D)	C2	1,296
Pv6/4.1	M	2-3	M	W	L	C2	1,704
Cr6/4-6	M	3-4	M-H	W	M (So/D)	C2	3,271
Qa2/6.2	L	1	H	F1	H (So,D)	C2	4,799

Total pipeline length in current map sheet: 14,519m (14.5km)

Sector Summary:

Constraints	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils
Low Constraint	8,227	8,227	-	7,337	2,962
Moderate Constraint	6,233	2,962	2,417	6,154	3,271
High Constraint	59	3,330	12,102	1,028	8,286

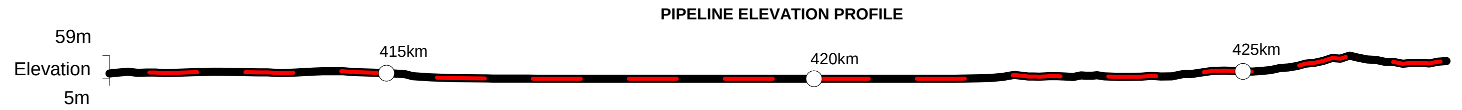
Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

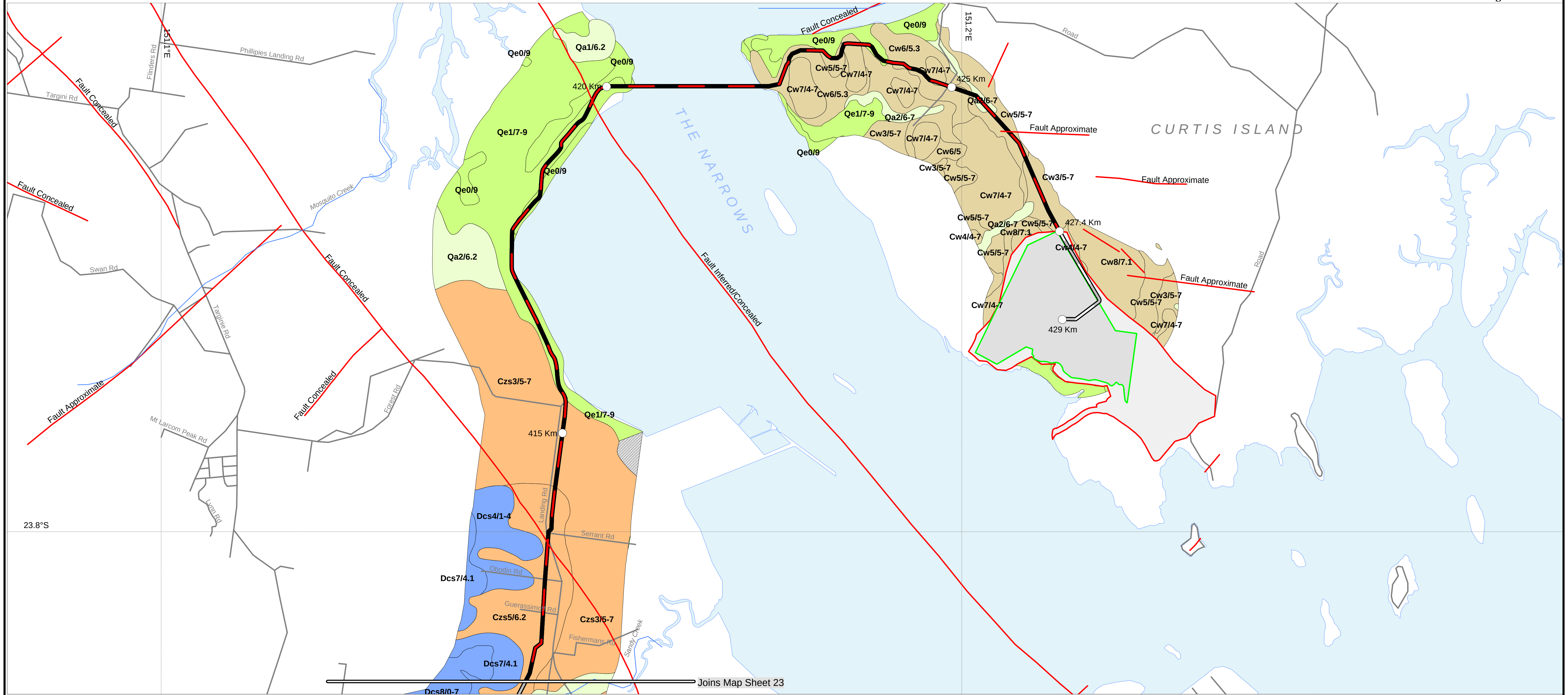
0 1 2km
Scale 1:50,000 (A3)
Datum: GDA94

Note: Figures 2-1 to 2-24 must be viewed with Figure 2b.

5km Distance Markers from Start of Pipeline
Gas Transmission Pipeline
Fault
Anticline
Syncline
River / Creek
Road

Client	Project	Title
URS	GLADSTONE LNG PROJECT TERRAIN, SOILS AND LAND CAPABILITY REPORT GAS TRANSMISSION PIPELINE	**GEOLOGICAL REGIMES AND TERRAIN UNITS**
	Drawn: CA · Approved: JB · Date: 01-02-2009	Figure: **2-23** · Rev:A
	Job No: **4262 6220** · File No: 42626220-g-679.wor	A3





Terrain Units & Constraints Intersecting Pipeline:

Terrain Unit	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Pipeline Length (m)
Cw4/4-7	L-M	1-2	L-M	W	L	C1	5
Qa2/6-7	L	1	M-H	F1	M (So/D,R1)	A	363
Cw7/4-7	H	2	M-H	X	L	C3	556
Cw3/5-7	L	1-2	L-M	W	M (R1)	C1	1,009
Czs3/5-7	L	1-2	M	W	L	C2	1,131
Cw5/5-7	L-M	1-2	M-H	W-I	M (R1)	C2	1,155
Qe0/9	M	1-2	L-M	F4	H (Sa,ASS)	D	1,261
Cw6/5.3	M	1-2	M-H	W	M (So/D)	C2	1,796
W	H	3	-	F4	-	D	1,872
Czs5/6.2	L-M	1-2	H	I	H (R1,So/D)	C2	2,538
Qe1/7-9	M	1-2	M	F3	H (Sa,ASS)	D	3,929

Total pipeline length in current map sheet: 15,615m (15.6km)

Sector Summary:

Constraints	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils
Low Constraint	6,201	13,187	2,275	5,096	1,692
Moderate Constraint	6,986	2,428	5,060	3,457	4,323
High Constraint	2,428	-	6,408	7,062	7,728

0 1 2km

Scale 1:50,000 (A3)
Datum: GDA94

Note: Figures 2-1 to 2-24 must be viewed with Figure 2b.

- 5km Distance Markers from Start of Pipeline
- Gas Transmission Pipeline
- Fault
- Anticline
- Syncline
- River / Creek
- Road
- LNG Facility Site Boundary
- LNG Facility Study Area

Client	Project: GLADSTONE LNG PROJECT TERRAIN, SOILS AND LAND CAPABILITY REPORT GAS TRANSMISSION PIPELINE	Title: GEOLOGICAL REGIMES AND TERRAIN UNITS	
URS	Drawn: CA	Approved: JB	Date: 01-02-2009
	Job No: 4262 6220	File No: 42626220-g-680.wor	Figure: 2-24
		Rev:A	A3

2.1.1 Results of Assessment

Reference to the gas transmission pipeline maps (refer **Figures 2–1 to 2-24)**, shows the occurrence and distribution of terrain units that intersect the pipeline together with a summary of the levels of constraints identified. For the gas transmission pipeline corridor as a whole, the levels of topographic constraints identified are outlined in Table 2-1 below:

Table 2-1 Topographic Constraints

Rating	Percentage of Gas Transmission Pipeline	Description
Low (L), or low to moderate (L-M)	84.5%	"L" and "L-M" constraints occur over 361.1 km (84.5%) of the gas transmission pipeline corridor.
Moderate (M)	6.5%	"M" constraints occur over 38.5 km (9.0%) of the gas transmission pipeline corridor.
Moderate to high (M-H) and high (H)	6.5%	"M-H" and "H" constraints occur over 27.8 km (6.5%) of the gas transmission pipeline corridor.

2.1.2 Constraints Mitigation Measures

Low, moderate and high topographic constraints relate to varying degrees of difficulty for pipeline construction on steeply sloping ground or in negotiating major rivers and tributary stream (wet) crossings along the pipeline route. This in turn influences the extent of clearing, the construction methods and types of equipment required to carry out the work. A total of approximately 28 km (6.5%) of the pipeline route has been rated as land presenting high topographic constraints for pipeline construction. The route selected through the range areas, wherever possible, follows ridge and spur lines or traverses the less steep mid to lower parts of the steep hill slopes. However some relatively short, steep and very rocky (difficult construction) sections will be encountered in the crossing of the Calliope Range and also in the Callide and Expedition Range areas. These will be subject to more detailed mapping and pre-construction site investigation and drilling to refine the preferred route and engineering design in order to minimise the extent of disturbance and associated environmental impact in these areas.

The pipeline descent of the Carnarvon Range escarpment and the crossing of the Dawson River at the base of the escarpment (Kp 39.4 km) is also a very critical, difficult and environmentally sensitive construction area. The use of directional drilling as an alternative to open cut construction methods may be subject to further detailed investigation in this area in order to minimise the extent of disturbance and environmental impact along the pipeline ROW through this sector.

The preferred construction method of open trenching and directional drilling options will also be subject to more detailed investigations for the proposed crossings of the major streams and rivers along the pipeline route to minimise environmental impact. These will include, but are not limited to, the pipeline crossings of Arcadia and Clematis Creeks, the confluence of Conciliation and Zamia Creeks, Mimosa Creek, the northern crossing of the Dawson River (Kp 245 km). Further to the east, major stream crossings of Kianga and Banana Creeks, Kroombit and Callide Creeks and the Calliope River near (Kp 380 km), will also be subject to further detailed investigations to determine the least environmentally intrusive construction options.

2.2 Pipeline Trench Excavation Parameters

An assessment has been made on a terrain unit basis of the likely ease or difficulty and the associated impacts with respect to the excavation of the materials that occur within the normal pipeline trench depth, typically within about 2.0-2.5 m below natural ground level. The basis for the assessment of the Excavation Rating was based on the criteria as outlined in Table 2-2 below:

Table 2-2 Excavation Parameters

Rating	Description
Rating 1	Essentially soil-like properties throughout typical trench depth; some low-strength extremely weathered (EW) to highly weathered (HW) soft rock may occur in the lower levels; excavation can most likely be achieved using a bucket-wheel excavator and/or (30T) excavator.
Rating 2	More difficult excavation conditions typically comprising shallow to medium deep soils, gravelly soils etc. underlain by HW-MW rock, or gravelly colluvium. Rocky soils including rock cobbles and small to medium-size rock boulders may occur; minimum 30T tracked excavator likely to be required for to complete trench excavation, with potential requirement for deep ripping of stronger rock lenses to facilitate rock removal.
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. Use of a heavy duty (45T) excavator with rock-breaking capability, a rock saw, or (65T) continuous chain digger or combinations of equipment types may be required to complete trench excavation.
Rating 4	Skeletal to shallow rocky soils and areas of rock outcrop with a high level of excavation difficulty likely to be encountered, including widely jointed (MW-F) high strength rock. A combination of heavy-duty (45T) excavator with heavy rock-breaking capability; some drilling and blasting may be necessary for rock removal to the required trench depth.

2.2.1 Results of Assessment

Reference to the gas transmission pipeline route sector maps (refer **Figures 2–1 to 2-24)**, shows the occurrence and distribution of terrain units that intersect the pipeline together with a route sector summary of the levels of constraints with respect to excavation conditions identified. For the gas transmission pipeline corridor as a whole, the levels of constraints with respect to excavation impacts are outlined in **Table 2-3** below:

Table 2-3 Excavation Conditions Constraint Levels

Rating	Percentage of gas transmission pipeline	Description
Rating 1 and Rating 1-2	68.6%	Conditions were collectively assessed to occur over a distance of 293.2 km (68.6%) of the pipeline corridor. These parameters are considered to present a low level of constraint for pipeline construction purposes and any associated environmental impacts.
Rating 2, Rating 2-3 and Rating 3	26.6%	Conditions were collectively assessed to occur over a distance of 113.5 km (26.6%) of the pipeline route. These parameters are considered to present a moderate level of constraint for pipeline construction purposes and any associated environmental impacts.
Rating 2-4 and Rating 3-4	4.8%	Conditions were collectively assessed to occur over a distance of 20.7 km (4.8%) of the pipeline route. These parameters are considered to present a high level of constraint for pipeline construction purposes and associated environmental impacts.

2.2.2 Impacts and Mitigation Measures

Low, moderate and high levels of constraints with respect to trench 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 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 pipeline facilities or other buried services or local infrastructure will need to be addressed.

With respect to clearing of existing or natural vegetation, wherever possible this will be confined to the pipeline ROW. 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 returned to the trench (with care not to damage the pipe coating) 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 Department of Mines and Energy (DME), local authority guidelines and AS 2885.

2.3 Erosion Potential

The occurrence and distribution of terrain units and associated erosion potential classes within the gas transmission pipeline corridor is shown in **Figures 2–1 to 2-24.** The cumulative distance of terrain units and the assessed erosion potential land class areas intersected along the pipeline corridor, are shown in **Figures 2–1 to 2-24.** The cumulative areas intersected along the total length of the pipeline are summarised as follows:

The gas transmission pipeline extends over an approximate distance of 429.0 km, but for the purposes of this report, terminates at Kp 427.4 at the LNG Facility site boundary on Curtis Island. Table 2-4 outlines the cumulative distances based on the terrain units intersected along the pipeline corridor:

Table 2-4 Land Erosion Potential

Erosion Potential Rating	Percentage of Gas Transmission Pipeline	Description
Low (L) or low to moderate (L-M)	6.0%	Low level of potential environmental impact. Intersected over a total distance of 25.0 km (6.0%) of the total pipeline corridor.
Moderate (M)	51.5%	Moderate level of potential environmental impact. Intersected over a total distance of 219.6 km (51.5%) of the total pipeline corridor.
Moderate to high (M-H) or high (H)	42.5%	High level of potential environmental impact. Intersected over a total distance of 180.9 km (42.5%) of the total pipeline corridor.

Approximately 43% of the gas transmission pipeline alignment has been rated as having moderate to high or high erosion potential due to a combination of highly erodible soils and associated terrain conditions. Accordingly some general erosion control measures have been recommended but are not limited to those outlined below, in order to minimise the potential effects of erosion during construction and the on-going operational life of the gas transmission pipeline.

2.3.1 Erosion Control Measures

Erosion along the gas transmission pipeline corridor on ancillary pipeline facilities, access tracks and on construction sites generally, cannot be eliminated completely, but implementation of the following general erosion control measures will help minimise erosion and reduce sediment loss from disturbed areas along the pipeline easement:

Recommended General Erosion Control Measures

- 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;

- Restricting heavy vehicle access along the right-of-way (ROW) during wet periods, except on designated tracks;
- Minimising the period that the bare soil is left exposed to erosion and revegetate as soon as practicable;
- Where possible utilise surface mulching to protect bare soil surfaces and respread cleared vegetation where practicable;
- Use sediment traps and sediment collection ponds to minimise off-site effects of erosion;
- Carry out progressive rehabilitation of disturbed areas

Erosion Control on Sloping Land:

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

Drainage Line Management:

- Where practicable, directionally drill required water course crossings to reduce area disturbance and minimise environmental impact in these areas;
- In other drainage lines retain a 20 m vegetative buffer until construction across the stream bed is imminent;
- Grade stream bed and bank materials away (upslope) from the stream bed 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 release a suitable distance downstream of the crossing site;
- Install temporary earth banks 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, reinstate the stream bed using material consistent with the existing stream bed material. Re-establish stream banks to a stable slope consistent with the existing bank slopes both upstream and downstream of the crossing site. Replace topsoil and revegetate the area 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 ROW to provide seed stock and to help stabilise the area..

Recommended Measures for Dust Mitigation:

- Employ construction methods that will aim to reduce exposure of disturbed areas to the minimum period and undertake revegetation or rehabilitation as soon as practicable after the completion of construction;
- Undertake regular spraying of access tracks to the pipeline easement using water trucks for dust suppression (where required), in particular in established farming and other built-up areas;
- Continued use of temporary access tracks by heavy vehicles tends to pulverise the soil and produce bulldust. Provide access to the pipeline easement at regular intervals to avoid continuous trafficking along the easement and help reduce the potential for bulldust to develop;
- Manage dusty areas by restricting access along the side of the easement to rubber tyred vehicles. Maintain these areas by regular use of water trucks and graders to assist dust suppression. Consider use of soil stabilisation additives when watering down to further maximise dust suppression;
- Consider use of cover crops to stabilise bare soil stockpiles or other bare areas.

The control of erosion and sediment movement within and from the pipeline easement will be employed both during the construction stage and subsequently during the operating life of the gas transmission pipeline. Where access is required in the long term, it is recommended that tracks will be constructed with a gravel surface and maintained to permit all weather access. Where access is required for temporary (construction) use only, it is recommended that 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 erosion control measures outlined above, together with some additional erosion control measures relevant to infrastructure structure development, line-of-route facilities and permanent and temporary access roads and tracks, included in **Appendix B-2** will be reviewed and where appropriate incorporated in a site-based environmental management plan and will be implemented to reduce erosion from disturbed areas.

2.4 Drainage Conditions along the Pipeline Corridor

Terrain units described in **Appendix A** of this report have been assessed in terms of inferred surface drainage status. Seven classes were identified as outlined in **Table 2-5** below:

Table 2-5 Surface Drainage Status

Drainage Class	Description
W	Moderately well to well drained surfaces, not flood prone
I	Impeded drainage areas with seasonally perched watertable; or surface water ponding in gilgai depressions.
X	Excessively well-drained surfaces (steep slopes, rapid runoff)
F1	Subject to short term flash flooding or surface sheetflow; locally prone to infrequent extra-tidal inundation.
F2	Infrequently flood prone (>10 year flooding frequency); prone to surface ponding in low-lying areas.
F3:	Periodically flood prone (2-10 year flooding frequency); prone to surface ponding in low-lying areas. In places along the coast these areas are prone to periodic supra-tidal inundation

Drainage Class	Description
F4	Subject to regular flooding (<2 year flooding frequency); prone to regular tidal inundation along the coast.

The cumulative distance of terrain units intersected along the pipeline centreline and the inferred drainage status are shown in **Figures 2 – 1 to 24**. The drainage status of terrain units intersected along the total length of the pipeline are summarised in Table 2-6 below:

Table 2-6 Impact due to Drainage Status of Terrain Units

Drainage Class Rating	Percentage of gas transmission pipeline	Description
W or W-I	45.8%	Occurs over a distance of 195.9 km (45.8%) of the pipeline length. These parameters were considered to present a low level of constraint for pipeline construction purposes and any associated environmental impacts.
X, I, F1 or F2	32.2%	Collectively assessed to occur over a distance of 137.5 km (32.2%) of the pipeline length. These parameters were considered to present a moderate level of constraint for pipeline construction and by association, a moderate level of environmental impact
F3 or F4	22%	Prone to either frequent or periodic flooding. Collectively assessed to occur over a distance of 94.0 km (22%) of the pipeline length. These areas were considered to present a high level of constraint for pipeline construction purposes and associated environmental impacts.

2.4.1 Impacts and Mitigation Measures

Areas assessed as presenting a moderate level of environmental impact primarily relate to land within the gas transmission pipeline corridor that is prone to occasional flooding and has soils which have impeded drainage characteristics. Periodically, these areas tend to pond water in the surficial soil layers following heavy rainfall, they become very boggy and trafficability of the natural surface is very difficult and restricted. It is recommended that construction activities cease and vehicular access in these areas be avoided during and immediately following periods of heavy rainfall. Other potential impacts relate to potential erosion effects due to rapid surface runoff in steeply sloping lands. Erosion control measures on sloping lands addressed in **Section 2.3.1** will be implemented to mitigate the potential effects of erosion in these areas.

Areas assessed as presenting a high level of constraint for pipeline construction and by association may present a high level of environmental impact, relates to land within the gas transmission pipeline corridor that is prone to periodic or regular flooding, including areas prone to regular or periodic tidal inundation. The engineering design will address potential pipeline buoyancy issues in these areas, as well as the impacts of pipeline construction in soft saturated ground conditions in coastal areas.

Drainage line management erosion control measures outlined in **Section 2.3.1** are recommended to mitigate environmental impacts relating to the potential effects of erosion in these flood prone areas.

2.5 Problem Soil Areas.

In relation to gas transmission pipeline construction, problem soil areas relate to the occurrence of soils with low to moderate and high levels of soil reactivity (R1-R3), sodicity (So), dispersive properties (D) and soil salinity (Sa). The properties may occur throughout the profile but more commonly occur in the deeper subsoil layers and in the soil substrate. The basis for the assessment of these soil attributes is included in **Appendix B-3.**

The cumulative distance of terrain units and the associated problem soil area categories intersected along the pipeline centreline are shown in **Figures 2 – 1 to 24**. The cumulative areas intersected along the total length of the gas transmission pipeline are summarised in Table 2-7 below:

Table 2-7 Problem Soil Area Ratings

Rating	Percentage of Gas Transmission Pipeline	Description
Low (L)	17.6%	Low level of environmental impact. Intersected over a total distance of 74.8 km (17.6%) of the total pipeline corridor.
Low to moderate (L-M) and moderate (M)	39.2%	Potential moderate level of environmental impact. Intersected over a total distance of 166.9 km (39.2%) of the total pipeline corridor. This category has been further subdivided as follows: - Terrain units and soils with low to moderately sodic and/or dispersive (So/D) subsoils occur over 95.1 km (22.3%) of the pipeline corridor. - Terrain units and soils with moderately reactive (R1) and shallow to medium deep highly reactive soils (R2) occur over 71.8 km (16.9%) of the pipeline corridor.
Moderate to high (M-H) and high (H))	43.2%	Potential high level of environmental impact. Intersected over a total distance of 183.8 km (43.2%) of the total pipeline corridor. This category has been further subdivided as follows: - Terrain units and soils with moderate to high (M-H) and highly (H) sodic and/or dispersive subsoils (So/D) locally with high levels of soil salinity occur over 24.0 km (5.6%) of the pipeline corridor. - Terrain units and soils with highly reactive (R3) occur over 154.6 km (36.3%) of the pipeline corridor. Terrain units and soils with high levels of existing and potential acid sulfate soils (ASS) occur over 5.2 km (1.2%) of the pipeline corridor.

2.5.1 Dispersive Soils and Sodicity

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 are susceptible to structural degradation on exposure tend to exhibit the following general problems:

- Severe surface crusting;
- Likely dispersion on wetting;
- Very low infiltration and hydraulic conductivity;
- Very hard dense subsoils;
- 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 2.3.1** 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

2.5.2 Reactive Soils

These relate primarily to the occurrence of highly reactive (cracking) clays that occur in terrain units mainly with Soil Group 8 and in places in Soil Group 9 soils occurrences. 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 have been identified to occur spread over approximately 43% of the pipeline corridor. These soils often occur in association, in particular, with Soil Group 6 and Soil Group 7 soils. The impact of differential soil movement with respect to the long-term integrity of the pipeline can be mitigated to a large extent by the use of an inert (sandy) padding material completely surrounding the pipeline. 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 pipeline construction.

2.5.3 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**.

Soils with moderate to high levels of soil salinity particularly in the deeper clay subsoil and substrate materials occur along the pipeline corridor in terrain units Qe0/9, Qe1/7-9, Qa2/6-7, Cw 3/5-7 and Cw5/5-7 on Curtis Island. On the mainland, saline soils also occur in terrain units associated with the Quaternary estuarine deposits (Qe) and in the Silurian-Devonian extrusive and volcaniclastic geological regimes (Dcs and Sf). Moderately to highly saline soils most likely occur in the Quaternary alluvial deposits, mainly in terrain unit Qa1/6-8 and in the older alluvial deposits in terrain units Czs1/6-8 and Czs2/6-8.

In areas with saline soils, a common salinity management recommendation – DNRQ (1997), 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 levels as a result of clearing. However much of the existing high risk salinity areas identified along the pipeline corridor have already previously been cleared for cropping and/or grazing and deep drainage 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 a soil resistivity survey along the pipeline corridor will be undertaken prior to the commencement of construction works, to determine the occurrence and distribution of saline soils and where corrosion protection may be required along the pipeline corridor.

2.5.4 Acid Sulfate Soils

Acid sulfate soils (ASS) have been identified to occur along the southern coastal fringe of Graham Creek and in places along the south western coastline on Curtis Island. On the mainland, ASS occur in the vicinity of the proposed bridge crossing of Port Curtis near Friend Point and on the estuarine flats over a distance of approximately 3 km to the south-west (refer to the **Appendix L4**).

Site specific ASS investigations along the pipeline corridor will be undertaken prior to construction to determine the occurrence and thickness of any Actual and/or Potential ASS (PASS) materials present. If Actual ASS are found to occur, lime treatment to neutralise the acidity levels will be required, as temporary or permanent embankment filling (required for pipeline construction) over Actual ASS (very strongly acidic) material is prohibited (under SPP 2/02) unless the material is treated. If PASS is found to occur, depending on the depth, thickness, acid generation potential and the likely period of exposure, lime treatment of the PASS material may also be necessary. If required, an ASS Management Plan will be developed as part of the overall Project Environmental Management Plan (EMP).

2.6 Agricultural Land Capability

The basis for the assessment of agricultural land capability is addressed in **Section 1.8** above. The cumulative distance of the respective Agricultural Land Class areas identified have been determined on a route sector by sector basis as shown in **Figures 2–1 to 2-24.** Assuming a nominal 30 metre wide pipeline easement, the combined areas of each land class that will be subject to at least temporary disruption of the prevailing land use as a result of the pipeline construction process, are summarised in Table 2-8 below:

Table 2-8 Agricultural Land Capability along the Pipeline Length

Rating	Percentage of Gas Transmission Pipeline	Description
Class A land	7.4%	Intersected over a cumulative distance of 31.5 km (7.4%) of the total pipeline corridor, which constitutes a combined land area of 94.6 ha.
Class B land	9.6%	Intersected over a cumulative distance of 41.0 km (9.6%) of the total pipeline corridor, which constitutes a combined land area of 122.8 ha.
Class C1 land	34.9%	Intersected over a cumulative distance of 149.4 km (34.9%) of the total pipeline corridor, which constitutes a combined land area of 448.3 ha.
Class C2 land	37.5%	Intersected over a cumulative distance of 160.3 km (37.5%) of the total pipeline corridor, which constitutes a combined land area of 480.9 ha.
Class C3 land	5.2%	Intersected over a cumulative distance of 22.3 km (5.2%) of the total pipeline corridor, which constitutes a combined land area of 66.9 ha.
Class D land	5.4%	Intersected over a cumulative distance of 22.9 km (5.4%) of the total pipeline corridor, which constitutes a combined land area of 68.6 ha.

2.6.1 Agricultural Land Capability Impacts and Mitigation Measures

Areas identified as Class A and B and C1 land may be subject to short term disruption of existing land use during the pipeline construction process. 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 the buried pipeline will be 1.2 m to allow for ongoing 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 owner/manager. As soon as construction is complete in these areas, temporary access tracks will be removed and disturbed land will be lightly ripped, topsoil will be replaced and the land returned as near as practicable to its pre-construction land use condition. Appropriate erosion control measures will be implemented where considered to be necessary or by agreement with the owner/manager.

Areas identified as Class C2 land are essentially good quality grazing land suitable for native or improved pastures, but cultivation is not normally undertaken. When construction is complete in these areas temporary access tracks will be removed unless otherwise by agreement with the owner/manager, 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 owner/manager.

Areas identified as Class C3 land comprise hilly and steep hilly lands typically treed but suitable for controlled light grazing where accessible. Class D (non-agricultural) lands may include very steep high hilly to mountainous lands, steep rocky escarpments, or major streamlines and rivers. When construction is complete in these areas, it is recommended that land management and erosion control measures described in **Section**

2.3.1 for sloping lands and drainage lines be implemented. In general, these areas will be revegetated as soon as practicable after construction has been completed.

2.7 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 the gas pipeline 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 the pipeline will be designed in accordance with this standard.

Conclusions

A terrain analysis of a 5 km wide gas transmission pipeline corridor was initially carried out, to assess the engineering and/or environmental constraints with respect to the location and construction of a pipeline and various possible alternatives being considered. A series of terrain units were identified for each of the main geological regimes identified within the gas transmission pipeline corridor based on landform characteristics (surface form and slope) and associated soils. Subsequently, a 2 km wide corridor was adopted for the EIS of the proposed pipeline route. Descriptions of the terrain units, together with an assessment of the more important engineering/environmental constraints and by association, potential environmental impacts for pipeline construction, were determined. The potential impacts assessed related to:

- Topographic constraints;
- Excavation conditions - relating to the ease or difficulty of excavation within the typical trench depth;
- Erosion potential - where the land is subject to clearing or disturbance associated with construction activities;
- Drainage status - assessment of area drainage conditions and susceptibility to flooding or tidal inundation in coastal areas;
- Problem soils - the occurrence of reactive soils, sodic, dispersive and/or saline soils, acid sulfate soils; and
- Agricultural land classes – changes to agricultural land capability due to development activities.

The extent of potential environmental impacts associated with terrain units intersected along the gas transmission pipeline alignment have been determined on a route sector by sector basis and for the alignment as a whole. Impact management strategies have been recommended in order to successfully mitigate the potential environmental impacts identified. However in places where potentially high area specific environmental impacts have been identified, more detailed geotechnical site investigations including acid sulfate soil investigations will be undertaken where necessary. These pre-construction investigations will include soil sampling and soil testing as appropriate to clearly define the extent of potential problem areas and to determine the appropriate engineering solutions or management strategies required to mitigate the impact.

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Terrain Unit Descriptions

Appendix A

Appendix A - Terrain Unit Descriptions and Assessment of Engineering/Environmental Constraints for Pipeline Construction

Geological Regime: Qe Quaternary (Holocene) marine and estuarine plain and tidal delta deposits

Terrain Unit	Landform	Soils	Topographic constraint	Excava-tion Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Remarks
Qe0/9	Tidal mangrove flats and tidal inlets; overall slopes mostly <1%, locally steeper on slopes to drainage	Uniform, gradational and duplex soils with a thin silty clay to silt loam surface soil over saturated, gleyed saline clay, clayey silt or sandy mud subsoils	M	1-2	L-M	F4	H (Sa, ASS)	D	Subject to tidal inundation; mostly deep soft saturated saline soils; may include ASS layers
Qe1/'7-9	Supra-tidal coastal flats, mudflats and saltpans, mostly bare or with sparse samphire; slopes <1%	Thin silty clay or silt loamy surface soils over deep soft saturated gleyed saline clay, clayey silt, silty sand or sandy mud soils; some uniform acidic and mod. saline clay soils (Type 7.3) along the inland margins	M	1-2	M	F3	H (Sa, ASS)	D	Subject to tidal inundation; mostly deep soft saturated saline soils; may include ASS layers
Qe2/7.3	Slightly elevated supra-tidal flats on the landward fringes of the estuarine plain; slopes mostly <1%	Deep uniform clay soils with acidic silty clay or heavy clay surface soils over red and grey mottled strongly acidic and moderately to highly saline heavy clay subsoils	L	1	M	F1	M (Sa, So/D)	C-D	Moderately dispersive, strongly acidic in the surface soil; strongly acidic, highly sodic and saline in the subsoils

Appendix A - Terrain Unit Descriptions and Assessment of Engineering/Environmental Constraints for Pipeline Construction

Geological Regime: Qa Quaternary Alluvium - channel and floodplain alluvium: gravel, sand, silt, clay

Terrain Unit	Landform	Soils	Topographic constraint	Excava-tion Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Remarks
Qa0/2-7	Major stream channels including floors, banks, levees and adjacent narrow floodplain areas	Stratified alluvial deposits, predominantly gravelly sand soils (Type 2.2), , occasional rock outcrop in stream floors; areas of uniform or gradational clay soils (Type 7.2) on stream banks and narrow floodplain areas	H	2	M-H	F4	M (R1)	D	Stratified alluvial deposits in main stream channel floors
Qa0/2-8	Major stream channels including floors, banks, levees and adjacent narrow floodplain areas	Stratified alluvial soils (Type 2.2), predominantly sand; silt, gravel, occasional rock outcrop in stream floors; cracking clay soils (Type 8.2) on adjacent narrow floodplain areas	H	2	M-H	F4	M (R1)	D	Stratified alluvial deposits in main stream channel floors
Qa0/5-6	Major streamlines with narrow braided channels up to 30m wide, incised 3-5m, with irregular steep banks, narrow sandy levees and interfluves	Sandy surface duplex soils (Type 5.2) on levees and interfluves; thin sandy to silt loamy surface duplex soils (Type 6.2) locally on stream banks and drainage flats and in tributary drainage floors	M-H	2	M-H	F4	M (S/D)	D	Stratified alluvial deposits in main stream channel floors
Qa0/5-8	Major stream channels including floors, banks, levees and adjacent narrow floodplain areas	Sandy to loamy surface duplex soils (Type 5.2) with acidic to neutral clay subsoils on levees and interfluves; cracking clay soils (Type 8.2) and some layered fine-textured alluvial soils on drainage flats	M-H	2	M-H	F4	M (D, R3)	D	Stratified sandy alluvial deposits in channel floors
Qa1/2-6	Low-lying flat stream floodplains (relatively broad areas), minor stream channels, levees, billabongs, wetlands; slopes mostly <1%	Stratified alluvial soils predominantly sandy (Type 2.2); mostly duplex soils (Type 6.2) with neutral to alkaline typically sodic medium to heavy clay subsoils in floodplains	L	1	H	F3	M (D)	C2	Periodically floodprone, or prone to surface water ponding after heavy rainfall
Qa1/5-2	Low-lying flat stream floodplains, minor stream channels, levees, billabongs, wetlands; slopes mostly <1%	Sandy surface duplex soils common on stream floodplains; stratified alluvial deposits, predominantly sand, in stream banks and levees	L	1	M	F3	M (D)	C2	Periodically floodprone, or prone to surface water ponding after heavy rainfall

Qa1/6.2	Drainage flats, floodplains and low stream terraces adjacent to major tributary streams; slopes mostly <1%	Thin silt to clay loamy surface bleached duplex soils with grey or brown alkaline, sodic medium to heavy clay subsoils	L	1	H	F3	H (So/D)	C2	Strongly sodic and dispersive subsoils
Qa1/6-8	Low-lying flat to broadly depressional plains and broad stream floodplains, minor stream channels, levees, billabongs, wetlands; slopes mostly <1%	Deep fine sandy to loamy surface duplex soils (Type 6.2) with neutral to alkaline typically sodic medium to heavy clay subsoils; areas of black or dark grey crack-ing clay soils (Type 8.3) with alkaline heavy clay subsoils in parts strongly acidic in the deeper subsoils	L	1	M	F3	H (R3, So/D)	C1	Moderately intensive gilgai development; strongly sodic dispersive and reactive clay subsoils.
Qa2/4-8	Gently sloping floodplains of upper parts of stream systems (relatively narrow, usually upstream from Qa1/ units); minor stream channel banks and floors; slopes mostly <2%	Gradational to uniform sandy, loamy, silty or clay loamy surface soils (Type 4.3) over sandy clay loam to light clay subsoils; areas of cracking medium to heavy clay soils (Type 8.2).	L	1	M	F1	M (R3)	C1	Locally moderately intensive melon-hole gilgai development
Qa2/6.2	Broad near level to gently undulating older alluvial plains and gently inclined alluvial fans; slopes mostly <2%	Thin bleached hardset silt to clay loamy surface duplex soils with grey or brown alkaline, sodic medium to heavy clay subsoils	L	1	M-H	F1	H (So, D)	C2	Marginal quality topsoil for rehabilitation purposes
Qa2/6-7	Near flat to gently undulating alluvial plains, stream terraces, backplains and gently inclined slopes to drainage; slopes mostly <2%	Deep fine sandy to loamy surface duplex soils (Type 6.2) with neutral to alkaline typically sodic medium to heavy clay subsoils; areas of uniform or gradational fine-textured alluvial soils (Type 7.2) with dark grey-brown neutral to moderately alkaline silty clay to medium clay subsoils	L	1	M	F1	M (So/D, R1)	A	Alluvial plain associated with Kroombit and Callide Creeks and locally along the Calliope River; Ag.land class C1 on narrower floodplains
Qa2/6-8	Gently inclined, mostly narrow floodplains with minor shallowly incised narrow streamlines in upper parts of some more major stream systems; slopes mostly <2%.	Deep fine sandy to loamy surface duplex soils (Type 6.2) with neutral to alkaline typically sodic medium to heavy clay subsoils; areas of black or dark grey cracking clay soils (Type 8.3) with alkaline heavy clay subsoils often strongly acidic in the deeper subsoils	L	1	M	F3	H (R3, So/D)	C1	Locally moderately intensive melon-hole gilgai development

Appendix A - Terrain Unit Descriptions and Assessment of Engineering/Environmental Constraints for Pipeline Construction

Geological Regime: Czs Cainozoic Sediments; sand plain, residual soils and older alluvial deposits, mainly sandy sediments, some gravel and clay

Terrain Unit	Landform	Soils	Topographic constraint	Excava-tion Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Remarks
Czs1/6-8	Very gently sloping, mostly low-lying plain areas; slopes mostly <1%	Mainly deep dark grey-brown cracking clay soils (Type 8.3) with prominent gilgai; dark brown cracking clay soils (Type 8.2) occur in slightly higher areas where gilgai are sparse or absent; thin silt to clay loamy surface duplex soils (Type 6.2) occur in higher parts	L	1	M	F2	H (R3, So/D)	C1	Moderately intensive gilgai development; strongly sodic dispersive and reactive clay subsoils
Czs2/6.2	Gently undulating, gently inclined plains and lowlands and lower colluvial slopes; slopes mostly <2%	Bleached silt loamy surface duplex soils with brown and grey alkaline sodic medium to heavy clay subsoils	L	1	M-H	I	H (R1, So/D)	C2	Marginal topsoil suitability; strongly sodic and dispersive subsoil layers
Czs2/5-8	Slightly elevated (upslope from Czs1/ and Qa1/ units), gently sloping erosional plains, outwash fans and older alluvial plains; slopes mostly <2%	Deep fine sandy to loamy surface duplex soils (Type 5.3) with acidic to mildly alkaline medium to heavy clay subsoils; areas of black or dark grey cracking clay soils (Type 8.3) with alkaline heavy clay subsoils often strongly acidic in the deeper subsoils	L	1	M	I	M (R1)	B	Areas of suitable topsoil resource; slightly or moderately dispersive clay subsoils; local melon-hole gilgai
Czs2/6-8	Gently undulating, gently inclined plains and lowlands with broad low rounded rises; slopes mostly <2%	Mainly deep dark grey-brown cracking clay soils (Type 8.3) in lower-lying areas with prominent gilgai, dark brown cracking clay soils (Type 8.2) occur in slightly higher areas where gilgai are sparse or absent; thin silt to clay loamy surface duplex soils (Type 6.2) occur in higher parts.	L	1-2	M	I	H (R3, So/D)	C1	Thin self-mulching surface soils occur in parts, coarse billy gravel also occurs in places; cleared prior brigalow lands
Czs3/5-7	Gently inclined, gently undulating footslope plains and lower dissection slope interfluves; slopes typically 1-3%	Shallow to medium deep bleached sandy and loamy surface red duplex soils (Type 5.1) in higher areas, medium deep uniform red clays or gradational clay loam over structured clay soils (Type 7.2) with red-brown and red medium clay subsoils in lower parts	L	1-2	M	W	M (So/D)	C2	Suitable topsoil resource; slight to moderately dispersive subsoils

Czs3/5-8	Gently to distinctly sloping erosional plains, outwash fans, old alluvial plains, broadly undulating areas; slopes typically 1-3%	Deep fine sandy to loamy surface duplex soils (Type 5.2) with acidic to mildly alkaline medium to heavy clay subsoils; areas of black or dark grey cracking clay soils (Type 8.2) with alkaline medium to heavy clay subsoils	L	1-2	M	W	M (So/D)	C1	Areas of suitable topsoil resource; slightly or moderately dispersive clay subsoils; local melon-hole gilgai
Czs4/4-6	Undulating plains and lowlands with broad low rounded rises with marginal slopes in the range 3-5%	Shallow brown and black massive loams and clay loam soils (Type 4.1) on rises, sandy and loamy surface brown and grey alkaline sodic duplex soils (Type 6.2) on lower slopes and in depressions	L-M	2	M (In depress-ions)	W	M (So/D)	C2	Suitable topsoil resource; sodic and dispersive subsoils
Czs4/6.3	Distinctly sloping areas, rolling rises and upland plateau remnants; slopes mostly in the range 3-5%	Moderately deep to deep duplex soils with relatively thin sand or loam over neutral to alkaline typically sodic medium to heavy clay	L-M	1-2	M	W	H (So/D)	C2	Suitable topsoil resource; strongly sodic and dispersive subsoils
Czs5/5-8	Strongly undulating to distinctly sloping hill and ridge slopes with slopes mostly in the range 5-12%	Deep fine sandy to loamy surface duplex soils (Type 5.3) with acidic to mildly alkaline medium to heavy clay subsoils; areas of black or dark grey cracking clay soils (Type 8.3) with alkaline heavy clay subsoils often strongly acidic in the deeper subsoils	M	1-2	M	W	M (So/D)	C2	Areas of suitable topsoil resource; slightly or moderately dispersive clay subsoils; local melon-hole gilgai
Czs5/6.2	Undulating fan slopes and colluvial footslopes, gently to moderately inclined with slopes mostly in the range 5-12%	Moderately deep to deep fine sandy to silt loamy surface duplex soils with brown and grey alkaline sodic medium to heavy clay subsoils	L-M	1-2	H	I	H (R1, So/D)	C2	Suitable topsoil resource; strongly sodic and dispersive subsoils

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Geological Regime: Tb Tertiary Volcanic rocks - volcanic rocks, predominantly mafic; basalt, trachyte, rhyolite

Terrain Unit	Landform	Soils	Topographic constraint	Excava-tion Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Remarks
Tb2/8.1	Gently sloping erosional plains; very gentle lower slopes of rises and uplands; slopes mostly <2%	Mostly shallow cracking clay soils, usually with a thin self-mulching or crusty medium to heavy clay surface soil over strongly structured heavy clay subsoil; possible cobbles of basalt etc on surface and within soil profile; possible areas of rock outcrop	L	2-3	M	F1	L-M (R2)	B	Surface cobbles limit agriculture; patchy topsoil resource
Tb3/8.1	Gently to distinctly sloping erosional plains; gently to moderately sloping middle and lower slopes of rises and uplands; slopes mostly in the range 1-3%	Mostly shallow cracking clay soils, usually with a thin self-mulching or crusty medium to heavy clay surface soil over strongly structured heavy clay subsoil; some cobbles of basalt etc on surface and within soil profile; possible areas of rock outcrop	L	2-3	M-H	W	L-M (R2)	B	Surface cobbles limit agriculture; patchy topsoil resource
Tb4/8.1	Upland plateau remnants; some distinctly sloping areas and rolling rises; slopes mostly in the range 3-7%	Mostly shallow cracking clay soils, usually with a thin self-mulching or crusty medium to heavy clay surface soil over strongly structured heavy clay subsoil; some cobbles of basalt etc on surface and within soil profile; possible areas of rock outcrop	L-M	2-3	M	W	L-M (R2)	C2	Surface cobbles limit agriculture; patchy topsoil resource
Tb5/7.1	Strongly undulating to distinctly sloping hill and ridge slopes, mostly in the range 5-12%	Mostly shallow clay soils, with light to medium, sometimes heavy, usually non-cracking clay surface soils over medium to heavy clay subsoils; frequently with rock in the profile; some surface cobbles of basalt etc and occasional areas of rock outcrop	L-M	2-3	H	W	M (R1)	C2	Some areas of rock may require heavy ripping or blasting

Tb6/7.1	Moderately steep slopes of hills and ridges; irregular and low hilly areas; slopes typically up to 25%	Mostly shallow clay soils (Type 7.1), with light to medium, sometimes heavy, usually non-cracking clay surface soils over medium to heavy clay subsoils; frequently with rock in the profile; some surface cobbles of basalt etc and occasional areas of rock outcrop	M	2-3	M-H	X	L	C3	Areas of rock may require heavy ripping or blasting
Tb8/0-7	Very steep slopes of hills and ridges, and very steep hilly lands; slopes mostly up to 50%	Rock outcrop (basalt etc) with skeletal stony or gravelly soils, usually with some clay; areas of mostly non-cracking uniform typically dark-coloured medium to heavy clay soils (Type 7.1), frequently with rock in the profile	H	3-4	M-H	X	L	D	Route should avoid this unit where possible; significant areas of rock outcrop

Appendix A - Terrain Unit Descriptions and Assessment of Engineering/Environmental Constraints for Pipeline Construction

Geological Regime: Ts Tertiary Sediments: As mapped includes Biloela Formation (Tobi); Sublabile to quartzose sandstone, siltstone,mudstone, minor conglomerate coal and limestone

Terrain Unit	Landform	Soils	Topographic constraint	Excava-tion Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Remarks
Ts0/1-6	Minor tributary drainage channels, with narrow levees and slopes to drainage and low stream banks	Medium to deep silt to clay loamy duplex soils (Type 6.2) with mainly gravelly sandy soils and some exposed ferricrete in stream channel floors	M	2	M	F4	M (So/D)	D	Sodic and dispersive subsoils in stream banks are susceptible to scour and gully erosion
Ts2/4.2	Gently sloping erosional plains; very gentle middle and lower slopes of rises and uplands	Gradational profiles with sandy loam to clay loam surface soils, sometimes with a lateritic layer, over sandy clay loam to light clay subsoils.	L	1-2	M	W-I	L	C1	Areas of suitable topsoil resource
Ts2/5-8	Near level to gently inclined lower colluvial/alluvial slopes in lower sectors of broadly undulating plains, locally with intensive gilgai development: slopes <2%, mostly <1%	Medium to deep dark brown and grey-brown cracking clay soils (Type 8.2) with deep dark brown to dark grey cracking clay soils (Type 8.3) together with loamy surface duplexsoils (Type 5.3) with yellow-brown to reddish-brown medium to heavy clay subsoils in heavily gilgaied areas	L	1	L-M	I	H (R3, D)	A	In the heavily gilgaied areas, the loamy surface duplex soils which occur locally on the gilgai mounds commonly exhibit a sporadic bleach
Ts2/7-8	Gently undulating plains and lowlands; slopes mostly <2%	Medium to deep dark brown and grey-brown cracking clay soils (Type 8.2) and uniform or gradational (non-cracking) clay soils (Type 7.2), comprising dark brown or reddish-brown structured clay or clay loam over structured alkaline, often calcareous, medium to heavy clay subsoils	L	1	L	W-I	H (R3)	A	The non-cracking clay soils locally tend towards incipient cracking clays; the surficial 0.2m is a suitable topsoil resource
Ts2/8.2	Crestal areas and higher parts of broadly undulating, gently sloping plains; slopes <2%, mostly <1%	Medium to deep cracking clay soils with thin slightly acidic self-mulching surface soils over dark brown or grey-brown strongly structured alkaline medium to heavy clay subsoils	L	1-2	M	W-I	M (R2)	A	Indurated mottled or pallid-zone substrate materials may occur between 1-1.5m (bgl)

Ts2/8.3	Near level to gently inclined lower colluvial/alluvial slopes in lower sectors of broadly undulating plains, locally with intensive gilgai development: slopes <2%, mostly <1%	Medium to deep cracking clay soils with dark brown or grey-brown thin crusty slightly acidic to alkaline surface soils over coarse blocky structured alkaline usually calcareous lighter-coloured heavy clay subsoils which tend to become mottled and strongly acidic in the deeper subsoils	L	1	L-M	I	H (R3)	C1	Intensive melon-hole gilgai, subject to surface water ponding for length periods after heavy rainfall
Ts3/5-8	Undulating to gently rolling plains and lowlands, broadly rounded low rises.	Duplex soils (Type 5.3) with sandy to loamy surface soils over mostly acidic to mildly alkaline sandy clay to medium-heavy clay subsoils; areas of cracking medium to heavy clay soils (Type 8.2)	L	1	M	I	M (So/D)	C2	Areas of suitable topsoil resource; slightly or moderately dispersive clay subsoils; local melon-hole gilgai
Ts4/4.2	Near level to gently undulating plateau crestal areas and crests on flat-topped hills with slopes 3-5% on the steeper margins	Medium to deep uniform or gradational sandy loam to sandy clay loam surface red earths, grading to clay loam or light clayey subsoils, generally with pisolitic (Fe) gravel in the deeper subsoils; some yellow earth soils may occur locally	L-M	1-2	L-M	W	L	C2	Erosion potential increases towards the outer margins of the unit; possible source of sand for pipe bedding
Ts4/5	Gently sloping upland plateau remnants, distinctly sloping areas and rolling rises; slope range mostly less than 5%	Duplex soils with thin to locally thick sandy to loamy surface soils (Type 5.2, 5.3) over mostly acidic to mildly alkaline sandy clay to medium-heavy clay subsoils	L-M	1-2	M-H	I	M (So/D)	C2	Areas of suitable topsoil resource; slightly or moderately dispersive clay subsoils
Ts4/5-7	Undulating plain and gently inclined broadly undulating dissection slope interfluves; slope range mostly 3-5%	Mainly deep uniform or gradational fine-textured structured clays or gradational clay loam over weakly structured alkaline clay soils (Type 7.2), some loamy surface red, brown or grey-brown acidic sodic duplex soils (Type 5.3) occur on rises	L-M	1-2	M-H	W	M (So/D)	C1	The deeper subsoil layers may be sodic and slightly to moderately dispersive
Ts4/6-8	Undulating plain and gently inclined broadly undulating dissection slope interfluves; slope range mostly 3-5%	Medium deep thin loamy surface duplex soils (Type 6.2), with medium to deep dark brown and grey-brown cracking clay soils (Type 8.2) in lower parts	L-M	1-2	M-H	W	M (R2 - So/D)	C1	Medium deep reactive clay soils, duplex soils have sodic and dispersive clay subsoils

Ts5/4-5	Gently to moderately inclined mid to lower slopes and dissection slope interfluves below Tertiary plateau remnants with mainly planar to concave slopes mostly in the range 5-12%	Medium to deep loamy red or yellow earth soils (Type 4.2) on upper slopes and crests of interfluves; sandy surface acidic yellow-brown duplex soils (Type 5.2) on mid to lower slopes	L-M	1-2	M	W	M (So/D)	C2	Type 5.2 duplex soils may have moderately sodic and dispersive subsoils
Ts5/5.1	Moderately inclined hill and ridge slopes, dissection slope interfluves and mildly dissected slopes mostly in the range 5-12%	Mostly shallow duplex soils (<0.5m) with sandy to loamy surface soils over mostly acidic to mildly alkaline sandy clay to medium-heavy clay subsoils.	L-M	2-3	M-H	I	M (So/D)	C1	Type 5.1 duplex soils are shallow and prone to erosion
Ts5/6-7	Gently to moderately inclined footslopes below adjacent higher hilly lands with slopes in the range 5-12%	Shallow to medium deep uniform gravelly clay soils (Type 7.1) and thin sandy to loamy surface duplex soils (Type 6.1) with red-brown or yellow-brown duplex soils with alkaline sandy clay to medium to heavy clay	L-M	1-2	M	W	M (So/D)	B	The Type 6.1 duplex soils may have strongly sodic and dispersive subsoils
Ts6/0-5	Hillslopes and discontinuous low ferruginous rocky scarps; overall slopes in the range 12-25%, locally steeper on the low scarps	Exposed rock and ferricrete locally with skeletal to shallow sands and rocky soils and shallow sandy red earths on the higher and steeper parts of slopes; shallow to medium deep sandy surface yellow-brown duplex soils (Type 5.1) on the footslopes	M	2-4	M-H	X	M (So/D)	C3	The Type 5.1 duplex soils may have moderately sodic and dispersive clay subsoils; some heavy rock breaking or blast-ing may be necessary for rock removal
Ts6/1-4	Isolated low hills and rises; hill slopes; low hilly lands; slopes mostly up to 25%	Rock outcrop, locally with skeletal gravelly or rocky soils (Type 1); areas of gradational sandy to loamy surface soils over sandy clay to medium clay subsoils.	M	3	M-H	W-X	L	C2	Severe erosion in parts, especially where vegetation is removed or reduced
Ts6/4-7	Low hilly lands and broad low rounded rises, with slopes 12-25% on the steeper margins	Shallow to medium deep uniform gravelly red-brown clay soils (Type 7.1) and shallow to medium deep uniform or gradational gravelly red loams or gravelly red earth soils (Type 4.1)	M	2-3	M-H	W-X	L	C2	Moderately severe surface sheet erosion evident on the steeper marginal slopes
Ts7/0-4	Steep hill and ridge slopes, mostly up to 40%	Rock outcrop, locally with skeletal gravelly or rocky soils (Type 4.1); areas of gradational sandy to loamy surface soils over sandy clay to medium clay subsoils.	H	3-4	H	X	L	C3	Steep rocky slopes

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Geological Regime: Jh Early Jurassic Hutton Sandstone, Bundamba Group - sublabile to quartzose sandstone, siltstone, mudstone; minor conglomerate and coal

Terrain Unit	Landform	Soils	Topographic constraint	Excava-tion Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Remarks
Jh0/0-2	Major stream channels including floors, banks, levees and adjacent narrow floodplain areas	Sandstone rock outcrop, boulders and cobbles in some parts; areas of deeper sandy soils (Type 2.2)	H	2-4	H	F4	L	D	Possible but sporadic source of bedding sand; areas of rock occur
Jh4/2-5	Upland gently sloping plateau remnants; some distinctly sloping areas and rolling rises with slopes mostly 3-5%	Shallow sand soils (Type 2.1) with some gravelly areas, overlying weathered sandstone etc (mostly adjacent to escarpments and steeper slopes); areas of moderately deep duplex soils (Type 5.3) consisting of sand or sandy loam over acidic to mildly alkaline sandy clay to light clay	L-M	3	H	W	M (So/D)	C2	Source of bedding sand; areas of moderately dispersive subsoils; high erosion potential; some occurrences of thick sandy surface duplex soils ((Type 5.2) also occur within the unit as mapped
Jh5/5.2	Strongly undulating to distinctly sloping areas, mostly leading away (downslope) from upland plateau remnants; slopes mostly 5-12%	Moderately deep to deep duplex soils consisting of a thick surface layer of sand or sandy loam over acidic to mildly alkaline sandy clay to light clay	L-M	3	H	W	M (So/D)	C1	Source of bedding sand; areas of moderately dispersive subsoils; high erosion potential

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Geological Regime: Je Early-Middle Jurassic Evergreen Formation, Bundamba Group - labile and sublabile sandstone, carbonaceous mudstone, siltstone and minor coal; local oolitic ironstone

Terrain Unit	Landform	Soils	Topographic constraint	Excava-tion Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Remarks
Je0/0-2	Major stream channels including floors, banks, levees and adjacent narrow floodplain areas.	Sandstone rock outcrop, skeletal stony or sandy soils; areas of shallow sand soils (Type 2.1), locally deeper in parts	H	3-4	H	F4	L	D	Possible but sporadic source of bedding sand; areas of rock occur
Je4/2-5	Upland gently sloping plateau remnants, with some distinctly sloping areas and rolling rises; slopes mostly 3-5%	Shallow sand soils (Type 2.1) with some gravelly areas, overlying weathered sandstone etc (mostly adjacent to escarpments and steeper slopes); areas of moderately deep duplex soils (Type 5.3) consisting of sand or sandy loam over acidic to mildly alkaline sandy clay to light clay	L-M	2-3	H	W	M (So/D)	C2	Source of bedding sand; areas of dispersive subsoils; high erosion potential; some areas of thick sandy surface yellow-brown duplex soils occur within the unit as mapped
Je5/2-5	Strongly undulating to distinctly sloping areas, mostly leading away (downslope) from upland plateau remnants; slopes mostly 5-12%	Shallow sand soils (Type 2.1) with some rocky areas (mostly adjacent to escarpments and steeper slopes); areas of moderately deep duplex soils(Type 5.3) consisting of sand or sandy loam over acidic to mildly alkaline sandy clay to light clay	M	2-3	H	W	M (So/D)	C2	Source of bedding sand; areas of dispersive subsoils; high erosion potential; some areas of shallow sandy yellow and red duplex soils (Type 5.1) and also thick sandy surface yellow-brown duplex soils occur within the unit as mapped
Je6/1-5	Isolated low hills and rises; hill slopes; low hilly lands; slopes mostly up to 25%	Shallow stony and sandy soils; areas of duplex soils (Type 5.3) consisting of sand or loam over acidic to mildly alkaline sandy clay to light clay	M	3	H	W	M (So/D)	C3	Areas of dispersive subsoils; high erosion potential
Je8/0-2	Very steep slopes of escarpments and ravines; slopes typically 50-100%	Sandstone rock outcrop with skeletal sandy or stony soils; areas of shallow to moderately deep sand soils (Type 2.1)	H	'3-4	H	X	L	D	Route should avoid unit where possible; heavy rock-breaking equip-ment and/or blasting may be required for rock removal

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Geological Regime: Jp Jurassic Precipice Sandstone (Bundamba Group); thick cross-bedded quartzose sandstone, minor lithic sandstone, siltstone and mudstone

Terrain Unit	Landform	Soils	Topographic constraint	Excava-tion Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Remarks
Jp0/0-2	Major stream channels including floors, banks, levees and adjacent narrow floodplain areas.	Sandstone rock outcrop, skeletal stony or sandy soils; areas of deeper sand soils (Type 2.2).	H	3-4	H	F4	L	D	Possible but sporadic source of bedding sand; areas of rock occur
Jp3/2-6	Undulating, gently inclined erosional lower slopes and colluvial lower footslopes; slopes mostly in the range 1-3%	Shallow to medium deep gravelly sands (Type 2.1) and shallow to medium deep gravelly sand or sandy loamy surface duplex soils (Type 6.1) with dark brown, grey-brown, in places reddish-brown alkaline, sodic sandy clay to medium to heavy clay subsoils	L	2	M-H	W	M (So/D)	C3	Moderately sodic and dispersive clay subsoils underlain by HW sandstone
Jp4/2-5	Broadly rounded, locally near level to gently inclined elongate hill crests with slopes 3-5% on the upper marginal slopes	Shallow to medium deep gravelly sands (Type 2.1) and shallow to medium deep sand or loamy sandy surface duplex soils (Type 5.1) with yellowish-brown, grey-brown or reddish-brown acidic sandy clay or medium to heavy clay subsoils	L-M	'2-3	M-H	W	L-M (So/D)	C2	Some rock outcrop may occur locally; HW sandstone generally encountered between 0.5-0.8m (bgl)
Jp5/2-5	Planar to concave mid to lower hill slopes mostly in the range 5-12%, locally steeper	Shallow to medium deep gravelly sands (Type 2.1) and shallow to medium deep sand or loamy sandy surface duplex soils (Type 5.1) with yellowish-brown, grey-brown or reddish-brown acidic sandy clay or medium to heavy clay subsoils	L-M	2	H	W	L	C2	Some rock outcrop may occur locally; HW sandstone generally encountered between 0.5-0.8m (bgl)
Jp6/0-2	Irregular planar locally benched hill slopes with local low rocky scarps; overall slopes up to 25%, locally steeper on the exposed rocky scarps	Rock outcrop with broken rock cobbles and boulders, with patches of shallow gravelly sand soils (Type 2.1), some shallow gravelly sandy duplex soils may also occur	M	3-4	H	W	L	C2	Heavy rock-breaking equipment and/or blasting may be required for rock removal
Je6/1-5	Isolated low hills and rises, hill slopes and low hilly lands; slopes typically up to 25%	Shallow stony and sandy soils (Type 1); areas of duplex soils (Type 5.1) consisting of sand or loam over acidic to mildly alkaline sandy clay to light clay.	M	2-3	H	W	M (So/D)	C3	Moderately sodic and dispersive clay subsoils underlain by HW sandstone; some rock outcrop may occur locally

Jp9/0-2	Precipitous cliffs and very steep escarpment and ravine slopes typically up to 100% with some near-vertical cliffs	Sandstone rock outcrop with skeletal sandy or stony soils; areas of shallow to moderately deep sand soils (Type 2.1).	H	3-4	H	X	L	D	Route should avoid unit where possible; heavy rock-breaking equipment and/or blasting may be required for rock removal

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Geological Regime: Rm Triassic Moolayember Formation, Mimosa Group - micaceous lithic sandstone, micaceous siltstone

Terrain Unit	Landform	Soils	Topographic constraint	Excava-tion Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Remarks
Rm0/0-2	Major stream channels including floors, banks, levees and adjacent narrow floodplain areas.	Weathered, relatively weak rock outcop areas in floors and banks of streams; areas of predominantly sand soils (Type 2.2)	H	3	H	F4	L	D	Possible but sporadic source of bedding sand; areas of rock occur
Rm2/6-8	Gently sloping erosional plains; very gentle middle and lower slopes of rises and uplands with slopes mostly <2%	Deep duplex soils (Type 6.2) with predominantly alkaline medium to heavy clay subsoils; areas of cracking clay soils (Type 8.2) , typically with self-mulching or crusty surface soil over strongly-structured dark-coloured heavy clay subsoils	L	1-2	M	I	H (R3, So/D)	B	Duplex soils have sodic and dispersive clay subsoils; cracking clays are moderately reactive
Rm3/6-8	Undulating to gently rolling plains and lowlands, broadly rounded low rises; slopes mostly 1-3%	Deep duplex soils (Type 6.2) with predominantly alkaline medium to heavy clay subsoils; areas of cracking clay soils (Type 8.2) , typically with self-mulching or crusty surface soil over strongly-structured dark-coloured heavy clay subsoils	L	1-2	M-H	W-I	H (R3, So/D)	B	Duplex soils have sodic and dispersive clay subsoils; cracking clays are moderately reactive
Rm4/5-7	Gently sloping upland plateau remnants and undulating to distinctly sloping areas; slopes typically 3-7%	Shallow to moderately deep duplex soils (Type 5.1, 5.2) with predominantly acidic to mildly alkaline medium to heavy clay subsoils; areas of mostly shallow uniform non-cracking clay soils (Type 2.1), typically with dark-coloured heavy clay subsoils	L-M	2	H	W	L-M (So/D)	C1	Possibly sodic and dispersive subsoils, susceptible to erosion
Rm5/5-7	Strongly undulating to distinctly sloping hill and ridge slopes; slope angles mostly 5-12%	Shallow to moderately deep duplex soils (Type 5.1, 5.2) with predominantly acidic to mildly alkaline medium to heavy clay subsoils; areas of mostly shallow uniform non-cracking clay soils (Type 7.1) with dark-coloured heavy clay subsoils also occur within the unit as mapped	L-M	2	H	W	L-M (So/D)	C2	Possibly sodic and dispersive subsoils, susceptible to erosion

Rm6/5-1	Isolated low hills and rises; hill slopes; low hilly lands; slopes mostly up to 20%	Shallow stony and sandy soils (Type 1); areas of shallow duplex soils (Type 5.1) consisting of sand or loam over acidic to mildly alkaline sandy clay to light clays	M	2-3	H	W	L	C3	Thin stony and sandy soils are erodible
Rm7/5-1	Steep hill and ridge slopes mostly up to 40%	Shallow stony and sandy soils (Type 1) with some rock outcrop; areas of shallow duplex soils (Type 5.1) consisting of sand or loam over acidic to mildly alkaline sandy clay to light clays	H	3	H	X	L	D	Thin stony and sandy soils are erodible; realtively weak, HW and MW to fresh rock may be encountered within trench depth
Rm8/0-2	Very steep slopes of escarpments and ravines; slopes up to 50%, some >100%	Mostly rock outcrop (sandstone, siltstone, etc) with thin or skeletal stony soils; areas of shallow to moderately deep sand or loam, often gravelly soils (Type 2.1)	H	3-4	M-H	X	L	D	Route should avoid unit where possible; heavy rock-breaking equipment may be required for rock removal

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Geological Regime: Rc Early-Middle Triassic Clematis Group - quartz-rich sandstone, conglomerate, siltstone, mudstone

Terrain Unit	Landform	Soils	Topographic constraint	Excava-tion Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Remarks
Rc4/0-5	Upland gently sloping plateau remnants, distinctly sloping areas and rolling rises; slopes mostly 3-5%	Rock outcrop (sandstone, conglom-erate, siltstone, mudstone) with skeletal sandy or stony soils; areas of shallow duplex soils (Type 5.1) with sandy to loamy surface soils over mostly acidic to neutral sandy clay to medium-heavy clay subsoils	L-M	2-3	M	W-I	L-M (D)	C3	Heavy rock-breaking equipment may be required; moderate erosion susceptibility in distinctly sloping areas, typically occurring at the margins of this terrain
Rc5/1-5	Strongly undulating to distinctly sloping areas, mostly leading away (downslope) from upland plateau remnants; slopes mostly 5-12%	Shallow stony and sandy soils (Type 1) over weathered rock; areas of shallow to moderately deep duplex soils (Type 5.1, 5.2) consisting of sand or loam over acidic to mildly alkaline sandy clay to light clay	M	2-3	M-H	W	L-M (D)	C2	Some areas of stronger rock may require heavy rock-breaking equip-ment; high erosion suscept-ibility in areas with significant slopes
Rc6/1-5	Isolated low hills and rises; hill slopes; low hilly lands; slopes mostly up to 25%	Shallow stony and sandy soils (Type 1); areas of mostly shallow duplex soils (Type 5.1) consisting of sand or loam over acidic to mildly alkaline sandy clay to light clay	M	2-3	H	W	L-M (D)	C3	Some areas of stronger rock may require heavy rock-breaking equipment; erosion susceptibility in steep slopes
Rc7/1-5	Steep hill and ridge slopes mostly up to 40%	Shallow stony soils (Type 1); some areas of shallow duplex soils (Type 5.1) consisting of sand or loam over acidic to mildly alkaline sandy clay to light clay	H	2-3	H	X	L-M (D)	C3	Some areas of stronger rock may require heavy rock-breaking equip-ment; erosion suscept-ibility in steep slopes
Rc8/0-2	Very steep slopes of escarpments and ravines; slopes mostly up to 50%	Rock outcrop (sandstone, conglom-erate, siltstone, mudstone) with skeletal sandy or stony soils; some areas of shallow to moder-ately deep sand soils (Type2.1)	H	3-4	M-H	X	L	D	Route should avoid unit where possible; heavy rock-breaking equip-ment and/or blasting may be required for rock removal

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Geological Regime: Ra Triassic Arcadia Formation, Rewan Group - lithic sandstone and green to reddish brown mudstone and minor conglomerate

Terrain Unit	Landform	Soils	Topographic constraint	Excava-tion Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Remarks
Ra2/5-1	Gently sloping erosional plains; very gentle middle and lower slopes of rises and uplands; slopes mostly <2%	Duplex soils (Type 5.1) with thin sandy to loamy surface soils over mostly acidic to neutral or slightly alkaline sandy clay to medium-heavy clay subsoils; areas of shallow rocky or gravelly soils (Type 1)	L	1-2	M	I	M (So/D)	C1	Some weathered rock may may be encountered within the pipeline trench depth
Ra3/4-5	Undulating to gently rolling plains and lowlands and broadly rounded low rises with slopes mostly <2%	Shallow to moderately deep gradational profiles (Type 4.1) with sandy loam to clay loam surface soils over sandy clay loam to light clay subsoils; areas of duplex soils (Type 5.1, 5.2) with sandy to loamy surface soils over mostly acidic to neutral sandy clay to medium-heavy clay subsoils	L	1-2	M-H	W-I	L-M (So/D)	C1	Areas of suitable topsoil resource; slightly or moderately dispersive clay subsoils
Ra4/1-5	Upland plateau remnants, distinctly sloping areas and rolling rises with slopes mostly in the range 3-5%	Skeletal stony soils (Type 1) and shallow sandy or loamy surface duplex soils (Type 5.1) over acidic to neutral clay subsoils underlain by weathered rock (predominantly sandstone)	L-M	2-3	M-H	W-I	M (So/D)	C2	Some mod. strong bands of little weathered rock may may be encountered within the pipeline trench depth
Ra5/4-5	Strongly undulating to distinctly sloping hill and ridge slopes, mostly in the range 5-12%	Shallow to moderately deep gradational profiles (Type 4.1) with sandy loam to clay loam surface soils over sandy clay loam to light clay subsoils; areas of duplex soils (Type 5.1, 5.2) with sandy to loamy surface soils over mostly acidic to neutral sandy clay to medium-heavy clay subsoils	L-M	1-2	M-H	W	L-M (So/D)	C2	Some areas of suitable topsoil resource; slightly or moderately dispersive clay subsoils
Ra6/1-5	Isolated low hills and rises, hill slopes and low hilly lands; slopes typically up to 25%	Shallow rocky or gravelly soils (Type 1) with sand, silt or clayey soil matrix; areas of shallow to medium deep duplex soils (Types 5.1and 5.3) with sandy to loamy surface soils over mostly acidic to neutral sandy clay to medium-heavy clay subsoils	M	2-3	M-H	W	L-M (So/D)	C3	Some mod. strong bands of little weathered rock may may be encountered within the pipeline trench depth

Ra8/1	Very steep slopes of escarpments and ravines; slopes up to 50%, some >100%	Shallow rocky or gravelly soils with sand, silt or clayey soil matrix, and areas of weathered rock outcrop	H	3-4	M-H	X	L	D	Route should avoid this terrain unit where possible; weathered rock likely to be encountered within the pipeline trench

Appendix A - Terrain Unit Descriptions and Assessment of Engineering/Environmental Constraints for Pipeline Construction

Geological Regime: Pii

Late Permian-Early Triassic Intermediate Intrusive Rock-types:- As mapped includes - Hornblende Diorite; Galloway Plains Igneous Complex; Zig-zag Granodiorite; Craiglands Quartz Monzodiorite;Dumgree Tonolite; Gabbro; Manersley Granodiorite - collectively comprising quartz diorite, tonolite, monzodiorite, gabbro rock facies

Terrain Unit	Landform	Soils	Topographic constraint	Excava-tion Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Remarks
Pii3/5-6	Gently undulating plains and broad low rounded rises; slopes in the range 1-3%	Sandy to loamy surface brown duplex soils (Type 5.3) with acidic sandy clay to medium clay subsoils on rises; sandy to loamy surface bleached duplex soils (Type 6.2) with grey-brown sodic medium to heavy clay subsoils on lower slopes and drainage flats	L	1	M-H	W	M-H (So/D)	C1	Moderately to strongly sodic and dispersive subsoils
Pii4/5.1	Strongly undulating lands and broadly rounded elong-ate low rises; upper marginal slopes in the range 3-5%	Shallow to medium deep loamy surface red duplex soils with acidic to neutral medium clay subsoils	L-M	1-2	M	W	M (So/D)	C2	Slightly to moderately dispersive subsoils
Pii6/4-5	Rolling to low hilly lands with narrow rounded crests on ridges and spurs with slopes in the range 12-25%	Shallow to medium deep sandy to loamy surface red and brown duplex soils (Type 5.1) with acidic to neutral sandy clay subsoils, and brown, red and yellow-brown gradational massive loams and clay loams (Type 4.1) in higher parts	M	1-2	M	W	L	C2	Slightly to moderately dispersive subsoils may be encountered in the subsoil layers of soil Type 5.1
Pii7/3-7	Rolling to steep hilly lands with narrow sharply rounded hill crests and steep irregular planar hill slopes in the range 25-35%, locally steeper	Shallow bleached sands earthy sands and gravelly loam soils (Type 3.1) and shallow stony brown and brownish black uniform structured clay soils (Type 7.1)	H	2-4	M-H	X	L	C3	Some strong rock may be encountered within trench depth
Pii8/0-4	Rolling to steep high hilly lands with narrow sharply rounded hill crests and steep planar hillslopes up to 50%	Shallow to medium deep brown, red or yellow-brown gradational massive gravelly loams and clay loam soils (Type 4.1)	H	2-4	M-H	X	L	C3	Alignment on the lower slopes of high steep hillslope; some strong rock may be encountered within trench depth

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Geological Regime: Pfi

Late Permian-Early Triassic Felsic Intrusives:- As mapped includes - Voewood Granite, Granodiorite, Bocoolima Granodiorite; Galloway Plains Igneous Complex, Rocky Point Granodiorite, Redshirt Granite -Littlemore Suite, Targinie Quartz Monzonite -collectively comprising granite, granodiorite and quartz monzonite rock facies.

Terrain Unit	Landform	Soils	Topographic constraint	Excava-tion Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Remarks
Pfi0/2-3	Drainage channels, stream banks levees and adjacent drainage flats; overall slopes mostly <1%	Stratified alluvial deposits mainly sand and gravelly sand soils (Type 2.2) in channel floors; gradational earthy sand soils (Type 3.2) with sandy light clay or clayey sand subsoils on banks and levees	M	2	H	F4	L	D	Potential source of pipe bedding material
Pfi3/2-5	Undulating plains and lowl-ands with broad low rounded rises; slopes mostly in the range 1-3%	Medium to deep uniform sands and loamy sand soils (Type 2.3) with pale brown, yellowish brown or yellowish red slightly to moderately acidic subsoils; some sandy loamy surface duplex soils (Type 5,2) with yellowish-brown, brown or reddish-brown acidic to neutral or slightly alkaline medium to heavy clay subsoils	L	1	M-H	W	L	C2	Potential source of pipe bedding material
Pfi4/5.1	Undulating lands and rolling rises with upper marginal slopes in the range 3-5%	Shallow to medium deep thick sandy to sandy loamy surface often bleached duplex soils with grey-brown, yellow-brown or reddish-brown moderately acid to neutral sandy clay loam to sandy clay subsoils	L-M	1-2	H	W	M (So/D)	C2	Moderately sodic and dispersive clay subsoils
Pfi5/2-5	Gently to moderately inclined planar to concave lower slopes and moderately inclined dissection slope interfluves with slopes up to 12%	Medium to deep uniform sands and loamy sand soils (Type 2.3) with pale brown, yellowish brown or yellowish red slightly to moderately acidic subsoils; some sandy loamy surface duplex soils (Type 5,2) with yellowish-brown, brown or reddish-brown acidic to slightly alkaline medium to heavy clay subsoils	L-M	1-2	H	W	M (So/D)	C2	Moderately sodic and dispersive clay subsoils
Pfi5/4.2	Gently to moderately inclined planar to concave lower slopes and valley footslopes with slopes in the range 5-12%	Medium deep brown, red-brown and yellow-brown gradational massive loams and clay loams	L-M	1-2	M	W	L	C2	Minor occurrence within the pipeline corridor

Pfi6/0-2	Low hilly lands with narrow sharply rounded crests of low hills, ridges and spurs with slopes mostly in the range 12-25%	Rock outcrop and shallow gritty sand to loamy sand soils (Type2.1) over HW rock; some sandy surface duplex soils (Type 5.1) may occur in lower parts	M	2-3	M	W	L	C2	Possible sources of sand for pipe padding material may occur within the unit
Pfi8/0-2	Steep high hilly lands and dissected escarpment slopes 50-100% , locally sub-vertical rocky scarps	Rock outcrop and shallow bleached sands and stony and gritty brown and black sand to loamy sand soils (Type2.1) over HW rock; some sandy surface duplex soils (Type 5.1) may occur in lower parts	H	2-4	H	X	L	D	Some shallow sandy surface duplex soils may occur in lower parts
Pfi8/0-4	Steep high hilly lands and rocky scarp slopes, up to 50-100%, locally steeper on rocky scarps	Rock outcrop and shallow brown red-brown and yellow-brown massive gradational loams and clay loam soils (Type 4,1)	H	2-4	M-H	X	L	C3	Minor occurrence within the pipeline corridor

Appendix A - Terrain Unit Descriptions and Assessment of Engineering/Environmental Constraints for Pipeline Construction

Geological Regime: Ps

Permian Sediments - Clastic sediments:- as mapped includes:- Blackwater Group; Back Creek Group - comprising sandstone, siltstone, shale, mudstone , tuff and conglomerate; Lakes Creek Formation and Berserker Beds - siltstone and lithic and lithofeldspathic sandstone.

Terrain Unit	Landform	Soils	Topographic Constraint	Excava-tion Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Remarks
Ps0/1-6	Tributary streamlines, with narrow channels (10-20 m), banks and levees, and locally depressional drainageways	Stratified alluvium, cobbles, gravel, sand and silt soils (Type 1) in channel floors; thin silt loamy surface duplex soils (Type 6.2) In banks, on levees and in drainage floors	M	2	H	F4	M-H (So/D)	D	Some cracking clay soils may be present locally in drainage floors
Ps2/5-8	Gently undulating and gently inclined erosional and colluvial plains and lower slopes to drainage; slopes mostly <2%	Medium to deep sandy, sandy loam surface or clay loamy surface duplex soils (Type 5.3) with yellow-brown or brown acidic to neutral medium to heavy clay subsoils on higher parts; with medium deep cracking clay soils (Type 8.2) with dark brown or grey-brown alkaline medium to heavy clay subsoils	L	1-2	M	I	M (R2, So/D)	C1	The cracking clay soils tend to occur in narrow strike-controlled belts in association with the sandy to loamy surface duplex soils; locally moderately severe surface sheet erosion is evident
Ps3/6.2	Undulating plains and gently inclined broad low interfluves; slopes mostly in the range 1-3%	Medium to deep silt loam to clay loamy surface bleached brown or grey-brown duplex soil with alkaline sodic medium heavy clay subsoils	L	1-2	M-H	W-I	M-H (So/D)	C2	Hardset silty surface, marginally suitable as topsoil resource; sodic and dispersive subsoils
Ps3/7-8	Undulating plains and broad low rounded rises; slopes mostly in the range 1-3% locally steeper on marginal slopes of rises	Shallow to medium deep uniform gravelly light to medium acid to neutral clay soils (Type 7.1) on rises; mostly shallow gravelly (HW rock); cracking clay soils (Type 8.1) on lower slopes	L	1-2	H	W	L	C1	Some rock outcrop; mostly underlain by HW rock (<0.5 m); moderately severe surface sheet erosion on higher parts
Ps4/7.1	Undulating plains and low rounded rises with slopes mostly in the range 3-5%	Shallow to medium deep gravelly uniform light to medium alkaline clay soils, some shallow rocky soils on higher parts of slopes	L-M	2-3	M	W	L	C2	Moderately severe surface sheet erosion

Ps4/4-8	Undulating plains with broad low rises and gently to moderately inclined broadly rounded dissection slope interfluves; slopes mostly in the range 3-5%, locally steeper on marginal slopes of rises	Deep gradational loamy surface red earth soils (Type 4.2) with clay loam to light clayey subsoils often with lateritic gravel included on mid to lower parts of interfluves; medium to deep cracking clay soils (Type 8.2) with dark brown or grey-brown alkaline medium to heavy clay sub-soils on the lower slopes	L-M	1-2	M-H	W	M (R2)	B	Coarse billy gravel may occur in places; the cracking clay soils may occur in strike-controlled belts
Ps5/6.2	Undulating, gently to moderately inclined footslopes and fans; slopes in the range 5-12%	Medium to deep silt loam to clay loamy surface bleached brown or grey-brown duplex soil with alkaline sodic medium heavy clay subsoils	L-M	1-2	M-H	W	M-H (So/D)	C2	Sodic and dispersive clay subsoils
Ps5/7-8	Gently to moderately inclined dissection slope interfluves and erosional lower slopes to drainage; slopes within the range 3-12%	Shallow to medium deep uniform gravelly light to medium acid to neutral clay soils (Type 7.1) on rises; medium to deep cracking clay soils (Type 8.2) with dark grey-brown or dark brown medium to heavy alkaline clay subsoils becoming acidic in the deeper subsoils occur on the lower slopes	L-M	1-2	M	W	M (R1-R2)	C1	A surface strew of billy gravel may occur in places; the cracking clays have thin self-mulching surface soils
Ps6/3-7	Rolling to low rounded hilly lands with planar to concave hill slopes in the range 12-25%	Shallow to medium gravelly sands or earthy sand soils (Type 3.1) and shallow uniform brown and brownish black stony structured clay (Type 7.1) or gradational clay loams over structured light to medium clay subsoils	M	2	M	W	L	C3	HW rock is usually encountered at about 0.5-0.8m (bgl)
Ps7/3-7	Rolling to steep low hilly to hilly lands with slopes mostly in the range 25-40%, locally steeper	Shallow gravelly sands or earthy sand soils (Type 3.1) and shallow uniform brown and brownish black stony structured clay (Type 7.1) or gradational clay loam over structured light to medium clay subsoils	H	2-4	M-H	X	L	C3	HW rock is usually encountered at about 0.4-0.6m (bgl)

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Geological Regime: Pv

Permian Volcanics - Intermediate extrusive/intrusive rocks; as mapped includes:- Inverness Volcanics - trachyte to dacite , volcanic breccia;- Chalmers Formation (Berserker Group) - rhyolitic to andesitic volcaniclastic breccia, siltstone and lithic sandstone; Camboon Volcanics (Back Creek Group) - andesite, basalt, dacite rhyolitic flows; Smoky Beds - andesitic conglomerate and sandstone; Youlambie Conglomerate - polymictic conglomerate, volcaniclastic sandstone, dacitic to rhyolitic ignimbrite.

Terrain Unit	Landform	Soils	Topographic constraint	Excava-tion Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Remarks
Pv0/7	Tributary stream channels and drainage lines with narrow alluvial flats adjacent	Layered alluvial soils (Type 7.2) with medium-textured clay loam surface soils over fine-textured silty clay or medium clay subsoils in banks and on slopes to drainage	H	2-3	M	F4	L	D	Stratified alluvial soils, rock cobbles, gravel and sand in channel floors
Pv0/6	Mostly narrow tributary drainage lines with low stream banks, narrow levees and alluvial drainage flats	Medium to deep thin silt loam or fine sandy loamy surface duplex soils (Type 6.2) with alkaline medium to heavy clay subsoils	M	2	H	f4	H (So/D)	D	Hard setting silt loamy surface soils, moderately sodic and dispersive clay subsoils
Pv4/1-4	Crestal areas and upper marginal slopes on low ridges and elongate low hills; slopes 3-5 % on the steeper margins	Shallow rocky soils (Type 1.1), with a clay loam or light to medium clay matrix, shallow gravelly uniform or gradational medium-textured soils (Type 4.1) with alkaline subsoils	L-M	2-3	M	W	L	C3	Shallow rocky soils with rock outcrop common
Pv4/6-8	Strongly undulating to low rolling rises with slopes mostly in the range 3-5%	Medium deep cracking clay soils (Type 8.2) with self-mulching surface soils and dark grey-brown to black alkaline medium to heavy clay subsoils; medium deep thin loamy surface duplex soils (Type 6.2) with alkaline sodic clay sub-soils on lower colluvial slopes	L-M	2	M	W	M (R2, So/D)	C2	Weathered basalt or other volcanic rocks generally encountered below about 0.8-1.0m
Pv5/6.1	Broadly rounded dissection slope interfluves and erosional lower slopes mostly in the range (5-12%)	Shallow to medium deep thin silt loam or fine sandy loamy surface often gravelly duplex soils with alkaline medium to heavy clay subsoils	L-M	2-3	M-H	W	M (So/D)	C3	Moderately sodic and dispersive clay subsoils
Pv6/4.1	Rolling rises and low hilly lands with broadly rounded hill and planar marginal slopes in the range 12-25%	Shallow (<0.5m) stony brown and black massive loams and clay loams underlain by HW rock	M	2-3	M	W	L	C2	Some rock outcrop may occur

Pv6/5-7	Strongly undulating to low rolling hilly lands with rounded crestal areas and marginal slopes in the range 7-12% and planar to concave hill slopes locally up to 25%	Shallow gravelly uniform clays or gradational clay loam over gravelly clay soils(Type 7.1) on upper slopes with some shallow sandy or loamy surface duplex soils (Type 5.1) with reddish-brown or brown acidic to neutral or slightly alkaline gravelly light to medium clay subsoils	M	2-3	M	W	L	C2	Bedrock usually occurs at depths of about 0.6m or less
Pv7/0-4	Steep dissected hilly lands with narrow rounded hill and ridge crest and planar to concave hill slopes up to 50%, mostly 20-30%	Rock outcrop and cobble-strewn surfaces with some areas of skeletal to shallow gravelly alkaline clay loam to light clay soils (Type 4.1)	H	2-4	M-H	X	L	C3	Moderately severe sheet erosion on upper marginal slopes
Pv7/4-7	Steep dissected hilly lands with narrow rounded hill and ridge crest and planar to concave hill slopes up to 50%, mostly 20-30%	Shallow stony brown and black massive loamy soils (Type 4.1) and shallow stony dark brown or brown strructured uniform clay soils (Type 7.1) or clay loam grading to light to medium gravelly clay subsoils	H	2-4	M	X	L	C3	Some occurrences of rock outcrop; moderately severe surface sheet erosion is occurring
Pv8/0-4	Steep high hilly to mountainous lands withnarrow sharply rounded crestal areas and hill and ridge slopes in the range 30->50%, locally with sub-vertical rocky scarps	Rock outcrop and cobble-strewn surfaces with some areas of skeletal to shallow gravelly alkaline clay loam to light clay soils (Type 4.1)	H	2-4	M-H	X	L	C3	Bedrock usually occurs at depths of about 0.6m or less

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Geological Regime: Ct

Carboniferous Torsdale Volcanics - dacitic to rhyolitic ignimbrite, volcaniclastic rocks and lava, subordinate andesitic rocks andvolcanilithic conglomerate and sandstone.

Terrain Unit	Landform	Soils	Topographic constraint	Excava-tion Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Remarks
Ct0/1-6	Tributary streamlines,with narrow channels (10-15m wide, 3-5m deep), channel banks, levees and locally depressional drainageways	Deep thin silt loamy or fine sandy loam surface duplex soils (Type 6.2) with medium to heavy clay subsoils in banks and on drainage flats; stratified coarse-textured alluvium (Type 1) (silt, sand, gravel and rock cobbles) in channel floors	M	2	M-H	F4	M (R1, So/D)	D	Moderately sodic and dispersive clay subsoils
Ct7/5-7	Low hilly to hilly lands, with broadly rounded crestal areas and moderately steep to steep planar to concave moderately dissected hill slopes up to 35%	Shallow to medium deep sandy to loamy surface duplex soils (Type 5.1) with acidic to mildly alkaline brown to reddish brown gravelly sandy clay to heavy clay subsoils on crests and upper slopes; shallow gravelly uniform structured clay soils (Type 7.1) or gradational clay loam over gravelly structured clay subsoils underlain by HW rock	H	2-3	M-H	W	L-M (D)	C2	Slightly dispersive clay subsoils; some medium deep cracking clay soils (Type 8.2) with pebbles and cobble patches may be encountered on the gentler lower slope approaches to erosion gullies

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Geological Regime: Cr Carboniferous Rockhampton Group:- mudstone, siltstone, volcaniclastic sandstone, polymictic conglomerate, oolitic limestone.

Terrain Unit	Landform	Soils	Topographic constraint	Excava-tion Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Remarks
Cr4/4-6	Undulating plains and rolling rises with slopes mostly in the range 3-5%	Shallow uniform or gradational brown and black gravelly loams and clay loam soils (Type 4.1) in higher areas; sandy to loamy surface bleached brown and grey alkaline sodic duplex soils (Type 6.1) in lower parts	L-M	1-2	M-H	W	M (So/D)	C2	Shallow sodic and dispersive subsoils
Cr6/4-6	Rolling to low hilly lands with broadly rounded crestal areas and upper marginal slopes, with planar to concave mid to lower hill slopes in the range 12-25%	Shallow uniform or gradational brown and black gravelly loams and clay loam soils (Type 4.1) in higher areas; sandy to loamy surface bleached brown and grey alkaline sodic duplex soils (Type 6.1) in lower parts	M	3-4	M-H	W	M (So/D)	C2	Some strong rock may be encountered within the pipeline trench depth which may require some drilling and blasting for rock removal
Cr7/3-7	Rolling to steep hilly lands with irregular planar moderately intensively dissected hill slopes in the range 12 to 30%, locally steeper in erosion gullies	Shallow uniform or gradational bleached sands, clayey sands and sandy loam soils (Type 3.1) and shallow stony brown and black uniform structured clay soils (Type 7.1) and gradational gravelly clay loam over structured clay subsoils	H	3-4	M-H	X	L	C3	Strong rock is likely to be encountered within the pipeline trench depth which may require some drilling and blasting for rock removal

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Geological Regime: Cw Carboniferous Wandilla Formation:- mudstone, lithic sandstone, greywacke, siltstone jasper, chert, slate and schist

Terrain Unit	Landform	Soils	Topographic constraint	Excava-tion Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Remarks
Cw3/5-7	Undulating plains and lowlands, undulating valley floors; slopes 1-3%	Medium to deep gravelly clay loam and silt loamy surface duplex soils (Type 5.3) with medium to heavy acidic sodic clay subsoils; medium to deep gradational gravelly clay loam over acidic structured clay subsoils (Type 7.3) on lower slopes	L	1-2	L-M	W	M (R1)	C1	Surficial soil horizons contain 40-60% fine to coarse gravel and stone
Cw4/4-7	Undulating plains dissection slope interfluves, low rises and locally low saddles between higher hilly lands; slopes in the range 3-5%	Shallow (<0.5m) uniform gravelly clay soils (Type 4.1), with friable to granular brown gravelly clay loam surface soils over gravelly loam-loamy gravel subsoils on mid to lower slopes; shallow uniform gravelly clay soils (Type 7.1) with red-brown or yellow-brown medium to heavy clay or gravelly clay subsoils on rises and low saddles	L-M	1-2	L-M	W	L	C1	Surficial soil horizons contain 40-60% fine to coarse gravel and stone
Cw5/5-7	Gently to moderately inclined planar to concave intermediate and lower hill and ridge slopes and dissection slope interfluves; slopes variable 5-12%	Medium to deep gravelly clay loam and silt loamy surface duplex soils (Type 5.3) with medium to heavy acidic sodic clay subsoils; medium to deep gradational gravelly clay loam over acidic structured clay subsoils (Type 7.3) on lower slopes	L-M	1-2	M-H	W-I	M (R1)	C2	Surficial soil horizons contain 40-60% fine to coarse gravel and stone; in some lower-lying areas the silt loamy surface duplex soils (Type 5.1) may be strongly sodic, disper-sive and moderately saline in the heavy clay subsoils
Cw6/5.3	Low rounded hills and rises and strongly undulating to low hilly lands, mostly with broadly rounded crestal areas and hill slopes mostly in the range 12-25%	Medium to deep (0.5-1.0 m+) dark brown gravelly clay loamy surface duplex soil with a pale or bleached gravelly loam or gravelly clay (A2) horizon over red, red-brown, yellow-brown and pale grey variegated medium to heavy acidic clay subsoils	M	1-2	M-H	W	M (So/D)	C2	Surficial soil horizons contain 40-60% fine to coarse gravel and stone; the HW rock substrate may be dispersive

Cw6/7.2	Rolling to low hilly lands with broadly rounded crestal areas and long irregular planar mid to lower slopes in the range 12-25%	Shallow to medium deep gradational gravelly red clay loam over structured clay subsoils or gravelly uniform structured clay soils	M	1-2	M	W	L (R1) (Locally)	A-C2	Mostly Land Class C2, some lower more gently sloping parts along the pipeline right-of-way comprise Land Class A
Cw7/4-7	Steep hilly lands with narrow rounded hill and ridge crests and steep irregular planar slopes 20-40%	Shallow (<0.5m) uniform gravelly clay soils (Type 4.1), with friable to granular brown gravelly clay loam surface soils over gravelly loam-loamy gravel subsoils on crests and upper slopes; shallow to medium deep uniform gravelly clay soils (Type 7.1) with red-brown or yellow-brown medium to heavy clay or gravelly clay subsoils on mid to lower slopes.	H	2	M-H	X	L	C3	Surficial soil horizons contain 40-60% fine to coarse gravel and stone; the clayey fines and deeper clay subsoils may be moderately sodic and dispersive
Cw8/7.1	Steep to very steep ridges and higher hilly lands, with narrow rounded crests on ridges and spurs and hill slopes mostly in the range 30-50%, locally steeper	Shallow to medium deep (0.5-0.8 m) gradational or uniform gravelly fine-textured soils with dark brown gravelly clay loam or gravelly loam surface soils, in places with a paler (A2) subsurface horizon over yellow-ish red to red fine structured heavy clay subsoils underlain by HW rock.	H	2	M-H	X	M (So/D) (deeper subsoil)	D	Sodic, moderately dispersive and strongly magnesic in the (B-C) horizon

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Geological Regime: Dcs

Late Devonian - Early Carboniferous Intermediate Extrusives and Volcaniclastic Sediments:- As mapped includes - Mount Alma Formation; Three Moon Conglomerate; Yarwun Beds; Doonside Formation, Curtis Island Group; Balnagowan Volcanic Member; collectively comprising andesitic to basaltic volcaniclastic rocks, altered basalt, sandstone, siltstone and conglomerate, chert, mudstone and limestone

Terrain Unit	Landform	Soils	Topographic constraint	Excava-tion Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Remarks
Dcs0/4-7	Tributary drainage channels, banks, narrow levees, slopes to drainage and drainage flats; overall slopes <2%	Layered coarse to medium-textured soils (Type 4.3) in stream terraces and in low banks; gradational fine-textured soils (Type 7.2) with clay loam surface soils ove dark brown or brown light to medium clay sub-soils forming stream banks and terraced slopes to drainage	M	2	M	F4	L	D	Some cracking clay soils may occur on flats adjacent to drainage lines
Dcs3/6.2	Undulating narrow valley floors and gently inclined planar to concave lower slopes in the range 1-3%	Sandy and loamy surface duplex soils with a bleached (A2) sub-surface horizon over brown and grey alkaline sodic medium to heavy clay subsoils	L	1	H	W-I	H (So/D)	C2	Moderate to highly sodic and dispersive clay subsoils
Dcs4/1-4	Broadly rounded crestal areas and upper marginal slopes (3-5%)	Very shallow (<0.3 m) rocky soils (Type 1) and shallow uniform gravelly loam soils (Type 4.1) with high amounts of HW to fresh angular rocky fragments included	L-M	3-4	M	W-I	L	C3	Some strong rock may occur that requires heavy rock-breaking equipment or drilling and blasting for removal
Dcs4/5-6	Strongly undulating plains and broad low rises with slopes in the range 3-5%	Shallow to medium deep sandy and loamy surface brown and brownish-black acidic duplex soils (Type 5.1) on higher parts, with medium to deep fine sandy and loamy surface duplex soils (Type 6.2) with a bleached (A2) sub-surface horizon over brown and grey alkaline sodic medium to heavy clay subsoils on mid to lower slopes	L-M	,2-3	H	W-I	H (So/D)	C2	Moderate to highly sodic and dispersive clay subsoils
Dcs5/6.1	Gently to moderately inclined lower erosional and colluvial slopes and broadly rounded dissection slope interfluves with slopes in the range 5-12%	Shallow to medium deep thin sandy clay loam to clay loam surface duplex soils with brown or reddish-brown medium to heavy alkaline sodic clay subsoils	L-M	2-3	M-H	W-I	M-H (So/D)	C2	Moderate to highly sodic and dispersive clay subsoils

Dcs6/4-7	Rolling low hills ridges and spurs with rounded crestal areas and planar to concave mid to lower slopes mostly in the range 12-25%	Shallow bleached sandy loam to loam soils (Type 4.1) and shallow to medium deep stony brown and brownish black gradational clay loam over structured clay subsoils or stony uniform structured clays	M	2-3	M-H	W-I	L	C2	Locally moderately severe sheet and gully erosion evident on mid to lower slopes
Dcs7/0-4	Steep moderately intensively dissected hilly lands with rounded crestal areas and upper marginal slopes and planar to concave mid to lower hill slopes; slopes generally 12-25%, increasing to 25-40% on the mid to higher parts of slopes	Rock outcrop and very shallow rocky soils together with stony sandy loam or stony loam soils (Type 4.1) in parts	H	2-4	M-H	X	L	C3	Moderate sheet erosion is evident on upper marginal slopes
Dcs7/4.1	Intensively dissected steep hilly lands with sharply rounded crests and variably steep irregular planar slopes 25-40%	Shallow stony brown and black uniform massive loams and clay loams and shallow gradational red and brown structured clay loams underlain by HW rock	H	2-4	M-H	X	M-H (Sa)	C3	Some saline outbreaks on lower slopes to drainage gullies
Dcs8/0-7	Steep high hilly to mountainous lands with narrow sharply rounded hill and ridge crests and steep to very steep irregular planar slopes typically 30-50%, frequently >50%	Shallow stony red, brown and black uniform structured clay soils (Type 7.1) and gravelly and stony gradational clay loams over structured clay subsoils underlain by HW rock	H	2-4	M-H	X	M (So/D)	C3	Moderately sodic and dispersive clay subsoils

Appendix A - Terrain Unit Descriptions and Assessment of Engineering/Environmental Constraints for Pipeline Construction

Geological Regime: Sf Silurian-Devonian Volcaniclastic Rocks:- As mapped includes - Erebus Beds and Mount Holly Beds; collectively comprising dacitic to rhyolitic and basaltic to andesitic volcaniclastic sandstone and conglomerate, with minor siltstone and fossiliferous limestone.

Terrain Unit	Landform	Soils	Topographic constraint	Excava-tion Rating	Erosion Potential	Drainage Status	Problem Soils	Ag Land Class	Remarks
Sf3/7.1	Gently undulating plains and lower valley footslopes; slope range mostly 1-3%	Shallow to medium deep gradational clay loamy surface soils over red and brown structured medium clay subsoils	L	2	H	W-I	H (Sa)	C2	Saline outbreaks on lower slopes and on drainage flats; severe sheet eroded and scalded areas evident
Sf4/4.3	Undulating plains and low rounded rises; slopes mostly in the range 3-5%	Shallow to medium deep gradational gravelly loamy surface soils over red and brown structured clay loam to light clayey subsoils	L-M	2	H	W	H (Sa)	C2	Saline outbreaks on lower slopes and on drainage flats; severe sheet eroded and scalded areas evident
Sf6/4-7	Strongly undulating to low hilly lands with rounded rises; slopes in the range 12-15%, locally up to 25%	Shallow uniform brown and black stony loams and clay loam soils (Type 4.1) and shallow gradational clay loam over red and brown structured light to medium clay subsoils (Type 7.1)	M	2-3	H	W	M-H (Sa)	C2	Saline outbreaks on lower slopes and on approaches to drainage gullies; sheet eroded and scalded areas evident on lower slopes
Sf7/4.1	Dissected hilly lands with narrow rounded ridge and hill crests and upper marginal slopes and steep irregular planar hill slopes 25-50%	Shallow uniform brown and black stony loams and clay loam soils underlain by weathered rock	H	2-4	M-H	X	M (Sa)	C3	Saline outbreaks on lower slopes and in drainage gullies; some heavy rock breaking or drilling and blasting may be required for rock removal

Erosion and Soil Attributes

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:

Erodibility Class	Description
Low	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	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 No's. 3 or 5) or aggregated slightly dispersive clay surface and/or subsoils;
High	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 No's. 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 the process of backfilling and compaction of the trench material and prior to the replacement of a suitable thickness of topsoil material,(normally 100-150 mm thickness), a crown will be developed to allow for settlement of the trench backfill. If necessary after settlement of the trench backfill some topping up of the trench may be necessary in places. Where possible local topsoil resources should be used for this purpose.

- 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

The following erosion control measures may be and are typically used to minimise the potential impact of erosion and to control sediment loss from disturbed areas:

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

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

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.