7.3 Land

7.3.1 Topography, Geomorphology, Geology and Soils

7.3.1.1 Introduction

The following section describes the existing topography, geomorphology, geology and soils of the gas transmission pipeline corridor, provides the results of the impact assessment undertaken and proposes a series of mitigation measures to minimise the impact of pipeline development activities on soils and terrain related environmental values.

Reference should be made to the more detailed information provided in Appendix L2.

7.3.1.2 Methodology

The terrain of the gas transmission pipeline corridor has been assessed in terms of geological regimes, landform types and associated soils. The corridor assessed comprised an area of 1 km each side of the identified gas transmission pipeline centreline. Terrain mapping has been carried out with reference to existing geological, topographic and soils information. This information was compiled using the background data sources (refer to Appendix L2), 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 relation to kilometre points (Kp's), where the start point (Kp 0) is approximately 2 km to the south of Hutton Creek in the Fairview CSG field and the end point (Kp 429) is at the proposed LNG facility site on Curtis Island.

The terrain analysis undertaken for the gas transmission pipeline corridor has essentially involved a preliminary desktop assessment of terrain conditions along the gas transmission pipeline corridor as a means of identifying areas of potential high engineering/geological constraints for gas transmission pipeline construction, as well as areas of potentially high environmental impact that may result from construction of the gas transmission pipeline in particular locations. The fieldwork undertaken was confined to the final sector of the pipeline route that terminates at the LNG facility on Curtis Island. Fieldwork involving drilling and soil sampling operations were undertaken as part of an acid sulfate soils (ASS) 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 gas transmission pipeline and associated facilities; in particular in those areas identified in this study as potential "high constraint" areas, to determine appropriate construction and management strategies. These investigations shall be included in the environmental management plan (EMP) that will be developed by Santos prior to pipeline construction commencing.

Agricultural Land

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

7.3.1.3 Regulatory Framework

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

7.3.1.4 Existing Environmental Values

Topography and Geomorphology

The gas transmission pipeline corridor shown on Figures 7.3.1 to 7.3.5, 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 are 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 gas transmission pipeline corridor in the vicinity of Kp 3 km, Kp 26 km and Kp 39 km respectively. The gas transmission 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 gas transmission pipeline 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 and areas of medium to heavy clays, form a discontinuous gently to moderately sloping transition to the dissected foot slopes 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.

At approximately Kp 136 km, the pipeline corridor changes direction to the east and commences a gradual ascent 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 Australian Height Datum (AHD). The gas transmission 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 Cooper 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 gas transmission pipeline corridor traverses undulating plains underlain by Tertiary sediments and gently to moderately inclined foot slopes 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 potential 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 foot slopes 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).

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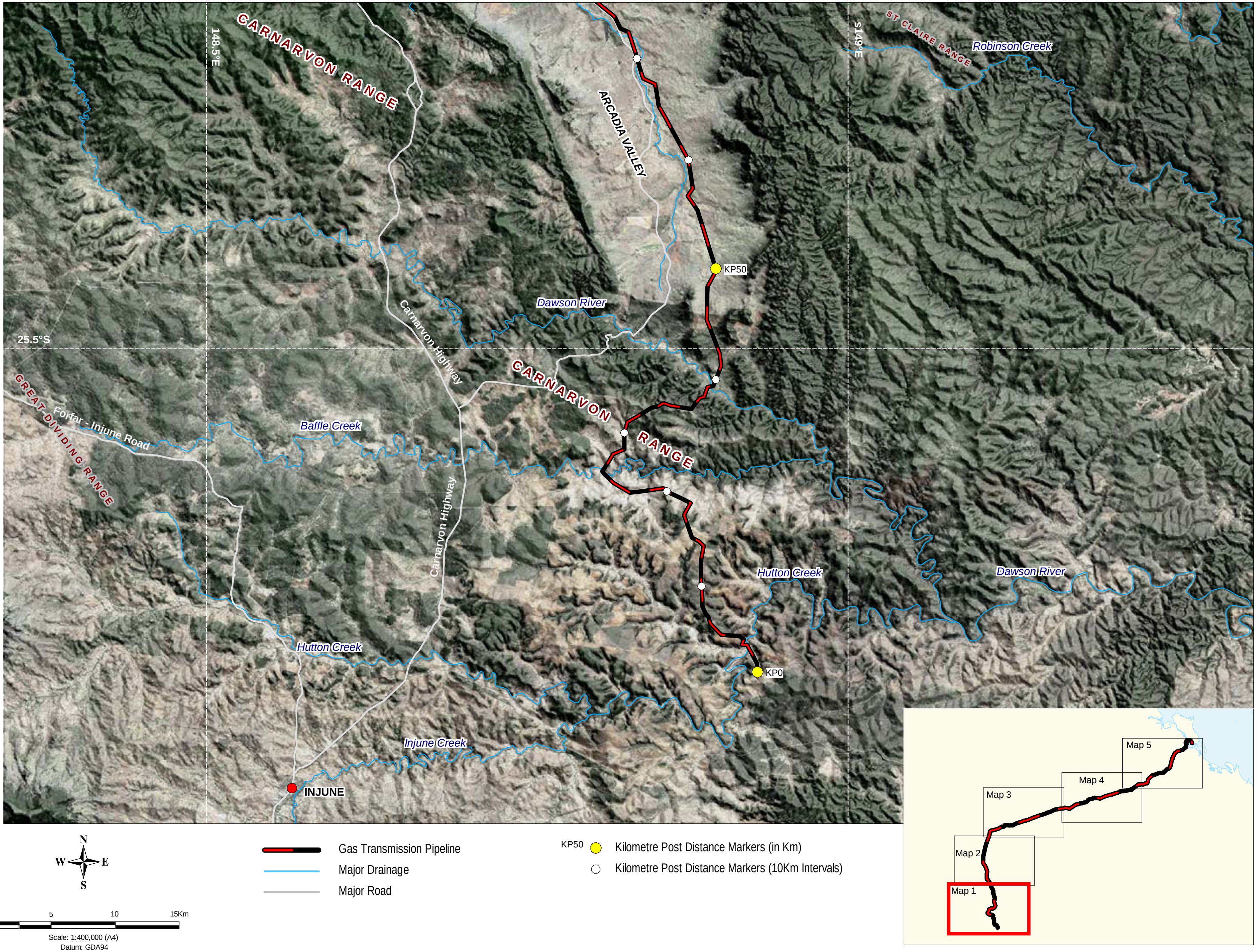

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GLADSTONE LNG PROJECT
ENVIRONMENTAL IMPACT STATEMENT

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Job No: **4262 6220** | File No: 42626220-g-911.wor

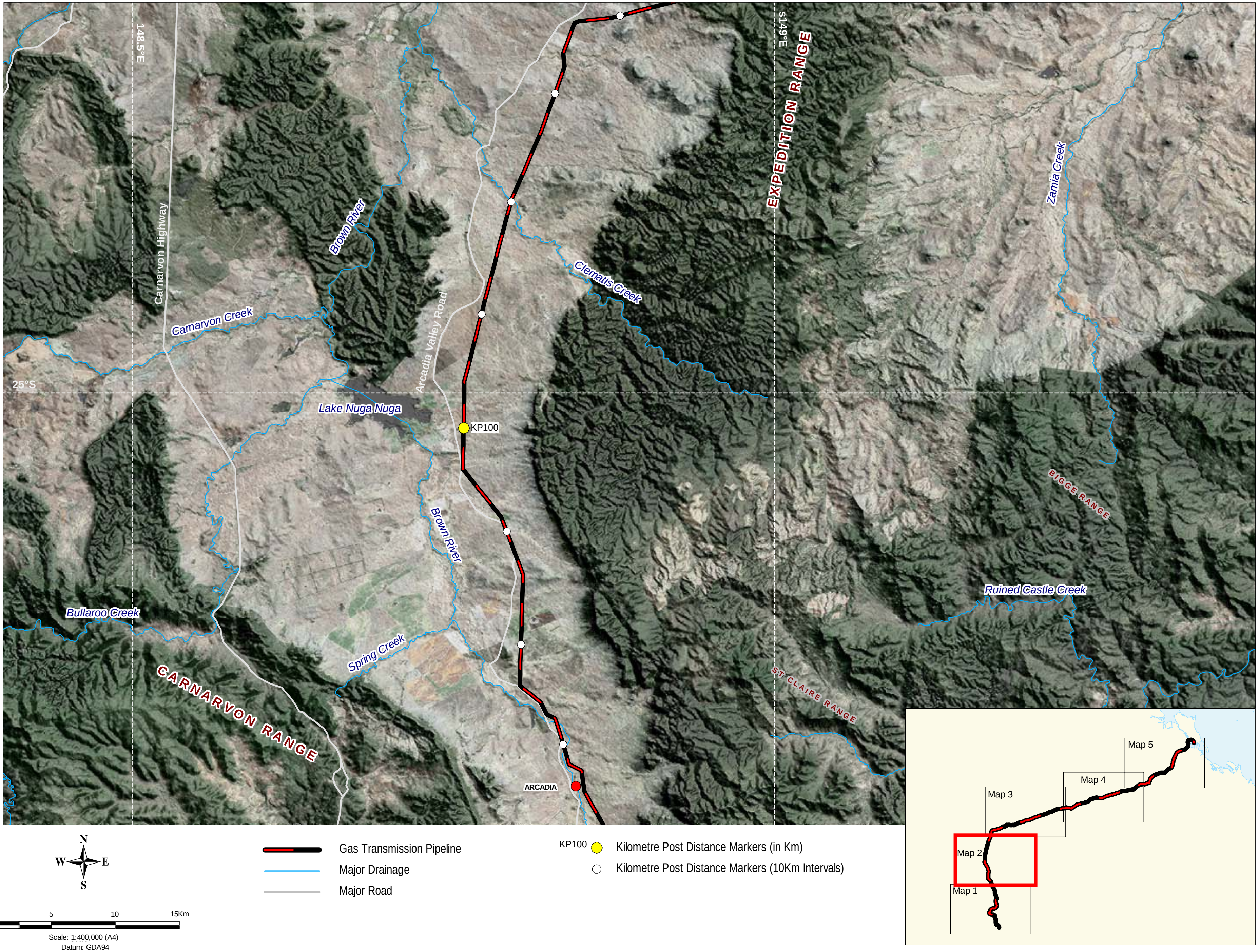
Title

GAS TRANSMISSION PIPELINE ALIGNMENT TOPOGRAPHY (MAP 1 OF 5)

Figure: **7.3.1**

Rev: A

A4



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Title

GAS TRANSMISSION
PIPELINE ALIGNMENT
TOPOGRAPHY
(MAP 2 OF 5)

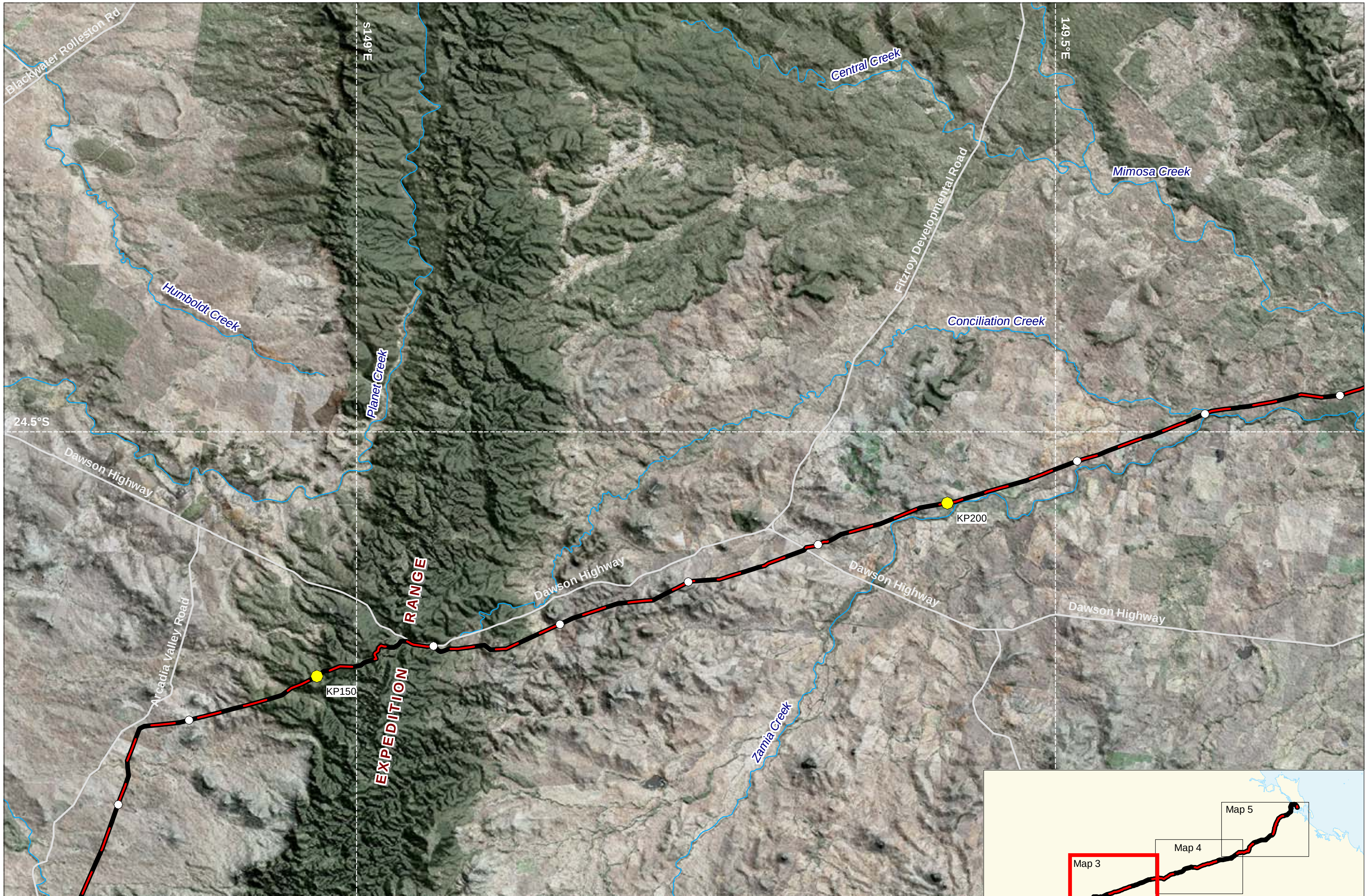
Drawn: CA | Approved: JB | Date: 13-05-2009

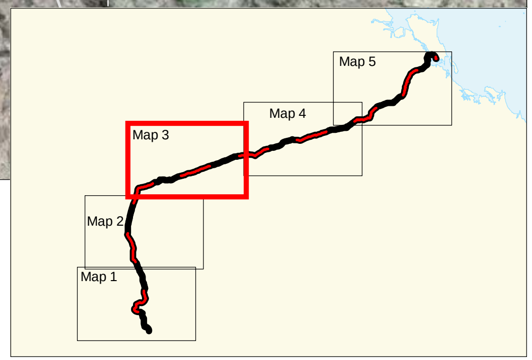
Job No: 4262 6220 | File No: 42626220-g-912.wor

Figure: 7.3.2

Rev: A

A4





N
W E
S

0 5 10 15Km

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

Gas Transmission Pipeline
Major Drainage
Major Road
KP200 Kilometre Post Distance Markers (in Km)
Kilometre Post Distance Markers (10Km Intervals)

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File No: 42626220-g-913.wor

Title
GAS TRANSMISSION PIPELINE ALIGNMENT TOPOGRAPHY (MAP 3 OF 5)

Figure: **7.3.3**

Rev: A

A4

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File No: 42626220-g-914.wor

Title
GAS TRANSMISSION PIPELINE ALIGNMENT TOPOGRAPHY (MAP 4 OF 5)

Figure: **7.3.4**
Rev: A
A4

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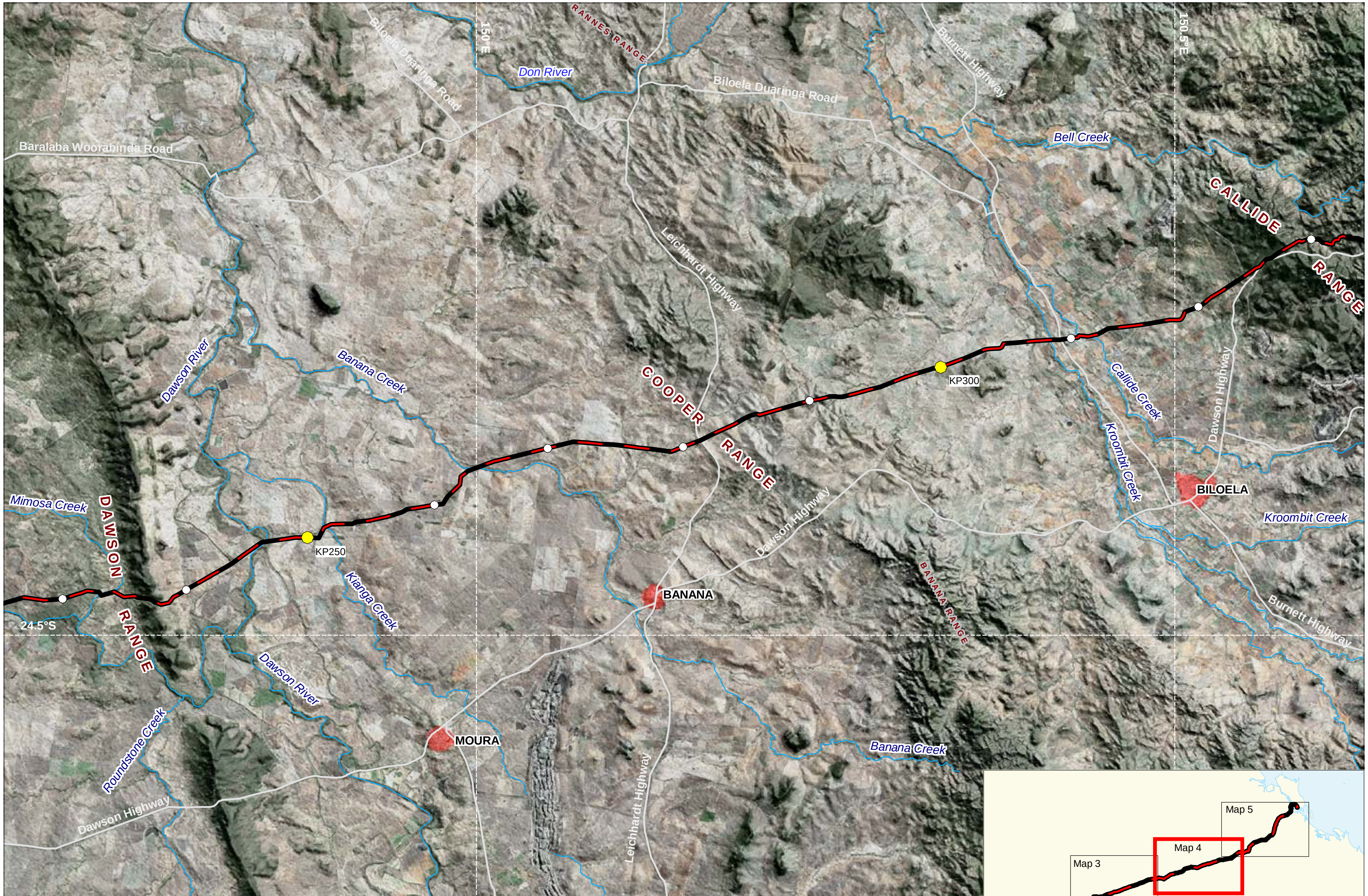
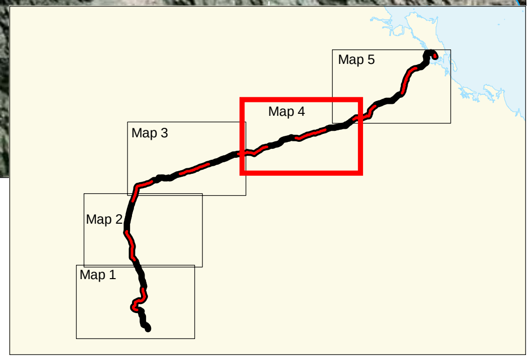


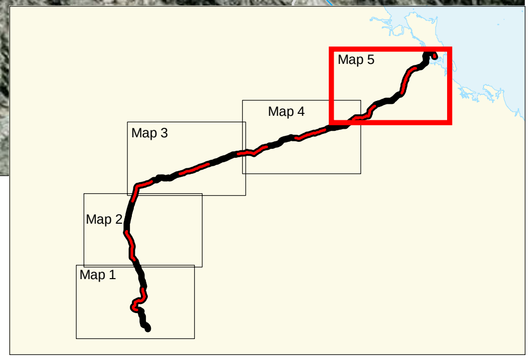


N
W E
S

Gas Transmission Pipeline
Major Drainage
Major Road

KP300 Kilometre Post Distance Markers (in Km)
Kilometre Post Distance Markers (10Km Intervals)

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



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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Job No: 4262 6220 | File No: 42626220-g-915.wor

Title

GAS TRANSMISSION PIPELINE ALIGNMENT TOPOGRAPHY (MAP 5 of 5)

Figure: **7.3.5**

Rev: A

A4

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 potential 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 gas transmission 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.

Terrain Units

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.

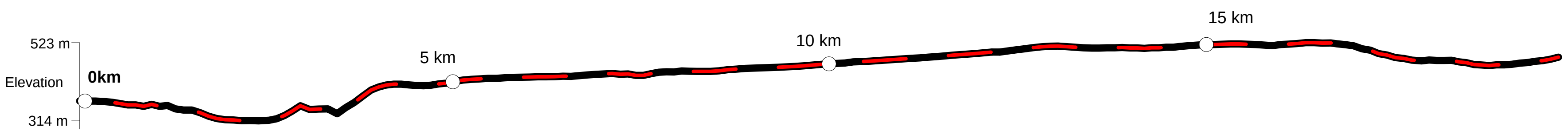
Terrain units were identified along the gas transmission pipeline corridor initially within a 5 km wide corridor, which included various potential alternative routes. Accordingly, not all of the terrain units identified in Appendix L2 occur within the 1 km wide corridor for the route finally adopted for the EIS. The terrain units that occur within the adopted gas transmission pipeline corridor are shown in Figures 7.3.6 to 7.3.29 where they are coloured on the basis of the geological regime in which they occur. The map sheet layout is shown in Figure 7.3.30 and a key to the identification of terrain units is provided in Figure 7.3.31.

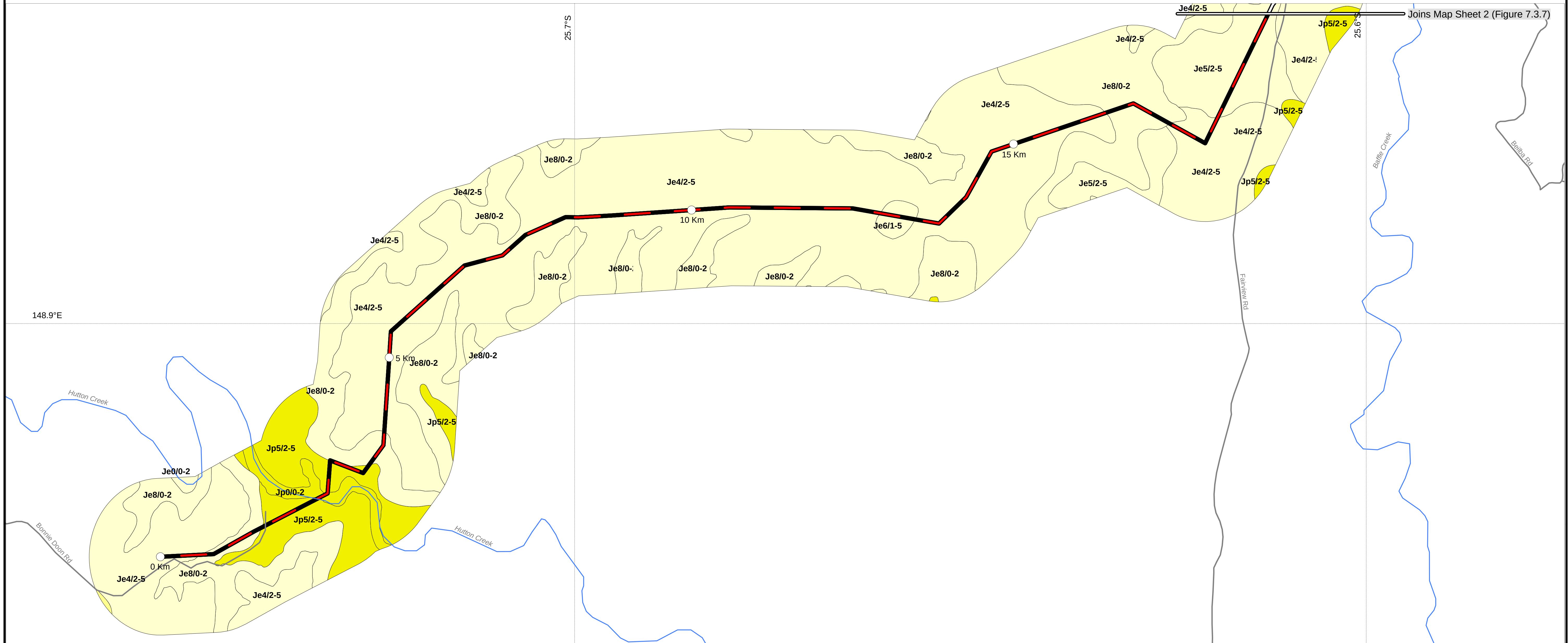
Geology

The geology of the gas transmission pipeline corridor 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 gas transmission pipeline corridor, including Curtis Island. The geology of the central and western sectors of the gas transmission pipeline corridor has been identified based on the GSQ Regional Mapping of the Bowen Basin. The southern sector of the gas transmission pipeline 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 outlined in the Table 7.3.1.

GAS TRANSMISSION PIPELINE ELEVATION PROFILE





Terrain Units & Constraints Intersecting the Gas Transmission 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)

Note: Figures 7.3.6 to 7.3.29 must be viewed with Figure 7.3.31, which shows the generic key / terrain unit legend.

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

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	-

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Note: Full A3 (to scale) map available in Appendix L2.

Client: LNG, URS

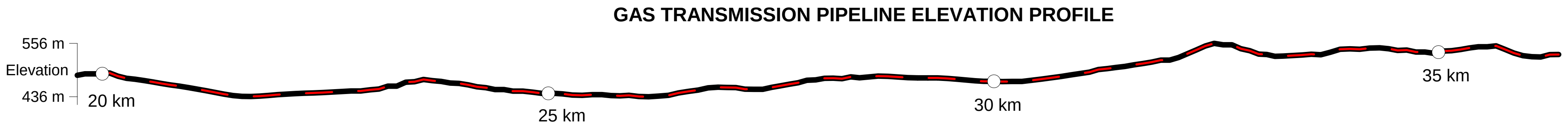
Project: GLADSTONE LNG PROJECT
ENVIRONMENTAL IMPACT STATEMENT

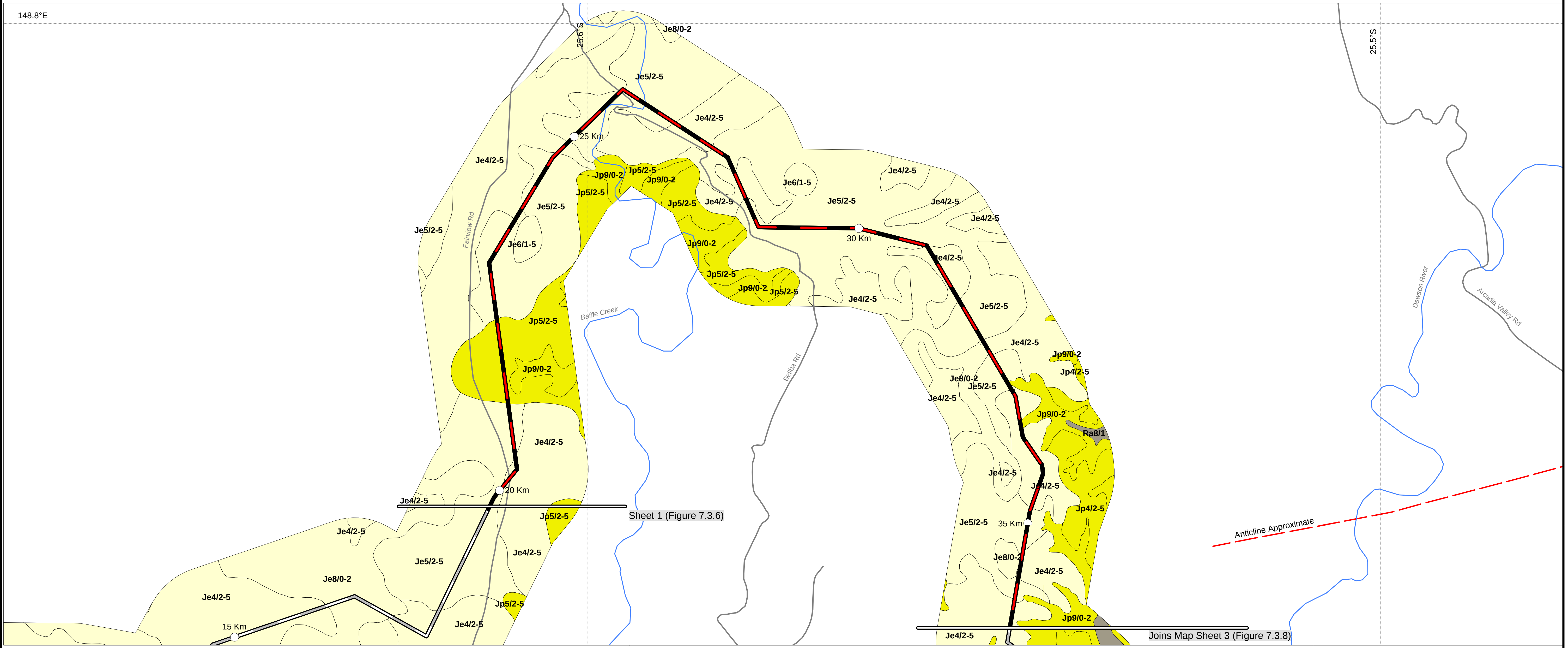
Title: **GEOLOGICAL REGIMES AND TERRAIN UNITS (MAP SHEET 1 of 24)**

Drawn: CA | Approved: JB | Date: 15-05-2009

Job No: **4262 6220** | File No: 42626220-g-918.wor

Figure: **7.3.6** | Rev: A | A3





Terrain Units & Constraints Intersecting the Gas Transmission 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)

Note: Figures 7.3.6 to 7.3.29 must be viewed with Figure 7.3.31, which shows the generic key / terrain unit legend.

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

Note: Full A3 (to scale) map available in Appendix L2.

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	-	-

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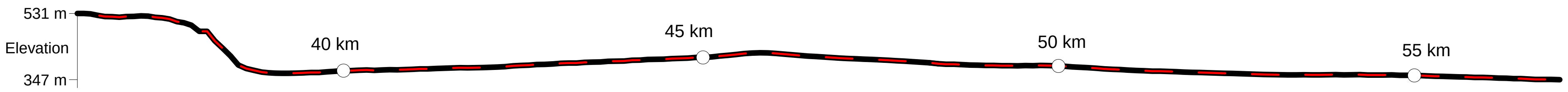
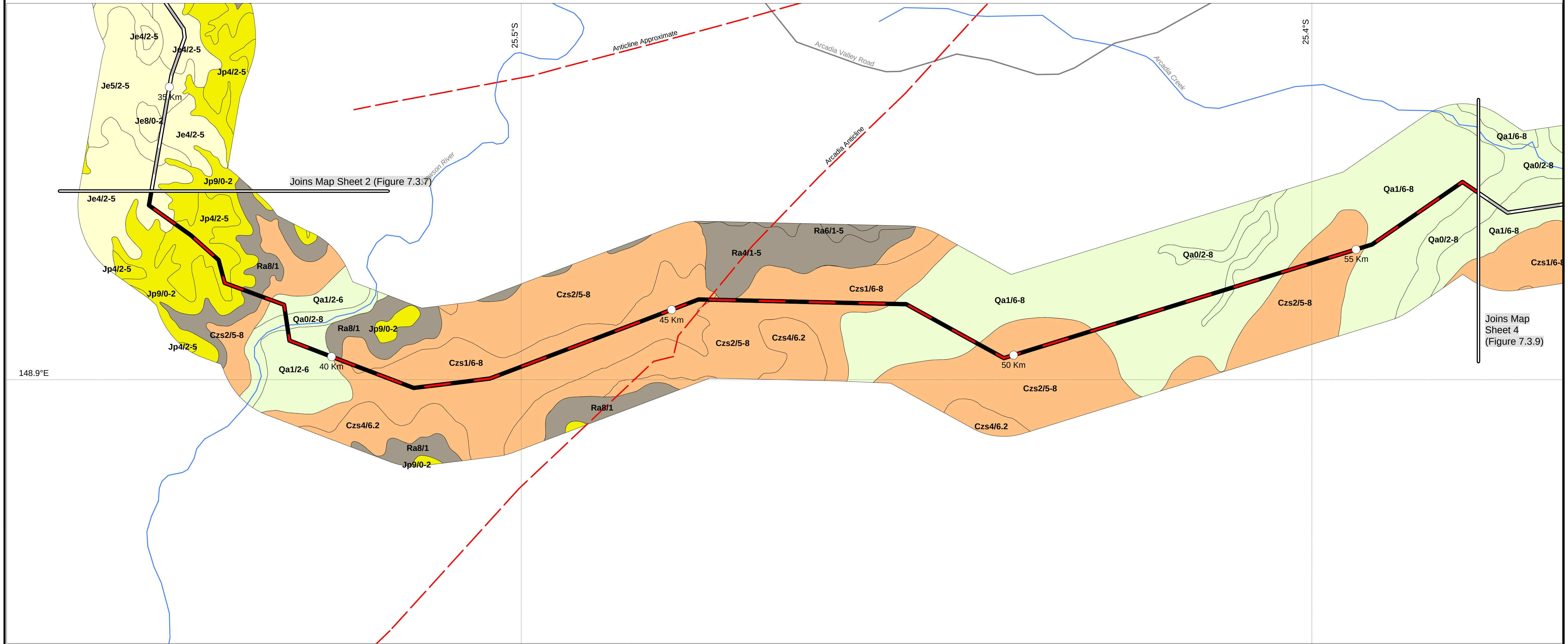
Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**GEOLOGICAL REGIMES AND TERRAIN UNITS (MAP SHEET 2 of 24)**

Drawn: CA | Approved: JB | Date: 13-05-2009
Job No: **4262 6220** | File No: 42626220-g-919.wor
Figure: **7.3.7** | Rev: A | A3

GAS TRANSMISSION PIPELINE ELEVATION PROFILE





Terrain Units & Constraints Intersecting the Gas Transmission 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)

Note: Figures 7.3.6 to 7.3.29 must be viewed with Figure 7.3.31, which shows the generic key / terrain unit legend.

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

Note: Full A3 (to scale) map available in Appendix L2.

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

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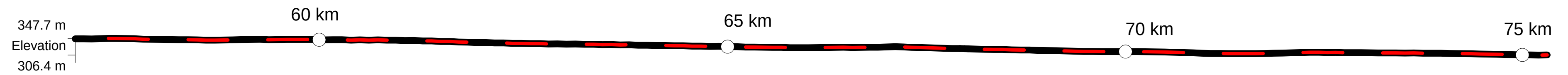
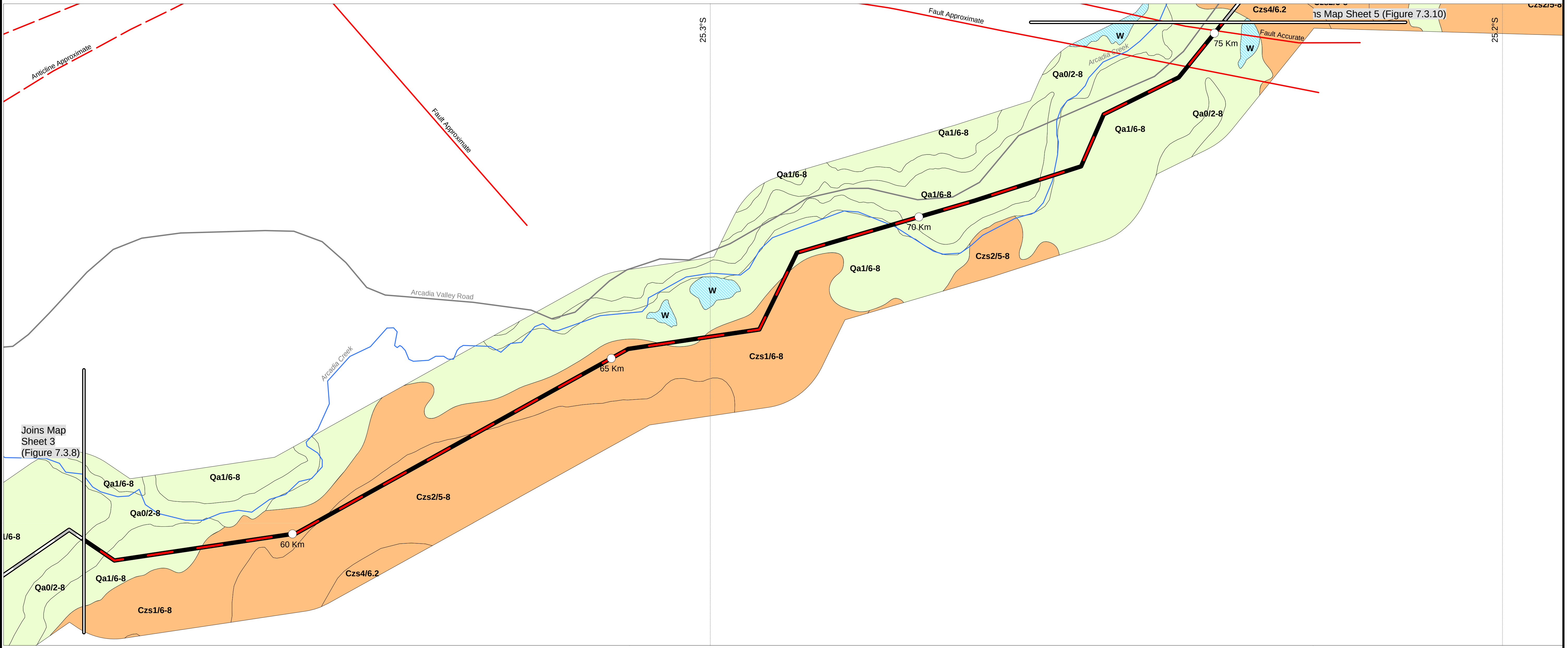
URS	Drawn: CA / Approved: JB / Date: 13-05-2009	Figure: 7.3.8
	Job No: **4262 6220** / File No: 42626220-g-920.wor	Rev: A / A3

GAS TRANSMISSION PIPELINE ELEVATION PROFILE





Terrain Units & Constraints Intersecting the Gas Transmission 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)

Note: Figures 7.3.6 to 7.3.29 must be viewed with Figure 7.3.31, which shows the generic key / terrain unit legend.

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

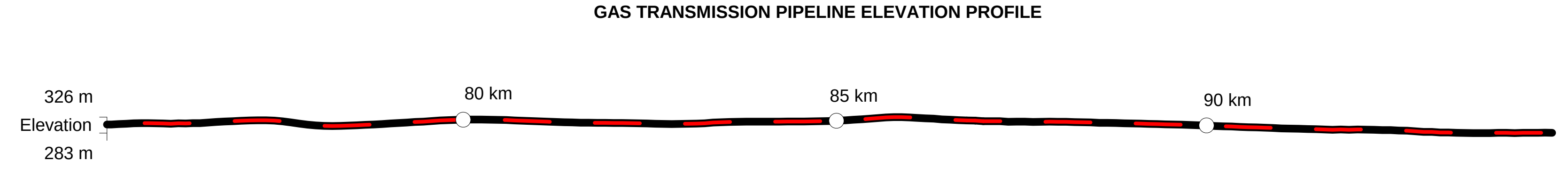
Note: Full A3 (to scale) map available in Appendix L2.

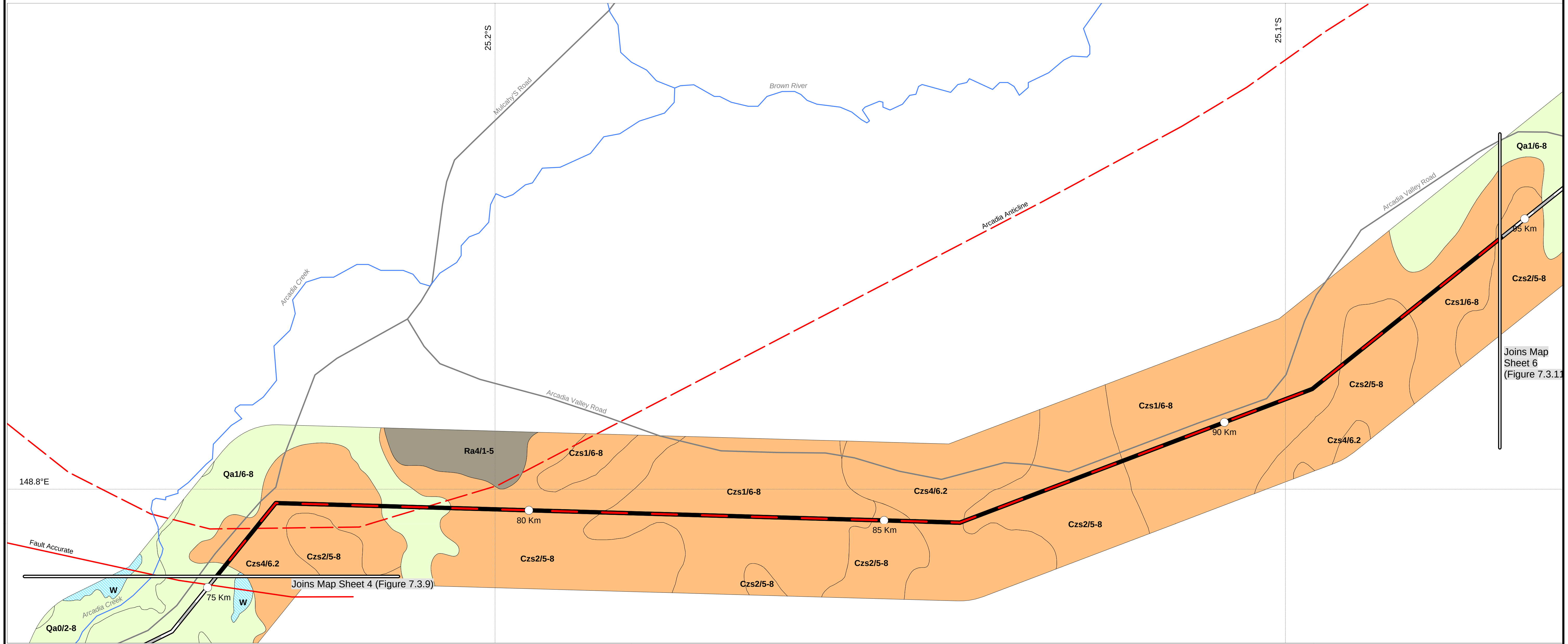
Sector Summary:

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

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

Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	GEOLOGICAL REGIMES AND TERRAIN UNITS (MAP SHEET 4 of 24)
	Drawn: CA · Approved: JB · Date: 13-05-2009	Figure: 7.3.9 · Rev: A
	Job No: 4262 6220 · File No: 42626220-g-921.wor	A3





Note: Figures 7.3.6 to 7.3.29 must be viewed with Figure 7.3.31, which shows the generic key / terrain unit legend.

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 the Gas Transmission 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)

Note: Full A3 (to scale) map available in Appendix L2.

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

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

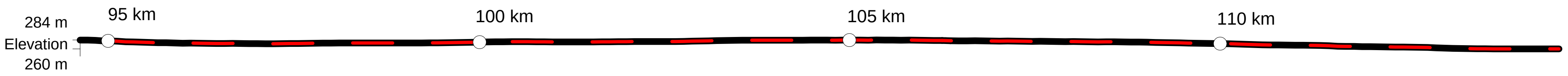
Client: LNG URS

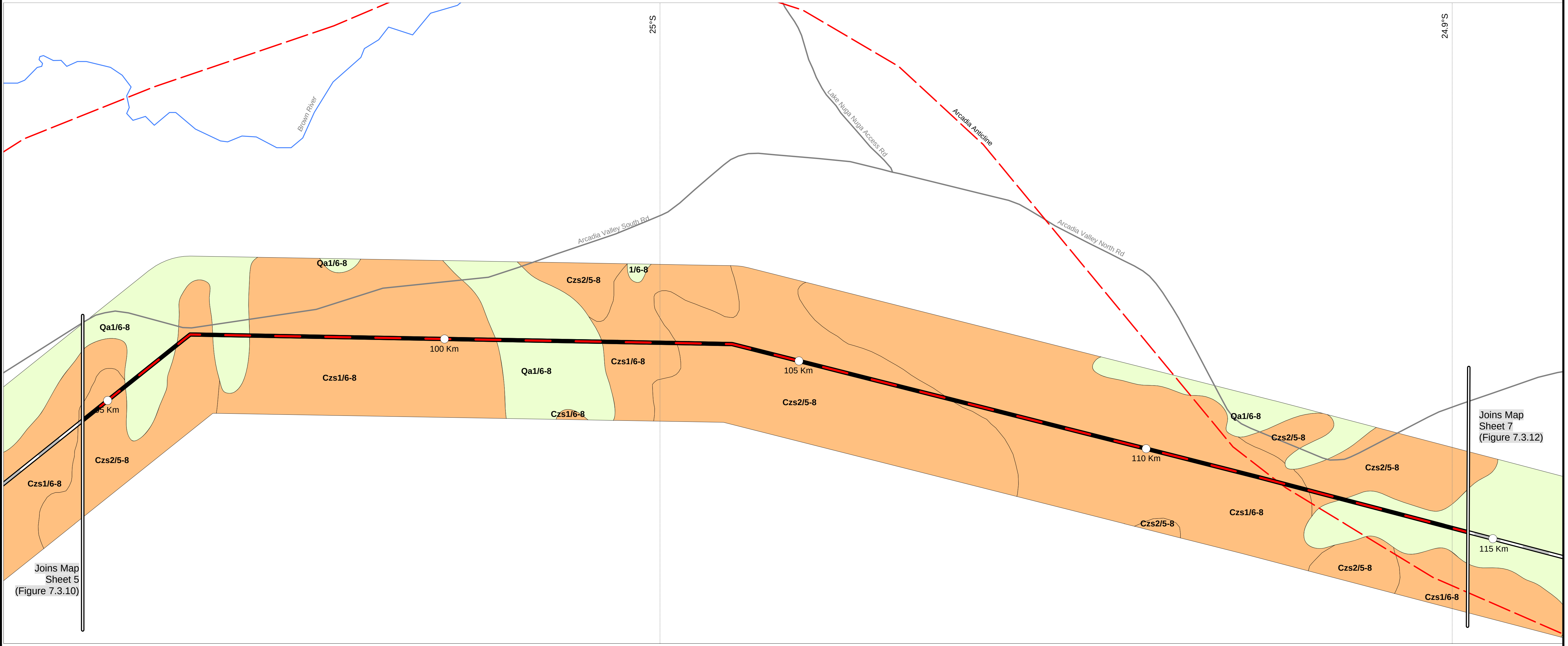
Project: GLADSTONE LNG PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Title: **GEOLOGICAL REGIMES AND TERRAIN UNITS (MAP SHEET 5 of 24)**

Drawn: CA	Approved: JB	Date: 14-05-2009	Figure: 7.3.10
Job No: 4262 6220	File No: 42626220-g-922.wor		Rev: A / A3

GAS TRANSMISSION PIPELINE ELEVATION PROFILE





Terrain Units & Constraints Intersecting the Gas Transmission 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)

Note: Figures 7.3.6 to 7.3.29 must be viewed with Figure 7.3.31, which shows the generic key / terrain unit legend.

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

Note: Full A3 (to scale) map available in Appendix L2.

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

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

Client

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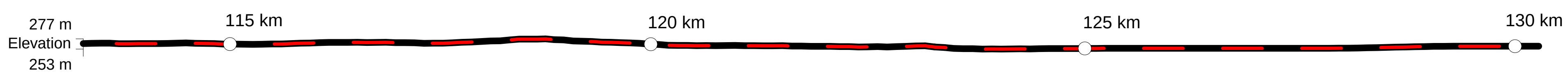
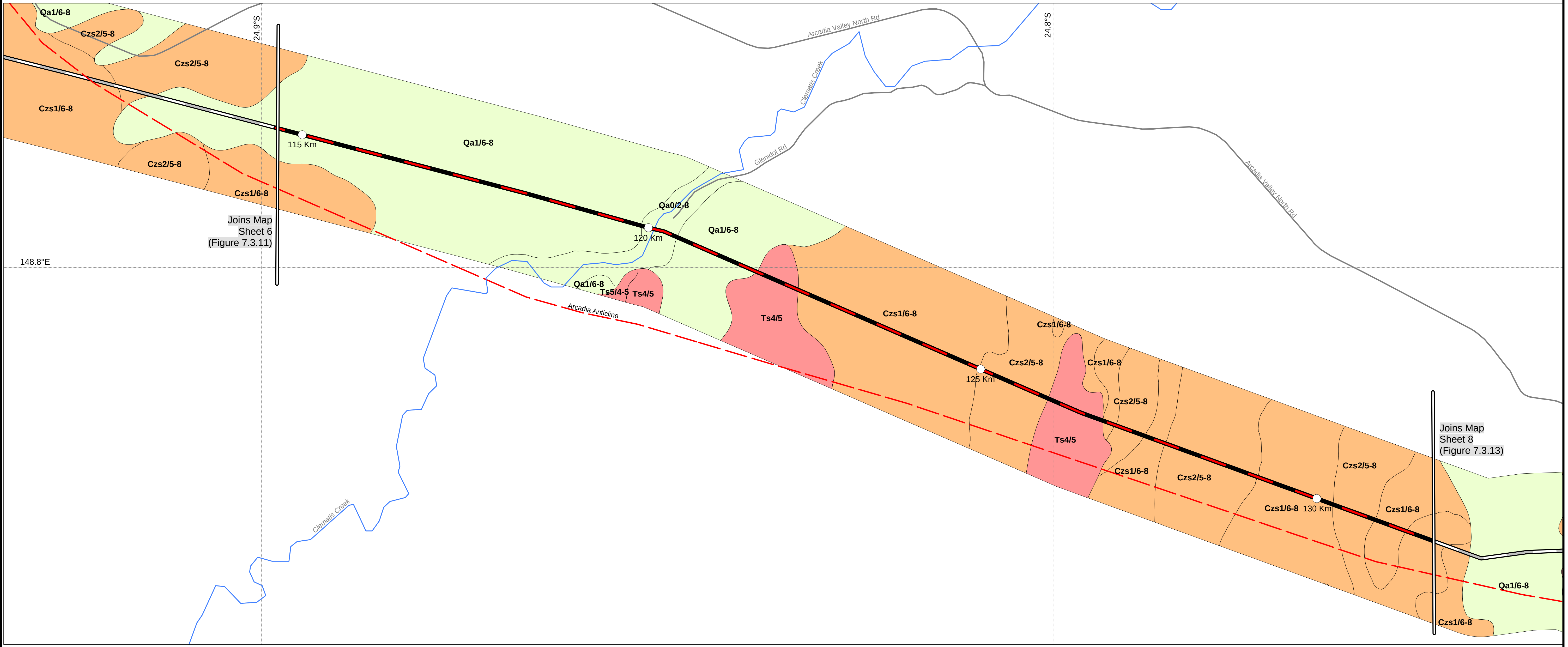
Project
GLADSTONE LNG PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Title
GEOLOGICAL REGIMES AND TERRAIN UNITS (MAP SHEET 6 of 24)

Drawn: CA | Approved: JB | Date: 14-05-2009
Job No: **4262 6220** | File No: 42626220-g-923.wor
Figure: **7.3.11** | Rev: A | A3

GAS TRANSMISSION PIPELINE ELEVATION PROFILE





Terrain Units & Constraints Intersecting the Gas Transmission 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)

Note: Figures 7.3.6 to 7.3.29 must be viewed with Figure 7.3.31, which shows the generic key / terrain unit legend.

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

Sector Summary:

Constraints	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils
Low Constraint	16,586	16,586	-	-	-
Moderate Constraint	-	519	15,138	10,099	5,831
High Constraint	519	-	1,967	7,006	11,274

Note: Full A3 (to scale) map available in Appendix L2.

Client: LNG / URS

Project: GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT

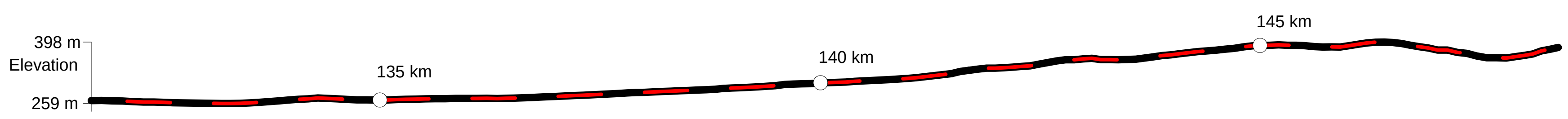
Title: **GEOLOGICAL REGIMES AND TERRAIN UNITS (MAP SHEET 7 of 24)**

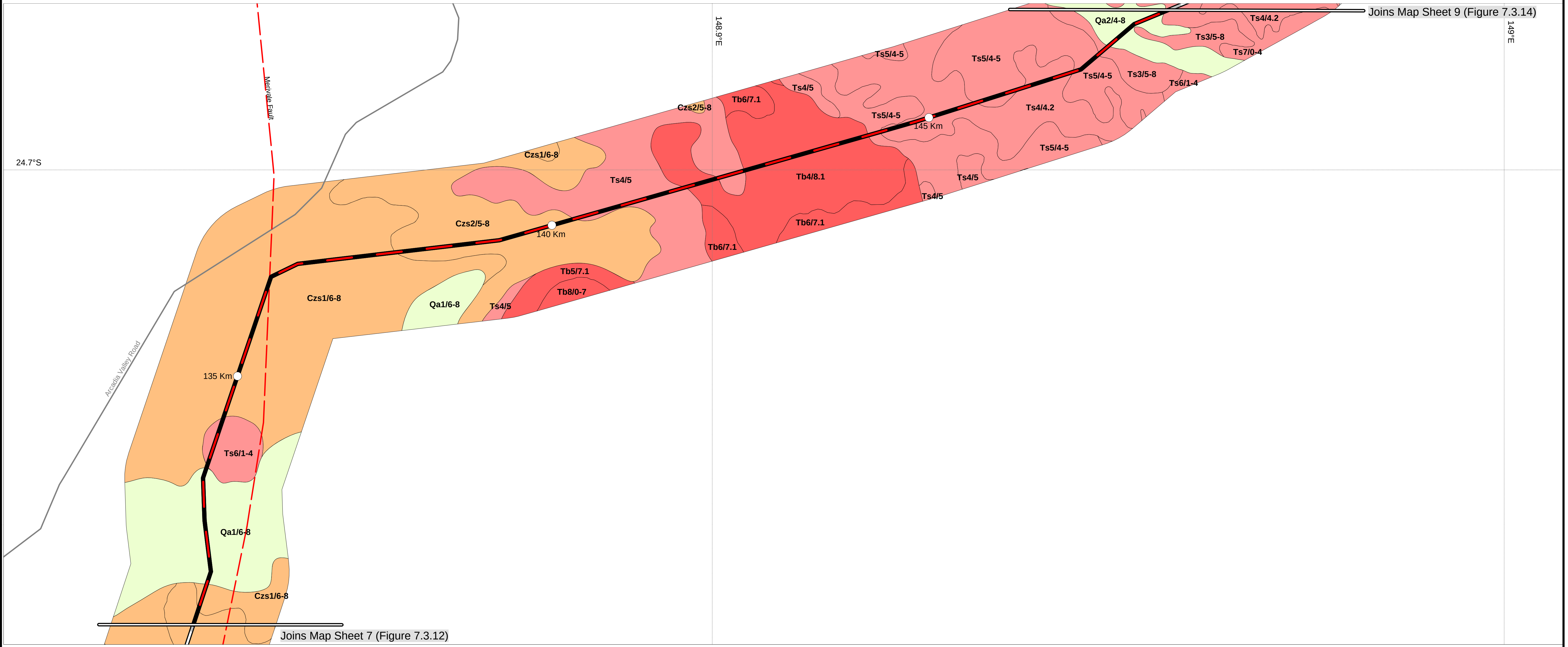
Drawn: CA | Approved: JB | Date: 14-05-2009

Job No: **4262 6220** | File No: 42626220-g-924.wor

Figure: **7.3.12** | Rev: A | A3

GAS TRANSMISSION PIPELINE ELEVATION PROFILE





Terrain Units & Constraints Intersecting the Gas Transmission 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

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

Note: Figures 7.3.6 to 7.3.29 must be viewed with Figure 7.3.31, which shows the generic key / terrain unit legend.

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

Note: Full A3 (to scale) map available in Appendix L2.

Client: LNG / URS

Project: GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT

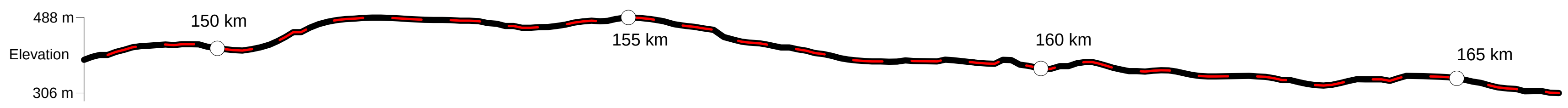
Title: **GEOLOGICAL REGIMES AND TERRAIN UNITS (MAP SHEET 8 of 24)**

Drawn: CA | Approved: JB | Date: 15-05-2009

Job No: **4262 6220** | File No: 42626220-g-925.wor

Figure: **7.3.13** | Rev: A | A3

GAS TRANSMISSION PIPELINE ELEVATION PROFILE



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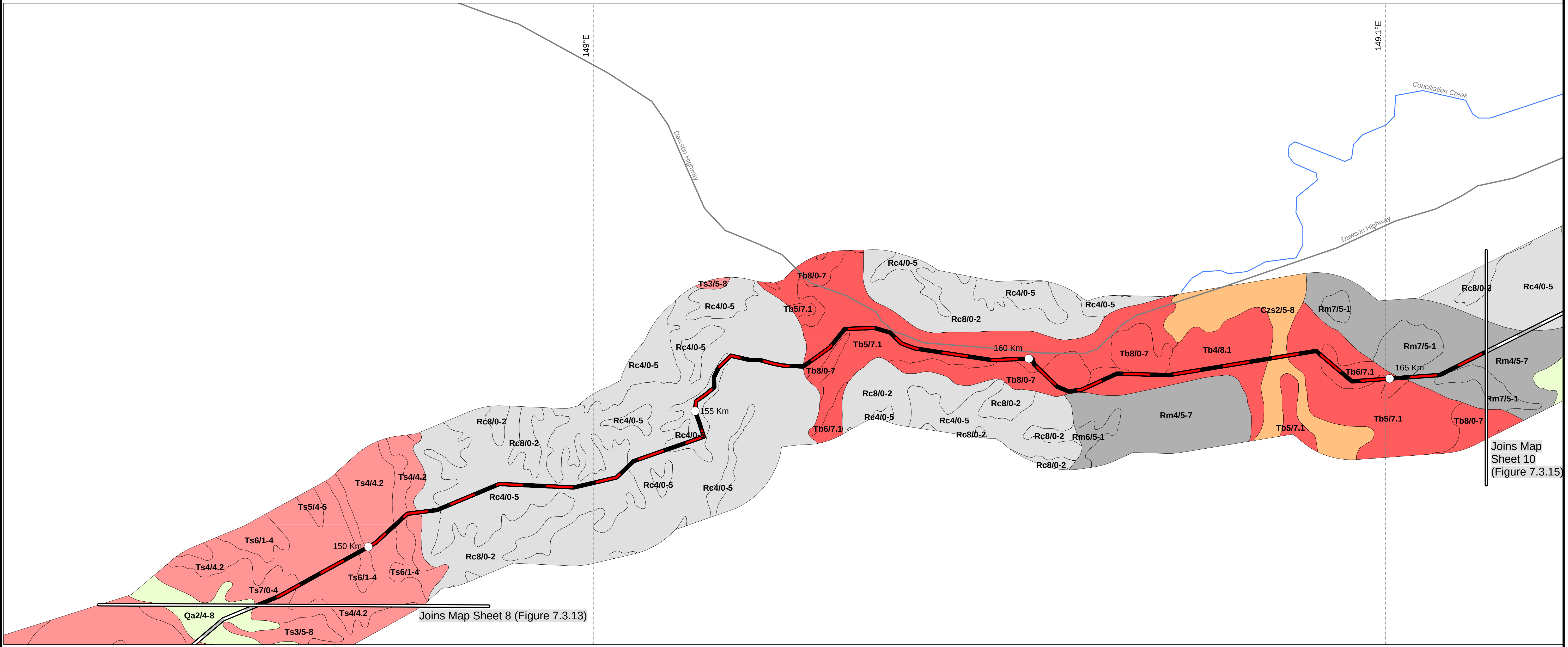


Note: Figures 7.3.6 to 7.3.29 must be viewed with Figure 7.3.31, which shows the generic key / terrain unit legend.

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 the Gas Transmission 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:

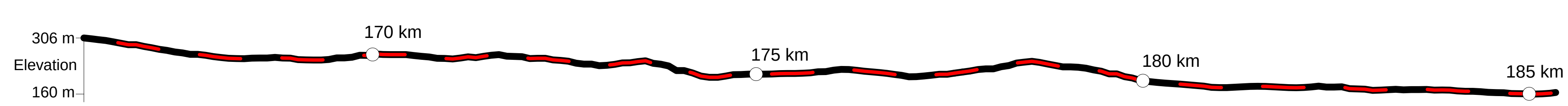
Constraints	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils
Low Constraint	13,250	1,756	1,519	13,013	6,124
Moderate Constraint	1,358	12,979	6,776	4,842	11,731
High Constraint	3,247	3,120	9,560	-	-

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

Note: Full A3 (to scale) map available in Appendix L2.

Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**GEOLOGICAL REGIMES AND TERRAIN UNITS (MAP SHEET 9 of 24)**
	Drawn: CA; Approved: JB; Date: 15-05-2009	Figure: **7.3.14**
	Job No: **4262 6220**; File No: 42626220-g-926.wor	Rev: A; A3

GAS TRANSMISSION PIPELINE ELEVATION PROFILE



Terrain Units & Constraints Intersecting the Gas Transmission 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)

Note: Figures 7.3.6 to 7.3.29 must be viewed with Figure 7.3.31, which shows the generic key / terrain unit legend.

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

Note: Full A3 (to scale) map available in Appendix L2.

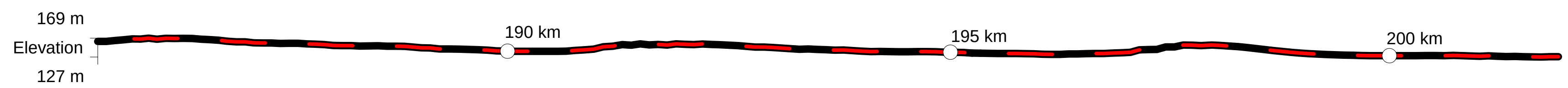
Sector Summary:

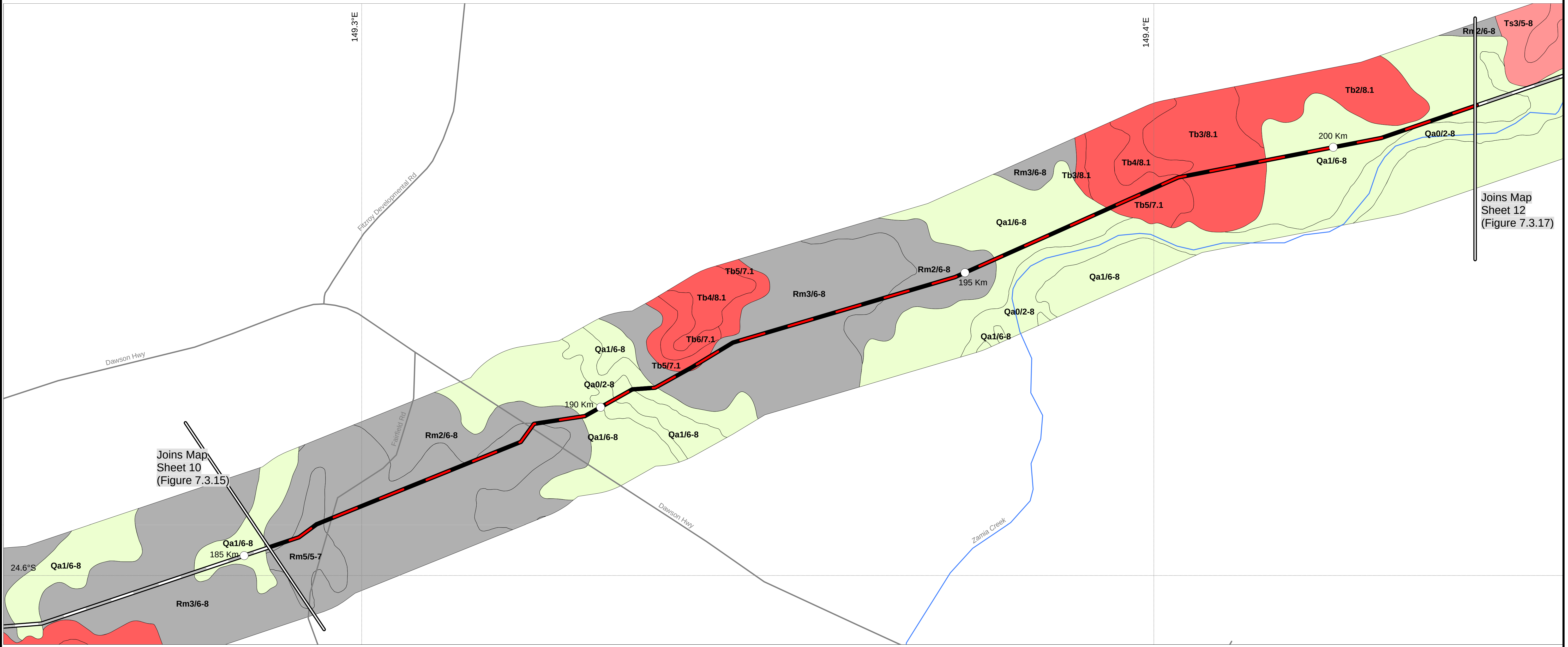
Constraints	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils
Low Constraint	17,587	6,225	-	13,473	1,496
Moderate Constraint	1,243	12,605	6,879	3,044	11,362
High Constraint	253	253	12,204	2,566	6,225

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

Client	LNG / URS
Project	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT
Title	GEOLOGICAL REGIMES AND TERRAIN UNITS (MAP SHEET 10 of 24)
Drawn: CA	Approved: JB
Date: 15-05-2009	Figure: 7.3.15
Job No: 4262 6220	File No: 42626220-g-927.wor
Rev: A	A3

GAS TRANSMISSION PIPELINE ELEVATION PROFILE





Terrain Units & Constraints Intersecting the Gas Transmission 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)

Note: Figures 7.3.6 to 7.3.29 must be viewed with Figure 7.3.31, which shows the generic key / terrain unit legend.

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

Note: Full A3 (to scale) map available in Appendix L2.

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

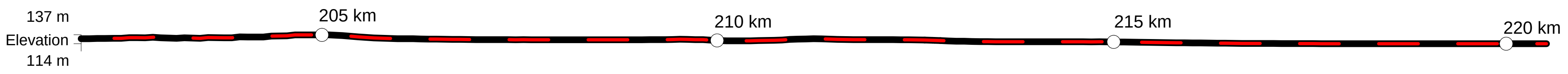
Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

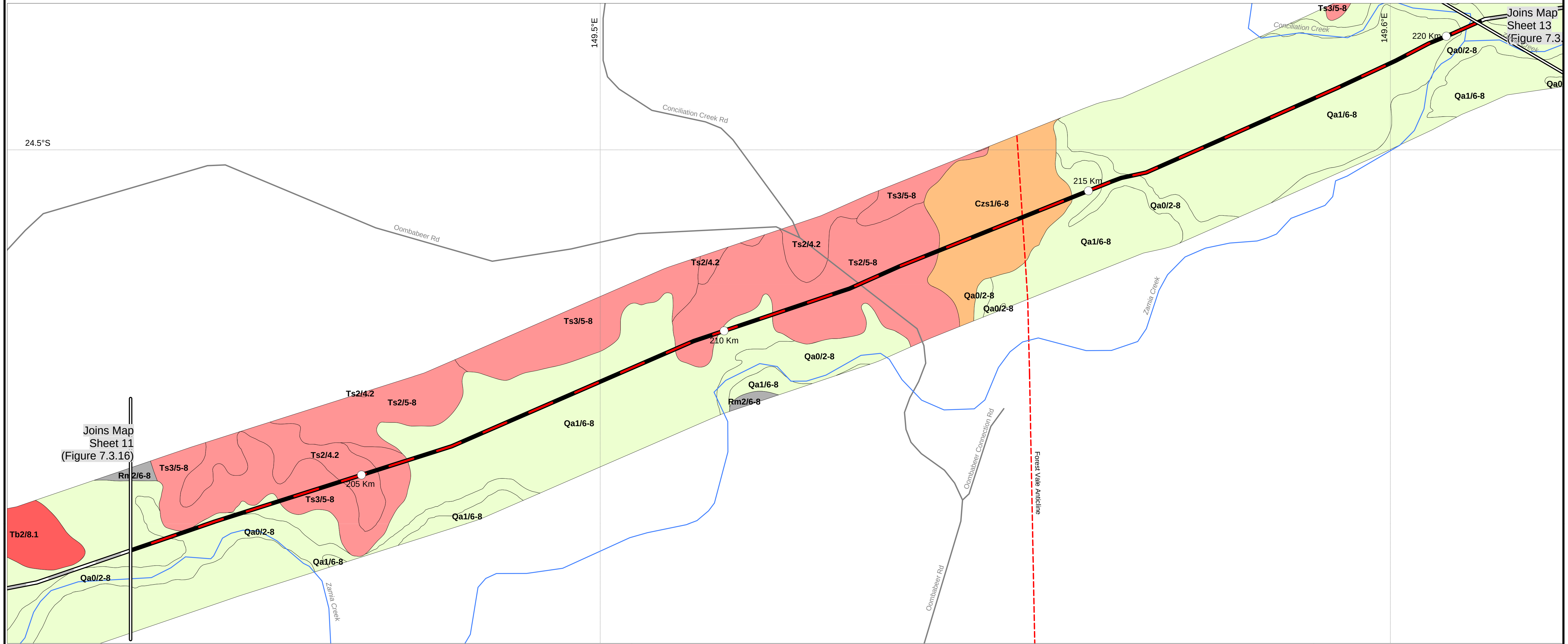
Client
Project
GLADSTONE LNG PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Title
GEOLOGICAL REGIMES AND TERRAIN UNITS (MAP SHEET 11 of 24)

Drawn: CA	Approved: JB	Date: 15-05-2009	Figure: 7.3.16	Rev: A
Job No: 4262 6220	File No: 42626220-g-928.wor			A3

GAS TRANSMISSION PIPELINE ELEVATION PROFILE





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Terrain Units & Constraints Intersecting the Gas Transmission 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)

Note: Figures 7.3.6 to 7.3.29 must be viewed with Figure 7.3.31, which shows the generic key / terrain unit legend.

0 1 2km

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

5km Distance Markers from Start of Pipeline
Gas Transmission Pipeline
Fault
Anticline
Syncline

Note: Full A3 (to scale) map available in Appendix L2.

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: LNG URS

Project: GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT

Title: **GEOLOGICAL REGIMES AND TERRAIN UNITS (MAP SHEET 12 of 24)**

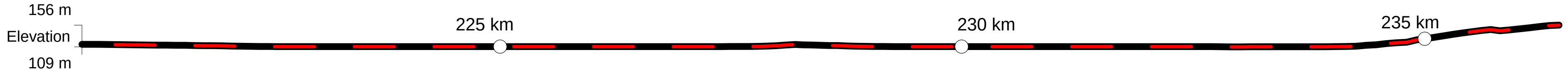
Drawn: CA	Approved: JB	Date: 15-05-2009
Job No: 4262 6220	File No: 42626220-g-929.wor	

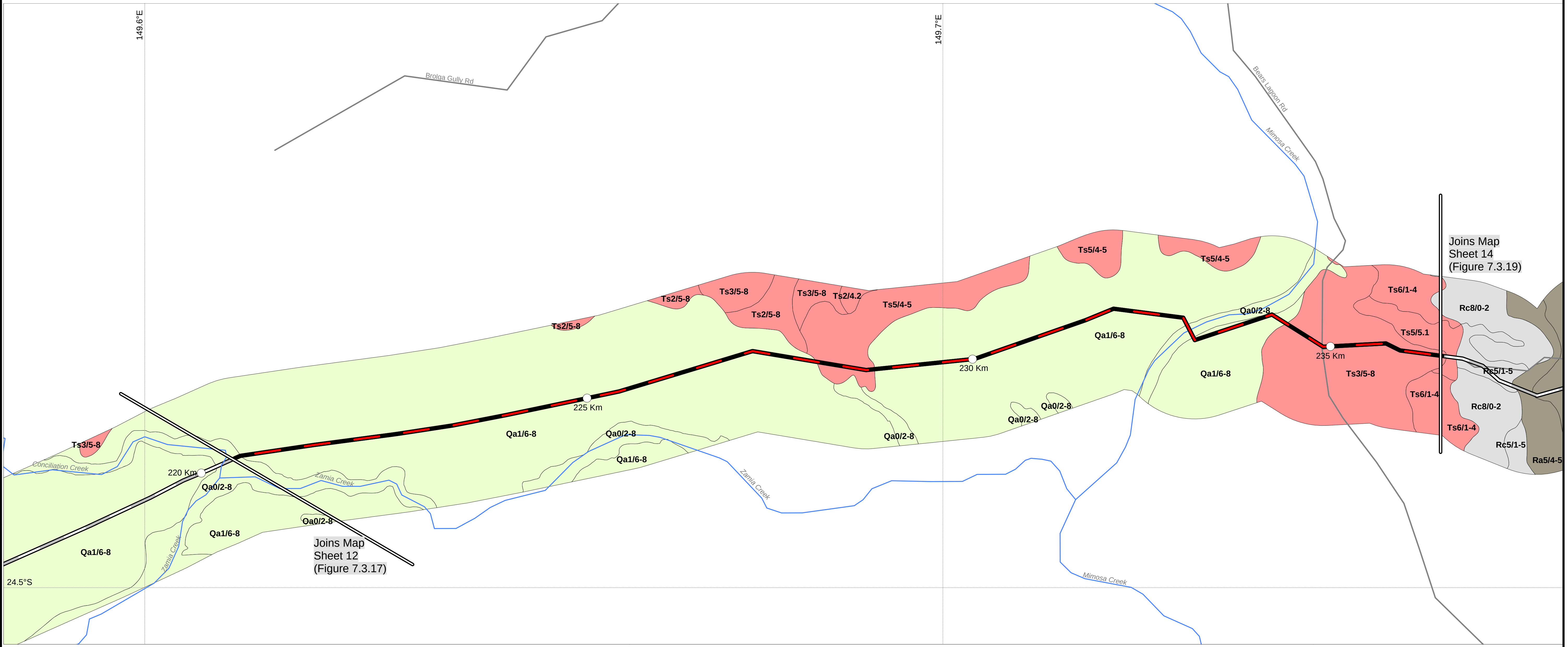
Figure: 7.3.17

Rev: A

A3

GAS TRANSMISSION PIPELINE ELEVATION PROFILE





Terrain Units & Constraints Intersecting the Gas Transmission 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)

Note: Figures 7.3.6 to 7.3.29 must be viewed with Figure 7.3.31, which shows the generic key / terrain unit legend.

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

Note: Full A3 (to scale) map available in Appendix L2.

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: LNG | URS

Project: GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT

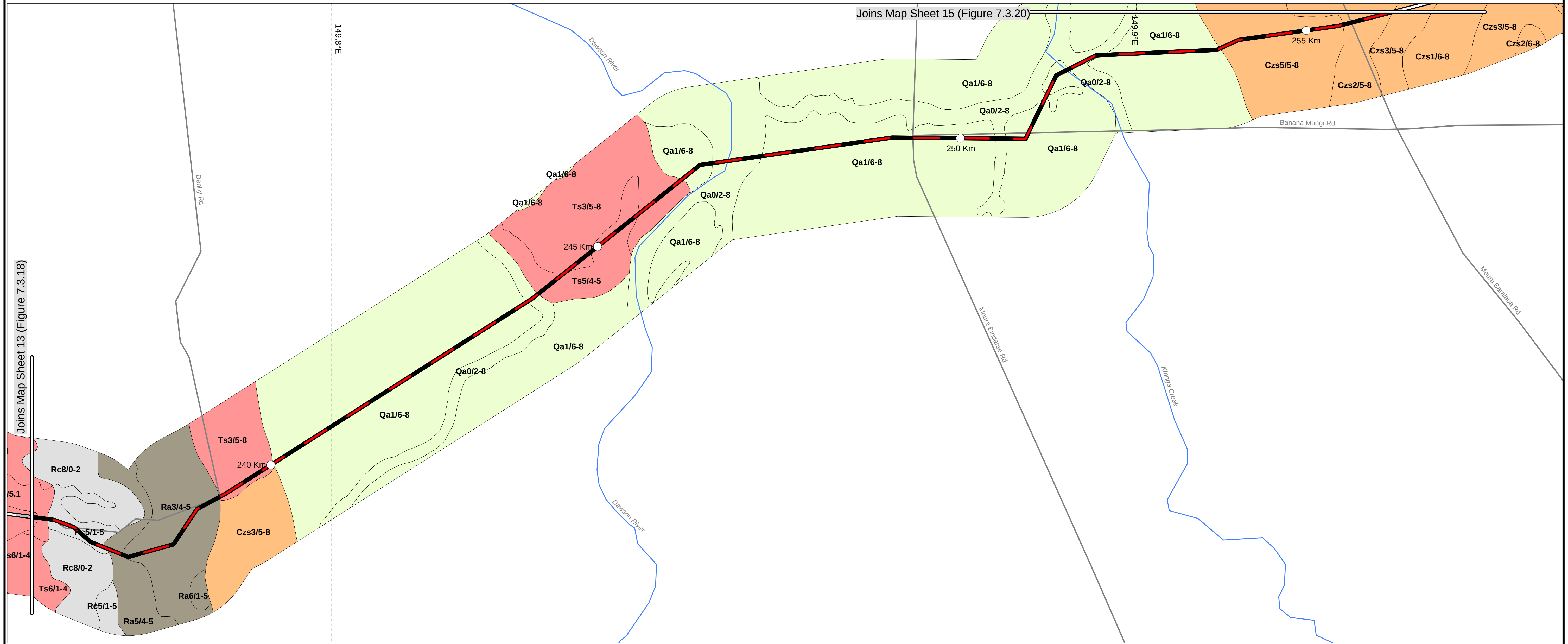
Title: **GEOLOGICAL REGIMES AND TERRAIN UNITS (MAP SHEET 13 of 24)**

Drawn: CA | Approved: JB | Date: 15-05-2009

Job No: 4262 6220 | File No: 42626220-g-930.wor

Figure: 7.3.18 | Rev: A | A3

GAS TRANSMISSION PIPELINE ELEVATION PROFILE



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Terrain Units & Constraints Intersecting the Gas Transmission 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

Note: Figures 7.3.6 to 7.3.29 must be viewed with Figure 7.3.31, which shows the generic key / terrain unit legend.

0 1 2km

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

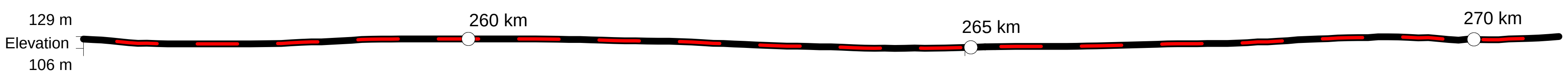
- 5km Distance Markers from Start of Pipeline
- Gas Transmission Pipeline
- Fault
- Anticline
- Syncline
- River / Creek
- Road

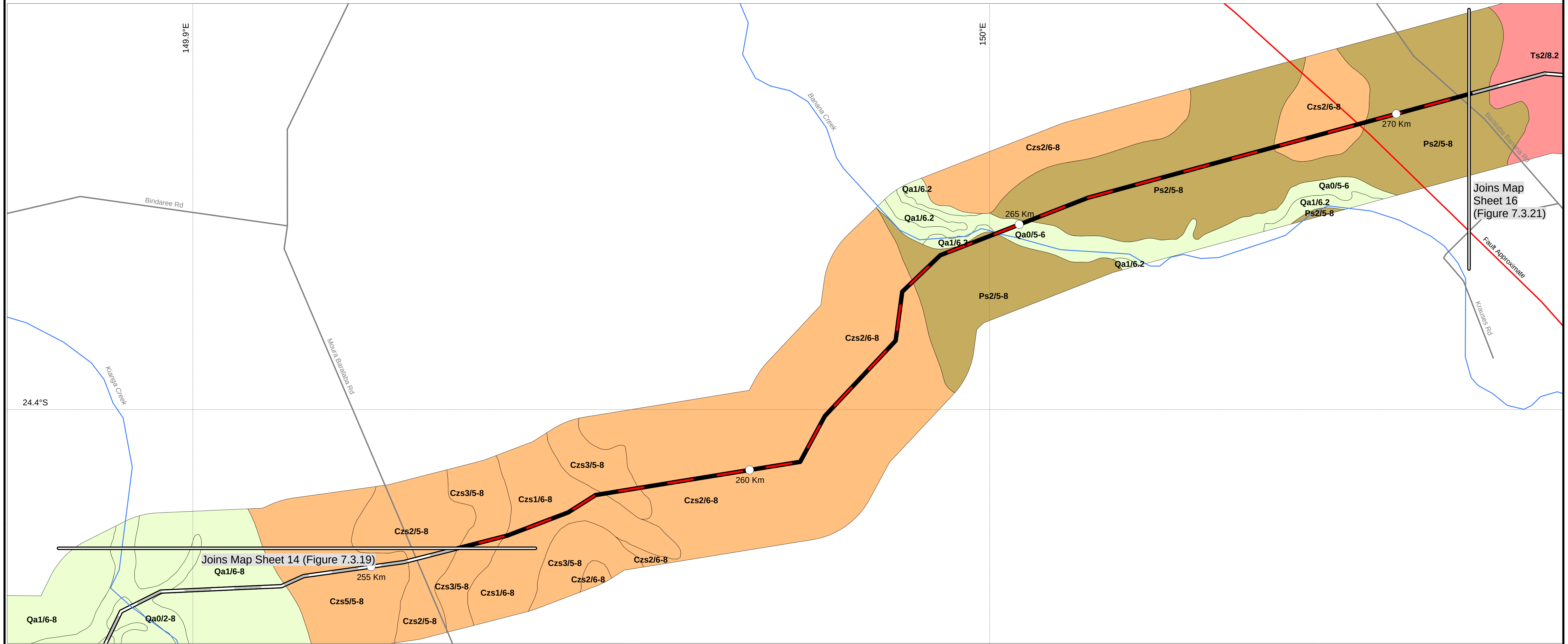
Note: Full A3 (to scale) map available in Appendix L2.

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

Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	GEOLOGICAL REGIMES AND TERRAIN UNITS (MAP SHEET 14 of 24)
	Drawn: CA; Approved: JB; Date: 15-05-2009	Figure: 7.3.19
	Job No: 4262 6220; File No: 42626220-g-931.wor	Rev: A; A3

GAS TRANSMISSION PIPELINE ELEVATION PROFILE





Terrain Units & Constraints Intersecting the Gas Transmission 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)

Note: Figures 7.3.6 to 7.3.29 must be viewed with Figure 7.3.31, which shows the generic key / terrain unit legend.

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

Note: Full A3 (to scale) map available in Appendix L2.

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

Client: LNG URS

Project: GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT

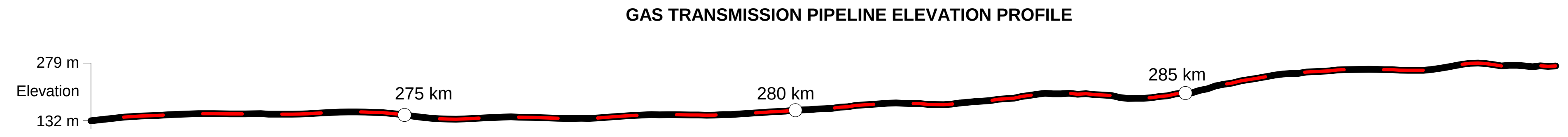
Title: **GEOLOGICAL REGIMES AND TERRAIN UNITS (MAP SHEET 15 of 24)**

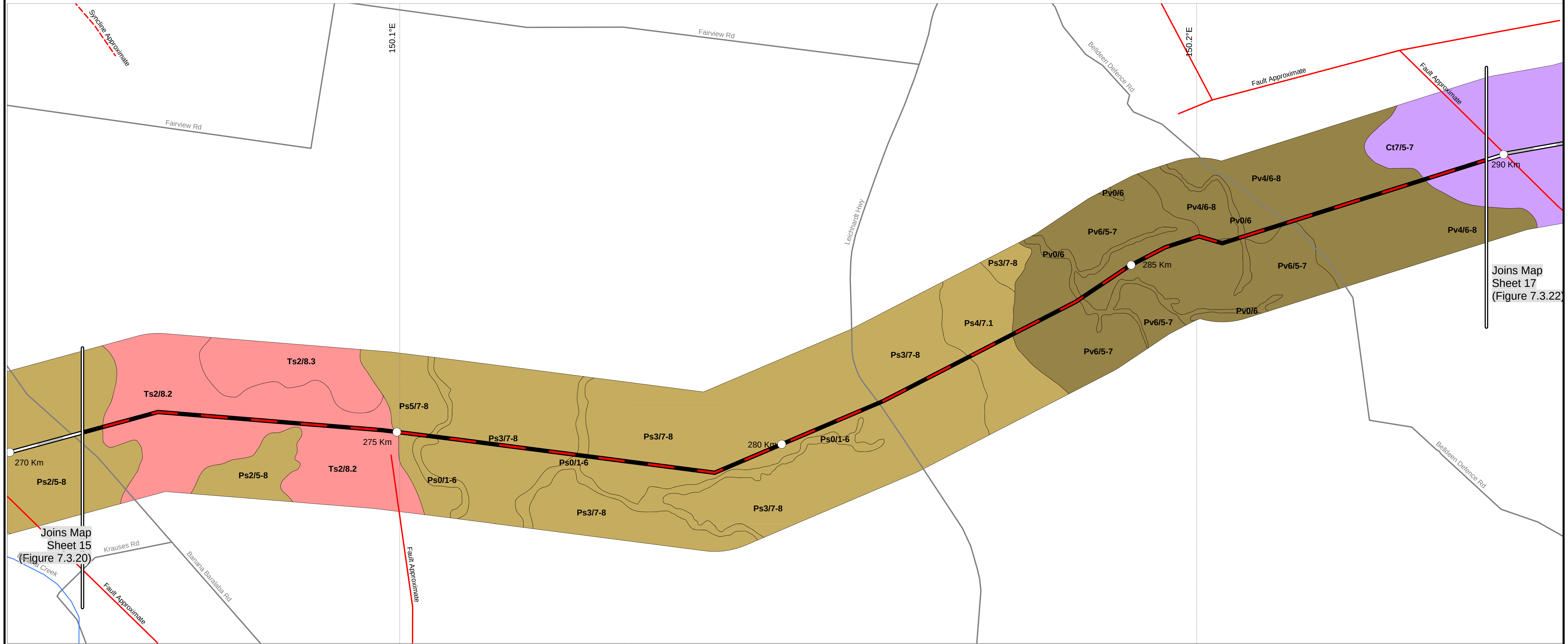
Drawn: CA | Approved: JB | Date: 15-05-2009

Job No: 4262 6220 | File No: 42626220-g-932.wor

Figure: 7.3.20 | Rev: A | A3

GAS TRANSMISSION PIPELINE ELEVATION PROFILE





Terrain Units & Constraints Intersecting the Gas Transmission 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)

Note: Figures 7.3.6 to 7.3.29 must be viewed with Figure 7.3.31, which shows the generic key / terrain unit legend.

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

Note: Full A3 (to scale) map available in Appendix L2.

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

Client

Project
GLADSTONE LNG PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Title
GEOLOGICAL REGIMES AND TERRAIN UNITS (MAP SHEET 16 of 24)

Drawn: CA | Approved: JB | Date: 15-05-2009

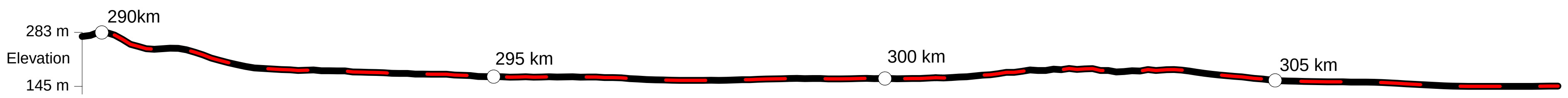
Job No: 4262 6220 | File No: 42626220-g-933.wor

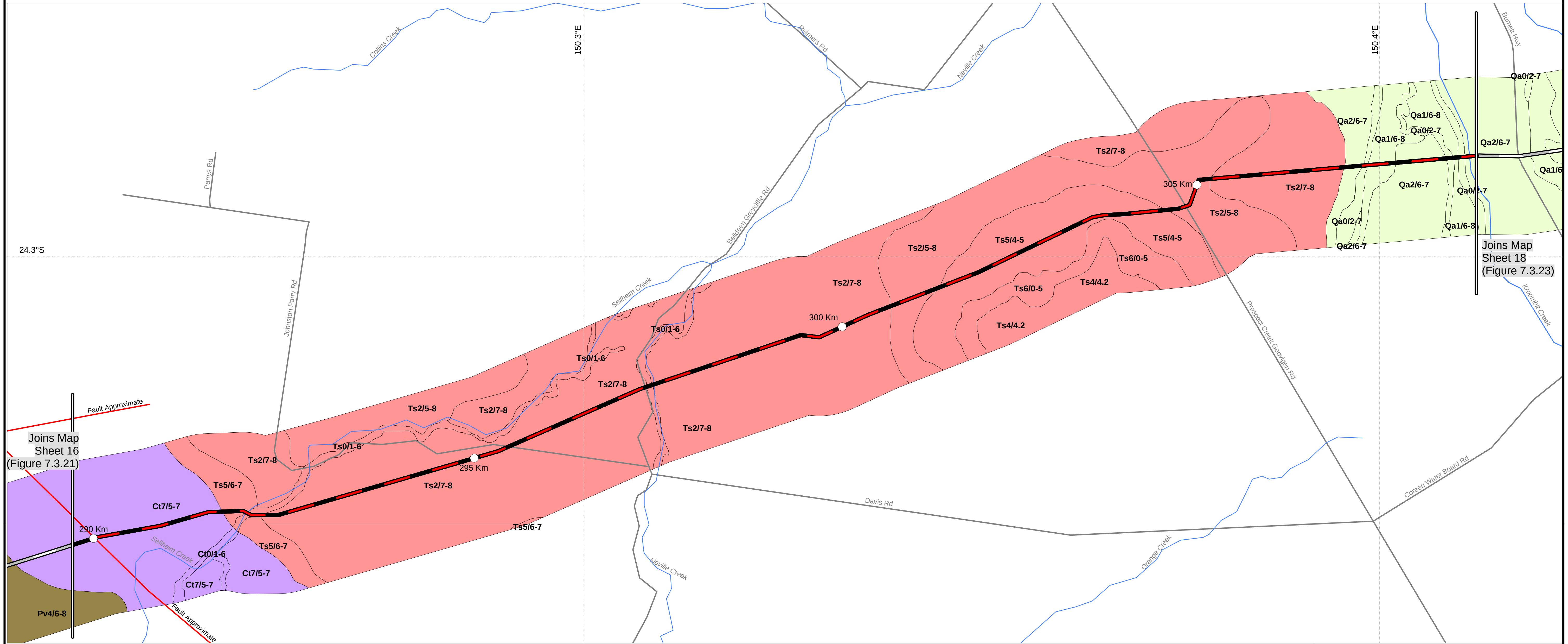
Figure: 7.3.21

Rev: A

A3

GAS TRANSMISSION PIPELINE ELEVATION PROFILE





Terrain Units & Constraints Intersecting the Gas Transmission 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)

Note: Figures 7.3.6 to 7.3.29 must be viewed with Figure 7.3.31, which shows the generic key / terrain unit legend.

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

Note: Full A3 (to scale) map available in Appendix L2.

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

Client

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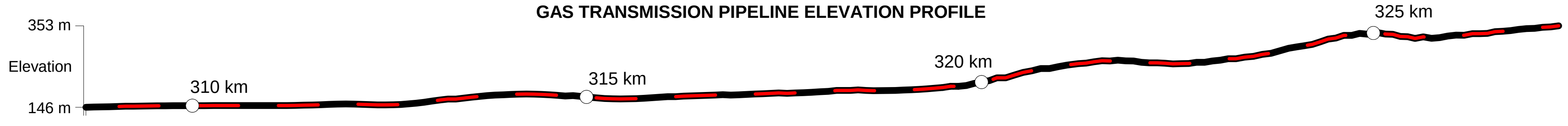
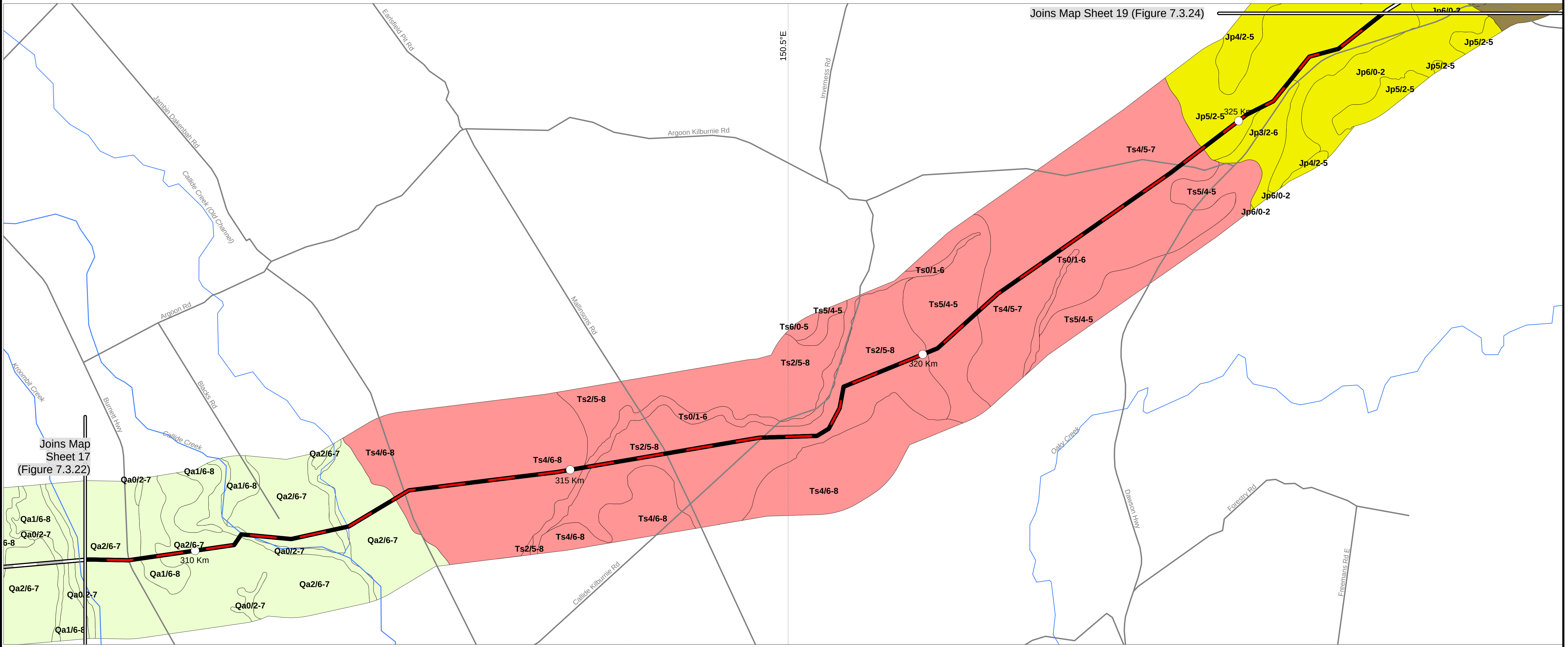
Project
GLADSTONE LNG PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Title
GEOLOGICAL REGIMES AND TERRAIN UNITS (MAP SHEET 17 of 24)

Drawn: CA	Approved: JB	Date: 15-05-2009	Figure: 7.3.22	Rev: A
Job No: 4262 6220	File No: 42626220-g-934.wor			A3

GAS TRANSMISSION PIPELINE ELEVATION PROFILE





Terrain Units & Constraints Intersecting the Gas Transmission 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)

Note: Figures 7.3.6 to 7.3.29 must be viewed with Figure 7.3.31, which shows the generic key / terrain unit legend.

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

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.

Note: Full A3 (to scale) map available in Appendix L2.

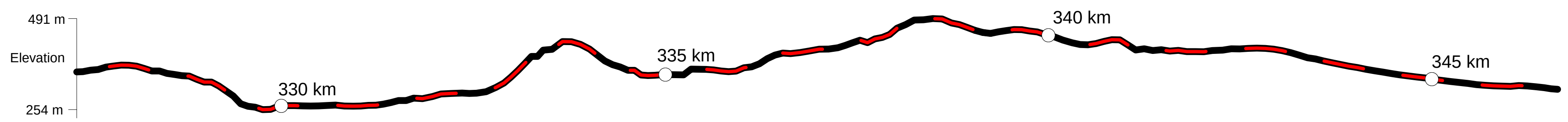
Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	GEOLOGICAL REGIMES AND TERRAIN UNITS (MAP SHEET 18 of 24)

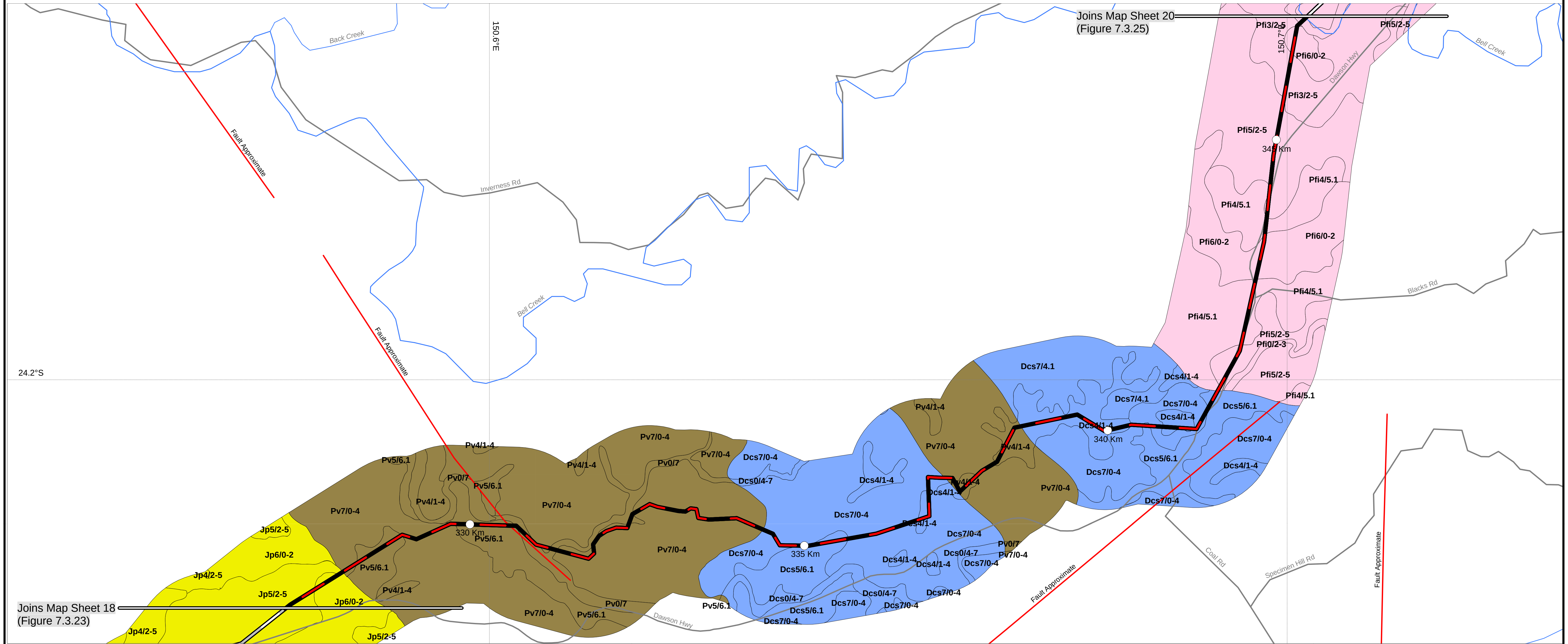
Drawn: CA | Approved: JB | Date: 15-05-2009

Job No: 4262 6220 | File No: 42626220-g-935.wor

Figure: 7.3.23 | Rev: A | A3

GAS TRANSMISSION PIPELINE ELEVATION PROFILE





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Terrain Units & Constraints Intersecting the Gas Transmission 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

Note: Figures 7.3.6 to 7.3.29 must be viewed with Figure 7.3.31, which shows the generic key / terrain unit legend.

0 1 2km

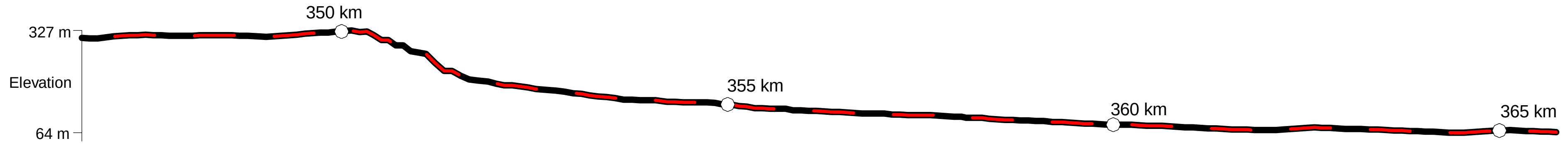
Scale 1:50,000 (A3)
Datum: GDA94

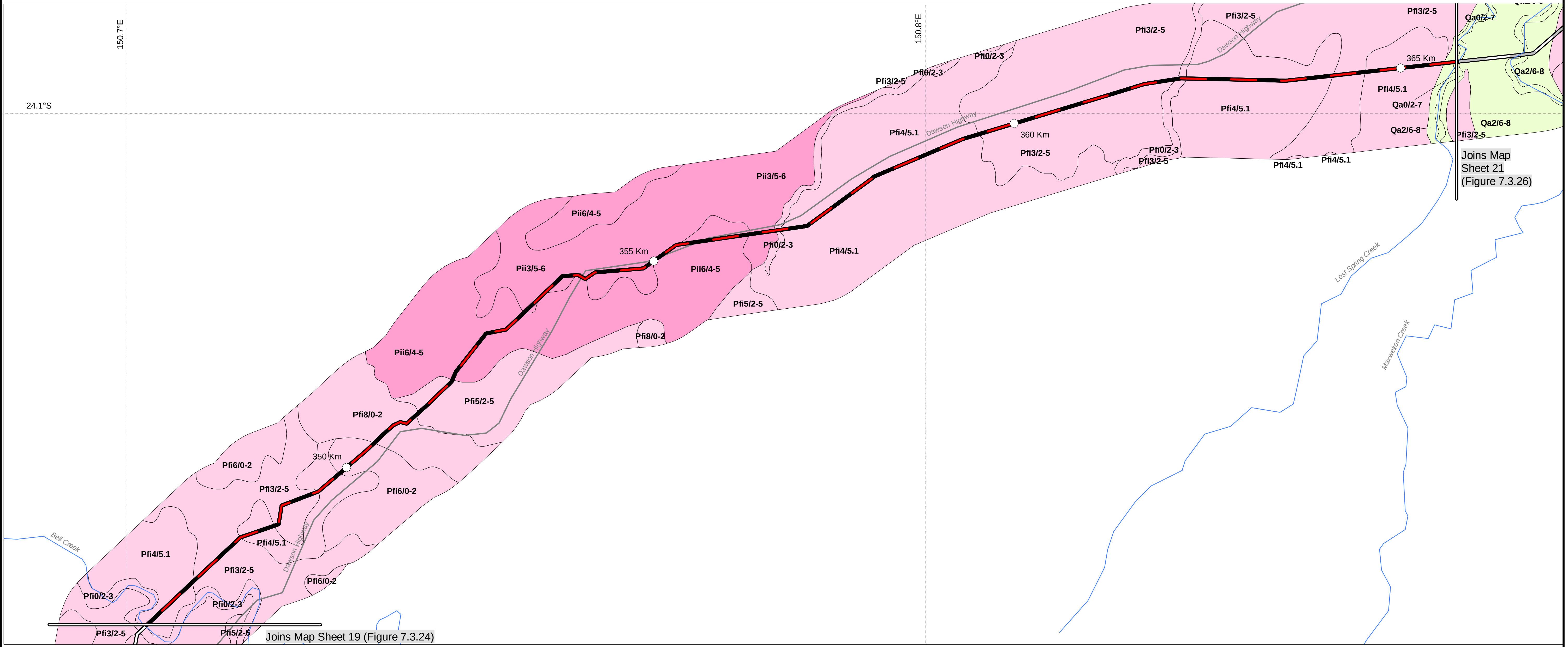
5km Distance Markers from Start of Pipeline
Gas Transmission Pipeline
Fault
Anticline
Syncline
River / Creek
Road

Note: Full A3 (to scale) map available in Appendix L2.

Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**GEOLOGICAL REGIMES AND TERRAIN UNITS (MAP SHEET 19 of 24)**
	Drawn: CA | Approved: JB | Date: 15-05-2009	Figure: 7.3.24
	Job No: 4262 6220 | File No: 42626220-g-936.wor	Rev: A | A3

GAS TRANSMISSION PIPELINE ELEVATION PROFILE





Terrain Units & Constraints Intersecting the Gas Transmission 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)

Note: Figures 7.3.6 to 7.3.29 must be viewed with Figure 7.3.31, which shows the generic key / terrain unit legend.

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

Note: Full A3 (to scale) map available in Appendix L2.

Sector Summary:

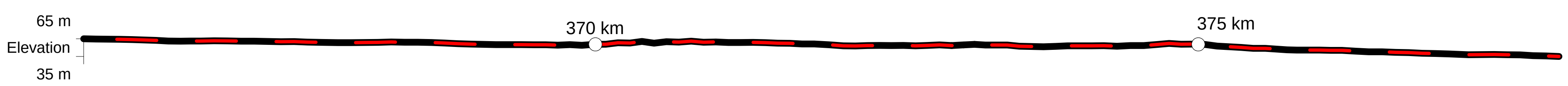
Constraints	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils
Low Constraint	15,014	17,594	-	18,040	8,681
Moderate Constraint	3,339	798	3,158	695	8,016
High Constraint	734	695	15,929	352	2,390

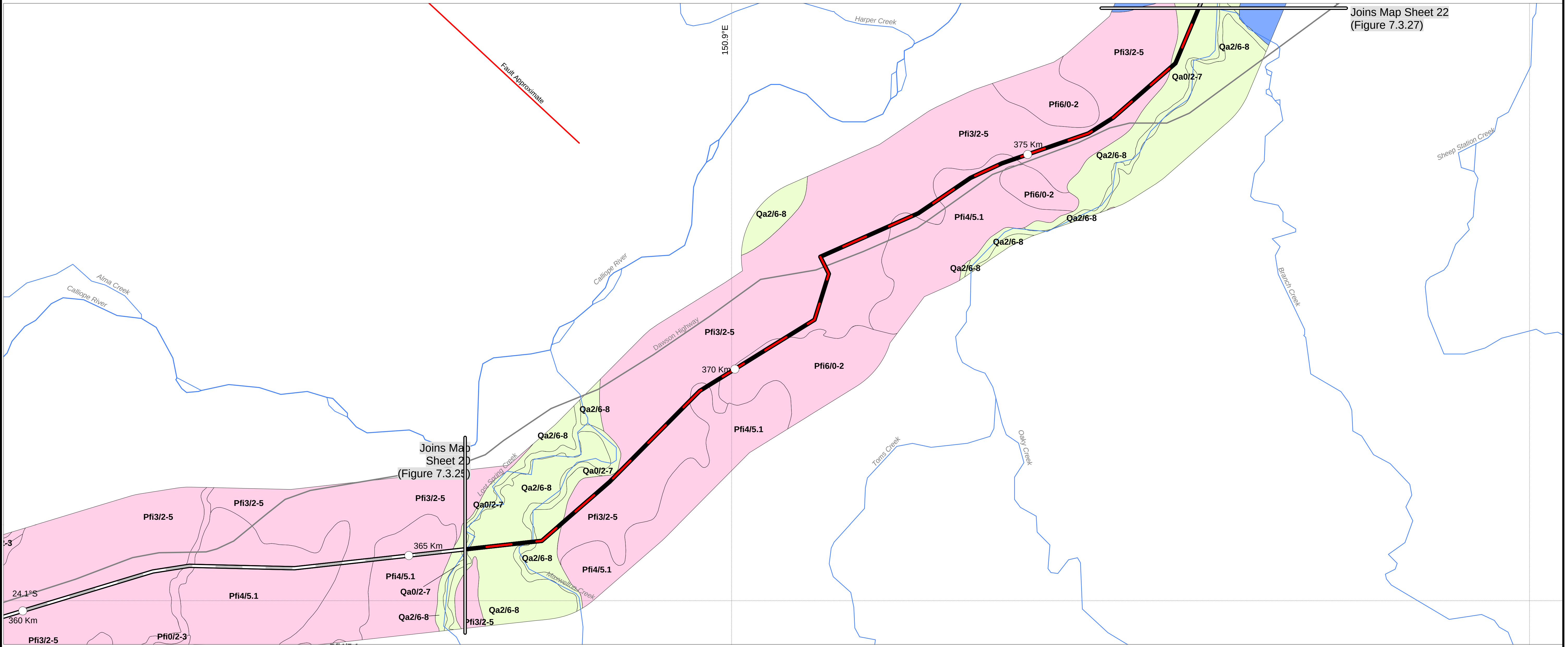
Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**GEOLOGICAL REGIMES AND TERRAIN UNITS (MAP SHEET 20 of 24)**

Drawn: CA | Approved: JB | Date: 15-05-2009
Job No: **4262 6220** | File No: 42626220-g-937.wor
Figure: **7.3.25** | Rev: A | A3

GAS TRANSMISSION PIPELINE ELEVATION PROFILE





Terrain Units & Constraints Intersecting the Gas Transmission 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)

Note: Figures 7.3.6 to 7.3.29 must be viewed with Figure 7.3.31, which shows the generic key / terrain unit legend.

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

Note: Full A3 (to scale) map available in Appendix L2.

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

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

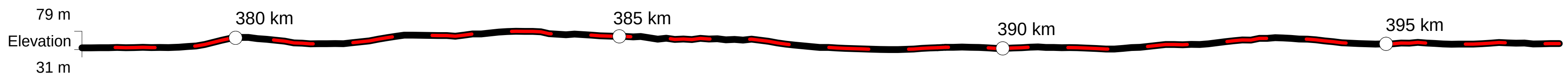
Client: LNG / URS

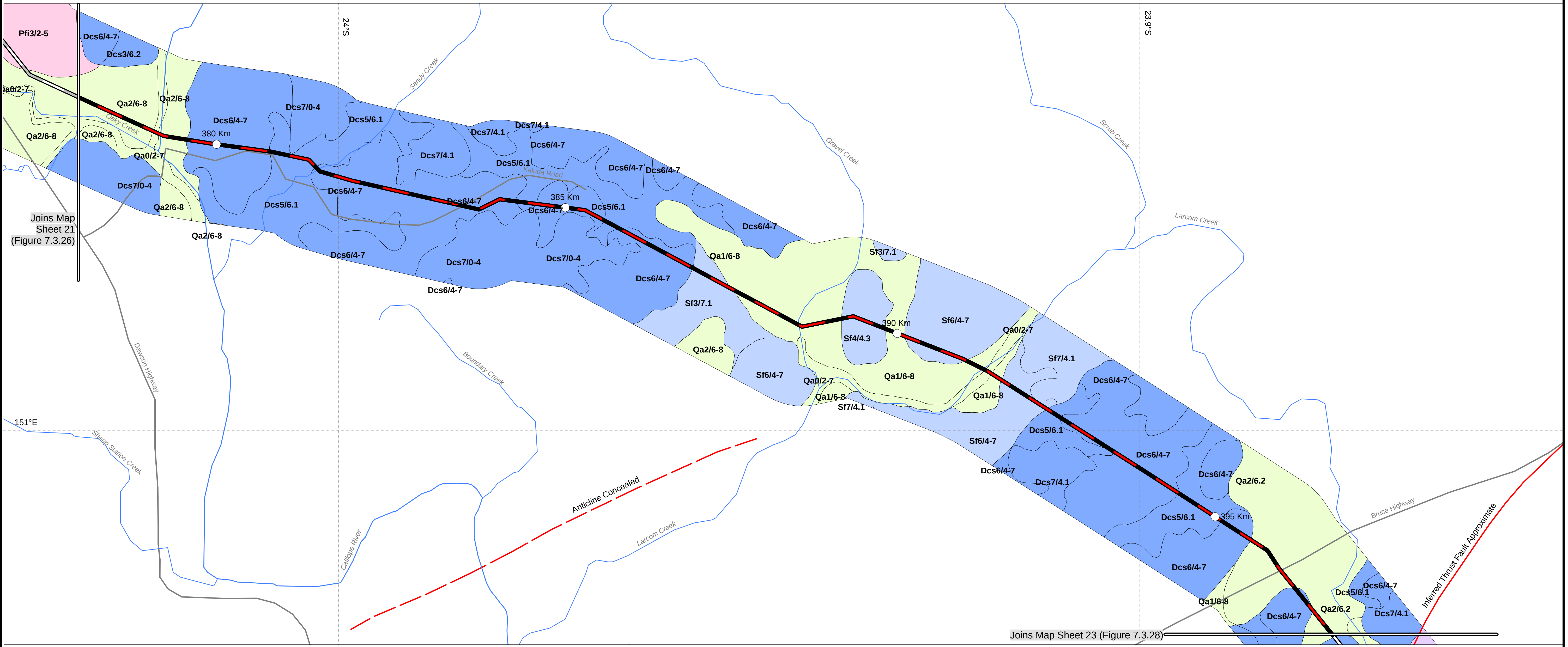
Project: GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT

Title: **GEOLOGICAL REGIMES AND TERRAIN UNITS (MAP SHEET 21 of 24)**

Drawn: CA	Approved: JB	Date: 15-05-2009	Figure: 7.3.26	Rev: A
Job No: 4262 6220	File No: 42626220-g-938.wor			A3

GAS TRANSMISSION PIPELINE ELEVATION PROFILE





Note: Figures 7.3.6 to 7.3.29 must be viewed with Figure 7.3.31, which shows the generic key / terrain unit legend.

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 the Gas Transmission 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)

Note: Full A3 (to scale) map available in Appendix L2.

Sector Summary:

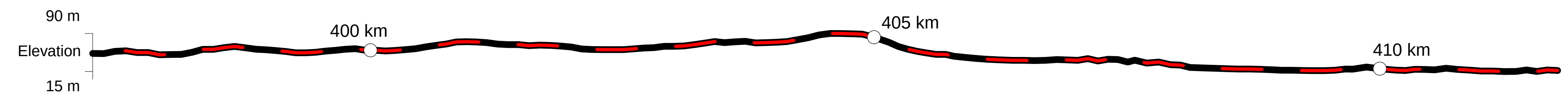
Constraints	Topographic Constraint	Excavation Rating	Erosion Potential	Drainage Status	Problem Soils
Low Constraint	8,561	5,211	-	13,855	8,874
Moderate Constraint	10,505	14,041	2,396	1,313	186
High Constraint	186	-	16,856	4,084	10,192

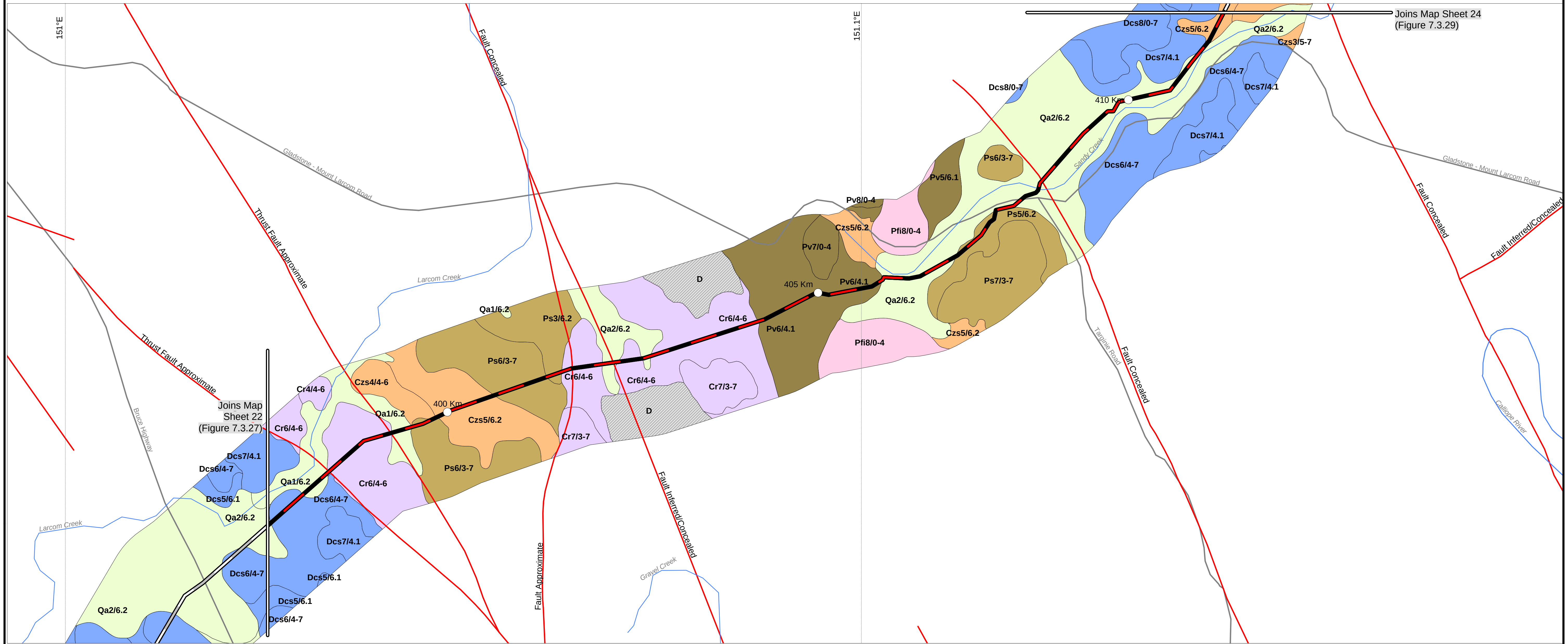
Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**GEOLOGICAL REGIMES AND TERRAIN UNITS (MAP SHEET 22 of 24)**

Drawn: CA | Approved: JB | Date: 15-05-2009
Job No: **4262 6220** | File No: 42626220-g-939.wor
Figure: **7.3.27** | Rev: A | A3

GAS TRANSMISSION PIPELINE ELEVATION PROFILE





Terrain Units & Constraints Intersecting the Gas Transmission 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)

Note: Figures 7.3.6 to 7.3.29 must be viewed with Figure 7.3.31, which shows the generic key / terrain unit legend.

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

Note: Full A3 (to scale) map available in Appendix L2.

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

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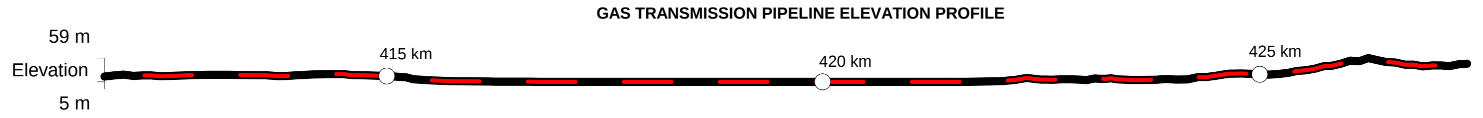
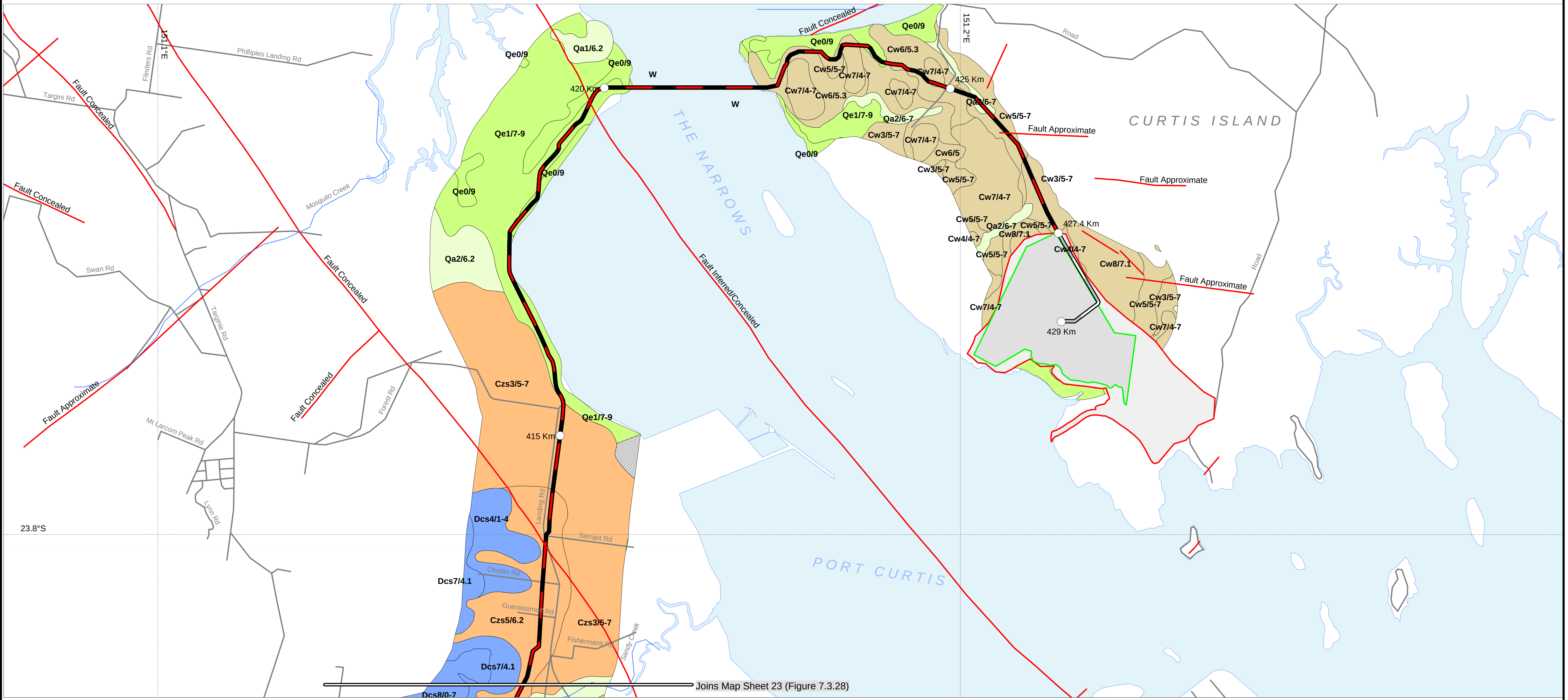
Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	GEOLOGICAL REGIMES AND TERRAIN UNITS (MAP SHEET 23 of 24)

Drawn: CA | Approved: JB | Date: 15-05-2009

Job No: 4262 6220 | File No: 42626220-g-940.wor

Figure: 7.3.28 | Rev: A | A3





Terrain Units & Constraints Intersecting the Gas Transmission 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

Note: Figures 7.3.6 to 7.3.29 must be viewed with Figure 7.3.31, which shows the generic key / terrain unit legend.

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
- LNG Facility Site Boundary
- LNG Facility Study Area

Note: Full A3 (to scale) map available in Appendix L2.

Client: LNG — URS

Project: GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT

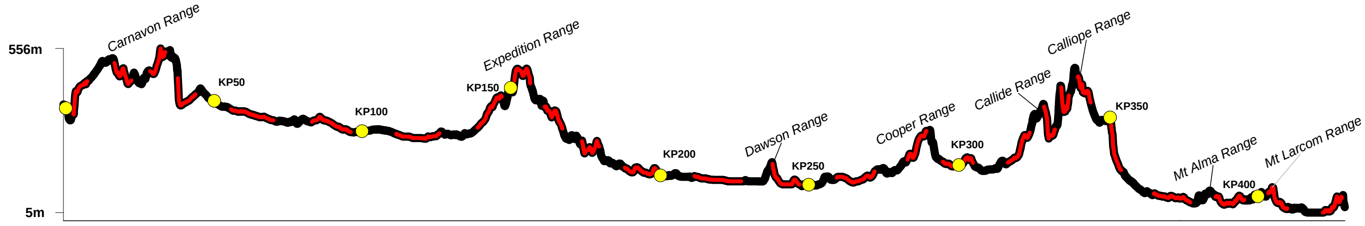
Title: **GEOLOGICAL REGIMES AND TERRAIN UNITS (MAP SHEET 24 of 24)**

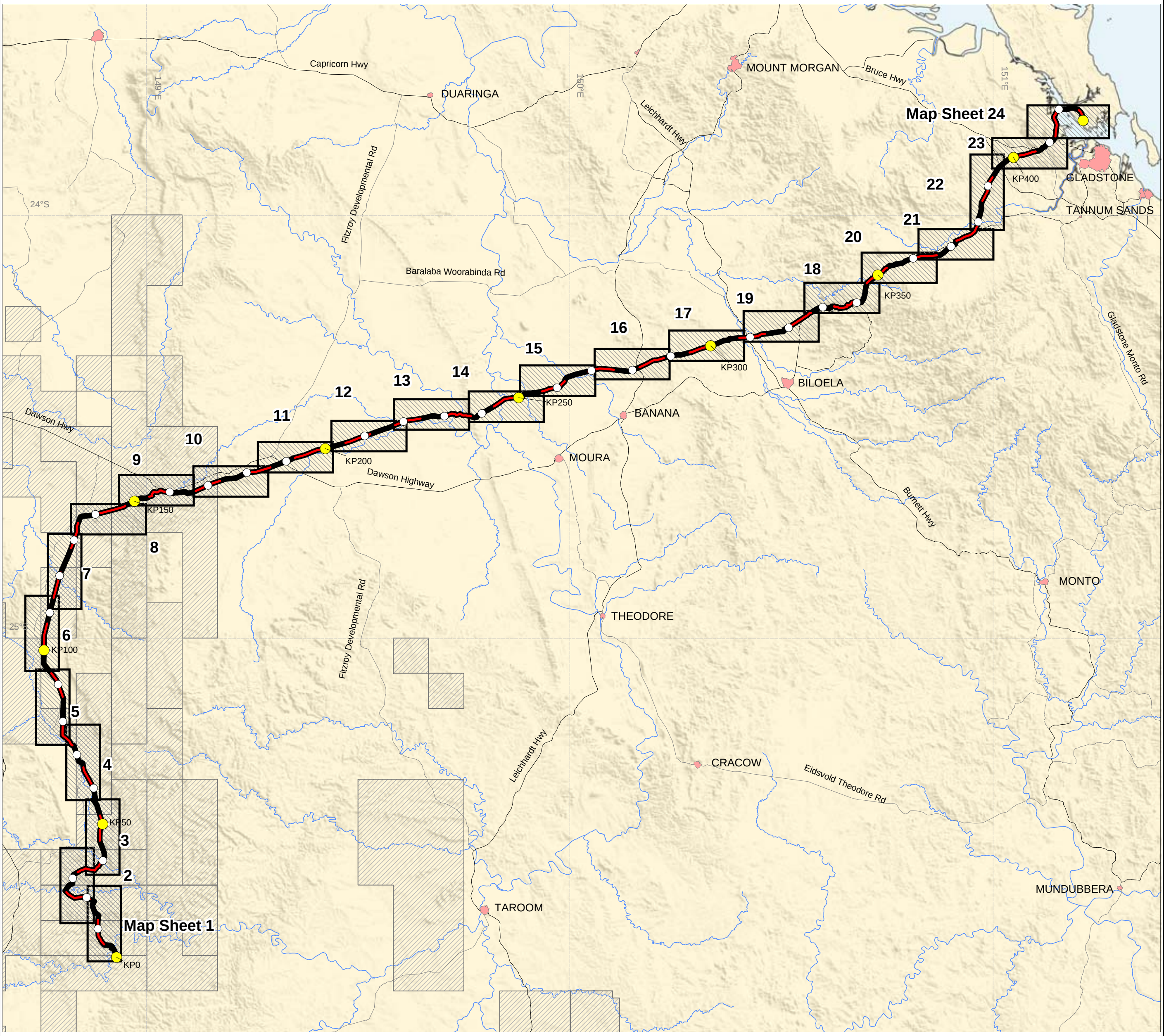
Drawn: CA | Approved: JB | Date: 15-05-2009

Job No: **4262 6220** | File No: 42626220-g-941.wor

Figure: **7.3.29** | Rev: A | A3

PIPELINE ELEVATION PROFILE





N
W E
S

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

Map Sheet Layout

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

Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	GAS TRANSMISSION PIPELINE CORRIDOR ELEVATION PROFILE AND MAP SHEETS LAYOUT ALONG GAS TRANSMISSION PIPELINE CORRIDOR
	Drawn: CA | Approved: JB | Date: 04-02-2009	Figure: **7.3.30** | Rev:A
	Job No: **4262 6220** | File No: 42626220-g-916.wor	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 7.3.31 must be viewed with Figure 7.3.6 to 7.3.29

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

Client

URS

Project
GLADSTONE LNG PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Title
GENERIC KEY TO THE IDENTIFICATION OF TERRAIN UNITS

Drawn: CA | Approved: JB | Date: 04-02-2009
Job No: **4262 6220** | File No: 42626220-g-917.wor
Figure: **7.3.31** | Rev: A | **A4**

Table 7.3.1 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-abile 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.

Geological Regime	Map Symbol	Description
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.
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 Figures 7.3.6 to 7.3.31.

Seismic Activity and Ground Stability

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

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

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

The GLNG Project area extends over a considerable distance, with some areas of the project falling within different expected earthquake intensities. The area with the highest earthquake risk is near Gladstone due to its close proximity to an earthquake source zone as defined in Gaull et al., 1990. From the coast, approximately 200 km inland to the west along the gas transmission 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).

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 Figures 7.3.6 to 7.3.31. 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 pipeline 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 Kp 216 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 pipeline 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 foot slope 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 three km east of Laird Point on Curtis Island, the 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 Kp 428 km.

Soil Groups and Soil Types

Major Soil Groups

The Key to the Identification of Terrain Units (Figure 7.3.31) should be read in conjunction with Figure 7.3.6 to Figure 7.3.29. This key includes a generic suite of nine broad Soil Groups that occur within the project area (as also described in Table 7.3.2 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 7.3.2 Soil Groups Identified Along the Gas Transmission Pipeline

Soil Group	Summary Soil Description	Soil Classification			
		Aust. Soil Group (1)	P.P.F. (2)	U.S.C. (3)	A.S.S. (4)
1	Skeletal, rocky or gravelly soils (>60% coarse fragments) with sandy, silty, loamy or clayey soil matrix	Shallow rocky soils	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 Lithosols	(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 Solods	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

Soil Group	Summary Soil Description	Soil Classification			
		Aust. Soil Group (1)	P.P.F. (2)	U.S.C. (3)	A.S.S. (4)
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	Ug5.12, 5.21 Ug5.24, 5.25 Ug5.38, Ug5.15, 5.16	CL-CH/CH, CH/CH	Vertosols Soil Order
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.	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, 1996).

With respect to the major soil groups identified in Figure 7.3.31 and described in the table 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 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 type variants identified within this group include:

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 sandy 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 sandy 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 coarse to medium-textured, uniform or gradational predominantly sandy earth soil profiles. Two soil type variants identified within this group include:

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, including:

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 including:

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 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, including:

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 – indicates medium to high levels of CEC and PAWC. The soils are non-saline and non-sodic in the surficial soil layers and become 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, including:

Soil Type 7.1 – These soil profiles occur mainly on low hilly, hilly and higher hilly lands where they have 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, 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 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 indicated 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, including:

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.

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 potential bridge crossing of Port Curtis and along the coastal fringe on Curtis Island.

Only the one general soil type was identified within this group as the soils varied considerably and include a wide range of deep to very deep, very soft, uniform, gradational and weak duplex soil profiles with highly organic silty clay, silty clay loam surface soils and seasonally or permanently saturated subsoils, typically gleyed and saline clays, clayey silt, silty sand or sandy mud.

No analytical data is available for the Group 9 soils, however soil chemistry data acquired for the GLNG EIS ASS investigations (refer to Appendix L4) 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 Figures 7.3.6 to 7.3.31.

Soil Erosion

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 a range of landform types associated with the Jurassic Sandstone geological regimes (Jh, Je and Jp), the Triassic Sandstone (Rm and Rc), the Silurian Volcanics (Sf), and the Permian sedimentary and intrusive rock types (Pfi) and (in parts) in the Cainozoic Sediments (Czs) geological regimes. All of the above units tend to have sand or sandy medium-textured surface soils, which in many parts have been subject to extensive grazing and related land-use activities. 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 with erosion potential rated simply as low (L), medium (M) or high (H) - (refer to Appendix L2 for the basis of assessment of erosion potential).

The occurrence and distribution of terrain units and associated erosion potential classes within the gas transmission pipeline corridor is shown in Figures 7.3.6 to 7.3.31. The cumulative distance of terrain units and the assessed erosion potential land class areas intersected along the pipeline corridor are shown in Figures 7.3.6 to 7.3.31. The cumulative areas intersected along the total length of the pipeline are summarised below.

The gas transmission pipeline extends over a total distance of 435 km, but for the purposes of this report, terminates at Kp 427.4 at the LNG facility site boundary on Curtis Island. Table 7.3.3 outlines the cumulative distances based on the terrain units intersected along the pipeline corridor.

Table 7.3.3 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.

Topsoil Resources

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

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. Indicative stripping depths of potential topsoil resources have been determined for each of the major soil groups and soil types identified, and are summarised in Table 7.3.4.

Table 7.3.4 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	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

Soil Group	Summary Soil Description	Soil Type	Indicative Stripping Depth (m)	Remarks
	and/or ferruginous gravelly lenses included.	4.3	0.3	Texturally suitable (0.3-0.6), but low soil nutrients.
5	Sand, loamy sand, sandy loam or loamy surface duplex soils over acidic to locally strongly acidic, in places neutral or slightly alkaline sandy clay to medium to heavy clay subsoils.	5.1	0.2	Strongly acidic in deeper subsoils.
		5.2	0.3	Bleached (A2) horizon (>0.3 m), source of bedding sand (0-0.6 m).
		5.3	0.2	Bleached (A2) horizon (>0.2 m).
6	Fine sandy, silty or clay loamy surface duplex soils with neutral to alkaline often calcareous, sodic and locally saline medium to heavy clay or heavy clay subsoils.	6.1	0.15	Shallow soils, bleached (A2) horizon, strongly alkaline subsoils.
		6.2	0.15	Thin pale or bleached layer over hard clay subsoils.
7	Shallow uniform often gravelly fine-textured soils, medium to deep uniform fine-textured (non-cracking) clay soils or gradational often stony or gravelly clay loam or light clay surface soils over alkaline medium to heavy clay subsoils, locally sodic and saline in the deeper subsoils – some deep incipient cracking clays.	7.1	0.2	Excess gravel/stone below 0.2 m.
		7.2	0.3	Texturally suitable (0.3-0.6 m), highly alkaline/calcareous below.
		7.3	0.2	Locally strongly acidic sodic and moderately highly saline in the subsoil below about 0.2 m
8	Shallow to medium to deep uniform fine-textured (cracking) clay soils, locally with thin self-mulching surficial soils with dark grey, brown or black mostly alkaline or alkaline over acidic heavy clay subsoils in areas with gilgai micro-relief.	8.1	0.2	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 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.

Agricultural Land

Agricultural land classes have been determined on a terrain unit basis. 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 gas transmission pipeline corridor assessment. The occurrence and distribution of agricultural land classes within the gas transmission pipeline corridor is shown in Figures 7.3.6 to 7.3.31. The cumulative distance of terrain units and associated agricultural land class areas intersected along the gas transmission pipeline centreline are shown on a sector by sector basis in Figures 7.3.6 to 7.3.31.

The basis for the assessment of agricultural land capability is addressed in the methodology section above. The cumulative distance of the respective agricultural land class areas identified has been determined on a route sector by sector basis as shown in Figures 7.3.6 to 7.3.31. Assuming a nominal 30 m wide gas transmission 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 7.3.5 below.

Table 7.3.5 Agricultural Land Capability along the Gas Transmission Pipeline Corridor

Rating[1]	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.

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

Acid Sulfate Soils

The Terms of Reference (ToR) for the GLNG Project require that an investigation and mapping of the occurrence and distribution of 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 in Appendix L4.

The 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 fringe of The Narrows, both on the mainland eastern coastline south of Friend Point and along the western coastline of Curtis Island to the south of Graham Creek and Laird Point. 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.

Load Bearing Capacity of Marine Plains

Areas of the site that are closer to the shore, in the mud flats, may have compressible characteristics lending to increased settlement, or may require alternative (i.e. deep) foundations (Bechtel, 2008). Piling would be limited to support marine structures or limited trestles where the heavy haul road may cross mud flats or soft-soil areas. Where required, expectation is that deep foundations will predominantly be end bearing, rather than relying on friction.

Additional geotechnical investigations will be required early during the FEED phase. These investigations need to include evaluation of soil over consolidation ratios and swell potential, as these can impact performance of shallow foundations.

Potential Impacts and Mitigation Measures

Topographic Constraints

Topographic constraints and their impact on the level of difficulty with respect to the construction of the gas transmission pipeline, relate primarily to the steepness of slopes, in particular the steepness of cross slopes and the degree of dissection along the gas transmission 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 corridor, have been rated as presenting a high (H) level of topographic constraint for pipeline construction.

Results of Assessment

Reference to the gas transmission pipeline maps (refer Figures 7.3.6 to 7.3.31), 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 7.3.6 below.

Table 7.3.6 Topography Constraints

Rating	Percentage of the 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.

Potential Impacts

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 gas transmission pipeline corridor. 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 gas transmission pipeline route has been rated as land presenting high topographic constraints for pipeline construction.

Mitigation Measures

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 site specific investigations for the detailed methodology for 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 site specific investigations to determine the least intrusive construction options.

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 7.3.7 below.

Table 7.3.7 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 (30 T) 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 30 T 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 (45 T) excavator with rock-breaking capability, a rock saw, or (65 T) 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 (45 T) excavator with heavy rock-breaking capability; some drilling and blasting may be necessary for rock removal to the required trench depth.

Results of Assessment

Reference to the gas transmission pipeline route sector maps (refer Figures 7.3.6 to 7.3.31), 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 7.3.8 below.

Table 7.3.8 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.

Potential Impacts

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, and the construction methods and types of equipment required to carry out the work. Other impacts relate to the amount of rock likely to be encountered and the suitability of the excavated spoil for trench backfill purposes.

Mitigation Measures

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 (refer to the separate Noise and Vibration report in Appendix U1). In general, any blasting that may be required will be carried out in accordance with relevant local authority guidelines and AS:2885. Areas that may require the employment of drill and blasting techniques will be carefully investigated with respect to the possible co-location of other pipeline facilities and/or buried services in the general vicinity, to ensure the integrity of and any safety issues related to such facilities.

The impacts and mitigation measures associated with the pipeline's crossing of Port Curtis are discussed in Section 8.7.

Soil Erosion

Potential Impacts

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 measures will help minimise erosion and reduce sediment loss from disturbed areas.

Mitigation Measures

General erosion control measures outlined below will be implemented where necessary to minimise the potential effects of erosion during construction and the on-going operational life of the gas transmission pipeline.

General Erosion Control Measures

- Limiting the area disturbed, and clearing progressively, immediately prior to construction activities commencing;
- Scheduling earthworks activities to avoid, where possible, the higher rainfall months of December to February;
- Safeguarding the surface layer by stripping and stockpiling topsoil prior to construction;
- Control runoff and sediment loss from disturbed areas using appropriate short term erosion control measures such as silt fences, hay bales, diversion mounds, etc;
- Using temporary soil diversion mounds to control runoff within and to divert water away from the construction site where practicable;
- Minimising the period that the bare soil is left exposed to erosion;
- Using sediment traps and sediment collection ponds to minimise off-site effects of erosion; and
- Maintenance of a regular monitoring program to ensure that the erosion control measures implemented are effective.

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, trench-breakers (vertical barriers to flow) will be installed at regular intervals to reduce flow along the trench and promote seepage to the groundwater. This will apply in particular where sodic and/or dispersive soils occur. The locations of the trench-breakers will be identified prior to backfilling of the trench.
- A series of low water diversion mounds will be installed across the entire width of the working area immediately following clearing, grading and stripping of topsoil. The diversion mounds will be located every 25 - 75 m depending on the surface gradient and soil type. Water contained by each mound will be diverted to stable vegetated land on the down-slope side of the easement or into an area protected by a silt fence if surface vegetation is sparse or absent.
- 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, required water course crossings will be directionally drilled to reduce area disturbance and minimise environmental impact in these areas;
- In other drainage lines a 50 m vegetative buffer will be retained until construction across the stream bed is imminent;

- Stream bed and bank materials will be graded away (upslope) from the stream bed and placed in temporary stockpiles, a minimum of 50 m beyond the bank and protected on the down-slope side by a silt fence;
- Where it is necessary to divert water flow around the crossing site, it will be pumped into a geofabric-lined containment area and control released a suitable distance downstream of the crossing site;
- Temporary earth banks will be installed across the approach slopes to the drainage line to divert upslope surface runoff down stream of the crossing site;
- When the pipe installation is complete the stream bed will be re-instated using material consistent with the existing stream bed material. Stream banks will be re-established to a stable slope consistent with the existing bank slopes both upstream and downstream of the crossing site. Topsoil will be replaced and the area revegetated as soon as practicable. In places it may be necessary to place jute matting or use rock armouring for erosion control purposes; and
- Stabilisation of these sites may be assisted by pushing disturbed riparian vegetation back over the ROW to provide seed stock and to help stabilise the area.

Dust Mitigation

- The construction methods employed 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;
- Contractors using access tracks to the proposed pipeline easement may be required to undertake regular spraying 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. Provision of access to the gas transmission pipeline corridor at regular intervals will avoid continuous trafficking along the corridor and help reduce the potential for bulldust to develop;
- Dusty areas will be managed by restricting access along the side of the corridor to rubber tyred vehicles. These areas will be maintained by regular use of water trucks and graders to assist dust suppression. Soil stabilisation additives may also be used when watering down to further maximise dust suppression; and
- Temporary use of cover crops may be utilised to stabilise bare soil stockpiles or other bare areas.

The control of erosion and sediment movement within the proposed gas transmission 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, tracks will be constructed with a gravel surface and maintained to permit all weather access. Where access is required for temporary (construction) use only, disturbed areas will be lightly ripped, restored to a stable condition and revegetated or returned to their pre-disturbance land use condition as soon as practicable following the completion of construction activities.

Infrastructure and Development Areas

The following erosion control measures are typically used to minimise the potential impacts of erosion and to control sediment loss from the pipeline ROW:

- 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;
- On 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; and
- Along the pipeline ROW, 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

- Unsealed or gravelled service tracks will be graded to a crown and provided with efficient surface drainage to prevent runoff eroding either the road surface or the adjacent land. Where necessary, low mounds angled across the track will be constructed to divert runoff (at non-erosive velocity) into adjacent areas;
- Cut and fill batters associated with service tracks will be formed to a safe slope and stabilized by vegetation, stone or rock armouring, or by the use of geo-fabric where appropriate;
- Where table drains need to be established, they will be constructed to a broad dish shape, seeded and fertilized or lined appropriately, to prevent erosion. Table-drains will be slashed periodically to ensure vegetation growth is not restricting drainage flow;
- Approaches on service tracks to gully and creek crossings will be 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 to reduce erosion;
- Where provision of access across gullies or creeks cause disturbance, re-vegetation work will be undertaken; and
- All temporary construction tracks and associated disturbed areas will be ripped, seeded and fertilized when construction is completed. Stockpiled topsoil will be re-spread before sowing. On steeper slopes the seeded areas will be protected if necessary.

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 cumulative distance of terrain units and the associated problem soil area categories intersected along the pipeline centreline are shown in Figures 7.3.6 to 7.3.31. The cumulative areas intersected along the total length of the gas transmission pipeline are summarised in Table 7.3.9 below.

Table 7.3.9 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% (total)	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% (total)	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.

Sodic and/or Dispersive Soils

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

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

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

Potential Impact

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

Mitigation Measures

Where sodic and dispersive soils do occur, adopting the relevant erosion control measures outlined in the previous section will assist in mitigating the deleterious effects of these problem soils. Where strongly or very strongly sodic and/or dispersive materials are identified; these materials will not be used for rehabilitation purposes. However, should suspected sodic or dispersive materials be exposed as a result of site earthworks (subject to confirmation by appropriate soil testing), then dolomite or gypsum-based soil conditioner will be spread and blended into the exposed surface soils to restore the ionic balance and thus reduce levels of sodicity and dispersion effects in the soils. The use of a suitable thickness of topsoil as a cover over sodic/dispersive soils will also help to minimise the deleterious effects of these soils.

Reactive Soils

These relate primarily to the occurrence of highly reactive (cracking) clays that occur in terrain units mainly with Soil Group 8 and in places in Soil Group 9 soils occurrences.

Potential Impact

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

Shallow to medium deep and deep highly reactive (Group 8) soils have been identified to occur spread over approximately 43 % of the gas transmission pipeline corridor.

Mitigation Measures

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 gas transmission 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 gas transmission pipeline construction.

Soil Salinity

Potential Impact

Primary soil salinity (high levels of soluble salts) is salinity that occurs naturally within the soil profile usually in the subsoil layers. Secondary salinity including saline surface outbreaks occur as a result of rising groundwater in these areas usually as a result of clearing of trees and deep-rooted vegetation. In 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.

Soils with moderate to high levels of soil salinity particularly in the deeper clay subsoil and substrate materials occur along the gas transmission pipeline corridor in terrain units Qe0/9, Qe1/7-9, Qa2/6-7, Cw3/5-7 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.

Mitigation Measures

In areas with saline soils, a common salinity management recommendation is to avoid clearing of trees and other woody vegetation (DNRQ, 1997) 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 (as part of EMP commitments) to determine the occurrence and distribution of saline soils and where corrosion protection may be required along the gas transmission pipeline corridor.

Topsoil Resources

Potential Impacts

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 qualified personnel during the topsoil pre-stripping operations to ensure that the maximum quantity and quality of useable topsoil resources is recovered for later use in site rehabilitation.

Mitigation Measures

Topsoil Stripping

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

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

Agricultural Land Capability

Potential Impacts

Areas identified as Class A, B and C1 land may be subject to short term disruption of existing land use during the 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.

Mitigation Measures

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 lands 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 agreed with the landholder. Elsewhere, disturbed areas will be graded to a level consistent with lands adjacent and pre-stripped topsoil will be replaced. Appropriate erosion control measures will be implemented where considered to be necessary or by agreement with the landholder.

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

Drainage Conditions along the Gas Transmission Pipeline Corridor

Results of Assessment

Terrain units described have been assessed in terms of inferred surface drainage status. Seven classes were identified as outlined in Table 7.3.10 below.

Table 7.3.10 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 7.3.6 to 7.3.31. The drainage status of terrain units intersected along the total length of the pipeline are summarised in Table 7.3.11 below.

Table 7.3.11 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.

Potential Impacts

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 may be restricted.

Mitigation Measures

Construction activities will cease and vehicular access in these areas will 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 above 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 above will be implemented to mitigate environmental impacts relating to the potential effects of erosion in these flood prone areas.

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 potential bridge crossing 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 gas transmission pipeline corridor in low lying areas will be undertaken prior to construction to determine the occurrence and thickness of any AASS and/or PASS materials present. If AASS 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 EMP.

Cumulative Impacts

Section 1 identifies other proposed gas transmission pipelines associated with other potential CSG Projects. There is limited information available as to the planned development or timing of these projects. However, a qualitative assessment can be made of the possible cumulative impacts.

Some sections of the proposed gas transmission pipeline corridor may be located within an area where these other pipelines are proposed to be located in the future. There is a minor potential for cumulative impacts associated with soils and terrain during construction and rehabilitation of each pipeline project.

In the event that the “Yarwun Neck” in the Gladstone State Development Area (GSDA) contains multiple pipelines, cooperation between the relevant pipeline development proponents and regulatory agencies will be required to minimise impacts such as erosion, drainage, depleted topsoil resources, and existing land use.

The Queensland Government has advised that its preference is for the gas transmission pipelines for all LNG facilities proposed for Curtis Island to be located in a common pipeline corridor across the Gladstone State Development Area, including the Port Curtis Crossing and Curtis Island pipeline sections to minimise potential impacts in this area.

It is expected that the other gas transmission pipeline development projects will include some or all of the proposed mitigation measures in relation to soils and land described in this section. By utilising the mitigation methods the expectation is the minimisation of the cumulative impacts on the receiving environment.

Table 7.3.12 provides a summary of potential land impacts and mitigation measures for the gas transmission pipeline.

Table 7.3.12 Potential Land Impacts and Mitigation Measures

Aspect	Potential Impact	Mitigation Measures	Objective
Construction			
Agricultural land capability.	Sterilisation of land.	<u>Class A, B and C1 land</u> • Soil cover thickness above buried pipelines or services should be 1.2m. If deep ripping is a normal practice or is proposed the minimum cover thickness may be extended to 1.8 m, if required by the property landholder. • As soon as practicable, temporary access tracks will be removed, disturbed land lightly ripped, topsoil replaced and the land returned as near as possible to pre-construction land use condition. • Erosion control measures will be implemented where necessary or by agreement with the landholder. <u>Class C2 land</u> • When construction activities are complete the temporary access tracks will be removed unless otherwise agreed with the landholder. • Disturbed areas will be graded to a level consistent with lands adjacent and pre-stripped topsoil will be replaced. • Erosion control measures will be implemented where necessary or by agreement with the landholder. <u>Class C3 & D land</u> • When construction activities are complete in these areas, land management and erosion control measures will be implemented. • These areas will be revegetated as soon as practicable after construction activities have been completed.	Minimisation of land sterilisation.
Topsoil resources.	Loss of topsoil.	• Topsoil shall be stored in stockpiles within the ROW. • Earthmoving plant operators will be trained and/or supervised to ensure that stripping operations are conducted in accordance with the EMP and anticipated in situ soil conditions. • Care will be taken during the stripping, stockpiling, and respreading operations to ensure that moisture content of the topsoil resources is such that structural degradation of the soil is avoided and excessive compaction does not occur. • Monitoring of soil type variability will be undertaken by qualified personnel during the topsoil	Maximisation of topsoil retention.

Aspect	Potential Impact	Mitigation Measures	Objective
		pre-stripping operations to ensure that the maximum quantity and quality of useable topsoil resources is recovered for later use in site rehabilitation. • Topsoil shall be stored in stockpiles located in areas that do not impinge on the construction disturbance footprint area and away from drainage lines. Drainage from higher areas will be diverted around stockpiles to prevent erosion. Sediment controls will be installed immediately down-slope of the stockpiles to collect any washed sediment. • Stockpiles will be formed in low mounds of height approximately 3 m maximum and maximum surface area, consistent with the storage area available. • If the stockpile is to be retained for a period of more than six months, the stockpile will be deep ripped and sown with local grass seed-stock, legumes. Where appropriate the use of suitable potentially threatened (local) plant species will be considered. • Topsoil stockpiles will be clearly sign-posted. • Control weeds on stockpiles.	
Erosion potential.	Erosion and sediment loss from disturbed areas (General).	• Limiting the area disturbed, and clearing progressively, immediately prior to construction activities commencing. • Safeguarding the surface layer by stripping and stockpiling topsoil prior to construction. • Control of runoff and sediment loss from disturbed areas using appropriate short term erosion control measures such as silt fences, hay bales, diversion mounds, etc. • Using temporary soil diversion mounds to control runoff within and to divert water away from the construction site where practicable. • Minimising the period that the bare soil is left exposed to erosion. • Using sediment traps and sediment collection ponds to minimise off-site effects of erosion.	Minimisation of erosion and sediment loss.
	Erosion and sediment loss from disturbed areas (Drainage line management).	• Where pipelines or other buried services are required to cross water courses, these areas will be directionally drilled, where practicable, to reduce surface area disturbance and minimise environmental impact. • In other drainage lines, a 50 m vegetative buffer will be retained, if required, until construction across the streambed is imminent. • Streambed and bank materials will be graded away (upslope) from the streambed and placed in temporary stockpiles, a minimum of 50 m beyond the bank and protected on the down-slope side by a silt fence. • Where it is necessary to divert water flow around the crossing site, it will be pumped into a geofabric-lined containment area and control released a suitable distance downstream of	Minimisation of erosion and sediment loss.

Aspect	Potential Impact	Mitigation Measures	Objective
		the crossing site. • Temporary earth banks will be installed across the approach slopes to the drainage line to divert upslope surface runoff down stream of the crossing site. • When the pipe installation is complete the stream bed will be re-instated using material consistent with the existing streambed material. Stream banks will be re-established to a stable slope consistent with the existing bank slopes both upstream and downstream of the crossing site. Topsoil will be replaced and the area revegetated as soon as practicable. In places it may be necessary to place jute matting or use rock armouring for erosion control purposes. • Stabilisation of these sites may be assisted by pushing disturbed riparian vegetation back over the re-instated area to provide seed stock and to help stabilise the area. This will also help restrict cattle from accessing the area; otherwise it may be necessary to install temporary fencing.	
	Erosion and sediment loss from disturbed areas (Dust mitigation).	• The construction methods employed should aim to reduce exposure of disturbed areas to the minimum period required and undertake revegetation or rehabilitation as soon as practicable after the completion of construction. • Access tracks may require regular spraying using water trucks for dust suppression, in particular in established farming and other built-up areas. • Temporary use of cover crops may be utilised to stabilise bare soil stockpiles or other bare soil areas. • 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. • Provision of access to the pipeline easement at regular intervals will avoid continuous trafficking along the easement and help reduce the potential for bulldust to develop.	Minimisation of erosion and dust generation.
	Erosion and sediment loss from disturbed areas (Infrastructure and development areas).	• 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, useable topsoil material will be stripped and stockpiled	Minimisation of erosion and sediment loss in infrastructure and developed areas.

Aspect	Potential Impact	Mitigation Measures	Objective
		separately adjacent to and along the trench. • On sloping ground 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 pipeline ROW, 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.	
	Erosion and sediment loss from disturbed areas (Erosion control on sloping land).	• On sloping ground where surface runoff or sub-surface drainage along trenches housing pipelines or other buried services may erode the backfill material, install trench-breakers (vertical barriers to flow) at regular intervals to reduce flow along the trench and promote seepage to the groundwater. This will apply in particular where sodic and/or dispersive soils occur. Identify the locations of the trench-breakers prior to backfilling of the trench. • Install a series of low water diversion mounds across the entire width of the working area immediately following clearing, grading and stripping of topsoil, located every 25 - 75 m depending on the surface gradient and soil type. Water contained by each mound will be diverted to stable vegetated land on the down-slope side of the disturbed area or into an area protected by a silt fence if surface vegetation is sparse or absent. • In sloping woodland areas felled timber and vegetative matter will be respread on the contour over the cleared working area to assist soil stabilisation and to discourage access into these areas.	Minimisation of erosion and sediment loss on sloping land.
	Erosion and sediment loss from disturbed areas (Roads	• Unsealed or gravelled service tracks will be graded to a crown and provided with efficient surface drainage to prevent runoff eroding either the road surface or the adjacent land.	Minimisation of erosion and sediment loss.

Aspect	Potential Impact	Mitigation Measures	Objective
	& Tracks).	Where necessary, low mounds angled across the track will be construction to divert runoff (at non-erosive velocity) into adjacent areas. • Cut and fill batters associated with service tracks will be formed to a safe slope and stabilized by vegetation, stone or rock armouring, or by the use of geo-fabric where appropriate. • Where table drains need to be established, they will be constructed to a broad dish shape, seeded and fertilized or lined appropriately, to prevent erosion. Table-drains will be slashed periodically to ensure vegetation growth is not restricting drainage flow. • Approaches on service tracks to gully and creek crossings will be as flat as practicable. The track will be sloped to direct runoff to a table-drain constructed as above. In some vulnerable areas, it may be necessary to spread and compact coarse aggregate along the approaches to the crossing to provide permanent, stable access, and reduce erosion. • Where provision of access across gullies or creeks cause disturbance, re-vegetation work will be undertaken. • All temporary construction tracks and associated disturbed areas will be ripped, seeded and fertilized when no longer required for use. Stockpiled topsoil will be re-spread before sowing. On steeper slopes the seeded areas will be protected where necessary.	
Problem soil areas	Erosion and sediment loss from disturbed areas (Areas of impeded drainage).	• In areas prone to occasional flooding and with soils of impeded drainage, construction activities will cease and vehicular access in these areas will be avoided during and immediately following periods of heavy rainfall.	Minimisation of erosion and sediment loss of soils with impeded drainage.
	Erosion and sediment loss from disturbed areas (Sodic and/or dispersive soils).	• Should suspected sodic or dispersive materials be exposed as a result of site earthworks, dolomite or gypsum-based soil conditioner will be spread and blended into the exposed surface soils to restore the ionic balance. • 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. • Where strongly or very strongly sodic and/or dispersive materials are identified; these materials will not be used for rehabilitation purposes.	Minimisation of erosion and sediment loss of suspected areas that have sodic or dispersive materials.
	Damage to structures, foundations and buried services due to differential ground movements caused by reactive soils.	• Detailed field investigations including drilling, soil sampling and testing will be undertaken to more clearly define the properties and extent of occurrence of these reactive soils and their potential impact on the long-term integrity of structures and/or buried services. • Use of an inert (sandy) padding material encasing the facility to mitigate the impact of	Minimisation of disturbance in reactive soils and mitigation of impacts on structures and buried services.

Aspect	Potential Impact	Mitigation Measures	Objective
		differential soil movement in reactive soils.	
	Impacts on plant growth and increased potential for corrosion of buried steel and/or concrete products due to soil salinity.	• Avoid clearing of trees and woody vegetation, or revegetate cleared areas as soon as practicable following disturbance.	Minimisation of soil salinity and mitigation of impacts on structures and buried services.
	Exposure of acid sulphate soils.	• Site specific ASS investigations along the pipeline corridor in low lying areas will be undertaken prior to construction to determine the occurrence and thickness of any AASS and/or PASS materials present. • If AASS are found to occur, lime treatment to neutralise the acidity levels will be undertaken as temporary or permanent embankment filling (required for pipeline construction) over AASS (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 EMP.	Avoidance of excavation in areas with ASS.
	Damage to structures, foundations and buried services due to ground movement and erosion.	• In areas 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.	Minimisation of impacts on structures and buried services.
Area excavation conditions	Disturbance related to drilling and blasting of rock.	• Where heavy rock-breaking and/or drilling and blasting is necessary for rock removal, the work will be carried out during normal daylight working hours to minimise the effects of noise impacts in built-up or established farming areas. • In general, any blasting that may be required will be carried out in accordance with relevant local authority guidelines and AS:2885. • Areas that may require the employment of drill and blasting techniques will be carefully investigated with respect to the possible co-location of other pipeline facilities and/or buried services in the general vicinity, to ensure the integrity of and any safety issues related to such facilities. • Where rock is encountered it will, wherever possible, be reused on the construction site or removed from the site and used for erosion control rip-rap or disposed of in alternative approved locations.	Minimisation of disturbance related to drilling and blasting, and optimisation of rock re-use.

Aspect	Potential Impact	Mitigation Measures	Objective
		• 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.	
Operation			
Agricultural land capability.	Sterilisation of land.	• Refer to construction section above.	Minimisation of land sterilisation.
Erosion potential.	Erosion and sediment loss from previously disturbed areas.	• Maintenance of a regular monitoring program to ensure that the erosion control measures implemented are effective. • Where necessary, implementation of additional mitigation measures to address any new or ongoing problem areas.	Minimisation of erosion and sediment loss from previously disturbed areas.
	Erosion and sediment loss from disturbed areas (Dust mitigation).	• Where access is required in the long term, tracks will be constructed with a gravel or sealed surface and maintained to permit all weather access.	Minimisation of erosion and dust generation.
Problem soil areas.	Erosion and sediment loss from disturbed areas (Sodic and/or dispersive soils).	• Maintenance of a regular monitoring program to ensure that the erosion control measures implemented are effective. • Where necessary, implementation of additional mitigation measures to address any new or ongoing problem areas.	
	Damage to structures, foundations and buried services due to differential ground movements caused by reactive soils.	• Refer to erosion and sediment loss from disturbed areas.	Minimisation of disturbance in reactive soils and mitigation of impacts on structures and buried services.
	Impacts on plant growth and increased potential for corrosion of buried steel and/or concrete products due to soil salinity.	• Refer to erosion and sediment loss from disturbed areas.	Minimisation of soil salinity and mitigation of impacts on structures and buried services.
Decommissioning and Rehabilitation			
Agricultural land capability.	Sterilisation of land.	• Refer to the construction section above.	Minimisation of land sterilisation.

Aspect	Potential Impact	Mitigation Measures	Objective
Topsoil Resources.	Loss of Topsoil.	• Refer to the construction section above.	Maximisation of topsoil retention.
Erosion Potential.	Erosion and sediment loss from disturbed areas.	• Refer to the construction section above.	Minimisation of erosion and sediment loss.
Problem Soil Areas.	Erosion and sediment loss from disturbed areas (Sodic and/or Dispersive Soils).	• Refer to the construction section above.	Minimisation of erosion and sediment loss.
	Exposure of acid sulphate soils.	• Refer to the construction section above.	Avoidance of excavation in areas with acid sulphate soils.

7.3.1.5 Summary of Findings

A comprehensive description of the main topographic features along the gas transmission pipeline corridor was completed and is provided in Appendix L2.

A suite of nine 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. This provides a means for establishing land rehabilitation targets upon decommissioning of the gas transmission pipeline and associated facilities.

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:

- 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, ASS; and
- Agricultural land classes - changes to agricultural land capability.

The potential impacts relating to the above issues have been addressed and mitigation measures have been recommended to mitigate the potential environmental impacts identified. Targets to achieve the recommended acceptable levels for land rehabilitation in areas disturbed by construction and development activities will be incorporated in the EMP to be developed for the gas transmission pipeline and associated infrastructure facilities. Monitoring of the success of the mitigation measures and the progress of land rehabilitation of disturbed areas along the ROW, will be carried out periodically (twice yearly) throughout the operating life-span of the LNG facility and for a suitable period following the decommissioning of the LNG facility by agreement with the local landholders and/or regulatory authorities.

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

7.3.2 Land Contamination

7.3.2.1 Introduction

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

7.3.2.2 Methodology

A land contamination assessment of the proposed gas transmission pipeline corridor was conducted. The purpose of this assessment was to:

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

The baseline assessment comprised a PSI, which involved a targeted desktop study aimed at identifying high risk sites or areas of potential concern (AOPC) within a 10 km wide, 435 km long gas transmission pipeline corridor.

The potential for existing land contamination was based on a desktop review of aerial photographs within the gas transmission pipeline corridor to identify land parcels potentially associated with notifiable activities, as contained in the *Environmental Protection Act* 1994 (EP Act). The baseline assessment was conducted in accordance with the DoE (1998) *Draft Guidelines for the Assessment and Management of Contaminated Land in Queensland* and included a Tier 1 and Tier 2 review as follows:

- Tier 1 comprised a review of aerial photography within the gas transmission pipeline corridor to identify high risk sites or AOPC. AOPC were identified based on the presence of visible infrastructure associated with potentially contaminating activities such as chemical storage tanks, cattle dip sites and industrial facilities.
- A Tier 2 assessment was then conducted on the identified AOPC and included:
  - a review of historical aerial photographs;
  - a search of historical titles;
  - a search of Environmental Protection Agency (EPA) land registers including the Environmental Management Register (EMR) and Contaminated Land Register (CLR); and
  - a search of local government records (e.g. development applications, chemical storage/dangerous goods licenses).
- A Tier 3 review (site inspection) of each AOPC and soil sampling (if required), will be conducted prior to pipeline construction, and form part of the EMP commitments.

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

A description of the gas transmission pipeline development used as the basis for the assessment is provided in Section 3.7. The assessment methodology used on this linear infrastructure was briefly discussed with Queensland EPA. The EPA was satisfied with the methodology as it is consistent with other pipeline Environmental Impact Statements.

The gas transmission pipeline corridor extends 435 km from the Fairview CSG fields, through the Arcadia Valley and onto Gladstone, crossing Port Curtis between Friend Point and Laird Point and terminating at the proposed LNG facility on Curtis Island. The environment ranges from forested hills, grazing pastures, rural residential to commercial/industrial zones as the gas transmission pipeline enters the Gladstone region. The gas transmission pipeline passes in the vicinity of the towns of Rolleston, Moura, Banana, Biloela, Yarwun and Gladstone. Extending from Gladstone, the gas transmission pipeline traverses mudflats, then is laid in a covered trench across the floor of The Narrows (the body of water separating Curtis Island from the mainland) then onto Curtis Island, before terminating at the proposed LNG facility near China Bay at the south west end of the island.

A full description of the environmental values of land use within the proposed gas transmission pipeline corridor is provided in Section 7.11.

7.3.2.3 Regulatory Framework

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

7.3.2.4 Existing Environmental Values

Baseline Contamination Assessment Findings

The Tier 1 assessment in the PSI identified six AOPC (refer Figure 7.3.32). Details for each AOPC and findings of the EPA register searches are provided in Table 7.3.13.

Table 7.3.13 AOPC

ID	AOPC	Lot & Plan	EMR	CLR	Land use & Potential Contaminant
1	Quarry	Lot 4 WT217	No	No	Quarry facilities: Fuels, wastes.
2	Stockyard	Lot 7 CUE37	No	No	Stockyard: potential cattle dip with pesticide use.
3	Open gravel area	Lot 525 CL40243	No	No	Open Gravel patch: unknown land use/ contaminants.
4	Stockyard	Lot 9 SP200837	No	No	Stockyard: potential cattle dip with pesticide use.
5	Industrial plant	Lot 1 SP200852	Yes	No	Industrial plant including several Above Ground Storage Tanks (AST), storage ponds. Current land use comprises integrated waste management, resource recovery, and transport services- potential contaminants include fuels, lubricants, chemicals (unknown).
6	Grass airstrip/hanger	Lot 1 SP108922	No	No	Aeroplane hanger- potential aviation fuels, lubricants.

Only the industrial plant (ID5) was listed on the EMR. The site was subdivided from Lot 135 RP801113, which was listed on the EMR. The following notifiable activity was listed for the industrial plant:

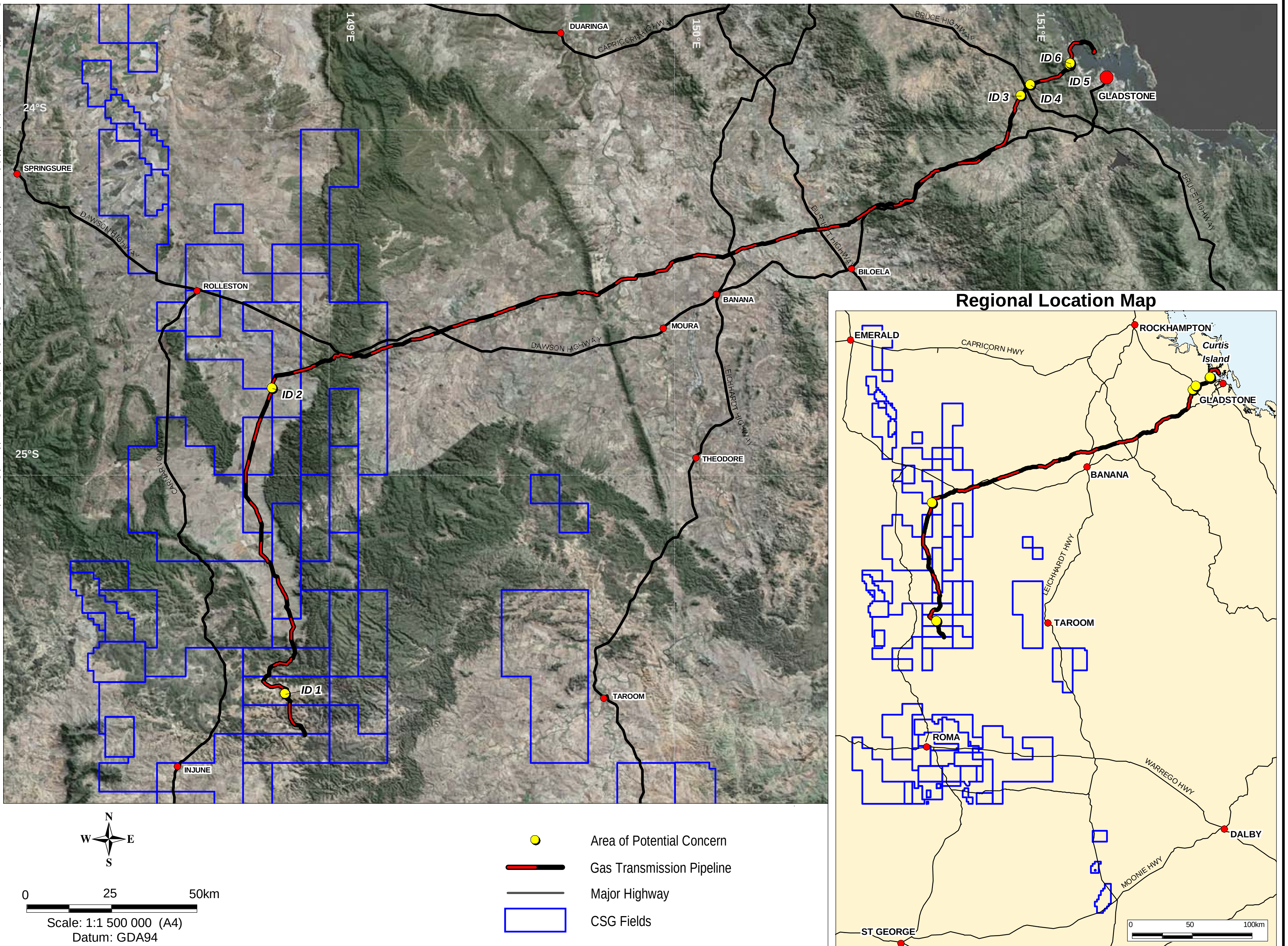
- Chemical Manufacture or Formulation (blending, mixing or formulating chemicals):
  - Designated dangerous goods under the dangerous goods code; and
  - Facility with a design capacity of more than one tonne per week.

7.3.2.5 Potential Impacts and Mitigation Measures

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

- The existing AOPC identified during the PSI; and
- GLNG gas transmission pipeline development activities.

The gas transmission pipeline route will intersect ASS in along the coastline. Impacts of ASS and mitigation are further discussed in Section 7.3.1.5 and the technical report for ASS can be accessed in Appendix L4.



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Client

URS

Project

GLADSTONE LNG PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Title

GAS TRANSMISSION PIPELINE IDENTIFIED AREAS OF POTENTIAL CONCERN

Drawn: CA | Approved: JB | Date: 04-02-2009

Job No: 4262 6220 | File No: 42626220-g-862.wor

Figure: 7.3.32 | Rev: A | A4

Areas of Potential Concern

Potential Impacts

The six existing AOPC as detailed in Table 7.3.13 have been identified within the gas transmission pipeline corridor. The major impact associated with these areas is excavation of potential contaminants during gas transmission pipeline construction or decommissioning activities, and either mobilisation of such contaminants off-site or exposure of contaminants to workers and the resultant health risks associated with this.

Mitigation Measures

The potential mitigation measures to minimise these impacts include:

- In the first instance ensuring pipeline development activities avoid the AOPC;
- Conduct site management works at these AOPC so that project related impacts are minimised (e.g. develop a site management plan limiting the nature of activities that can be carried out on the site); or
- Remediate the AOPC prior to pipeline development activities occurring.

As part of the pipeline development EMP more detailed (Tier 3) assessments will be conducted at each identified AOPC to assess which of the above mitigation measures is appropriate at each site. In addition, site protocols will be developed by the pipeline construction contractor/proponent to manage any areas of potential contamination concern that may be exposed as part of pipeline development activities.

Gas Transmission Pipeline Development Activities

Potential Impacts

Potential land contamination risks associated with the gas transmission pipeline development primarily relate to the construction and decommissioning phases, as the operation of the pipeline will have minimal contamination potential due to the nature of the product (gas).

During the construction phase potential sources of contamination include the excavation of existing (pre-construction) contaminated soil. Other potential risks include fuel spills associated with the storage and refuelling of construction equipment and the storage and treatment of ASS at the coastline portion of the gas transmission pipeline (Appendix L4). Sewage treatment plant (STP) waste and the generation of putrescible waste associated with worker accommodation will also be generated. Putresible waste however will not be disposed or stored within the gas transmission pipeline corridor (refer Section 5).

Other potential risks include fuel spills associated with the storage and refuelling of construction equipment and the storage and treatment of ASS.

Mitigation Measures

- Construction wastes will be managed through the waste management plan (Section 5).
- Stockpiles, workshop areas, chemical stores, fuel tanks and waste disposal/storage areas will be located on hardstand or compacted soil. Contaminated runoff from these areas will be collected and remediated or disposed of in an approved manner.
- Relevant Australian Standards (e.g. for the storage and handling of flammable and combustible liquids and dangerous goods) will be complied with.
- Where possible, hazardous chemicals and materials will be replaced with less harmful alternatives. Material safety data sheets (MSDS) for chemicals used or brought onto the sites will be accessed via the Santos intranet.

- Spills will be cleaned up immediately. For significant chemical or fuel spills, the Emergency Response Plan will be followed and the appropriate authorities notified as soon as possible.
- Detailed records will be kept of any activities or incidents that have the potential to result in land contamination. Records will be kept on an inventory that contains information on storage location, personnel training and disposal procedures for all chemicals, fuel and other potential contaminants used on site. Santos has existing databases for recording the above data, which will be maintained and reviewed regularly.
- Regular inspections of containers, bund integrity, valves, and storage and handling areas will be carried out as part of routine environmental audits.
- All staff will be trained in appropriate handling, storage and containment practices for chemicals, fuel and other potential contaminants as relevant.
- Santos will utilise management procedure EHS08 Contaminated Site Management, which was developed to protect the environment, where contamination has or may have occurred.
- Where relevant, Santos will utilise management procedure HSH08 Chemical Management and Dangerous Goods, which was developed to manage the associated risk with the handling, use and storage of chemicals.

Cumulative Impacts

Section 1 identified other proposed gas pipelines associated with other potential CSG Projects. There is limited information available as to the planned development or timing of these projects. However, a qualitative assessment can be made of the possible cumulative impacts.

Sections of the proposed gas transmission pipeline corridor are located within areas where these other pipelines may be constructed. There is a minor potential for cumulative impacts associated with land contamination during construction and operation such as pigging during operational maintenance and hydro-testing during construction. Given the broad area of operation and adoption of management measures by Santos and expected to be adopted by other operators for the management of existing contaminated land and prevention of potential land contamination during construction and operation, the cumulative impacts are expected to be minimal.

Table 7.3.14 provides a summary of potential land contamination impacts and mitigation measures for the gas transmission pipeline.

Table 7.3.14 Potential Impacts and Mitigation Measures

Aspect	Potential Impact	Mitigation Measures	Objective
Construction			
Surface Water/ Soil- hydrocarbon.	Hydrotest (pigging) water potentially contains elevated salts and residue biocide and anti-fouling chemicals.	• Hydrotest waters will be captured in detention ponds and treated prior to discharge. Treatment will be conducted onsite via water treatment plant or where unavailable, trucked to a wastewater treatment facility. Evaporation ponds may also be considered.	To ensure produced water is appropriately treated and disposed.
Surface Water/ Soil- hydrocarbon contamination.	Storage areas- storage of fuel, oils, lubricants, solvents and waste oil- loss of hydrocarbon waste to the surrounding environment.	• All fuel/ oil storage areas will be bunded. • Bunded areas will be regularly inspected for evidence of leakage of storage tanks/ containers. • Any spills will be immediately contained and reported. Contaminated soil will be removed and remediated and any contaminated water (e.g. stormwater in bund) treated.	To ensure no loss of hydrocarbons to the environment.
	Diesel spill from construction equipment during operation.	• All vehicles to be checked for integrity of fuel tank and responsible driving to prevent perforation of tank during clearing operations. • Any spills will be immediately reported and contained. Contaminated soil will be removed and remediated and contaminated water treated. • All vehicles to carry spill kits for small spills.	To ensure no loss of fuel to the environment.
Surface Water/ Soil- chemical contamination.	Diesel spill from construction equipment during operation. Spills/ loss of other chemicals e.g. anti-fouling agent, biocide.	• All vehicles to be checked for integrity of fuel tank and responsible driving to prevent perforation of tank during clearing operations. • Any spills will be immediately reported and contained. • Contaminated soil will be removed and remediated and contaminated water treated. • All vehicles to carry spill kits for small spills.	To ensure no loss of chemicals to the environment.

Aspect	Potential Impact	Mitigation Measures	Objective
Surface Water/ Soil- chemical contamination.	Horizontal Directional Drilling (HDD) wastewater and flocculation entering nearby water course.	• All wastewaters will be contained in temporary dams and treated with flocculent. • Storage of gypsum will be in dry bunded areas.	To ensure all wastewater is captured and treated and not released to nearby water courses.
	Exposure of contaminated soil within AOPC or other unknown sites.	• A Tier 3 inspection of each AOPC will be conducted to identify potential for contamination. Where contamination potential is identified, a Phase II Environmental Site Assessment will be undertaken to delineate contamination. • Contaminated sites will be avoided where possible, and if disturbed will be remediated.	To prevent the disturbance of existing contaminated sites. To remediate any contaminated land to be disturbed by the pipeline development.
Surface Water/ Soil- hydrocarbon.	Hydrotest (pigging) water potentially contains elevated salts and residue biocide and anti-fouling chemicals.	• All pigging wastewater will be captured in retention ponds and treated prior to discharge. Treatment may be conducted onsite via water treatment plant or where unavailable, trucked to a wastewater treatment facility.	To ensure produced water is appropriately treated and disposed.
Surface Water/ Soil- nutrient and hydrocarbon.	STP- system failure, overflow or inadequate treatment.	• Treatment system will be maintained and quality of outflow monitored.	To ensure no change to groundwater/ surface water quality and soil characteristics.
Surface Water/ Soil- hydrocarbon.	Potentially contaminated storage pond discharge to surrounding environment.	• Capture of first flush runoff in basins and treatment prior to discharge to Stormwater Balance Pond and constructed wetland. • Water quality and dam capacity of sediment ponds will be monitored and where exceedances identified, remediation measures adopted. • No discharge to effluent where water quality exceeds discharge criteria. • Evaporation ponds will be considered.	To ensure no unauthorised discharge to surrounding environment. To meet at a minimum the water quality discharge criteria for stormwater effluent.
Surface water / soil contamination.	Pigging works introduce antifouling and/or biocide chemicals to receiving environment.	• All pigging wastewater will be captured in detention ponds and treated prior to discharge. Treatment will be conducted onsite via water treatment plant or where unavailable, trucked to a wastewater treatment facility.	To ensure pigging activities do not introduce untreated waste water to the environment.

Aspect	Potential Impact	Mitigation Measures	Objective
Operation			
Surface Water/ Soil- hydrocarbon contamination.	Storage areas- storage of fuel, oils, lubricants, solvents and waste oil- loss of hydrocarbon waste to the surrounding environment.	• Refer to the construction section above.	To ensure no loss of hydrocarbons to the environment.
Surface Water/ Soil- chemical contamination.	Diesel spill from construction equipment during operation. Spills/ loss of other chemicals e.g. anti-fouling agent, biocide.	• All vehicles to be checked for integrity of fuel tank and responsible driving to prevent perforation of tank during clearing operations. • Any spills will be immediately reported and contained. Contaminated soil will be removed and remediated and contaminated water treated. • Permit to Work System- vehicle inspection prior to entering the work site. • EHS performance review- Schedule waste treatment/ disposal. • All vehicles to carry spill kits for small spills.	To ensure no loss of chemicals to the environment.
Surface water / soil contamination.	Pigging works introduce antifouling and/or biocide chemicals to receiving environment.	• Refer to the construction section above.	To ensure pigging activities do not introduce untreated waste water to the environment.
Surface Water/ Soil- nutrient and hydrocarbon.	STP- system failure, overflow or inadequate treatment.	• Refer to the construction section above.	To ensure no change to groundwater/ surface water quality and soil characteristics.
	Wastewater storage pond and constructed wetland sludge potentially containing concentrated effluent contaminants.	• Storage pond to be lined and sludge (where present) will be characterised prior to infilling and remediation.	To ensure no net change in soil characteristics as a result of the operation of the storage pond and wetland.

Aspect	Potential Impact	Mitigation Measures	Objective
	STP wastewater pond and constructed wetland- overflow or system failure.	• Effluent quality and system capacity will be monitored and maintained.	To ensure no change to groundwater quality or soil contamination status.
Decommissioning and Rehabilitation			
Surface Water/ Soil- hydrocarbon.	Removal of dam infrastructure / disposal of accumulated salts, boron, fluoride, and other water parameters.	• Ponds will be managed in accordance with proposed end use including: – Left insitu where arrangement with stakeholder exists for continued use of facility; and – Excavated to remove accumulated sediment including salts and metals prior reinstatement of landform.	To ensure hydrotest treatment facilities are appropriately remediated.
Surface Water/ Soil- chemical contamination.	Diesel spill from construction equipment during operation. Spills/ loss of other chemicals e.g. anti-fouling agent, biocide.	• All vehicles to be checked for integrity of fuel tank and responsible driving to prevent perforation of tank during clearing operations. • Any spills will be immediately reported and contained. Contaminated soil will be removed and remediated and contaminated water treated. • All vehicles to carry spill kits for small spills.	To ensure no loss of fuel or chemicals to the environment.
Surface water / soil contamination.	Pigging works introduce antifouling and/or biocide chemicals to receiving environment.	• Refer to the construction section above.	To ensure pigging activities do not introduce untreated waste water to the environment.

7.3.2.6 Summary of Findings

Baseline Contamination Assessment

The PSI identified six sites as AOPC as part of the desktop review. Of these, only the industrial plant on Lot 1 SP200852 was currently listed on the EMR as having the potential for land contamination.

The AOPC identified in the Tier 1 and Tier 2 desktop reviews are considered to have a low contaminated land project risk given the flexibility of the gas transmission pipeline route to deviate around these sites. Following final agreement on pipeline alignment a protocol will be developed to further assess (and manage as required) these AOPC (or any other AOPC that may be encountered as pipeline development progresses). These assessments will include site inspections (Tier 3) as deemed necessary and possible soil testing where required.

Gas Transmission Pipeline Development Activities

A review of potential sources of land contamination associated with the construction, operation and decommissioning of the gas transmission pipeline identified the following activities:

- Waste (liquid and solid wastes);
- Disposal of Hydrotest water;
- Fuel storage;
- Machinery fuel leaks; and
- Potential risks associated with the storage and treatment of ASS.

The risk assessment identified these activities to have a low residual risk following the adoption of proposed mitigation measures. With the adoption of established Santos management the risk that the development of the gas transmission pipeline will result in land contamination will be minimised.