4 GEOLOGY AND SOILS

Chapter 4 identifies issues associated with the routes of pipelines to be developed as part of the Pipeline Component of the Queensland Curtis LNG (QCLNG) Project, particularly potential impacts on soil stability and restoration post construction.

The Pipeline Component comprises an Export Pipeline, Lateral Pipeline and Collection Header. The pipeline works will traverse a broad range of land systems with varying soil characteristics.

Erosion and sedimentation along pipeline routes are the main potential impacts. This chapter identifies mitigation strategies that can be incorporated into detailed design and construction plans and processes to preserve topsoil and successfully rehabilitate impacted land.

4.1 METHODOLOGY

Soils studies have been based on desktop analysis and field work. Information (including associated Geographic Information System (GIS) data where available) for the desktop component was derived mainly from published Department of Natural Resources and Water (now part of Department of Environment and Resource Management) and CSIRO sources, while geological information was derived from 1:250,000 Geological Series mapping (Geological Survey of Queensland 1971).

Field investigations were conducted along the pipeline corridors between September 2008 and February 2009 (via four separate visits). This comprised field observations at key points along the corridors as well as detailed soil sampling at 62 sites. Soils were either hand-augered (generally to a depth of up to 1 m sufficient to characterise the soil or to auger refusal) or profiles in cuttings were cleaned back and described. Analysis focused on those issues of significance to the development of the pipeline corridors including:

- the susceptibility of the different soil types to erosion, with a particular focus on subsoil erodibility and dispersibility
- the ease of handling and rehabilitation of the various soil types
- areas of Good Quality Agricultural Land (GQAL) that may be affected by the Project.

A full copy of the Pipeline Soils Report is provided in *Appendix 4.1.*

Analysis of the soils for the final section of the Export Pipeline route (coastal lowlands from kilometre point (KP) 368 to the LNG Facility) was undertaken as part of the LNG Facility studies (refer to *Volume 5, Chapter 4*). Key findings in relation to the Export Pipeline are incorporated in this chapter.

4.2 PROJECT ENVIRONMENTAL OBJECTIVE AND VALUES

The Project environmental objective for geology and soils is to protect soils from contamination and erosion arising from Project activities.

The following sections outline the existing environmental values related to geology and soils.

4.2.1 Geology

The main geological values and descriptions for the three pipeline corridors are presented in *Figure 4.4.1* and described in the following section.

4.2.1.1 Export Pipeline

The Export Pipeline has been investigated in two parts (refer to *Appendix 4.1*) to address both Option 1 and Option 2 routes. The two options follow the same route from KP 0 to approximately KP 50 and from KP 225 to the terminal on Curtis Island. Option 2 has since been adopted as the preferred route but the information within this chapter addresses both options where appropriate.

Due to the overall pipeline length and location, the geology of the Export Pipeline route is quite variable.

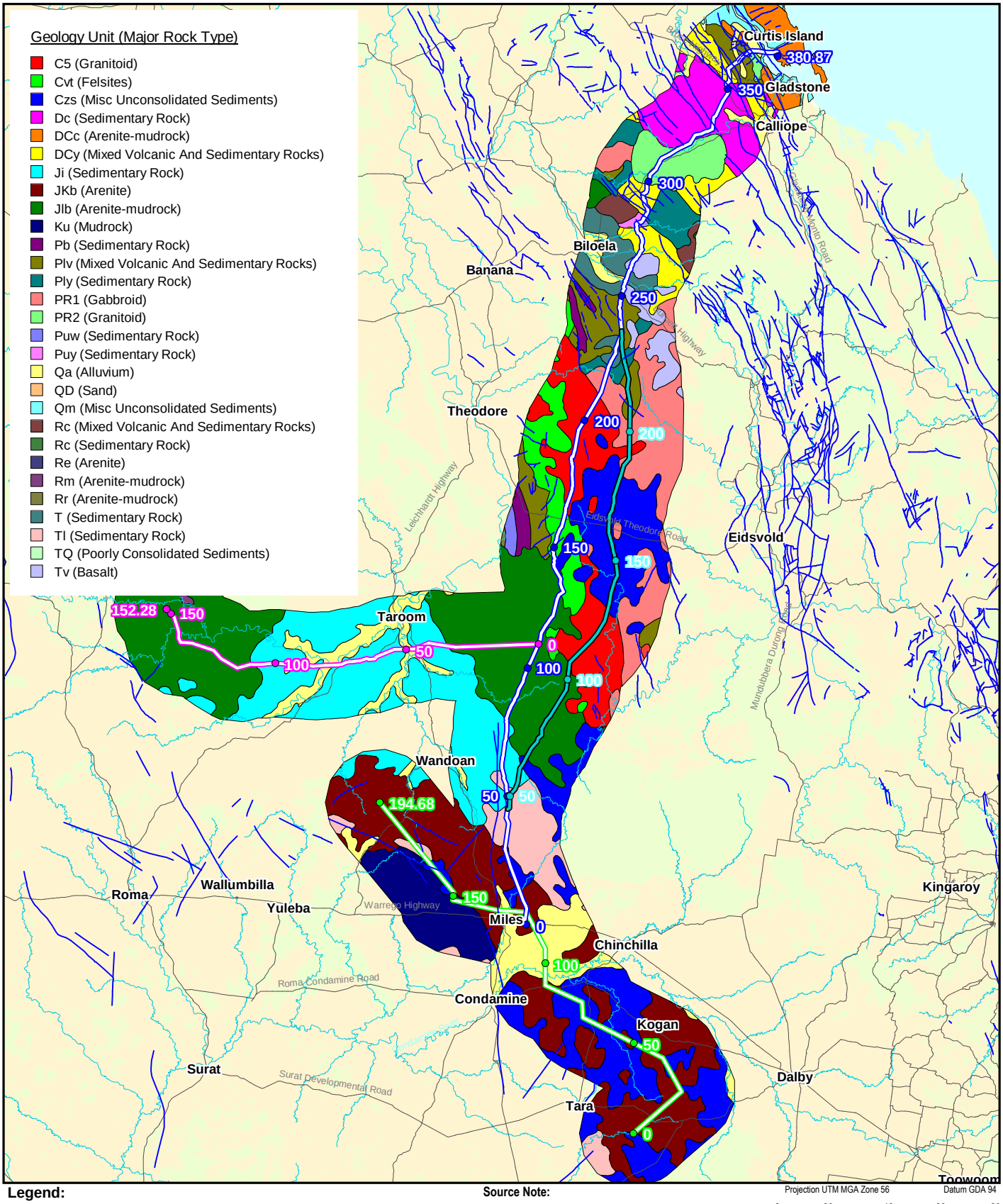
The initial 40 km of the route near Miles comprises mainly the Kumbarilla Beds from the late Jurassic to early Cretaceous period. Minor areas associated with the Injune Creek Group (similar to the Kumbarilla Beds) are also found. These beds consist mainly of sandstones, siltstones and mudstones.

From KP 42 to KP 58 there is an extensive area of deeply weathered deposits associated with the Tertiary period (i.e. 65 million to 1.8 million years ago). These deposits are in various stages of consolidation (with the extensive Chinchilla Sands lying to the east of the route) but comprise mainly quartzose sandstones with lateritic material evident in places.

Minor bands of quaternary alluvium associated with the larger streams traverse the route in a mainly east-west direction. Lithic sandstones/mudstones of the Injune Group and quartzose sandstones of the Hutton Sandstone Formation are then prevalent.

From around KP 50 to KP 110 both Option 1 and Option 2 are predominantly siltstones and labile sandstones of the Evergreen Formation (Jurassic period).

From approximately KP 110 to KP 150 Option 1 lies mainly over quartzose sandstones associated with the Precipice Sandstone Formation. The Option 2 route traverses the Boogal Granite and Kilboggan Adamellite formations with increasing areas of duricrusted siltstones and sandstones in the north and some alluvium associated with the Auburn River and its tributaries.



Legend:

- Export Pipeline & Kilometre Point
- Lateral Pipeline & Kilometre Point
- Upstream Infrastructure Corridor & Kilometre Point
- Export Pipeline Option 2 & Kilometre Point
- Fault Line

Source Note:

1:250,000 Topographic vector copyright Geoscience Australia
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Projection UTM MGA Zone 56 Datum GDA 94

0 20 40 60 80

Kilometres

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Project	Queensland Curtis LNG Project	Title	Geological Formations and Fault Lines
Client	QGC - A BG Group business		
Drawn	Mipela	Volume 4	Figure 4.4.1
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North from KP 150, the geological characteristics change substantially with highly altered beds from the Carboniferous period (Torsdale Beds) and Palaeozoic volcanics and intrusives (comprising Moocoorooba adamellite and Glandore granodiorite) dominating to approximately KP 220.

Between KP 220 and KP 276, a complex of Tertiary, Jurassic and Permian sediments are found with some Palaeozoic volcanics and basaltic material. Some major stream crossings and associated quaternary alluvium are also found in this section.

Complex geological conditions are then found within the steep terrain of the Callide Range between KP 276 and KP 291 (comprising a mix of highly altered rocks from the Devonian and Carboniferous periods). Grey tonalite (similar to granitic material) occurs between KP 291 and KP 321.

Palaeozoic siltstones and mudstones associated with the Mt Holly Beds, Doonside Formation and Crana Beds and Palaeozoic volcanics associated with the Berserker Beds are found between KP 321 and the northern study limits for the pipeline route (KP 368).

The tidal zone between the eastern shores of Friend Point (on the mainland) and the western margins of Curtis Island are comprised of Holocene sediments or mainly coastal origin with surficial alluvial material.

The main geological unit on Curtis Island is the Wandilla Formation. This formation plus the Doonside Formation are included within the Devonian- Carboniferous Curtis Island Group comprising metamorphic material consisting of mudstones, arenite and cherts with some quartz greywacke.

Significant geological constraints along the proposed route are summarised in *Table 4.4.1.*

Table 4.4.1 Export Pipeline Rock Areas

KP	Observation
Option 1	
110 – 115	Medium-to-high constraint; some significant rock areas in proximity to Cockatoo Creek
129.5 – 146	High constraint; significant stony matrix and shallow soils
146 – 175	High constraint; significant stony matrix and shallow soils; some areas of granitic rock will make for difficult trenching conditions
190.5 – 218	Medium-to-high constraint; some gravels and rock areas
276. – 291	High constraint due to presence of stone and rock at shallow depth; some blasting may be required
291 – 321	Medium-to-high constraint; some gravels with rock areas near western section
Option 2	
110-147	Medium to high constraint – some gravels and rock areas
210-223	Medium to high constraint – some component rock possible

4.2.1.2 *Lateral Pipeline*

Geological conditions along the Lateral Pipeline route comprise mainly labile and sublabile Jurassic sediments associated with the Evergreen Formation, Birkhead Formation and Injune Group and sublabile and quartzose sandstones associated with the Hutton Formation. Significant sections of quaternary alluvium are also traversed.

Significant geological constraints along the proposed route are summarised in *Table 4.4.2*.

Table 4.4.2 Lateral Pipeline Rock Areas

KP	Observation
109 – 120.5	High constraint, extensive sandstone rock at shallow depths
120.5 – 152	High constraint, extensive sandstone rock at shallow depths, watercourse crossings may require significant earthworks

4.2.1.3 *Collection Header*

The Collection Header is underlain by sedimentary rocks from mainly the Jurassic and Cretaceous periods (notably the Kumbarilla Beds). However, extensive areas of Tertiary deposits (comprising mainly deeply weathered material/unconsolidated sediments) are also found. Some areas comprise fractured to moderately competent sandstone, siltstones and mudstones at a relatively shallow depth which may present some trenching difficulties. Quaternary alluvium is extensive in proximity to the Condamine River and, to a lesser extent, other streams such as Wambo Creek.

No significant geological constraints along the proposed route have been identified.

4.2.1.4 *Geological Stability*

The seismicity of the pipeline study area is reported (as part of coverage of all of Queensland) by the Queensland University Advanced Centre for Earthquake Studies (QUAKES). Records of earthquakes, for the region containing the pipeline routes, for the period 1850 to February 2009 indicate that few earthquakes have been registered within the study area. There has been some minor activity to the south of Biloela (around level 4 on the Richter scale - a level which rarely causes damage and is often barely felt). The study area is thus considered to be an area of low seismic risk to pipelines, with no historical evidence of past earthquakes that would potentially cause damage to a pipeline similar to that proposed for this Project.

Field investigations and aerial photo interpretation have indicated no evidence of significant ground instability and landslides in the pipeline corridors. Studies into terrain, geological conditions, landforms and soil types along the routes similarly suggest an acceptable risk in this regard. The risk of landslip along the route is considered low. Any localised areas of potentially higher risk will

be addressed as part of detailed geotechnical investigations and engineering design.

4.2.1.5 *Geological Materials*

Rocks and rocky areas likely to be impacted by Pipeline Component construction are likely to be inert from a geochemical perspective, particularly given the shallow depth of trenching proposed. The potential for release of any heavy metals with excavation in rock is thus likely to be negligible.

4.2.2 Soils

4.2.2.1 *Soil Types*

For the purposes of this report, the *Atlas of Australian Soils* (CSIRO 1967) has been used as the primary basis for classification and mapping. The Atlas was originally mapped at a scale of 1:2 million. However, the majority of the study area (i.e. the Fitzroy River catchment) was remapped using the Atlas as a base at a scale of 1:1 million (Isbell and Hubble 1967).

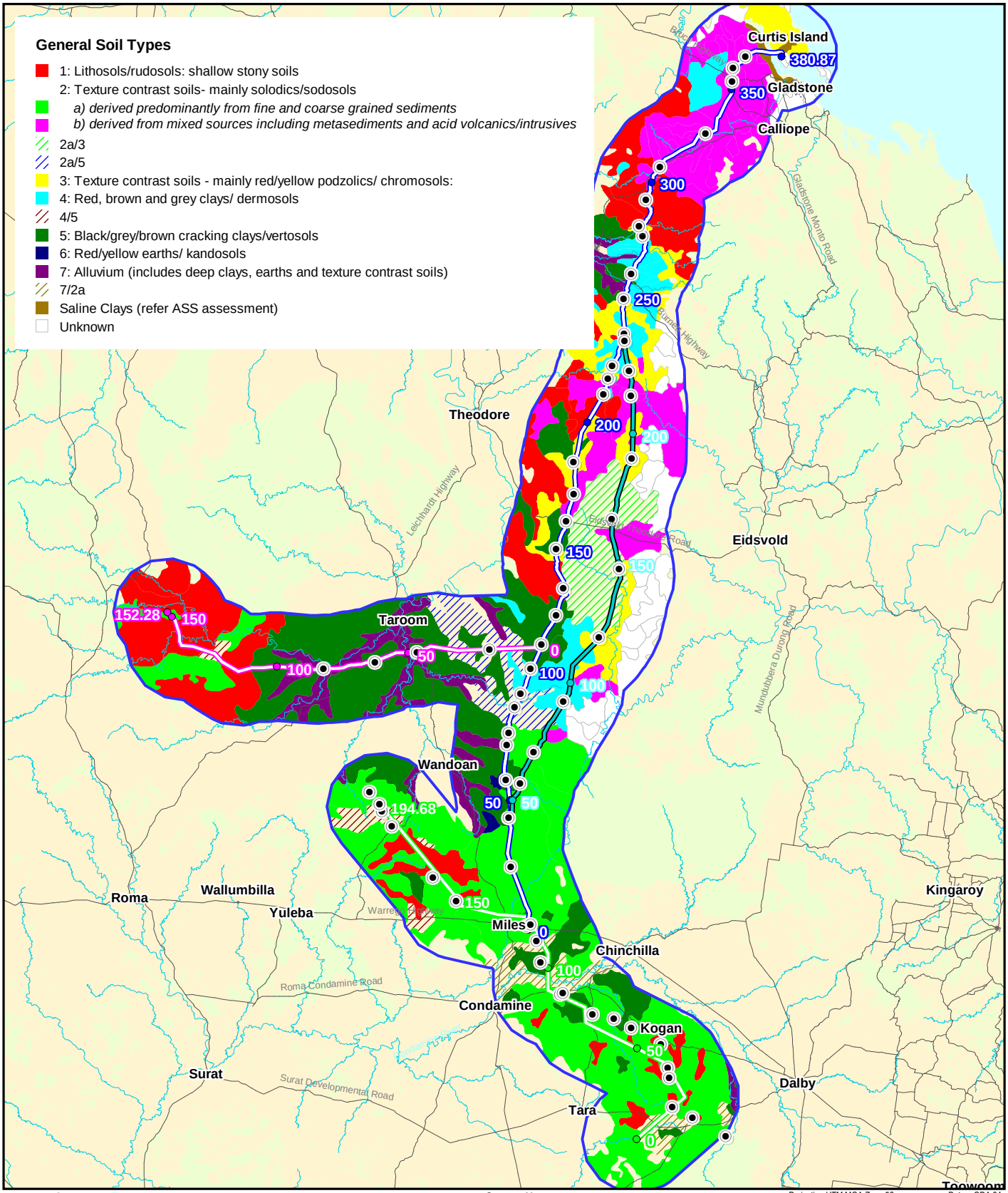
The soil units identified along the pipeline corridors are illustrated in *Figure 4.4.2.* The key soil units identified in association with the pipeline corridors are described in *Table 4.4.3*.

Significant sections in proximity to the Auburn River area are comprised of shallow red texture contrast or gradational soils.

Table 4.4.3 Soils Located along Pipeline Routes

Soil Unit/Location	General Characteristics
1. Lithosols/Rudosols Prevalent in northern and central section of mainline Generally associated with the steeper hilly lands along the routes	Topsoils are generally less than 5 cm deep with abundant gravel or stone Significant rock, often competent, may be found at a shallow depth, often within 15 cm of the surface Rock outcrops may be present Nutrient levels are very low and are usually acid soils
2a. Texture contrast soils (derived from fine and coarse grained sediments) Sodosols Primarily located on the southern section of the export pipeline and along the Collection Header (to the south and west of Wandoan)	Generally shallow erodible surface soil, low in organic matter Highly sodic and dispersive subsoil, prone to gully and tunnel erosion Nutrient levels in the surface soils are low-to-very low The depth of topsoil can be quite variable (some can be over 60 cm) Very prone to gully and tunnel erosion with a surface soil that is prone to sheet erosion
2b. Texture contrast soils (derived	Topsoil depth highly variable (5 cm to 30 cm)

Soil Unit/Location	General Characteristics
from mixed sources) /Sodosols Primarily located in association with the central and northern limits of the Export Pipeline	Low nutrient levels Subsoils are less dispersive and with lower sodicity compared to 2a. Less prone to gully and tunnel erosion than 2a due to more stable subsoil Significant gravel content in subsoil
3. Texture contrast soils – mainly red/yellow podzolics/Chromosols Primarily located along the central section of the Export Pipeline	Mainly shallow sandy loam surface soils, often gravelly Nutrient levels are low Subsoils are generally red or yellow clay with a blocky structure and often moderately permeable Subsoils are usually acid to neutral, non-sodic and non-dispersive to moderately dispersive They commonly intergrade with the gradational soils described below or the 2b soils described previously
4. Red, brown and grey clays/*Dermosols* Mainly located in the low hills to the south of Thangool and other locations on both the Export Pipeline and Lateral Pipeline	Topsoil depth generally between 50 cm and 100 cm Surface and subsoil profiles are generally moderately permeable Subsoils are usually moderately sodic and dispersive (based on the results undertaken for this report) Fertility levels are generally low to moderate Comparatively stable. However, the significant clay content in the surface soil can result in compaction issues if excessively
5. Black/grey or brown cracking clays/Vertosols. Primarily located west of Wandoan and Taroom in proximity to the mainline and Lateral Pipeline and along some sections of the Collection Header chiefly as grassland plains adjacent to some of the major streams	Finely structured surface (may form a weak surface) and well structured upper subsoil Gilgai may or may not be present Lower subsoil is generally strongly sodic with very high salinity levels Dispersion levels are variable, but generally high along pipeline routes Subsoils shrink and swell and may develop large vertical cracks when dry Medium-to-high fertility levels
6. Red/yellow earths/ Kandosols Primarily occur north of the Miles area	Poor water-holding ability Prone to sheet erosion once disturbed over extensive areas
7. Alluvium (including deep clays, earths and texture contrast soils). Variable over the study area	Variable depending on soil type



Legend:

- Export Pipeline & Kilometre Point
- Lateral Pipeline & Kilometre Point
- Upstream Infrastructure Corridor & Kilometre Point
- Export Pipeline Option 2 & Kilometre Point
- Soil Sample Locations
- Study Area

Source Note:

1:250,000 Topographic vector copyright Geoscience Australia
Soils base data sourced from Digital Atlas of Australian Soils

Projection UTM MGA Zone 56 Datum GDA 94

0 20 40 60 80

Kilometres

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Project	Queensland Curtis LNG Project
Client	QGC - A BG Group business

Title **Dominant Soils**

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Drawn	Mipela	Volume 4	Figure 4.4.2
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Topsoil Fertility and Depth

The topsoil thickness for the various soil types varies significantly. This is an important consideration for the development and rehabilitation of pipeline routes. Some topsoils are particularly shallow (i.e. <5 cm) to virtually non-existent, especially in steeper areas where surface stone predominates.

Most topsoils with the exception of many of the cracking clay soils, have low nutrient levels (i.e. they are low in nitrogen, phosphorous and potassium) and low to moderate levels of organic matter. All topsoils associated with the texture contrast soils have very low available phosphorus levels and low or very low cation exchange capacities (i.e. nutrient retention capacity).

4.2.2.2 Existing Erosion

The majority of the area likely to be impacted by the pipelines is currently relatively stable with only short sections exhibiting significant existing erosion levels, primarily in the form of gully erosion.

Significant existing erosion areas are mainly located around local drainage channels, especially in the southern sections of the Collection Header and Export Pipeline routes (i.e. in the vicinity of Wambo and Columboola Creeks) where previous disturbances have exposed highly dispersive sodic subsoils prone to gully and tunnel erosion (often associated with the effects of existing adjacent infrastructure such as roadways).

4.2.2.3 Soil Salinity and Sodicity

The major proportion of the Export Pipeline and Collection Header routes and, to a lesser extent, the Lateral route, is comprised of texture contrast soils with sodic and saline subsoils at varying depths but generally within the trenching depth for pipeline establishment. These soils have formed on a range of parent materials (primarily of Jurassic and Tertiary origin), and occupy mainly valley floors and lower-to-mid-sloping terrain.

These soils tend to have poor drainage characteristics due to very dense and slowly permeable subsoils. The dense subsoils also restrict root penetration. These soils have poor fertility, but can be productive with adequate inputs.

4.2.2.4 Acid Sulfate Soils (ASS)

In general, acid sulfate soils (ASS) are commonly found in coastal areas below 5 m (Australian Height Datum) AHD. This may include soils that occur below 5m AHD even if the land surface elevation is above 5 m AHD. Therefore land in alluvial valleys with surface elevations less than 20 m may still contain pyritic material at depth (DLGP & NRM, 2002).

The presence of ASS or potential acid sulfate soils (PASS) has been regarded as a possible issue for the Export Pipeline within the Gladstone region. PASS contain sulfide material that is likely to generate acid upon disturbance and exposure to oxygen. Actual acid sulfate soils (AASS) are soils in which some oxidation of sulfides has already occurred and are characterised by a low soil pH.

Due to the elevation of the majority of the pipeline corridors, there is no likelihood of ASS occurring within the maximum depth of trenching of the pipelines for the Collection Header, Lateral and the majority of the Export Pipeline route. However, the development of the Export Pipeline across Kangaroo Island and across The Narrows to Curtis Island, near Gladstone, contains appreciable areas of coastal lowlands. As such, there is a significant likelihood that ASS are present.

An investigation to assess areas within the project site less than 5 m AHD was undertaken (refer to Appendix 5.2) to:

- identify sediments and soils possibly containing actual acid sulfate soils (AASS) or potential acid sulfate soils (PASS)
- characterise the sediments/soil through sampling, field and laboratory analysis
- quantify the AASS and/or PASS, using the approach as recommended by the Queensland Acid Sulphate Soils Investigation Team (QASSIT) and detailed in (Ahern et al 1998) Guidelines for Sampling and Analysis of Lowland Acid Sulphate Soils (ASS) in Queensland.

The investigation identified areas of both ASS and PASS along the Export Pipeline route in association with the tidal flats on the mainland and Curtis Island. Variability in the sampling results indicated the presence of “hot spots” both across the sites and within individual profiles. This presence of these hot spots identified across the sampling locations indicates that further sampling would be necessary to fully delineate the acid-generating potential of the sediments primarily in the areas designated for excavation of the pipeline trench. Refer to *Volume 5, Chapter 4 f*or a more detailed description of the findings on ASS.

4.2.3 Good Quality Agricultural Land

The Queensland Government introduced a State Planning Policy in 1992 (SPP 1/92) to protect GQAL. In support of this policy, four classes of agricultural land were defined for Queensland:

Class A Crop land

Class B Limited crop land

Class C Pasture land

Class D Non-agricultural land.

An assessment has been carried out to determine the areas along the pipeline routes that would be considered to be GQAL as defined in State Planning

Policy 1/92. *Figure 4.4.3* illustrates that the majority of the Export Pipeline and the Collection Header routes are within Class C pasture lands and Class D non-agricultural lands. A summary of the Class A (crop land) and Class B (limited crop land) lands intersected by the pipelines is presented in *Table 4.4.4.*

Table 4.4.4 Summary of Good Quality Agricultural Land

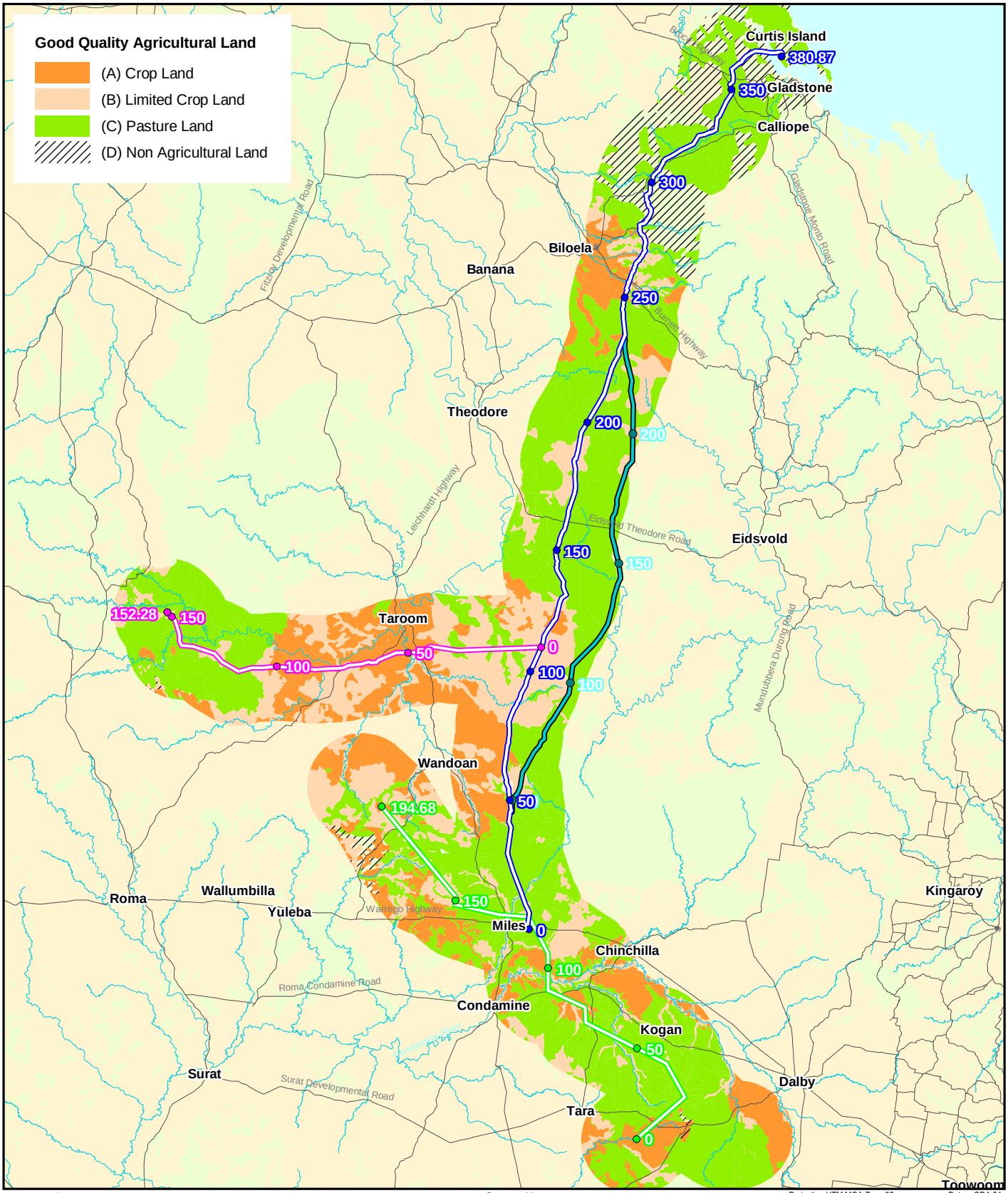
Pipeline Route	GQAL Affected (km)			GQAL Affected (ha)			Comments
	Class A	Class B	Total	Class A	Class B	Total	
Export							
Option 1	63	67	130	252	266	518	Predominantly around the east of Taroom and Callide valley areas
Option 2	54	66	120	212	268	480	
Lateral	45	24	69	180	96	276	Mainly to west of Wandoan-predominantly improved pasture
Collection Header	36	27	63	288	216	504	Mainly alluvium in proximity to Condamine River

Based on the data presented in *Table 4.4.4* it has been estimated that approximately 120 km (i.e. 31 per cent) of Option 2 of the Export Pipeline route would be considered GQAL. This is less than the Option 1 route which would traverse approximately 130 km (i.e. 34 per cent of its length) of GQAL. The Lateral Pipeline is estimated to traverse 69 km of GQAL (i.e. 46 per cent of its length) while 63 km (i.e. 31 per cent) of the Collection Header would be considered GQAL. Based on Option 2 of the Export Pipeline (i.e. the preferred route) the total length of Class A land intersected by the pipelines would be 135 km and Class B land would be 117 km.

4.3 ASSESSMENT OF POTENTIAL IMPACTS

The most significant soil and terrain impacts are generally associated with the construction phase. Construction activities which have the potential to impact on the soils and terrain of the Project area include:

- pipeline route clearing and excavation activities
- development of additional access tracks
- establishment and operation of any construction work areas
- establishment of stockpiling areas for pipe
- refuelling of construction equipment.



Legend:

- Export Pipeline & Kilometre Point
- Export Pipeline Option 2 & Kilometre Point
- Lateral Pipeline & Kilometre Point
- Upstream Infrastructure Corridor & Kilometre Point

Source Note:

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Projection UTM MGA Zone 56 Datum GDA 94

0 20 40 60 80

Kilometres

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Project	Queensland Curtis LNG Project
Client	QGC - A BG Group business

Title: **Distribution of Good Quality Agricultural Land**

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The main issues in regard to the potential impacts of the Pipeline Component on soils and soil management are summarised below and discussed further in the following section:

- excessive stoniness/rock along the route creating additional disturbance or delays in construction
- instigation or exacerbation of soil erosion along the routes (with consequent reduction in land capability, downstream water quality etc)
- inadequate stabilisation and rehabilitation/revegetation of the disturbed areas within the cleared easements
- excessive dust generation due to vehicular movement along the pipeline access routes during construction
- loss of GQAL.

The pipeline routes have been selected to avoid or minimise impacts associated with land and terrain constrains. The implementation of control measures and sediment and erosion control devices during construction will ensure that any impacts are temporary in nature and limited to the immediate construction area.

4.3.1 Geology

4.3.1.1 Rock/Stoniness

The presence of significant stone or rock along the pipeline routes and within the proposed trenching depth for pipeline placement may present a significant construction constraint. Constraints may manifest as delays in construction, with associated increased construction costs, a possible increase (albeit generally minor) in the area of disturbance to facilitate the fracturing of rock and suitability of trench backfill for rehabilitation purposes.

Significant surface or near-surface stone can also affect topsoil stripping procedures. Surface rock following restoration is only expected to be a concern to agricultural landholders, in areas where it does not occur pre-construction.

It is expected that approximately 15 to 20 per cent of the Export Pipeline and 30 per cent of the Lateral Pipeline will have a high risk of rock being present. In addition, many areas of shallow fractured or competent sandstone or siltstone will be encountered, particularly along the Collection Header and Lateral Pipeline. The ease with which construction machinery can trench through these areas has not been determined and will be subject to further construction geotechnical investigations in the detail design of the pipelines.

A number of cuttings in creeks exhibit exposed rock at depths of less than the expected depth of the pipeline. Given that many crossings will need to be excavated to significant depths due to the incised nature of the watercourses as discussed in *Chapter 9* of this volume, rock may need to be sawn or

blasted. If it is not adequately buried during restoration, the rock will appear as surface cobbles and small boulders which may downgrade the land use capability in these areas.

Mitigation measures will be incorporated into the construction plan for the pipeline works requiring that any rock exposed as a result of construction activities is removed, particularly in agricultural areas.

4.3.2 Soils

4.3.2.1 Soil Stability and Erosion

An assessment of erosion potential of the pipeline routes was undertaken based on field observation of soil properties, existing erosion, landform/slope and analysis of key indicators from laboratory test work. The erosion potential was ranked in accordance with four categories as summarised in *Table 4.4.5.*

Table 4.4.5 Erosion Potential Category

Category	Erosion Potential	Description
1	Low	The combination of surface slope, run-on/run-off and soil erodibility is such that no appreciable erosion damage is anticipated. Only limited erosion control works generally required.
2	Minor to Moderate	Localised short-term erosion may occur. Erosion control can be achieved using standard topsoil management and revegetation techniques, and other site-specific soil conservation works. No special constraints in regard to erosion protection are envisaged.
3	Significant	Short-term significant but localised erosion has the potential to occur due to the combination of slope, soil erodibility factors and extent of run-on/run-off. Erosion may include some sheet and gully erosion (due to dispersive subsoils). Erosion control can be achieved using structural works, topsoil management and revegetation techniques, and other site-specific intensive soil conservation works. Active on-going monitoring will be required until successful rehabilitation/stabilisation achieved.
4	Very High	• Potential for high-to-very-high soil losses within the alignment due to steepness of slopes, soil erodibility factors and surface run-off conditions. Intensive soil conservation works will be required to minimise the effects of erosion. Rehabilitation will require significant effort. Intensive monitoring of erosion and rehabilitation success required particularly after significant rainfall.

The erosion potential of the pipeline routes based on these rankings is summarised in *Table 4.4.6* and illustrated on *Figure 4.4.4 and Figure 4.4.5.*

Table 4.4.6 Summary of Erosion Potential

Pipeline Component	Erosion potential (km)				Comments – susceptible areas
	1	2	3	4	
Export					
Option 1	21.5	157.5	182.5	15	Mainly to the east of Cracow (KP 135) and through the steep Callide Range crossing (KP 280 – 296)
Option 2	32.5	162.5	166.5	15	
Lateral	26	63.5	36	27	Highest risk is in western end of route where passing through the Hutton and Precipice Sandstone Formations (KP 110 to KP 120 and KP 135 to KP 150)
Collection Header	9	84.5	112	10.5	Significant sections along route have very sodic/dispersive soils and prone to gully/tunnel erosion; this includes sections between KP 35 and KP 45 and the western section from KP 200

This study has found that some 47 per cent of the Export Pipeline, 42 per cent of the Lateral Pipeline and 61 per cent of the Collection Header have a high- (category 3) to very high- (category 4) erosion potential. In general, the Option 2 Export Pipeline route has less risk of highly erodable soils than does the Option 1 route. However the actual area of disturbance for each of the pipelines in significantly or highly erodible lands is not significant.

The erosion potential throughout much of the southern area (mainly the Collection Header corridor) is mitigated by the relatively low sloping terrain (most of which is level to <3 per cent grade). However the extremely high dispersion levels in the sodic subsoils of the texture contrast soils will require focused erosion control strategies.

The instigation or exacerbation of gully and tunnel erosion in proximity to drainage lines will be a potential risk associated with pipeline construction. Where shallow texture contrast soils are found in steeper terrain near the central and northern sections of the Export Pipeline (refer to *Figure 4.4.5*), the potential for erosion will be significant if not properly managed.

Areas of steep terrain near the western end of the Lateral Pipeline (i.e. around KP 110 to KP 122 and KP 135 to KP 148) and to the south of the Callide Power Station (in the Callide Range crossing area of the Export Pipeline – KP 280 – KP 296) also have a very high erosion risk. The predominance of stone within the soil profile will tend to mitigate the potential severity of erosion in these cases.

The cracking clay soils primarily associated with (former) brigalow vegetation also have significantly dispersive sodic subsoils that will require careful management strategies. However, these soils will be more conducive to vegetative rehabilitation due to the inherent fertility levels and better soil structure. This is evidenced by the existing vegetation cover on previously disturbed areas associated with infrastructure corridor projects in the region.

With the implementation of the erosion control measures as discussed in *Section 4.4*, the elevated soil erosion potential risk would only exist for short periods. In these areas, it will be desirable to undertake pipeline construction and rehabilitation during the periods when the likelihood of high intensity rainfall events are lower, from March to October. Construction scheduling of the pipeline works will take this into consideration.

No long-term significant erosion issues are likely, provided rehabilitation strategies are implemented effectively and the pipeline routes are regularly inspected to address any erosion ”hot spots” or failed rehabilitation efforts.

4.3.2.2 Loss/Disturbance to Topsoil

Potential impacts to topsoil may occur as a result of:

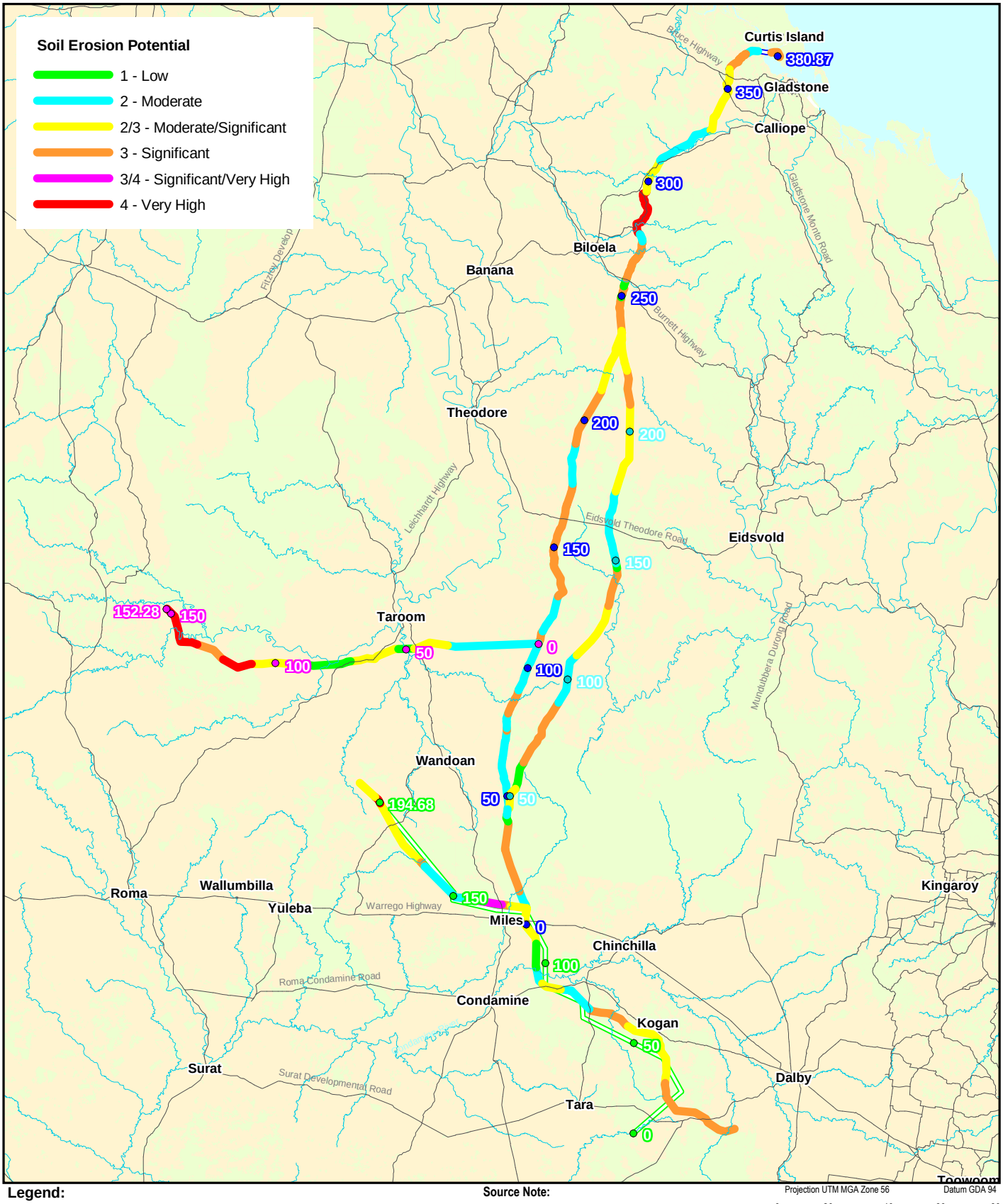
- inadequate removal of topsoil prior to trenching
- mixing of topsoil with subsoil during excavation or stockpiling
- mixing of trench spoil and topsoil during backfilling and restoration.

The depth and fertility of topsoil within the soil to be disturbed along the pipeline routes is important for the successful reinstatement and rehabilitation of the pipeline routes.

The pre-stripping and segregation of topsoil from subsoil is conventional practice for pipeline establishment. It will be necessary to be able to recognise the distinction between the two layers in the field as part of the stripping operation. This is particularly important because, as indicated earlier, major sections of all three routes have soils where the subsoil is significantly-to-strongly sodic, dispersive and saline at depth. Such characteristics apply to most of the texture contrast soils and cracking clay soils.

It is estimated that some 53 per cent of the Export Pipeline route, 71 per cent of the Lateral Pipeline and 88 per cent of the Collection Header have subsoils that are strongly sodic and/or highly dispersive. Soils along Option 2 of the Export Pipeline route are generally less sodic and dispersive, reflecting the greater proportion of soils derived from Palaeozoic intrusives. Management of these soils, in regard to erosion control and rehabilitation, presents one of the major challenges for the development of the pipelines. These soils are especially prone to gully and tunnel erosion, even in low-sloping situations, where concentrated run-off may occur in minor drainage channels

No significant areas of exposed saline scalds are likely to be traversed along the pipeline routes. However, there is the potential for local scalds to occur mainly at toe slopes in the areas of shallow cracking clay soils to the west of Wandoan (part of the Lateral Pipeline route mainly around KP 60 to KP 75) and to the south of Thangool (around KP 260 to KP 264). The segregation of topsoil from subsoil will be especially important in such areas. More



Legend:

- Export Pipeline & Kilometre Point
- Export Pipeline Option 2 & Kilometre Point
- Lateral Pipeline & Kilometre Point
- Upstream Infrastructure Corridor & Kilometre Point

Source Note:

1:250,000 Topographic vector copyright Geoscience Australia
Erosion data provided by Houghton Environmental Management

Projection UTM MGA Zone 56 Datum GDA 94

0 20 40 60 80

Kilometres

N

QUEENSLAND CURTIS LNG
A BG Group business

ERM
Environmental Resources Management Australia Pty Ltd

Project	Queensland Curtis LNG Project	Title	Erosion Potential
Client	QGC - A BG Group business		
Drawn	Mipela	Volume 4 Figure 4.4.4	
Approved	CDiP	File No EO5-P-MA-96123	
Date	28.05.09	Revision A	

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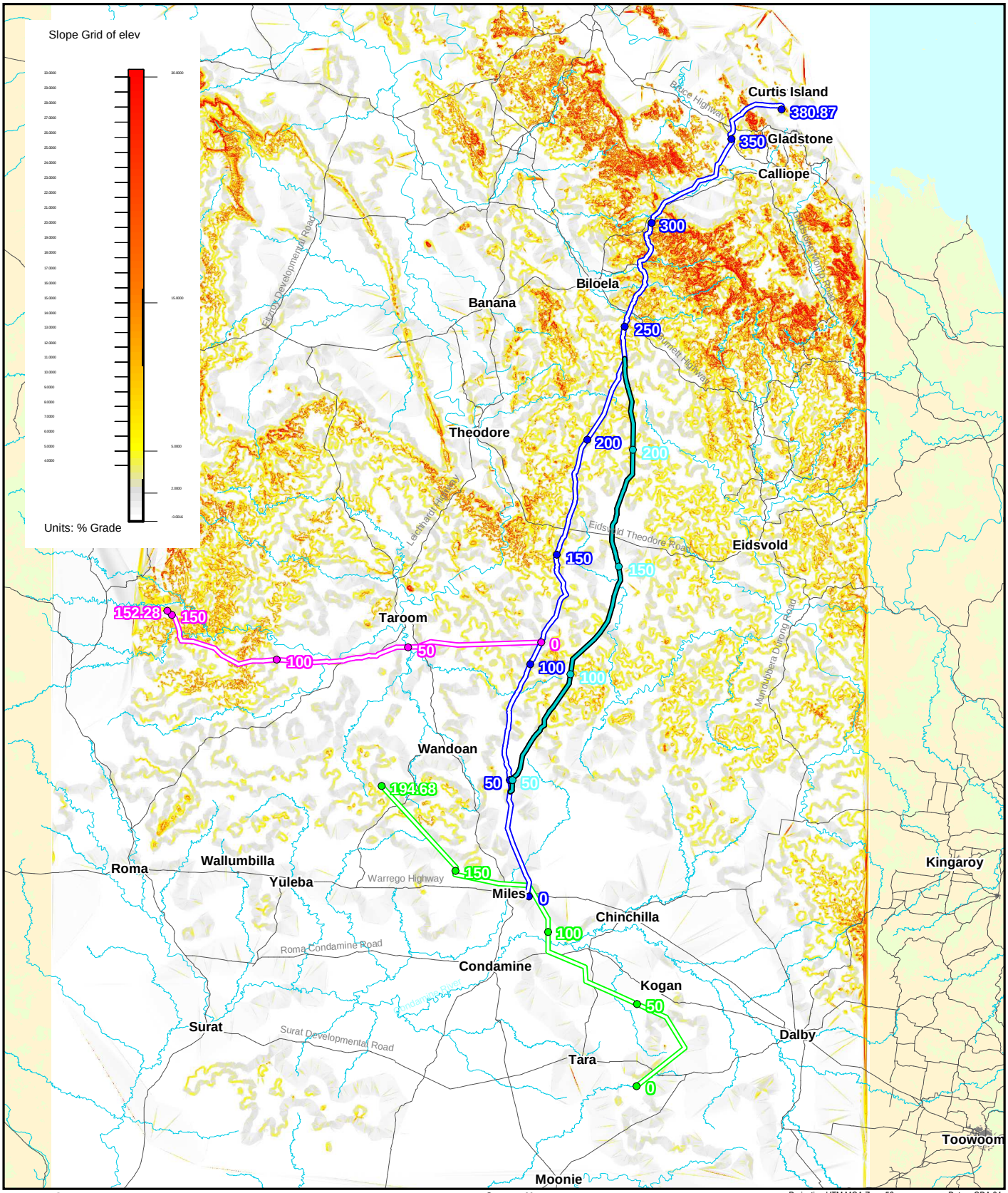

Legend:

- Export Pipeline & Kilometre Point
- Lateral Pipeline & Kilometre Point
- Upstream Infrastructure Corridor & Kilometre Point
- Export Pipeline Option 2 & Kilometre Point

Source Note:

1:250,000 Topographic vector copyright Geoscience Australia
Slope data derived from 1:250,000 topographic contours layer

Projection UTM MGA Zone 56 Datum GDA 94

0 20 40 60 80

Kilometres

N

QUEENSLAND CURTIS LNG
A BG Group business

Project	Queensland Curtis LNG Project
Client	QGC - A BG Group business
Title	**Slope**

ERM
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Drawn	Mipela	**Volume** 4	**Figure** 4.4.5
Approved	CD	File No	EO5-P-MA-96120
Date	28.05.09	Revision	A

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importantly, any water diversion works associated with pipeline establishment and erosion control in these areas will need to ensure that localised water-ponding does not occur to the extent that there is potential for saline shallow groundwater to rise to the surface causing scalding.

It is expected that the period of stockpiling of topsoil adjacent to the pipeline trench would be short (i.e. months rather than years). Thus, it is unlikely that there will be any significant deterioration in topsoil quality.

4.3.2.3 Dust

Due to the nature of the soil, the dry climate and the ongoing traversing of soil there may be issues with a complete loss of surface soil cohesion in some areas. This loose material will generate wind-blown dust and cause dry bogging of vehicles and equipment.

Once a soil turns to dust, it can be difficult to manage. Grading the loose material and returning it to the track, a little at a time while wetting it constantly may have some success. Final rehabilitation and revegetation can be difficult because the soil structure may have been destroyed.

Soils of the pipeline routes that have a significant clay content in the surface, notably the cracking and non-cracking grey, brown and dark clays, are least prone to dust generation whilst those with a fine sandy/silty surface are most prone. The objective of the control measures will be to reduce the exposure periods for non-vegetated areas and undertake revegetation as soon as practical after construction.

4.3.3 Good Quality Agricultural Land

The pipeline routes have been selected to avoid existing or potential cropland as much as possible. As discussed in *Section 4.2.3* approximately 120 km of the Export Pipeline route, 69 km of the Lateral and 63 km of the Collection Header would be considered GQAL. This equates to approximately 680 ha of Class A and 580 ha of Class B GQAL that could be affected by the pipelines.

It is estimated that approximately 49 km of the pipeline routes (16 km Export pipeline, 10 km Lateral and 23 km Collection Header) are currently cultivated and cropped on a frequent basis. However, there remains the possibility that much of the other Class A and, to a lesser extent, the Class B lands, could be subject to cropping activity in the future.

Nevertheless, the effects of the pipeline development on GQAL are expected to be minor as the pipelines would be established to a sufficient depth to ensure that possible cropping activity would not be compromised. Where deep ripping in cropland is likely to be practised by farmers in the future (to be ascertained during ongoing consultation), then deeper trenching may be required.

Following pipeline establishment and rehabilitation, it is expected that the original productive value of the land would be restored and there would be minimal long-term effect on agricultural productivity.

The establishment of an access track would remove only a very small area of land from production. Any losses would be the subject of compensation arrangements.

4.4 MITIGATION AND MANAGEMENT MEASURES

The following section provides a summary of the mitigation measures proposed for the development of the pipelines. Reference should also be made to the EMP which is provided in *Volume 10* of this EIS.

The mitigation measures have been developed to take into consideration the nature of the proposed development activities and the wide range of constraints associated with the pipeline routes. The primary objectives are to:

- preserve topsoil quantity and quality
- limit the area of disturbance
- control overland water flows around disturbed areas
- minimise the potential for erosion and sedimentation, particularly associated with sodic suboils
- maintain the cropping productivity of the area.

4.4.1 General Erosion Control Measures

Construction practices that reduce soil erosion and sedimentation will be adopted, and intensive ongoing monitoring of the effectiveness of erosion control measures will be implemented in areas of higher erosion susceptibility.

Control measures are likely to comprise a mix of structural controls and various soil management strategies and include:

- reducing the period of exposure of bare areas as much as possible and the period over which trenches are kept open
- avoiding, where practicable, significant side slopes above the trenched areas that may contribute significant run-off to the trench
- ensuring access tracks do not create significant diversions of natural flows or, if unavoidable, direct flows to stable discharge points
- establishing quick-growing and (preferably) native species and/or those that are compatible with the adjacent grazing uses
- actively monitoring the routes, especially following high-intensity rainfall (generally >25 mm day)
- placement of temporary and permanent erosion control banks and

sediment collection devices across slopes and in the vicinity of drainage lines along the easements as necessary

- ensuring that temporary sediment collection devices are constructed so that they are both wide enough and buried well into the soil.

4.4.2 *Topsoil and Subsoil Management*

Measures to preserve and manage topsoil for use in restoration will include:

- ensuring that procedures are developed and followed for minimising mixing of topsoil with subsoil, in particular where high salinity subsoils are present
- stockpiling topsoil and subsoil separately
- stockpiling stripped vegetation separately
- placing stockpiles on the high side of the RoW on hill slopes
- limiting topsoil stockpiles to approximately 2 m in height and create gaps at regular intervals for drainage and possible stock and wildlife movement
- preventing the use of topsoil for padding or backfill
- utilising cut and fill areas, where possible, as temporary workspaces for placing topsoil
- installing silt-fencing on the down slope of soil stockpiles near drainage lines and place stockpiles at least 10 m away from banks
- re-spreading and compacting subsoil over the trench, with crown development, and use subsoil for the construction of contour banks on steep slopes and above banks at water crossings
- deep-rip areas of the easement that have been compacted by construction traffic
- re-spreading topsoil only after subsoil has been evenly re-spread and slightly roughened
- installing jute matting (or similar) immediately following the re-spreading of topsoil on drainage lines
- undertaking revegetation as soon as possible after topsoil re-spreading.

Due to the size/volume of the actual pipeline disposal of excess material will be required (note that the volume of bedding sand required is expected to be minimal in most locations due to the screening of trenched material by the excavating machine).

Options for the disposal of this excess material comprise:

- using the spoil to reclaim existing gully erosion or for contour bank or ''whoa boy'' construction along the route, given that the material is of low sodicity and dispersibility
- using as fill for other construction purposes e.g. building pads, as road base etc.

- establishing shallow mounds in locations in proximity to the pipeline route. Such locations would need to be away from concentrated or significant upslope run-off flows and would be topsoiled and revegetated
- possibly removing some subsoil in flood plain situations, rather than mounding up the easement with this excess material, to avoid the risk of overland flow diversions
- mounding of suitable excess spoil in grazing areas will only be done where there is minimal catchment area above the mounding.

4.4.3 *Slope Management*

Additional management measures to be applied in sloping areas include:

- installing trench breakers (e.g. cement-filled sandbags) at regular intervals on steep slopes and the approaches to watercourses to force groundwater seepage along the pipe trench to the surface
- marking the location of trench breakers prior to backfilling
- installing final diversion berms immediately downslope of the trench breaks so seepage water will be diverted from the trench away from the easement
- installing a series of earth banks on slopes generally >2 per cent. The earth banks will need to be installed every 20 m to 70 m (depending on gradient and soil types) immediately following clear and grade
- reinstating earth banks, as required, until restoration when they may need to be permanently established, especially on very steep slopes
- constructing earth banks to ensure water is discharged onto stable land on the downslope side of the easement.

4.4.4 *Ancillary Pipeline Facilities and Access Tracks*

Erosion control measures previously outlined will be implemented in the planning, installation and restoration of ancillary pipeline facilities. Upon completion of the pipeline construction, temporary access tracks will be closed and rehabilitated to a condition compatible with the surrounding land use unless otherwise agreed with the relevant landholder.

Soil windrows should be removed and contour deep ripping undertaken to relieve compaction and develop a suitable seedbed. The track will be reseeded with a suitable pasture mix.

4.4.5 *Revegetation*

In order to prevent future erosion and sedimentation associated with the easement, it will be necessary to undertake revegetation works as soon as practicable after completion of pipeline construction. It will be necessary to determine a suitable seed species mix and rate of application (including fertiliser) for each of the regions through which the pipeline passes.

In cropping areas, landholders may wish to undertake their own seeding or have a sterile cover crop sown. Information as to how this will be managed is provided in *Volume 4, Chapter 7*.

Good Quality Agricultural Land

Most of the land along the pipeline routes is suitable for pastoral use with significant sections also suitable for cropland with appropriate inputs.

The installation of the pipelines and ancillary infrastructure has the potential to affect GQAL although the burial depth of the pipeline (below plough depth) should not affect cropping activity to any significant extent. GQAL is regarded as a finite resource and as such is protected through State Planning Policy 1/92.

Any disturbance is to be rehabilitated as quickly as possible and productivity of the affected land will be returned, as near as is practicable, to its pre-disturbance levels. To this end the mitigation and management measures for soil management and erosion and sediment control (described previously) will be adopted. Provided these measures are adopted, land use along the easement for the pipeline routes should not be significantly compromised in the long term.

4.5 CONCLUSION

QGC has identified the geology and soil characteristics of the routes for pipelines that form the Pipeline Component of the Queensland Curtis LNG (QCLNG) Project. The erodibility of the soils, combined with variable topsoil thickness and low fertility mean that the management of topsoil and rehabilitation practices will be a significant issue for pipeline construction works.

In addition, some areas of saline subsoil occur, the exposure of which can lead to further erosion and affect the success of rehabilitation measures. Specific mitigation measures have been proposed with the primary objective of:

- preserving topsoil quantity and quality
- limiting area of disturbance
- controlling overland water flows around disturbed areas
- minimising the potential for erosion and sedimentation, particularly associated with sodic suboil
- maintaining the cropping productivity of the area.

It has also been identified that approximately 252 km of the combined pipeline routes is considered GQAL which, based on 40 m to 80 m clearing widths, equates to approximately 1260 ha. Mitigation measures have been proposed to reduce the potential impacts on current cropping land within the pipeline easements.

A summary of the impacts outlined in this chapter is provided in *Table 4.4.7*.

Table 4.4.7 Summary of Impacts for Soils and Geology

Impact assessment criteria	Assessment outcome
Impact assessment	Negative
Impact type	Direct
Impact duration	Short term (limited to construction phase)
Impact extent	Local
Impact likelihood	High

Overall assessment of impact significance: minor in the short term to negligible in the long term. This is based on the successful implementation of proposed mitigation measures. In coastal areas around Gladstone and on Curtis Island potential acid sulfate soil could be disturbed during construction of the Export Pipeline. However, impacts would be localised and risks and impacts can be avoided or reduced through the implementation of the Acid Sulfate Soil (ASS) Management Plan to be developed for the Project.