Wandoan Coal Project
Geology, mineral resources, overburden and soils impact assessment
Southern CSM Water Supply Pipeline

October, 2008

Wandoan Joint Venture

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Glossary

A horizon	See topsoil
Acid generating potential	Potential of spoil material to form acid conditions when oxidised (i.e. contact with air).
Action Plan	Internal document of a business centre or employee defining goals to be achieved in the budget period. Action items may also be referenced in an employee's job description.
Alluvium	Any stream laid sediment deposit found in a stream channel and in low parts of a stream valley subject to flooding.
Anthropogenic	Caused or influenced by humans.
Australian Height Datum (AHD)	A level datum, uniform throughout Australia, based on an origin determined from observations of mean sea level at tide gauge stations, located at more than 30 points along the Australian coastline.
Best Practice Environmental Management	Management of an activity to minimise environmental harm through cost-effective measures, assessed against measures currently used for the activity by the mining industry in Queensland.
Borehole	A hole produced in the ground by drilling or driving.
Bushland	A functional, multi layered, semi-natural plant community including a permanent tree layer, natural or established (e. g. on spoil). The area would be capable of sustaining flora and fauna habitats.
California bearing ratio (CBR)	A measure of the bearing capacity of a soil obtained from a standard soil penetration resistance test.
CHPP	Coal handling and preparation plant
Chromosol	Soils with strong texture contrast between A horizons and B horizons, in which the B horizons are not strongly acid and are not sodic, as defined by Isbell (1998).
Clay	Particles with a diameter less than 0.002 mm (McDonald et al.1998)
Clean water	Rainfall runoff flowing off lease in compliance with licence conditions.
Competent rock	Rock that is considered suitable for the intended use.
Competent spoil	Non acid, non dispersive durable spoil with potential characteristics to resist erosion.
Controlled discharge	Release of lesser quality water from the mining lease into better quality receiving water under conditions that allow for measured dilution to a predetermined water quality standard.
Cover material	Soil or other suitable plant growth medium placed on reshaped spoil surfaces; typically non crusting and low salinity.
Dermosol	Soil with a structured B2 horizon and lacking strong texture contrast between the A and B horizons, as defined by Isbell (1998).
Diversions/diversion channels	Structures for the controlled re-direction of drainage lines and watercourses around open cut pits and infrastructure areas.
DTPA	Diethylene triamine pentaacetic acid. A chemical used for the extraction of metal ions during chemical analysis.
Dyke	Sheet-like igneous intrusion cross cutting bedding planes, commonly sub-vertical.
EC	Electrical conductivity, a measure of the dissolved salts in a substance
Erosional stability	The ability of a rehabilitated area to resist the natural forces of soil erosion.
Exploration track	Temporary vehicle traffic route used for exploration or infrequent access from which topsoil has not been removed.

Externally drained	Rainfall runoff water that reports to the external environment of a structure via local drainage systems.
Feldspar	A group of abundant rock forming minerals of the general formula MAI (Al, Si)3O8, where M can be potassium (K), sodium (Na), calcium (Ca), barium (Ba), rubidium (Rb), steradian (Sr) or iron (Fe).
FoS	Factor of Safety.
Functional vegetation	Vegetation that consists of species able to survive and regenerate under specific conditions, providing soil erosion control and fauna habitat.
Geochemistry	The chemical characteristics of a soil or rock material.
Geomorphology	Study of the characteristics, origin and development of land forms and the processes that act on them.
Geotechnical stability	Resistance of a natural slope or earth structures to mass movement and erosion.
Gilgai	The phenomena of an irregular land surface with mounds and depressions formed due to clay horizons shrinking and swelling with alternate drying and wetting cycles.
Graded banks	Cross slope earthen banks constructed on reshaped spoil areas, typically at horizontal intervals of approximately 50 m and 1 to 1.5% longitudinal gradient, to reduce the effective slope length and control the runoff flow rate.
Holocene	The most recent epoch of geological time, spanning to 10,000 years before present.
Hostile spoil	Acid, sodic or saline spoil deleterious to seed emergence, geotechnical and geochemical stability of spoil.
Incident register	A database of environmental incidents, causes and remedial actions.
Internal drainage	Drainage of rainfall runoff from reshaped spoil areas confined and ponded within the spoil area.
Leaching profile	Vertical change in chemical concentrations down the soil profile due to leaching.
MLA	Mine Lease Application
NATA	National Association of Testing Authorities Australia
Overburden	The soil or other mineral matter which has to be removed to gain access to the underlying material.
PAWC	Plant available water capacity.
Plan	Set of actions required to ensure the achievement of a stated objective/program.
Plant growth medium	Material which is typically non crusting and has low salinity levels, in which plant seed will germinate and establish.
Policy	Stated commitment to achieving objectives.
Program	Management supported work commitment, budget and time frame to achieve a stated objective.
Quaternary	The geological period of time from the present to two million years ago.
Refuse dump	Site to be used for the permanent placement of waste.
Regional Ecosystems	A vegetation community, within a bioregion, that is consistently associated with a particular combination of geology, landform and soil, As defined by Sattler & Williams (1999) in The Conservation Status of Queensland's Bioregional Ecosystems.
Regulated waste	Non-domestic waste as defined in Schedule 7 of the Environment Protection (Waste) Regulation 1998, (whether treated or immobilised) and includes: for an element — any chemical compound containing the element anything that has contained the waste.
Rehabilitation	Reshaping of a disturbed area to a geotechnically and geochemically stable condition, followed by revegetation.

Revegetation	Establishment of suitable plant species to support the agreed post mining land use and control soil erosion to sustainable levels.
Rock mulch	Durable or competent rock purposely placed on an area under rehabilitation to provide additional resistance to erosion.
Saline	Presence of salts, in water or spoil, generally undrinkable or in sufficient concentration to impair plant growth.
Sand	Natural mineral particles with a diameter between 0.02 mm to 2.0 mm (McDonald et al.1998)
Sediment dams	Large impoundment structures used to retain rainfall runoff to allow settlement of suspended particles, prior to discharge.
Sill	Sheet-like igneous intrusion within coal seams or along bedding plane partings.
Silt	Mineral particles with a diameter between 0.002 mm to 0.02 mm (McDonald et al.1998)
Silt traps	Small impoundment structures built within a drainage line, which retard water flow and allow suspended solids to settle out.
Sodic	A soil is considered sodic when the exchangeable sodium percent (ESP) is greater than 6. Sodic conditions usually result in clay dispersion and surface crust formation.
Sodosol	Soils with a strong texture contrast between A horizons and sodic B horizons which are not strongly acid, as defined by Isbell (1998).
Soil	That part of the upper weathered layer of the earth's crust which can support plant growth
Soil horizons	Soil horizons as defined by McDonald et al. (1998) are:
	O — surface layer dominated by organic material in varying stages of decomposition
	A — one or more surface mineral horizons with some organic accumulation
	A1 — mineral horizon at or near the surface with some accumulation of humified organic matter. It is usually darker than underlying horizons
	A2 — mineral horizon having less organic matter, sesquioxides and/or silicate clay than immediately adjacent horizons. It is usually paler in colour than the A1 or B horizon
	A3 — transition horizon between the A and B horizons, which is similar to the A horizon
	B — one or more mineral soil layers characterised by a concentration of silicate clay, iron, aluminium and/or organic material; and/or a differing structure, consistence or colour of the A horizon
	B1 — transitional horizon between the A and B horizon which is similar to the B horizon
	B2 — horizon dominated by an illuvial, residual or other concentration of silicate clay, iron, aluminium and/or humus, and/or maximum development of pedological organisation
	B3 — transitional horizon between the B and C horizon which is similar to the B horizon
	C — consolidated and unconsolidated material below the A and B horizon. Usually partially weathered and little affected by pedological processes.
Spoil area	Area where overburden has been dumped.
Subsoil	The B horizon within the soil profile which lies immediately below the topsoil or A horizon. The subsoil is not enriched with organic material as is the topsoil. It may also be subject to clay and/or salt accumulation.
Suitably qualified person	A person whose professional training or experience is relevant to the matter being considered (EPA, 2007)
Sump	Temporary excavation for the storage of water.

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Tension cracks	Cracks at the ground surface which occur due to tensional forces in the soil or rock mass, behind the crest of a slope.
Test pit	An excavation for examination of subsurface soil conditions
Topsoil	The uppermost horizon (or A horizon) of the soil profile which usually contains the organic matter, biota and a concentration of the nutrients.
Vertosol	Clay soil with high shrink-swell properties as defined by Isbell (1998).
Waters	River, stream, lake, lagoon, pond, swamp, wetland, unconfined surface water, bed and bank of any waters, dams, non-tidal or tidal waters or any part-thereof.
Wetland	Area where natural flow has been permanently interrupted and will remain as a feature of the landform after mining.
WJV	Wandoan Joint Venture

Executive summary

This geology, mineral resources, and soils assessment was undertaken to assess and define the existing land-related site characteristics that may impact on or be impacted by the proposed Southern CSM Water Supply Pipeline (the proposed pipeline) associated with the Wandoan Coal Project, to assess the soil management requirements and reuse potential.

The soils and land suitability assessment comprised a review of available published data, classification and mapping of soils, and a land suitability assessment.

The proposed pipeline study area is located in an area mainly underlain by the Jurassic age Injune Creek Group rocks and Quaternary age alluvium along existing streams. The study area consists of six land resource areas (LRA), Brigalow Uplands, Glenhaughton Forest, Poplar Box Flat Plains, Cypress Pine Sands, Brigalow Plains and Light Forests. The Brigalow Uplands, north of the Great Dividing Range, consists of undulating hills at a surface elevation (RL) of approximately 280 m to 420 m Australian height datum (AHD). The Glenhaughton Forest and Light Forests LRA comprising the Great Dividing Range and undulating hills south of the range, comprise undulating hills between 460 m to 230 m AHD.

The Poplar Box Flat Plains, Cypress Pine Sands and Brigalow Plains LRA occur on alluvial floodplains of the various creeks that traverse the proposed pipeline study area south of the Great Dividing Range, with a typical floodplain width of between 1 km and 2 km.

Sixteen different soil types are anticipated to occur within the proposed pipeline study area, including cracking and non-cracking clays on the undulating hills north of the Great Dividing Range, and sandy to loamy texture contrast soils on and south of the range. Floodplain soils south of the range also comprise of sandy to loamy soil. The soils with sandy to loamy topsoil will be highly susceptible to wind and water erosion following disturbance, and the area of these soils cleared or disturbed for works will need to be minimised, and suitable erosion and sediment control measures implemented.

Subsoils over much of the proposed pipeline study area are alkaline, sodic and dispersive and will require specific management techniques such as minimising exposure to prevent erosion, including tunnel erosion. Soils identified as most susceptible to erosion include Cheshire, Teviot and Braemar.

Based on the former Taroom Shire Council Planning Scheme (2006) and Murilla Shire Council Planning Scheme (2006) all of the undulating hills north of Gilugulgul and some floodplain south of the Great Dividing Range are classed as good quality agricultural land (GQAL).

A land suitability assessment for dry land cropping, and beef cattle grazing was carried out for the proposed pipeline study area, which generally supported the GQAL mapping, but found the floodplains south of the Great Dividing Range not to be GQAL. The proposed pipeline is not expected to impact the land suitability classification of land within the study area, but will limit the potential for some agricultural practices or infrastructure to be sited on the land.

1. Introduction

1.1 Project background

The Wandoan Coal Project (the Project) comprises the development of thermal coal resources situated immediately west of the Wandoan township, located in the Dalby Regional Council. The Project is located approximately 350 km northwest of Brisbane and 60 km south of Taroom as shown in Figure 1-1. The Project will be developed by the Wandoan Joint Venture. The joint venture partners are Xstrata Coal Queensland Pty Ltd (XCQ), ICRA RPW Pty Ltd and Sumisho Coal Australia Pty Ltd.

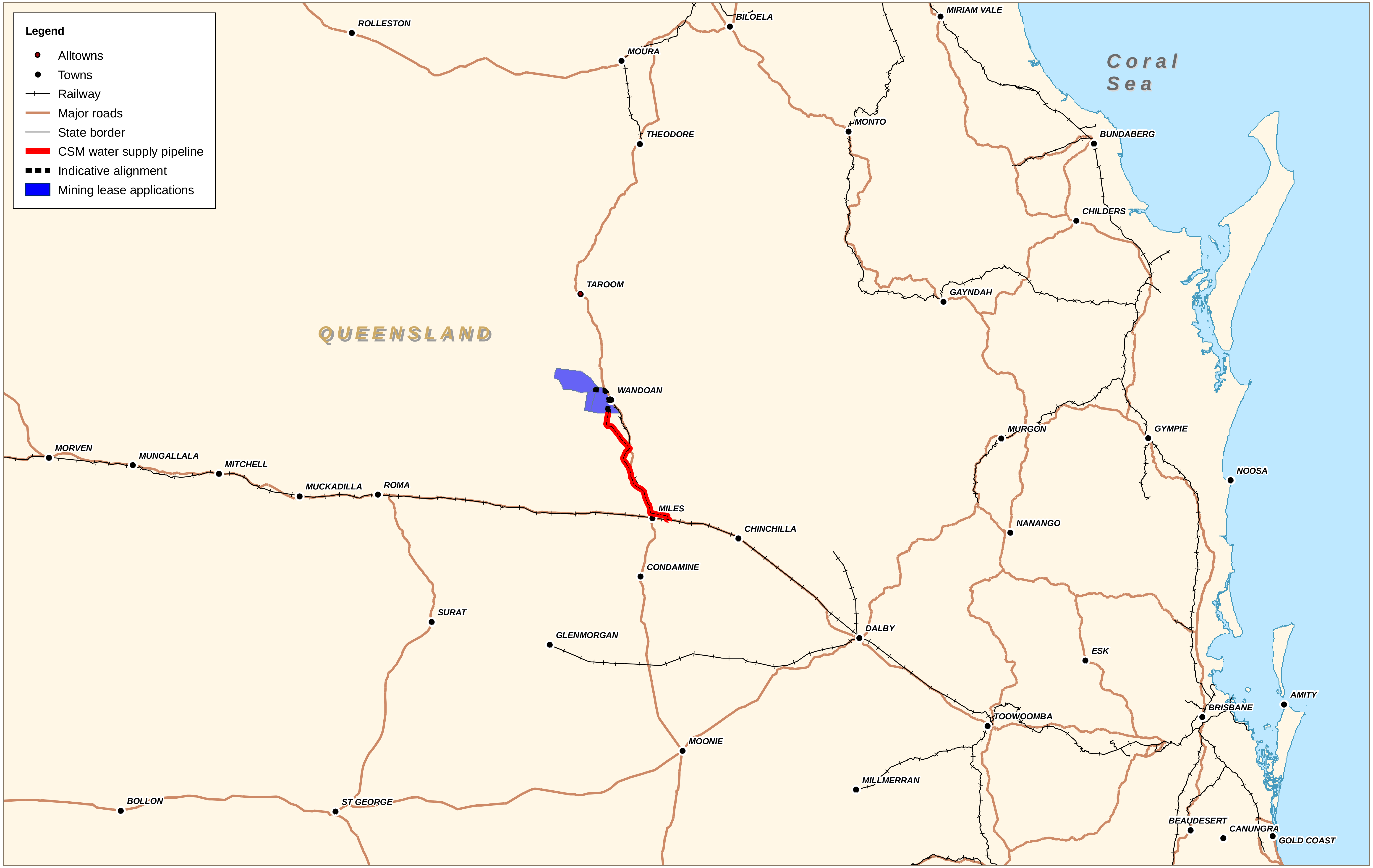
The Project will include on-site coal handling and processing which will require a constant and reliable water supply, which is anticipated to peak at approximately 9,100 ML/a. A potential water resource to help satisfy this demand has been identified as a by-product of coal seam methane (CSM) extraction from wells associated with the Condamine Power Station, approximately 100 km south of the Wandoan Coal Project site.

This technical report covers a proposed water pipeline corridor to transfer CSM water from the Condamine Power Station to Wandoan Coal Project mining lease application (MLA) areas. The portion of the Project covered by this technical report will be referred to as the Southern CSM Water Supply Pipeline (the proposed pipeline).

1.2 Description of study area

The study area for this geology, mineral resources, overburden and soils assessment comprises an approximately 100 km long corridor from the Condamine Power Station to the mining lease application (MLA) areas of the Wandoan Coal Project (refer Figure 1-2).

The study area mainly crosses cleared land on low undulating hills and timbered areas of the Great Dividing Range. The hydrology in the proposed pipeline study area is dominated by a number of north and south flowing ephemeral creeks on the northern and southern side of the Great Dividing Range.



J:\A442-ENG\PROJ\2133006C__Wandoan_prefea\10_GIS\Projects\Env\Technical Report\Figure 1-1 Project Location.mxd

Source: Roads, QLD State Digital Road Network (2004); Towns, Coastline , boundaries, 1:250K Topo, Geoscience Australia (2006)

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0 25 50 75 100 125
Kilometers

Figure 1-1
Project Location

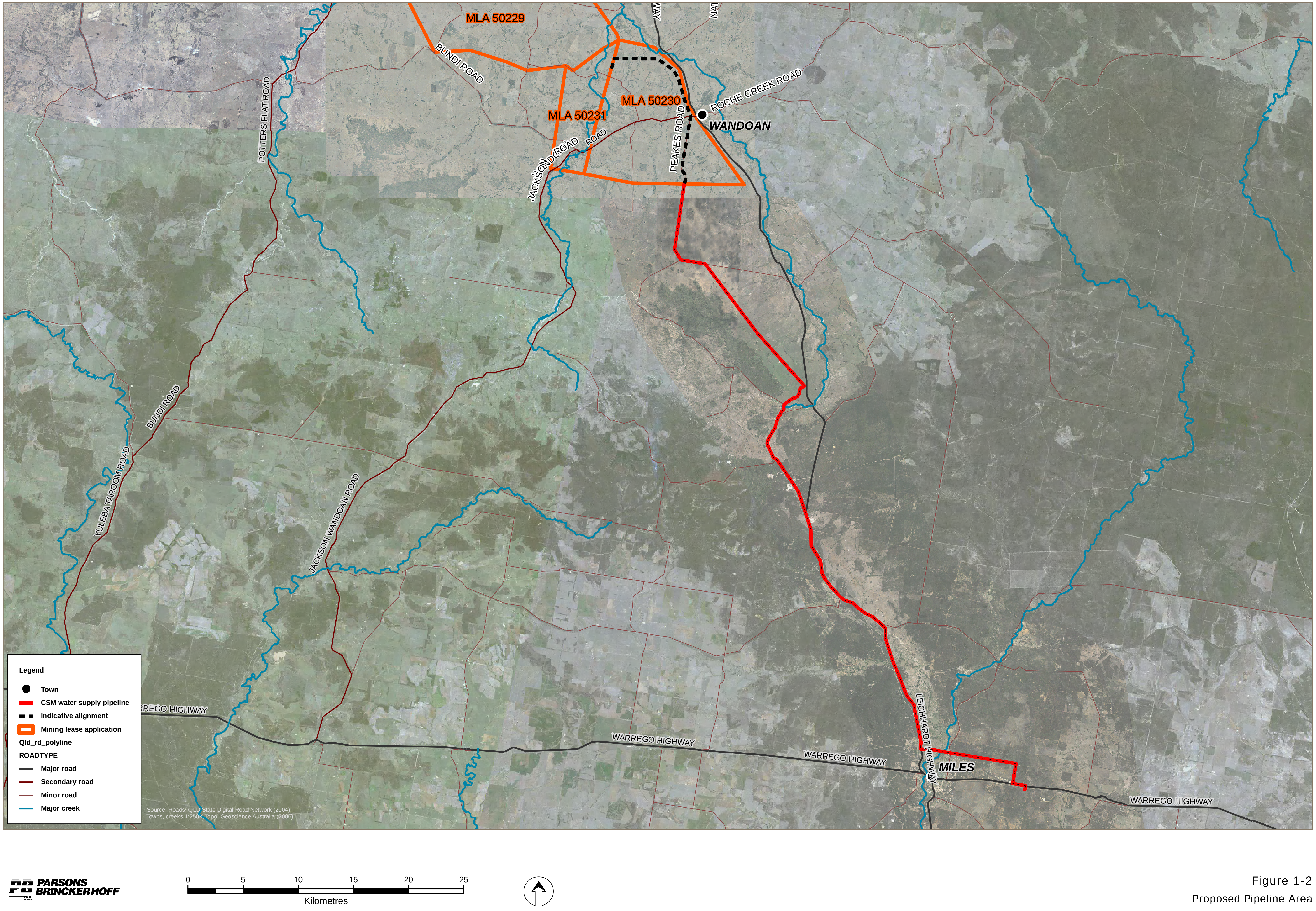

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Figure 1-2

Proposed Pipeline Area

2. Methodology of assessment

2.1 Relevant legislation and guidelines

2.1.1 State planning policy 1/92 Development and conservation of agricultural land, 1992

State planning policy 1/92 is based on the principle that land suitable for agricultural purposes is limited in Queensland, and that suitable ‘good quality’ land should be protected for agricultural uses.

The State Planning Policy makes allowances for developments on high quality agricultural land where the project provides an overriding public benefit and there are no other suitable sites for the purpose.

The State Planning Policy 1/92 is largely implemented at the local government level, and requires local governments to include maps of good quality agricultural land (GQAL) in their planning schemes.

2.1.2 Planning guidelines: The identification of good quality agricultural land, 1993

The Planning Guidelines assist the implementation of State Planning Policy 1/92, through the provision of a methodology for assessing and identifying agricultural land classes and subsequently GQAL.

Under the Planning Guidelines, land is classified into classes, ranging from Class A being cropping land with moderate to no production limitations, to Class D being land not suitable for agriculture due to extreme limitations. Which agricultural land classes are considered GQAL within each local government areas was established during the preparation of the planning guidelines in 1993, based on publicly available land resource mapping such as Department of Primary Industries manuals and CSIRO reports. The planning guidelines acknowledge that much of this mapping is at a broad scale, and that site-specific assessments may be needed to confirm the distribution of QGAL.

2.1.3 Environmental Protection (Water) Policy 1997

The Environmental Protection (Water) Policy (EPP (Water)) is a policy under the Environmental Protection Act 1994. The policy defines and protects environmental values of Queensland waterways.

Under Section 32 of the EPP (Water) it is an offence to allow sand, silt or mud to accumulate in a waterway or where it could wash into a waterway unless it is permitted by an Environmental Authority under the *Environmental Protection Act 1994*.

2.1.4 Land suitability classification for cropping and grazing in the semi-arid sub-tropics of Queensland

The land suitability classification system used in this assessment was produced by the Department of Mines and Energy in 1995, and provides a framework for the assessment of the suitability of land for cropping and grazing purposes, based on a range of soil and landscape characteristics (Grey and Macnish 1985). The guidelines were prepared for use in relation to mining and exploration projects for the assessment of pre-disturbance and post-disturbance land capability, but have now been widely adopted as a tool to assess land use potential relating to a range of infrastructure projects.

2.2 How the study was conducted and information obtained

The soils and land suitability assessment comprised a desktop review of available published data to:

- define potential soil types occurring along the corridor
- define anticipated lateral extent of various soils
- assess land suitability classes
- assess available topsoil types and suggested stripping depths
- assess erosion potential of the topsoil and subsoil materials.

2.2.1 Review of existing information

A number of previous studies have been conducted into soils and their properties at, and around, the proposed pipeline. Previous investigations that provided information for this report regarding soil and landscape characteristics include:

- Gray, H.J and Macnish, S.E (1985) Land Management Field Manual Wandoan District.
- Forster, B.A (1985). Evaluation of Agricultural Land in Taroom Shire.
- Maher, J.M. (1996) Understanding and Managing Soils in the Murilla, Tara and Chinchilla Shires.

2.2.2 Field assessment

No field work was conducted for this assessment. However all previous studies had a field assessment component.

2.2.3 Laboratory testing

No laboratory testing was conducted for this assessment. Soil characteristics were derived from review of previous studies

2.2.4 Soil mapping and classification

Classification of soils for the proposed pipeline study area was based on published soil classification data as listed in Section 2.2.1 of this report, and review of topography and aerial photography.

The adopted soil classification system is the Australian Soils Classification system (Isbell 1996). Where soil descriptions correlate with soil types in the references in Section 2.2.1, soil names from these references have been adopted.

2.2.5 Overburden assessment

No overburden assessment was conducted for this study as no mining activity is proposed within the proposed pipeline corridor.

2.2.6 Land suitability assessment

Land suitability assessments incorporating the proposed pipeline study area have previously been conducted by Grey and Macnish (1985) and Forster (1985), while Maher (1996) identified soil properties for use in a land suitability assessment. The findings of these assessments were reviewed in relation to the proposed pipeline study area, and the land assessed for its suitability for dry-land cropping and cattle grazing on improved pasture. The criteria used for assessing the suitability of land for specific agricultural uses are included in Attachment A. The land was then classified into one of five land suitability classes for each potential land use assessed, relating to the land use limitations.

The land classes are shown below:

- Class 1 — suitable land with negligible limitations and is highly productive requiring only simple management practices
- Class 2 — suitable land with minor limitations which either reduce production or require more than simple management practices to sustain the use
- Class 3 — suitable land with moderate limitations — land which is moderately suited to a proposed use but which requires significant inputs to ensure sustainable use
- Class 4 — marginal land with severe limitations which make it doubtful whether the inputs required to achieve and maintain production outweigh the benefits in the long-term
- Class 5 — unsuitable land with extreme limitations that preclude its use.

The findings of the land suitability assessment were then assessed against the GQAL mapping under the former Taroom Shire Council Planning Scheme (Taroom Shire Council 2006) and Murilla Shire Council Planning Scheme (Murilla Shire Council 2006) to assess the accuracy of the GQAL mapping.

2.3 Limitations

The assessment has been based on a desktop review of published land resource related reports. Soil in these reports have generally been mapped to the ‘land resource area’, with a description of the occurrence of soils within these land resource areas, and are mapped to 1:100,000 to 1:150,000 scale.

No field investigation or field confirmation of soil types or soil boundaries have been conducted with this assessment, although a review of topography and aerial photography has been carried out.

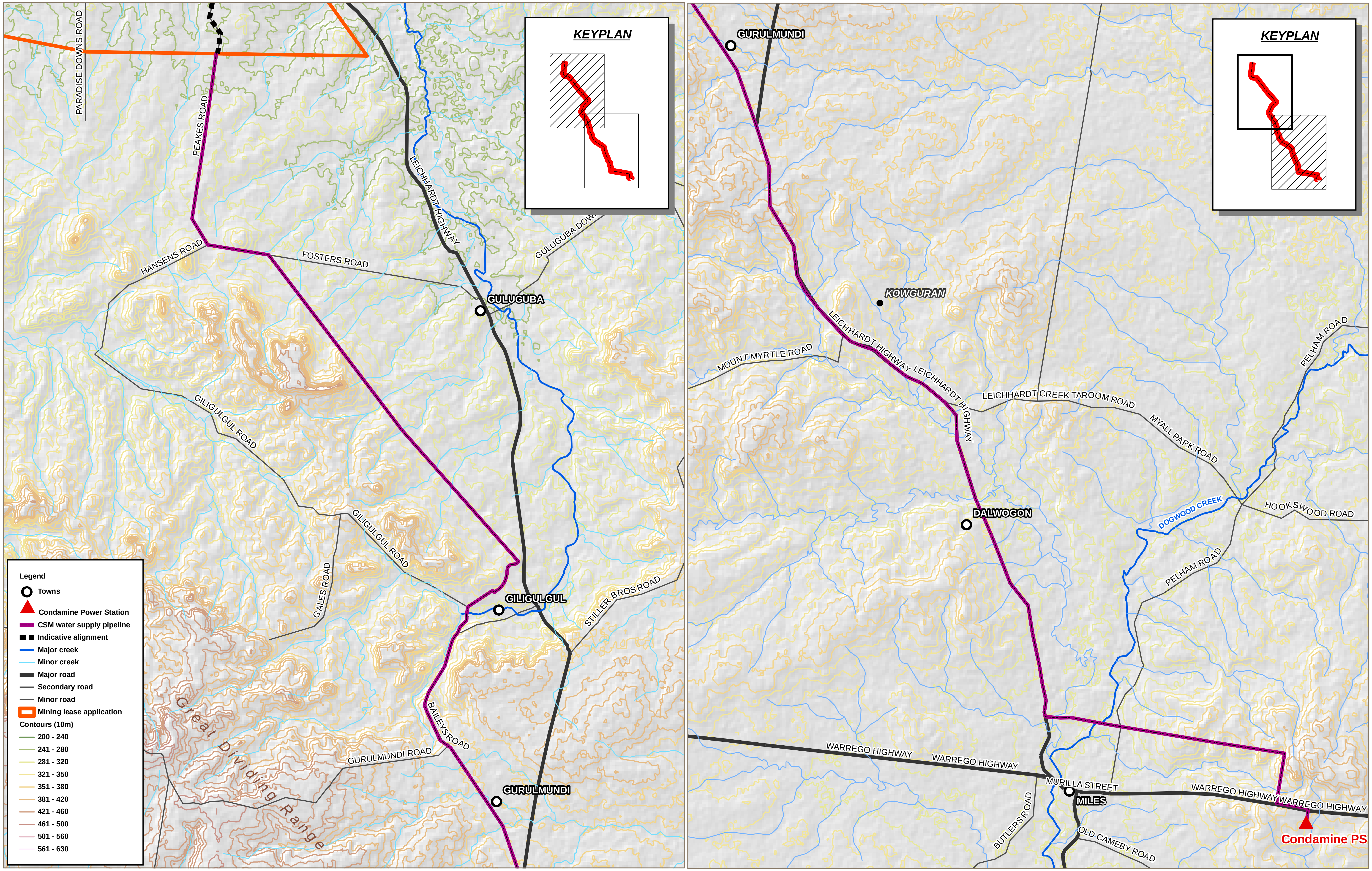
Soils are not discrete units, and variation of properties will occur within each of these soil types. The scale of mapping also will not identify small isolated occurrences of difference soils within each mapped unit.

3. Existing environment

3.1 Topography

The topography of the proposed pipeline study area is shown on Figure 3-1. Three main terrain elements are present in the proposed pipeline study area:

- low undulating hills north of the Great Dividing Range (GDR), with surface levels (RL) between 280 m and 420 m Australian height datum (AHD). Surface elevation and relief generally increases to the south. The proposed pipeline corridor approximately follows the 320 m contour through this landscape. This area is generally cleared of vegetation and used for cattle grazing or fodder cropping
- undulating hills of the GDR and south of the range. The GDR has a maximum height of about 460 m AHD, and the proposed pipeline corridor crosses the GDR at approximate RL 380 m. South of the GDR the topography is gently undulating with decreasing altitude to the south. The southern portion of the study area, south of Dalwogon, has RLs between about 320 m and 380 m AHD. In this portion of the corridor, the vegetation has not generally been cleared
- alluvial floodplains of Nine Mile Creek, Eleven Mile Creek, Wallan Creek and associated streams. The study area follows the upper edge of the Eleven Mile Creek floodplain south from approximately Kowguran. The Eleven Mile Creek floodplain is up to about 3 km wide, with a number of smaller streams joining the main creek, each having floodplains of approximately 1 km width. These floodplains have generally been cleared of vegetation and used for cattle grazing or fodder cropping.



Source: Roads, QLD State Digital Road Network (2004); Towns, creeks 1:250K Topo, Geoscience Australia (2006)

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0 2 4 6 8 10

Kilometres

Figure 3-1:
Site Topography

3.2 Vegetation

A detailed description of the vegetation in the proposed pipeline study area is found in Chapter 17A Terrestrial Ecology and associated technical report. Encountered vegetation in the study area was diverse due to the range of geological units traversed by the proposed pipeline.

The southern end of the study area, from the Condamine Power Station to the Leichhardt Highway, is dominated by tall Acacia shrublands. Dominant species in these shrublands included *Acacia shirleyi* (Lancewood) and *Acacia aprepta* (Miles Mulga). Interspersed amongst the tall Acacia shrublands were ironbark dominated woodlands typically with *Eucalyptus crebra* (Narrow-leaved Red Ironbark) and *Eucalyptus fibrosa* ssp*. nubila* (Blue-leaved Ironbark).

The section of the study area within the road reserve of the Leichhardt Highway and the southern end of Bailey's Road reserve was dominated by eucalypt woodlands. These woodlands were dominated by a range of species including *Corymbia citriodora* (Spotted gum), *Angophora leiocarpa* (Smooth-bark apple), *Eucalyptus crebra* (Narrow-leaved Red Ironbark) and *Eucalyptus fibrosa* ssp*. nubila* (Blue-leaved Ironbark).

The dominant vegetation community on lateritised sedimentary rocks along the northern section of road reserve of Bailey's Road was *Eucalyptus populnea woodland* (Poplar Box) with an *Allocasuarina leuhmanii* (Belah) understory.

To the north of Giligulgul the study area traverses mainly freehold properties that have been predominantly cleared of remnant vegetation. Some regrowth (non-remnant status) vegetation was present within these properties and was dominated by *Acacia harpophylla* (Brigalow).

The remainder of the study area, including the majority of northern extent of the study area, consisted of cleared or highly disturbed vegetation (non-remnant) that is no longer analogous with a RE and generally represented open pastoral expanses or degraded road reserves dominated by pastoral grasses.

3.3 Geology

3.3.1 Regional geology

The proposed pipeline study area is located with in the Surat Basin, an eastern lobe of the Great Artesian Basin. The Surat Basin contains up to 2,500 m depth of sediments comprised mainly of Jurassic clastic continental rocks and Early Cretaceous marine beds (Green and Chestnutt 2007).

The geological history of the Miles–Wandoan region is dominated by deposition of sedimentary material, rock formation and uplift and subsequent erosion. During the Late Triassic, freshwater streams deposited sand over much of the region. This was followed by a period of widespread erosion in the Late Triassic, and then a cyclic period of fluvial sedimentation followed by erosion between the Early Jurassic and Early Cretaceous. Extensive coal deposits formed during Middle Jurassic time.

Since the Late Jurassic the Surat Basin has been relatively stable. A marine transgression in the Early Cretaceous was the last major sedimentary episode, after which the sea withdrew during the Late Cretaceous.

Deep weathering of the land surface occurred during the tertiary, however subsequent erosion has since stripped this profile from the northern areas of the Surat Basin (Slater 1986). South of Wandoan large areas of deeply weathered and lateritised material form plateaus along the GDR, and mesa topography elsewhere.

3.3.2 Local geology

The summary of geology underlying the proposed pipeline corridor has been referenced from detailed studies of the geology of the Wandoan region including photogeological interpretation (Snodin 2004) and the Roma and Chinchilla sheets of the Geological Survey of Queensland's 1:250,000 series. The geologic units in the region occur in generally west-north-west to east-south-east trending bands, which have been dissected by generally north or south trending creeks draining the GDR. Soils and the underlying rock of the proposed pipeline corridor are from the following main geological units:

- quaternary age alluvium (Qa) consisting of sand, silt, mud and gravel along creeks and drainage lines. In the vicinity of Condamine Power Station Site this alluvium becomes sandy alluvium of the Condamine River
- quaternary age sand plains (Czs) sourced from eroded Kumbarilla beds, south of the GDR including the floodplain of Wallan Creek and the upper floodplain of Eleven Mile Creek
- Jurassic to Lower Cretaceous age Kumbarilla beds (Jsk) on the southern slopes of the GDR and southern undulating landform, consisting of clayey labile to quartzose sandstone, siltstone, mudstone and polymictic conglomerate. Much of the profile is deeply weathered, containing younger ferruginous material
- Middle to Upper Jurassic age Orallo Formation (Jso) on the topographically higher ground including the GDR, consisting clayey lithic sandstone, siltstone, mudstone, claystone, minor bentonite and polymictic conglomerate
- Middle to Upper Jurassic age Gubberamunda Sandstone (Jsg) on topographically higher ground on the northern slopes of the GDR, consisting of quatrzose to sublabile sandstone, conglomerate and siltstone
- Middle to Upper Jurassic age Injune Creek Group (Jsi) forms the undulating terrain north of the GDR, comprising sandstone and mudstone with coal. In the study area this unit is anticipated to comprise the Juandah Coal Measures, Springbok Sandstone and Westbourne Formation.

The geology of the proposed pipeline study area is shown on Figure 3-2.

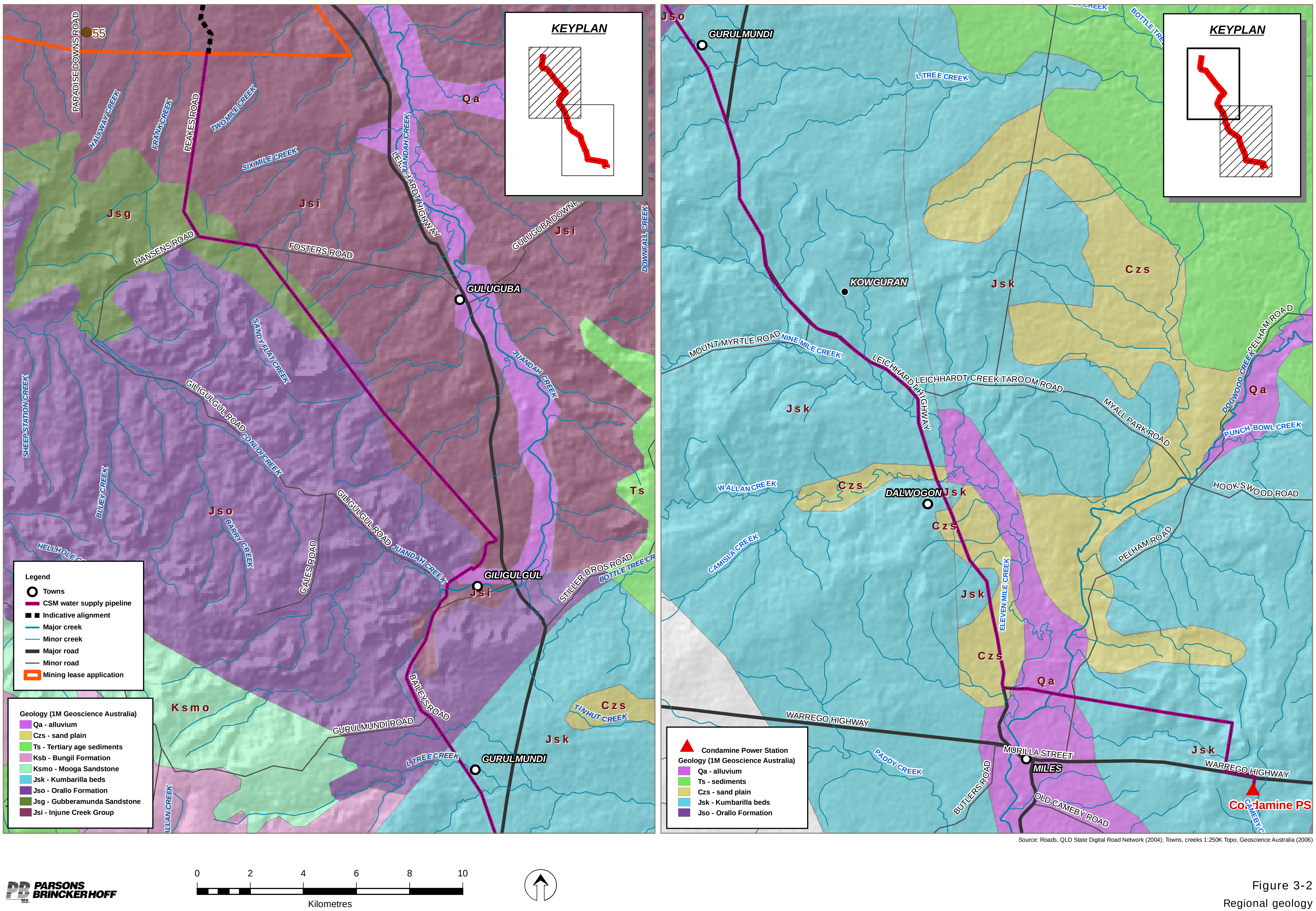

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Figure 3-2
Regional geology

3.4 Mineral resources

According to the NRW's Interactive Resource and Tenure online maps (accessed on 15 August 2008), a number of petroleum leases (PL), and exploration permit for petroleum (EPP) exist over the proposed pipeline study area (refer Figure 3-3). The petroleum leases include the leases from which the CSM water is being sourced. These PL and EPP are summarised below:

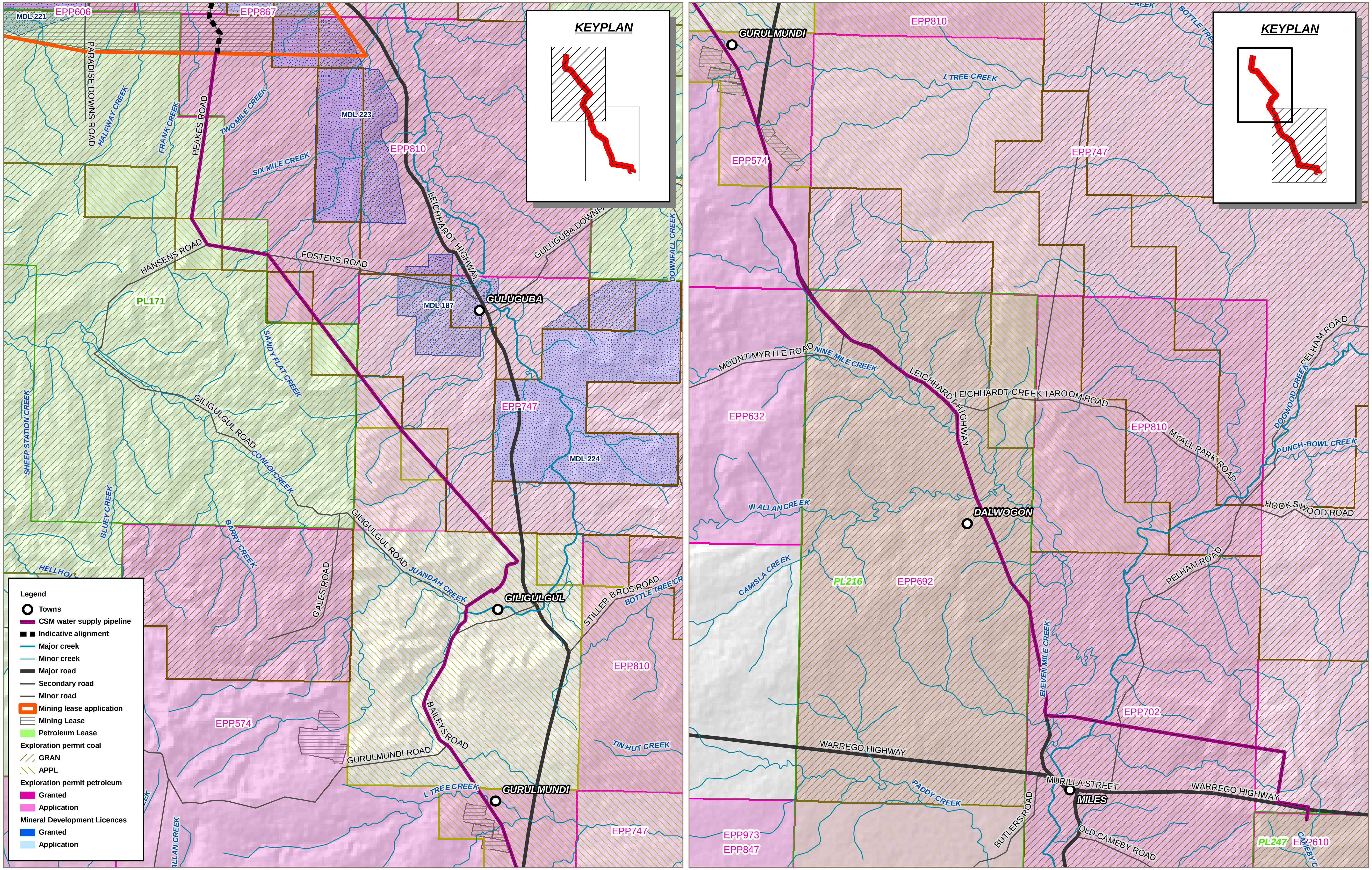
- PL216 (application) held by Origin Energy SCG Limited
- PL171 (granted) held by Roma Petroleum NL
- PL247 (application) held by Queensland Gas Company Limited
- PL267 (application) held by Origin Energy CSG Limited
- EPP747 (application), help by Arrow Energy Ltd
- EPP810 (granted) held by Arrow Energy Ltd
- EPP574 (granted) held by Victoria Petroleum NL
- EPP632 (granted) held by Queensland Gas Company Ltd
- EPP610 (granted) held by Queensland Gas Company Limited
- EPP702 (granted) held by Origin Energy CSG Limited
- EPP692 (granted) held by Origin Energy SCG Limited.

A number of exploration permits for Coal also exist along the proposed pipeline corridor:

- EPC1165 (granted), held by Metrocoal Limited
- EPC1134 (application), held by Surat Coal Pty Limited
- ECP1251 (application), held by Metrocoal Limited
- EPC1278 (application), held by Surat Coal Pty Ltd
- EPC787 (granted) held by Xstrata Coal Queensland
- EPC792 (granted) held by Xstrata Coal Queensland
- EPC 1118 (granted) held by Cougar Energy UCG Pty Ltd.

The proposed pipeline study area passes in close proximity to a number of small mining leases near Gurulmundi. These are:

- ML5907 (Ausben No. 2), held by Unimin Australia Limited
- ML5909 (Ausben No. 1), held by Unimin Australia Limited
- ML50058 (Ausben No. 3), held by Unimin Australia Limited
- ML5902 (Claymundi), held by Unimin Australia Limited
- ML5905 (Benton No. 1), held by Unimin Australia Limited
- ML5898 (Slippery), held by Unimin Australia Limited
- ML5906 (Benton No. 2), held by Unimin Australia Limited.



Source: Roads, QLD State Digital Road Network (2004); Towns, creeks 1:250K Topo, Geoscience Australia (2006)

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0 2 4 6 8 10

Kilometres

Figure 3-3:

Extractive resources, permits and leases within the pipeline study area

3.5 Geomorphology

Despite being highly weathered and displaying low relief, the GDR forms a topographic high in the region, being up to about 460 m AHD. Drainage over the study area is generally towards the north and south from the GDR, with sediment from the GDR in the centre of the study area slowly transported by the creeks via the floodplains towards the Dawson River, located to the north of the study area and the Condamine River in the south-east of the study area.

The narrow floodplains, gentle slopes and confined meanders of drainage lines suggest that the landscape is geologically young north of the GDR. The ephemeral creeks are slowly cutting into and eroding the undulating hills, with lateral erosion of the valleys being the main large-scale landscape altering activity (Maher 1996). Temporary deposition of eroded material occurs on the narrow floodplains. Erosion rates are anticipated to be low due to the relatively dry climate and low topographic gradient. Most erosion will occur during infrequent high rainfall events.

South of the GDR the topographic highs of the undulating terrain drain towards the south trending Eleven Mile Creek, Dogwood Creek and eventually the Condamine River. North of Miles Eleven Mile Creek and Dogwood Creek form a wide floodplain with mixed granular and clayey sediments, mainly sourced from coarse grained sedimentary rocks. Adjacent to the floodplain, extensive sand sheets have developed on Mesozoic sedimentary rocks.

East of Dogwood Creek the drainage is mainly east-west trending, draining the topographic high areas that are commonly associated with lateritised portions of sedimentary rocks.

Due to the relatively low relief and dry climate, the erosion rates in the topographic high areas and on the floodplains are anticipated to be low. Gullyhead erosion and intermittent transport of alluvial sediments appear to be the dominant geomorphic process operating in the area.

3.6 Overburden

Overburden is not relevant to this assessment

3.7 Soils

3.7.1 Land resource areas

Land resource areas (LRAs) are reoccurring landscape units with similar geology, landforms, soils and vegetation associations. They are used to simplify and aid quick field identification of land resource unit mapping and subsequent management. The LRAs of the proposed pipeline corridor are shown in Figure 3-4.

The *Wandoan District Land Management Field Manual* (Gray and Macnish 1985) identified two LRAs in the proposed pipeline study area, and *Understanding and Managing Soils in the Murilla, Tara and Chinchilla Shires* (Maher 1996), identified five LRAs in the study area. These previously identified LRAs are shown in Table 3-1.

Table 3-1: Identified land resource areas

LRA	Landform	Soil type	Vegetation	Land use
Brigalow uplands	Undulating plains with broad ridges and low hills, on sandstones and shales.	Grey and brown non-cracking and gilgaied cracking clays; shallow sandy and loamy soils on ridges and some texture contrast soils	Brigalow open forest and softwood scrub. Brigalow open forest with either poplar box or belah or Dawson gum or bauhinia. Scattered wilga and softwood scrub species frequently occur.	Predominantly winter grain cropping with occasional summer cropping. Grazing of native and improved pastures.
Glenhaughton forest	Undulating plains, broad ridges and dissected hills on sandstones and shales.	Shallow sandy and loamy soils, deep sands and texture contrasts soils with some small areas of clays..	Narrow-leaved ironbark, spotted gum, silver-leaved ironbark, poplar box and cypress pine open forest to woodland. Softwood scrub species frequently occur as an understory.	Mainly low intensity grazing. Suitable for logging for hardwood and for apiculture.
Poplar box flat plains	Gently undulating to flat plains.	Bleached sands over mottled, yellow or grey clays.	Woodlands of poplar box and bull oak. Associated with narrow-leaved ironbark, false sandalwood, cypress pine and molly box.	Mainly low intensity grazing. Suitable for logging for hardwood and for apiculture.
Cypress pine sands	Flat to gently undulating sandy alluvial plains.	Deep sands; deep bleached sands over mottled, yellow or grey clays; and bleached clay loams over black or grey clays.	Sandier soils consist of cypress pine, tumbledown gum and rough barked apple. Heavier soils consist of poplar box or bull oak woodland.	fodder cropping and grazing of native and improved pastures.
Brigalow plains	Flat clay plains.	Grey cracking clays.	Predominantly brigalow, belah, wilga forest and associated false sandalwood.	Predominantly cattle grazing on native and sown pastures. Limited fodder cropping.
Light forests	Plateaus and low sandstone hills to undulating plains.	Very shallow, gravelly, red soils and shallow, gravelly, texture contrast soils.	Open forest of ironbark and wattles.	Mainly low intensity grazing. Suitable for logging for hardwood and for apiculture.
Ironbark/bull oak forest	flat to gently undulating plains derived from weathered sandstone.	bleached sands over mottled, yellosih brown clays, deep sands, and very shallow, gravelly, red soils.	Open forest of bull oak, bull oak and cypress pine or bull oak and narrow-leaved ironbark.	Predominantly cattle grazing on native and sown pastures. Limited fodder cropping.

Source: After Grey and Macnish 1985, Map 3, Maher 1996, Map 1.

3.7.2 Soil description and mapping

A number of soils have been identified as occurring within the LRAs along the proposed pipeline study area. These soils are described in Table 3-2 and are anticipated to occur along the proposed pipeline corridor. A key to the location of soils within each LRA is provided in Figure 3-5.

Table 3-2: Soils of the proposed pipeline corridor

Soil name	Landscape position	Description	Chemical properties	Soil type
Brigalow uplands				
Cheshire	Occurs on steeper gradient upper slopes (up to 3%).	Shallow, non-cracking uniform clay. The topsoil is a dark sandy clay to light clay, underlaid by a brown to grey-brown medium clay subsoil.	Soils are strongly sodic below 0.3 m and with low to high salinity below 0.5 m. Subsoils are strongly alkaline and dispersive.	Dermosol
Downfall	Occurs on mid to lower slopes of approximately 2% grade in areas of sediment/slopewash accumulation.	Brown-grey cracking clay, with A horizon less than 0.3 m. Fine structured surface soils. The subsoil is grey or yellow-brown heavy clay.	Soils are strongly sodic below 0.3 m and with low to high salinity below 0.3 m. Subsoils are alkaline, and dispersive.	Vertosol
Kinnoul	Occurs on ridgetops and upper slopes within the Brigalow Uplands, and is commonly covered by regrowth brigalow softwood scrub.	Brown to brown-black uniform non cracking light to medium clay. The soil has a shallow profile, generally less than 0.45 m to weathered sedimentary rock.	Soils are non sodic and non saline.	Dermosol
Rolleston	Occurs on mid and lower slopes.	Dark brown-grey heavy clay topsoil. Fine to medium structured surface. Pale yellow-brown to yellow-orange subsoil. Common land use is cropping.	Soils are sodic to strongly sodic below 0.3 m and with low to high salinity below 0.6 m.	Dermosol
Rugby	Occurs on ridges in Brigalow areas.	Brown non-cracking uniform soil with sandy loam to clay loam surface.	Soils are strongly sodic in the weathered zone.	Dermosol
Teviot	Occurs on gently inclined midslopes with a gradient of 1% to 3%.	Uniform cracking clay. The topsoil is a brown grey to dark brown-grey clay. Coarse structured surface. Grey to yellow-brown subsoil. Common land use is cattle grazing.	Soils are sodic to strongly sodic below 0.3 m and with low to high salinity below 0.3 m.	Vertosol
Glenhaughton forest				
Texture contrast soils	Occurs throughout a variety of landforms and slope positions.	Brown texture contrast soil, with massive hard setting sandy loam surface soils over medium to heavy clay subsoils. Commonly uncleared.	Soils have variable properties, but generally have strongly sodic subsoil.	Sodosols

Soil name	Landscape position	Description	Chemical properties	Soil type
Poplar box flat plains				
Braemer	Occurs on mid to upper slopes of 1-3% in sandstone plains and rises.	Grey-brown texture contrast soil, with massive sandy loam surface soil over conspicuously bleached sandy loam over greyish brown light clay.	Soils have very low fertility, with strongly sodic and highly saline subsoils.	Brown Sodosol
Weranga	Occurs on slopes, rounded hilltops and undulating plains of 0-3% slope.	Brown texture contrast soil with massive loamy sand surface soils over mottled, pale brown light medium clay.	Subsoils are sodic and saline, with low nutrient content.	Brown sodosol
Cypress pine sands				
Chinchilla	Occurs on terraces, sand ridges and flat alluvial plans and creek channels draining weathered sandstone country.	Red-brown texture contrast soil with loose sandy loam surface soil over massive red loamy sand.	Soils are non saline and non sodic, with neutral pH, becoming acidic with depth.	Rudosol
Davy	Flat to gently undulating alluvial plains, terraces and creek banks draining from sandstone hills.	Brown uniform soils, with loose sandy loam surface soils over pale yellowish brown loamy sand.	Soils are non saline and non sodic.	Rudosol
Combidiban	Occurs on sandy alluvial plains and terraces of small creeks, and on flat sandy plains above clay plains	Grey-brown texture contrast soil, with loose sandy loam surface soils over dark greyish brown light to medium clay.	Subsoils are sodic	Grey chromosol
Bogandilla	Occurs on valley floors and flat plains associated with local drainage lines, and on lower slopes on the edge of brigalow clay plains.	Dark brown texture contrast soil, with clay loam hardsetting surface over dark grey-brown medium clay.	Soils are strongly sodic and highly to very highly saline in the subsoil.	Black sodosol
Brigalow plains				
Tara	Occurs on flat to very gently undulating plains and footslopes (<1%) associated with elevated plains.	Brown cracking clay, with loose, light clay surface soil over well structured grey-brown heavy clay.	Subsoils are sodic, saline and alkaline.	Grey vertosol
Light forests				
Minnabilla	Occurs on eroded ridge tops, scarps and slopes of gently undulating plains to low hills with laterised sandstone.	Yellowish red uniform sandy clay loam soil, with weathered sandstone fragments from 0.1m, and a soil profile depth of less than 0.45 m.	Non saline and non sodic throughout, with acid pH.	Rudosol
Binkey	Occurs on upper slopes of ridges and hilltops of plateaus within laterised sandstone remnants.	Brown texture contrast soil, with sandy loam surface soil over light yellowish brown medium heavy clay.	Soils are acid to strongly acid throughout, with sodic to strongly sodic subsoils and with low nutrient availability.	Brown kurosol

Soil name	Landscape position	Description	Chemical properties	Soil type
Ironbark/bull oak forest				
Braemar	as per braemar under 'poplar box flat plains'.	as per Braemar under 'poplar box flat plains'.	as per braemar under 'poplar box flat plains'.	as per 'poplar box flat plains'
Cutthroat	Occurs on flat to gently undulating plains.	brown texture contrast soil with dark brown loamy sand over yellow brown sandy clay overlying sandstone.	Soils are non saline, with neutral pH and sodic lower subsoils. Soils have low nutrient availability and plant available water capacity.	Brown Sodosol
Channing	Occurs on flat to gently undulating plains derived from outwash of laterised sandstone.	Brown-grey texture contrast soil with sandy loam to loam surface soil over red brown clay, overlying sandstone.	Soils are acid to strongly acid throughout, with strongly sodic and extremely saline subsoils, and with low nutrient availability and plant available water capacity.	Red Kurosol

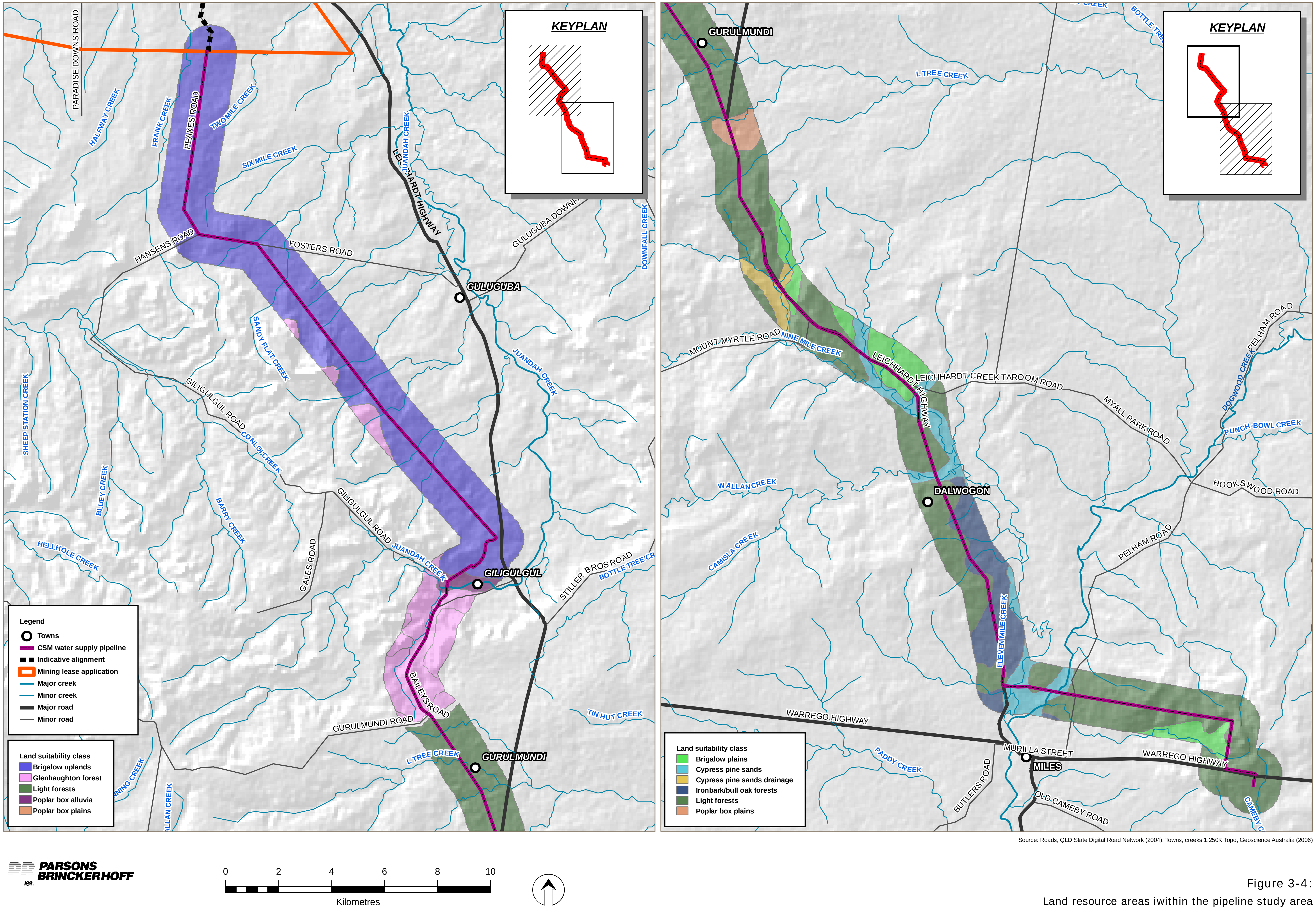


Figure 3-4:
Land resource areas iwithin the pipeline study area

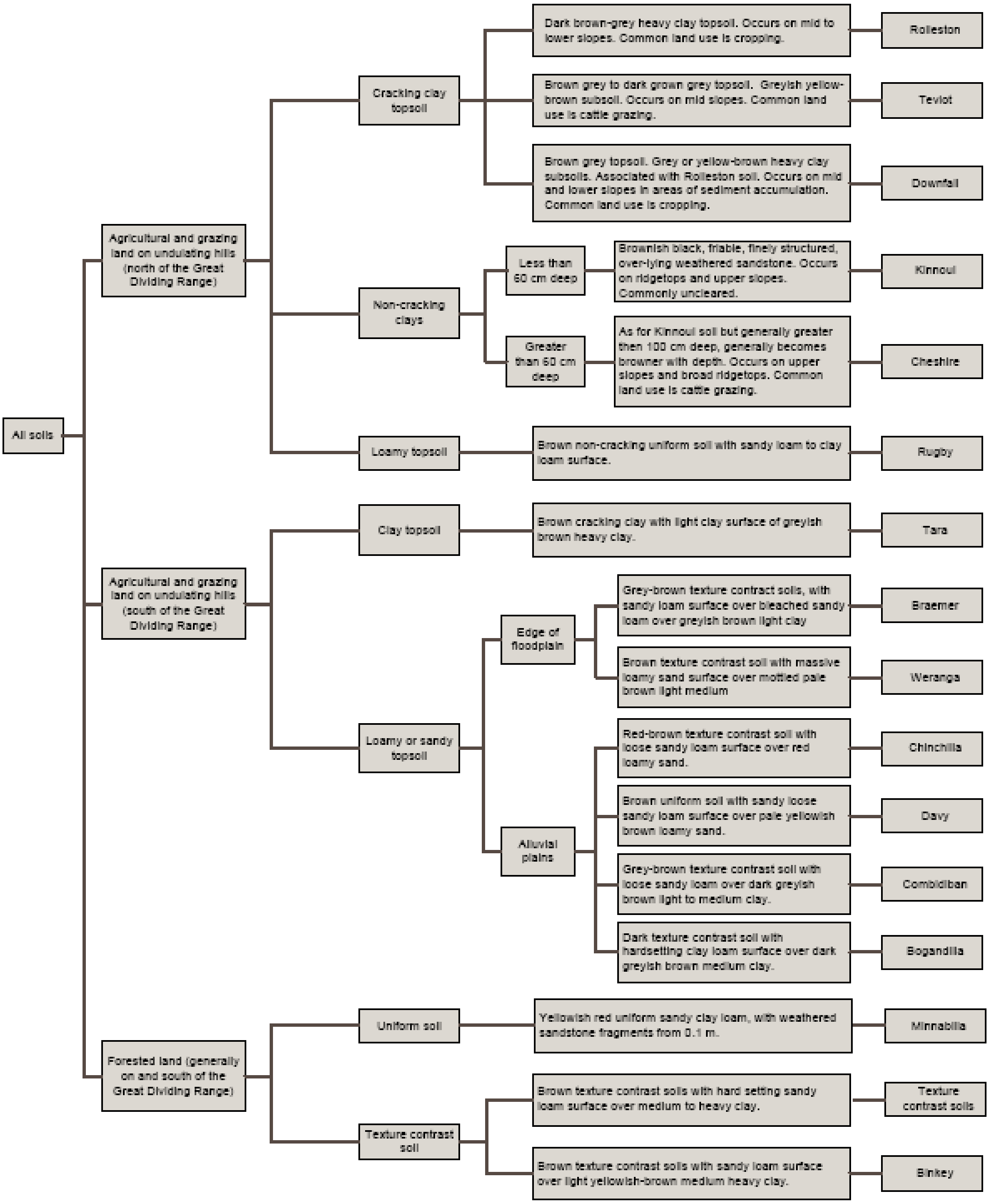


Figure 3-5: Key to soils in the proposed pipeline study area

3.7.3 Land suitability assessment

Land suitability and capability assessments for parts of the Wandoan-Miles region have previously been conducted by Grey and Macnish (1985) and Forster (1985). Forster's assessment classed the Brigalow Upland soils (with a slope of up to 6%) as arable. Grey and Macnish, found the Brigalow Uplands LRA to generally be Class 3 to 4 land. Limitations were mainly related to erosion, surface crusting and moisture availability. The above assessments were conducted prior to the release of *Land Suitability Assessment Techniques* (Department of Mines and Energy 1995), and do not meet the current requirements within this guideline. Maher (1996) mapped soils within the southern portion of the study area, and while did not conduct a land suitability assessment, he identified soil limitations which have been incorporated into this land suitability assessment.

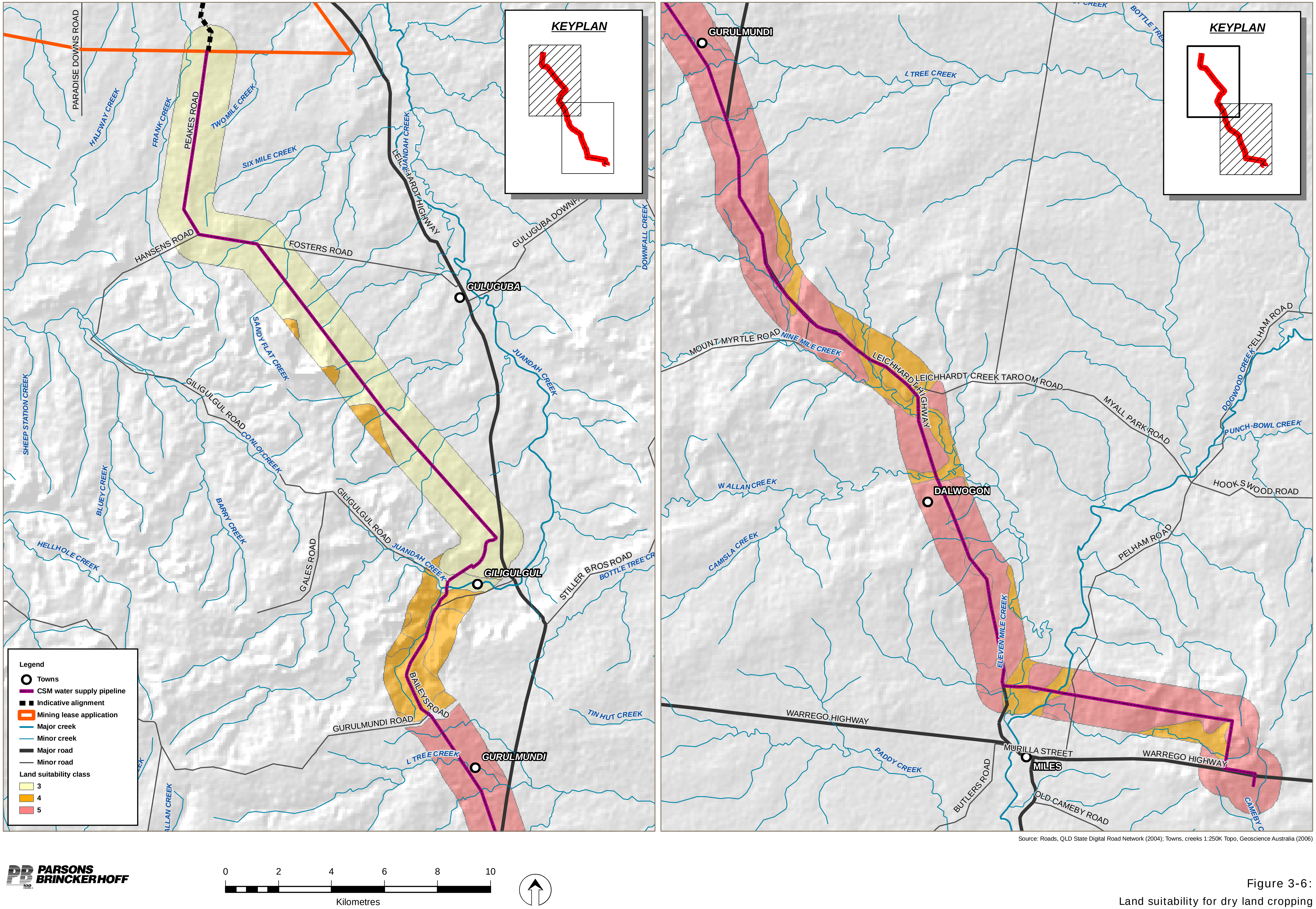
The land suitability classes for the current assessment were derived from a combination of the identified soil types and geomorphic/topographic position. Tables showing the classes assigned for each criteria are provided in Attachment A. The land suitability class for a soil/landscape position relates to the highest (i.e. poorest) ranking criteria for the assessment.

Land suitability maps of the proposed pipeline study area for dry land cropping and beef cattle grazing are shown in Figures 3-6 and 3-7 respectively. Soils of the Brigalow Uplands LRA are a combination of Class 3 and Class 4 for dry land cropping. The mapping on Figure 3-6 presents this LRA as Class 3, although some soils on steeper upper slopes (Cheshire and Kinnoul) will be Class 4 due to high erosion potential by surface runoff and the presence of alkaline subsoils that results in low nutrient availability; and some soils on lower slopes (Downfall and Rolleston) will be Class 4 due to high alkalinity within 60 cm of the soil surface resulting in nutrient deficiency.

Cropping currently occurs within this Class 4 land, however, long term sustainability is limited due to low nutrient and high alkalinity conditions, shallow rooting depth, and the requirement for heavy application of fertilisers.

Glenhaughton Forests and all soils south of the GDR rated Class 4 and 5 for dry land cropping due to limited soil water holding capacity. Grazing and fodder cropping currently occurs within the Cypress Pine Sands LRA. This LRA was classed as Class 4 and 5 for dry land cropping as a result of the extremely low water holding capacity of the sandy soils. Agriculture on this land will require significant input to manage water, and therefore some areas of this LRA are suitable for irrigated cropping.

North of the GDR, most of the study area is classed as Class 2 for beef cattle grazing. South of the GDR the study area is classed Class 3 to 5 for beef cattle grazing due to low soil water holding capacity.



Source: Roads, QLD State Digital Road Network (2004); Towns, creeks 1:250K Topo, Geoscience Australia (2006)

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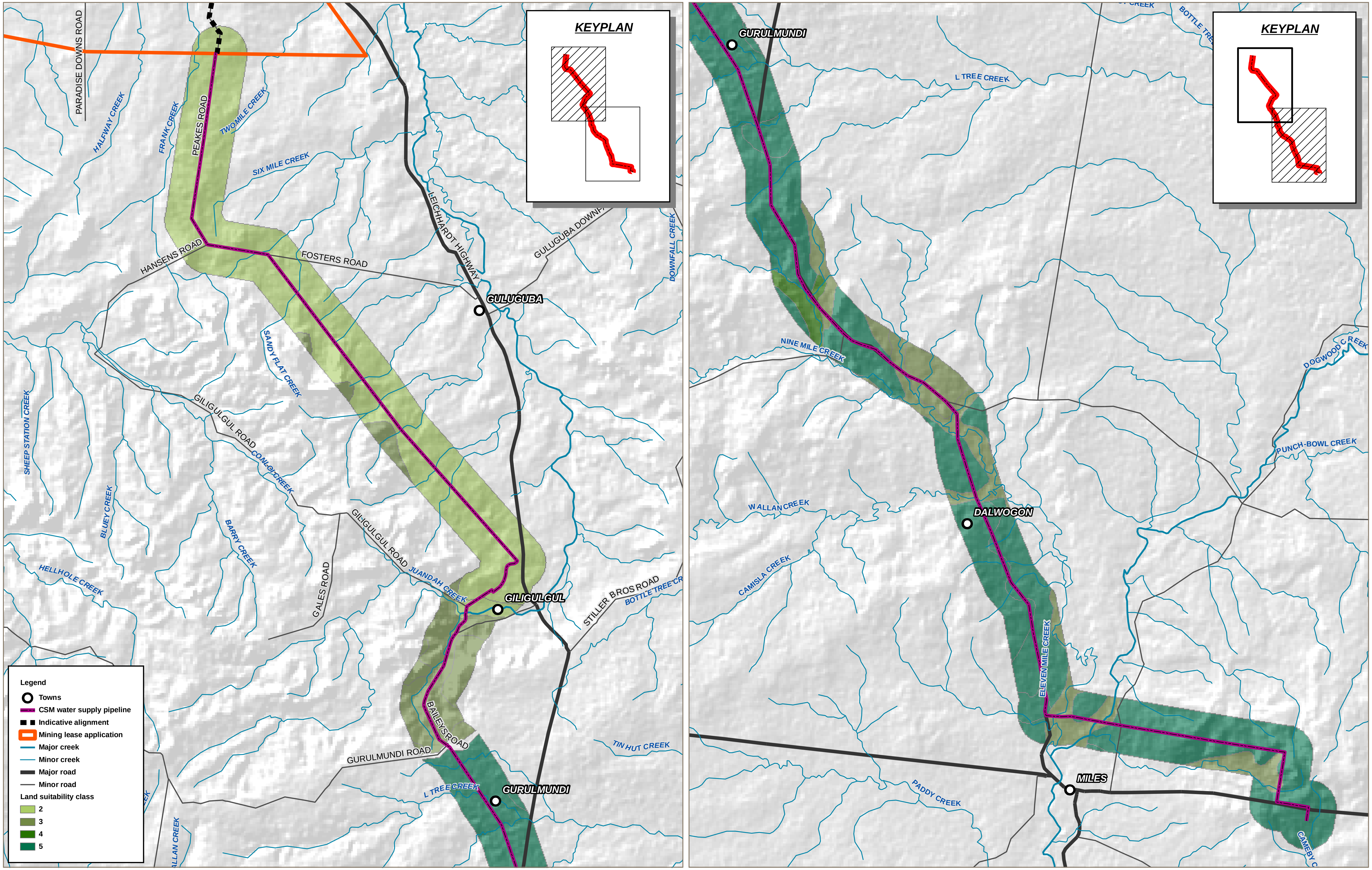
Figure 3-6:
Land suitability for dry land cropping



Source: Roads, QLD State Digital Road Network (2004); Towns, creeks 1:250K Topo, Geoscience Australia (2006)

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0 2 4 6 8 10

Kilometres

Figure 3-7:
Land suitability for beef cattle grazing

3.8 Good quality agricultural land

In accordance with Section 2 and Attachment 2 of '*The Planning Guidelines: The Identification of Good Quality Agricultural Land*' (Department of Primary Industries and Department of Housing, Local Government and Planning Queensland 1993), agricultural land classes A, B and C are considered GQAL in the area formally known as the Taroom Shire, and classes A and B are considered GQAL in the area formally known as the Murilla Shire.

Agricultural land classes A, B and C are respectively be defined as:

- Class A: Crop land — land that is suitable for current and potential cropping with limitations to production which range from none to moderate level
- Class B: Limited crop land — land that is marginal for current and potential cropping due to severe limitations, and suitable for pastures. Engineering and/or agronomic improvements may be required before the land is considered for cropping
- Class C: Pasture land — Land that is suitable only for improved or native pastures due to limitations which preclude continuous cultivation for crop production, but some areas may tolerate a short period of ground disturbance for pasture establishment.

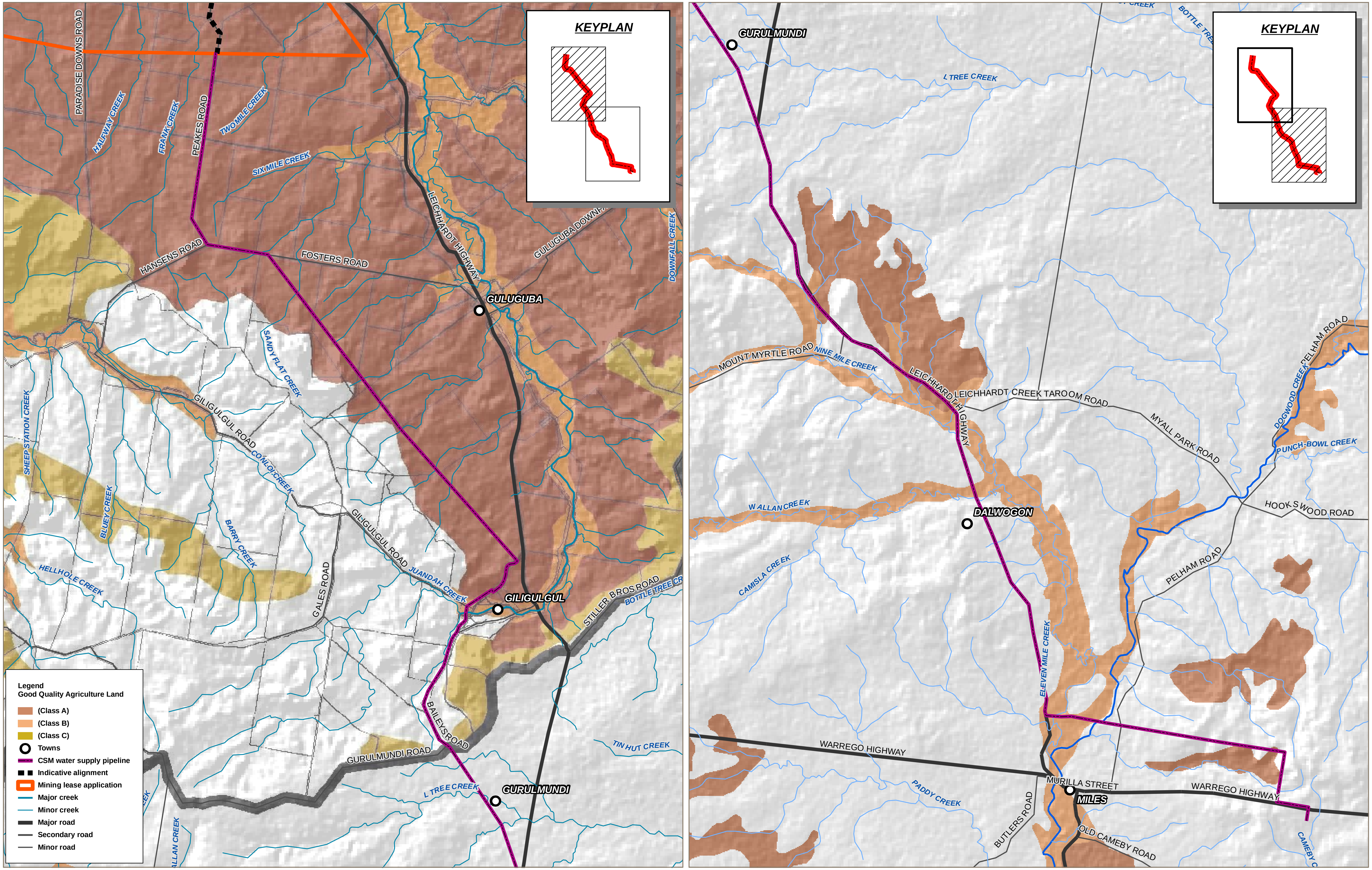
GQAL mapping of the proposed pipeline study area, under the Taroom and Murilla planning schemes is shown in Figure 3-8, and indicates that much of the proposed pipeline study area is mapped GQAL.

Under the Taroom Shire Council Planning Scheme and Murilla Shire Council Planning Scheme most land within the proposed pipeline study area north of the Great Dividing Range is classified as Class A agricultural land, while most land on and south of the Great Dividing Range is not GQAL, with the exception of the floodplain of Eleven Mile Creek. However, the findings of this land suitability assessment presented in Section 3.7.3 indicate greater than 'moderate' limitations to dryland cropping for areas on the floodplains south of the GDR and over the lower slopes of the Brigalow Upland Soils. Consequently, the findings of this assessment suggest a different distribution of GQAL than the Taroom and Murilla planning schemes, with Class B agricultural land as a more appropriate classification for the lower slopes north of the GDR, and Class D land for the floodplains south of the GDR. This classification is mainly governed by the very low water holding capacity of soils in these areas, as represented by Land Suitability Class 3 and Class 5 respectively on Figure 3-6.

3.9 Soil conservation plans

Soil conservation plans can be developed by the Department of Natural Resources and Water for individual properties or a collection of neighbouring properties to manage water runoff flow. These plans are generally prepared at the request of landowners, and consist of a map and specification for soil conservation measures and practices to control erosion. Plans can also be approved under the *Soil Conservation Act 1986*.

No properties in the proposed pipeline study area are covered by soil conservation plans registered with the Department of Natural Resources and Water.



Source: Roads, QLD State Digital Road Network (2004); Towns, creeks 1:250K Topo, Geoscience Australia (2006)

PARSONS BRINCKERHOFF

0 2 4 6 8 10
Kilometres

Figure 3-8:
Good quality agricultural land

4. Description of proposed development

The proposed pipeline involves the construction and operation of a water supply pipeline from the Condamine Power Station to the Wandoan MLAs, carrying coal seam methane by-product water.

The proposed pipeline will be approximately 101 km long and have a nominal diameter of 600 mm. The proposed pipeline will be buried with approximately 0.6 m to 1.0 m cover, and constructed using a section trench and backfill method.

The width of the proposed construction corridor will be about 20 m. Pre-construction works will include clearing of vegetation (where required), stripping of topsoil and formation of construction access tracks. Trenching would be used to construct the majority of the proposed pipeline route and would be prepared ahead of construction. It is expected that a wheel trencher and excavator would be used to dig the trench for the majority of the route, being approximately 1.2 m to 1.6 m deep and 0.9 m wide. In some areas, harder rock may be encountered and hydraulic rock breaking equipment may be required. Following construction of the proposed pipeline, the trench will be backfilled, compacted and topsoiled.

All construction activities will be undertaken within the proposed construction corridor.

5. Potential impacts

5.1 Topography

The proposed pipeline will have negligible impact on topography as the trench will be fully backfilled and rehabilitated to the original ground surface and landform.

5.2 Overburden

Overburden is not relevant to this assessment

5.3 Uncovering fossil material

Proposed pipeline construction works will only impact the top one to two metres of soil, and as a result fossil material in not expected to be impacted.

5.4 Soils

5.4.1 Alkalinity, sodicity and dispersivity

Most soils within the study area (with the exception of Kinnoul, Chinchilla, Davy and Minnabilla) have either sodic or alkaline subsoils. Brigalow Upland soils (with the exception of Kinnoul), are strongly sodic from about 0.3 m depth, and are also alkaline. Binkey subsoils are strongly sodic and acidic. The subsoils of Cheshire, Rolleston and Teviot, Binkey, Bogandilla, Weranga are anticipated to be strongly dispersive.

Alkaline and sodic soils are generally dispersive, and have high erosion potential if exposed. Sodic, alkaline and/or acidic subsoils are also poor plant growth mediums due to unfavourable growth conditions and low nutrient availability, and should not be used in rehabilitation of disturbed areas as surficial soils. The topsoil portion of these soils is considered suitable for use in rehabilitation.

5.4.2 Erosion

All soils in the proposed pipeline study area will be subject to erosion if vegetation is removed and the ground is disturbed.

Soils most susceptible to wind erosion are soils with sandy or loamy topsoils, which include the soils of Glenhaughton Forest, Poplar Box Flats, Cypress Pine Sands, Light Forests and Ironbark/Bull Oak Forest. If groundcover is disturbed, these soils will also be highly susceptible to water erosion including sheet erosion and gully erosion.

Soils with dispersive (sodic) topsoil or upper subsoil as discussed in Section 5.4.1 above are also susceptible to erosion by water. Soils on steep and moderate upper slopes, as occur on undulating terrain, have higher risk from erosion by water than soils on gentle slopes and floodplain.

Exposure of dispersive subsoils as described in Section 5.4.1 has the potential to cause gullyhead erosion, even if only small areas of subsoil are exposed. After initiation, this erosion is anticipated to continue upslope and expose more dispersive soils.

Soils of Teviot and Braemar, and those within the Glenhaughton Forest LRA are potentially susceptible to tunnel erosion. Tunnel erosion forms when water infiltrates into dispersive subsoils and flows through cracks and channels. Dispersive clays are then suspended in the water, until the opening in the soil is enlarged and extended to form an outlet. Once a tunnel is initiated, free flowing water can enlarge it further.

5.4.3 Salinity

Soil salinity in the proposed pipeline study area is of limited extent and is not considered a high risk. However, some upper and mid slope soils within the Brigalow Uplands LRA (Cheshire and Teviot), Poplar Box Flat Plains and soils on the edge of alluvial plains (Bogandilla and Tara) have moderately to highly saline subsoils, and changes to the soil moisture regime due to vegetation removal or other impact may increase near surface soil salinity.

5.5 Land use suitability

The water supply proposed pipeline will to be buried, and no reduction in land suitability class is expected as a result of the proposed pipeline. Once construction has been completed, existing agricultural land uses will generally be able to continue over the corridor. Limitations to the siting of infrastructure such as sheds or irrigation equipment, and to practices that require excavation or disturbance of the soil will result from the proposed pipeline.

6. Mitigation measures

6.1 Topography

The proposed pipeline will have negligible impact on topography, and as such, mitigation measures are not required.

6.2 Overburden

Overburden is not relevant to this assessment.

6.3 Uncovering fossil material

Fossil material is not expected to be uncovered during this work.

6.4 Soils

6.4.1 Dispersivity and erosion

As discussed in Section 5.4.2, the sandy and loamy soils south of the GDR have a high erosion risk, and most soils along the study corridor have sodic subsoils, and will be susceptible to erosion is exposed. Teviot, Glenhaughton Forest soils, and Braemar are also susceptible to tunnel erosion. All soils will erode if vegetation is removed and rehabilitation is not undertaken within an appropriate timeframe. Generally wind and water erosion control measures will be applied to all soils in the proposed pipeline study area, which include:

Site preparation and planning:

- an erosion and sediment control plan should be prepared and implemented prior to the commencement of construction, specifying the locations and types of sediment and erosion control measures to be used
- vegetation clearing (including grass cover) should be limited to the minimal amount required for proposed pipeline works
- site drainage, sediment and erosion controls should be implemented and in place prior to, or as soon as possible, following the removal of vegetation
- traffic should be confined to defined roads and access tracks to minimise soil disturbance
- infrastructure, parking and laydown areas should be located at sites with minimal slope grade
- hardstands should be constructed out of erosion resistant material.

Managing water erosion:

- erosion and sediment control measures should be installed on disturbed slopes to minimise erosion and sediment released into waterways. This is especially important for soils with sandy topsoil or dispersive subsoils

- water runoff should be directed around or away from disturbed areas using diversion bunds and catch drains as appropriate
- run-off from disturbed areas should be directed to sedimentation basins
- exposed soils should be revegetated as soon as practical after works have been completed. Soils on Light Forests LRA and Cypress Pine LRA will need to be revegetated with low water tolerant plants, or have soil amelioration measures to increase the water holding capacity of the soil
- disturbed and rehabilitated land should be retained with a rough surface (as opposed to a smooth surface) to slow overland water flow
- the reinstated landsurface should be shaped to ensure that rain water is not channelised, but is allowed to disperse over a large area
- all soil stockpiles should be bunded. Short term stockpiles may be bunded by sediment fencing, while long term stockpiles should have measures such as earthen bunds. Drainage works installed to divert overland flow from upslope of the longterm stockpile areas away from and around the stockpiles. Sediment traps or similar features will need to be installed downslope of stockpiles to present eroded sediment entering waterways
- erosion should be remediated as soon as practicable. This may include levelling the eroded area, capping with non-dispersive topsoil, application of seed and applying erosion control measures to prevent water impacting the site. The longer erosion is allowed to develop, the more costly and difficult it is to remediate
- any soil conservation measures, such as contour banks, that are disturbed during works should be reinstated following construction.

Managing wind erosion:

- watering trucks should be used during windy conditions for dust suppression
- vegetation clearing (including grass cover) should be limited to the minimal amount required for the proposed pipeline works
- long-term (greater than three months) stockpiles of topsoil will be planted with vegetation to minimise entrainment of soil particles into the air and minimise erosion through raindrop impact
- exposed soils should be revegetated as soon as practical after works have been completed.

Managing dispersive soils:

- exposure of alkaline or sodic subsoils (e.g. all soils other than Kinnoul, Chinchilla, Davy and Minnabilla) should be avoided where possible, and should be limited to the minimal amount of time practicable
- alkaline or sodic subsoils should not be left exposed on the surface, and should be covered with topsoil or other material.

Tunnel erosion control

- fill around the proposed pipeline should be compacted to at least the density of the surrounding soil material, and the filled trench left slightly higher than the natural land surface to minimise ponding or infiltration around the pipe

- all dispersive soils along the corridor should be fully capped with at least 0.2 m of non-dispersive topsoil. Deeper topsoil depths have the potential to store rainwater and reduce infiltration into dispersive subsoils
- the final land surface should be designed and managed to prevent the ponding of water on Teviot soils, to reduce the potential for infiltration into subsoils.

Monitoring

- regular (e.g. weekly or fortnightly) monitoring for erosion should be conducted during construction, including the trench and water management infrastructure
- erosion monitoring should continue until the vegetation cover has become fully established
- monitoring for the development of tunnel erosion should be undertaken 3 monthly for 12 months following the completion of construction.

6.4.2 Salinity

As discussed in Section 5.4.3, high salinity levels are toxic to many plant species, and rehabilitation of saline soils can be difficult and costly. The following measures should be applied in relation to soil salinity:

- the topsoil of Teviot is saline and generally should not be used as a topsoil layer in rehabilitation. Where suitable supply of other topsoil is available, this should be used in preference to Teviot, or Teviot soil mixed with this soil. Salt tolerant vegetation species may be required for rehabilitation on Teviot topsoils
- the subsoils of Cheshire, Teviot, Poplar Box Flat Plains soils, Bogandilla and Tara are saline and should be buried below the rooting depth plants and crops.

6.4.3 Compaction

The compaction of surface soil increases the potential for rainwater induced erosion, and reduces seed germination and root establishment of vegetation. The following measures should be applied in relation to compaction:

- soils that will be trafficked or compacted during construction should have water control and sediment containment measures installed to minimise potential erosion and sediment entering into waterways
- previously compacted areas that are to be rehabilitated should be remediated by ripping the top layer of soil. Ripping the top layer of soil breaks down the soil structure, and as a result protection of these areas from re-compaction (i.e. vehicles or grazing animals) after ripping is required to allow the soil structure to reform
- compaction of topsoil can be reduced by selection of appropriate earthmoving machinery for these soils (i.e. light weight vehicles with large wheel/track size).

6.4.4 Topsoil reuse

As discussed in Section 3.8, some soils within the proposed pipeline study area are classed as Good Quality Agricultural Land. Suggested stripping depths and identified constraints for various encountered soil types are provided in Table 6-1. Topsoil should be managed as follows:

- stripped separately to subsoil and stockpiled during clearing for reuse in site rehabilitation
- stored in stockpiles no more than 3 m high to retain seed germination potential
- stored for the shortest period practicable, and where possible reused within six months of stripping to maximise the retention of the seed bank in the soil
- reused in the general area from which it was stripped
- during site rehabilitation works topsoil should be spread to a depth of not less than 0.2 m
- control measures such as fencing should be installed on newly topsoiled areas to exclude vehicle or stock access until a vegetation cover has established. Watering may need to be provided in the germination or early development stages of vegetation, together with appropriate seasonal timing of the revegetation works.

Table 6-1: Topsoil stripping depths and potential constraints for reuse

Soil type	Surface soil composition	Topsoil stripping depth (m)	Potential constraints
Brigalow uplands LRA			
Cheshire	light clay	0.4	▪ highly alkaline and saline subsoil ▪ dispersive subsoil
Downfall	clay	0.15	▪ shallow topsoil depth ▪ dispersive subsoil
Kinnoul	clay	0.3	▪ low nutrient availability in topsoil ▪ dispersive subsoil ▪ shallow soil depth
Rolleston	clay	0.2	▪ alkaline ▪ topsoil may be dispersive ▪ dispersive subsoil
Teviot	clay	0.2	▪ dispersive subsoil ▪ moderately alkaline and saline
Rugby	loam	0.4	▪ sodic lower subsoil

Soil type	Surface soil composition	Topsoil stripping depth (m)	Potential constraints
Glenhaughton Forest			
Texture contrast soils	sandy loam	-	▪ stone and gravel ▪ very low pore available water capacity (soil water storage capacity) ▪ low nutrient availability ▪ susceptible to wind erosion following disturbance
Poplar box flat plains			
Braemar	sandy loam	0.15	▪ very low pore available water capacity (soil water storage capacity)
Weranga	loamy sand	0.05	▪ very low pore available water capacity (soil water storage capacity) ▪ sodic and dispersive subsoils ▪ highly saline lower subsoils ▪ impermeable subsoil ▪ low nutrient availability
Cypress pine sands			
Chinchilla	sandy loam	0.3	▪ low pore available water capacity (soil water storage capacity) ▪ susceptible to wind erosion following disturbance
Davy	sandy loam	0.4	▪ low pore available water capacity (soil water storage capacity) ▪ low nutrient availability ▪ susceptible to wind erosion following disturbance
Combidiban	sandy loam	0.3	▪ very low pore available water capacity (soil water storage capacity) ▪ variable topsoil depth ▪ susceptible to wind erosion following disturbance
Bogandilla	clay loam	0.1	▪ strongly sodic and dispersive subsoil ▪ highly saline lower subsoil ▪ low pore available water capacity (soil water storage capacity)
Brigalow plains			
Tara	light clay	0.4	▪ sodic subsoils ▪ low to medium pore available water capacity (soil water storage capacity) ▪ gilgai (stripping difficulties)

Soil type	Surface soil composition	Topsoil stripping depth (m)	Potential constraints
Light forests			
Minnabilla	sandy clay loam	0.1	▪ very low pore available water capacity (soil water storage capacity) ▪ very shallow profile depth ▪ stone and gravel
Binkey	sandy loam	0.3	▪ very low pore available water capacity (soil water storage capacity) ▪ stone and gravel ▪ acidic throughout ▪ low nutrient availability ▪ strongly sodic and dispersive subsoil
Ironbark/bull oak forest			
Braemar	sandy loam	0.15	▪ very low pore available water capacity (soil water storage capacity)
Cutthroat	loamy sand	0.3	▪ sodic lower subsoil ▪ very low pore available water capacity (soil water storage capacity) ▪ low nutrient availability
Channing	sandy loam to loam	0.15	▪ acidic throughout ▪ sodic and saline subsoil ▪ low pore available water capacity (soil water storage capacity)

6.4.5 Soil conservation plans

As discussed in Section 3.10, no approved soil conservation plans are present in the proposed pipeline study area. Existing soil conservation measures should be retained and or reinstated following construction works where they currently exist.

6.5 Construction materials

No significant earthworks or earth embankment structures are proposed for the proposed pipeline. Any catch drains or temporary sediment basins excavated for the proposed pipeline should be designed to minimise the potential for gullyhead erosion, such as limiting flow velocity, implementing trapezoidal design waterways, and avoiding perched waterways. Should there be any excess excavated material left after trench backfill, it should be shaped into stabile landform and topsoiled.

Most excavated material is anticipated to be suitable for use as trench backfill material. Weathered rock, forming particles larger than about 100 mm will be used in the upper portion of the backfill profile.

Bedding material and rip-rap is anticipated to be imported for the proposed pipeline but sourced within the region.

All temporary earthworks areas should be fully rehabilitated after the completion of the construction phase.

7. Residual impacts

Following mitigation, the residual impacts are anticipated to be as follows:

- a buried pipeline
- some limitations on land use such as the siting of infrastructure such as sheds or irrigation equipment, and to practices that require excavation or disturbance of the soil.

8. Conclusions

This study has identified and mapped the broad soil types and rocks with the proposed pipeline study area. Based on existing literature the study area is covered by a number of different soils derived from sedimentary or alluvial parent material, which all can be grouped into mappable LRAs.

Soils over much of the proposed pipeline study area have sandy or loamy topsoil and/or alkaline, sodic and dispersive subsoils, and will require soil specific management techniques, such as minimising disturbance and exposure, to prevent erosion including tunnel erosion.

Based on the former Taroom Shire Council Planning Scheme (2006) and Murilla Shire Council Planning Scheme (2006) the undulating hills north of the GDR and some floodplain south of the range are classed as good quality agricultural land (GQAL), although this assessment found these floodplain to have a lesser suitability for agriculture due to very low water holding capacity of the soils.

A land suitability assessment for dry land cropping, and beef cattle grazing was carried out for the proposed pipeline study area. The proposed pipeline is not expected to impact the land suitability classification of land within the study area, but will limit the potential for some agricultural practices or infrastructure to be sited on the land.

9. Summary of mitigation strategies

Recommended mitigation strategies to minimise potential impacts of the proposed pipeline to soils and land resources, as previously detailed in this geology, mineral resources, overburden and soils impact assessment, are summarised below:

- an erosion and sediment control plan should be prepared and implemented prior to the commencement of construction, specifying the locations and types of sediment and erosion control measures to be used
- vegetation clearing (including grass cover) should be limited to the minimal amount required for Project works
- site drainage, sediment and erosion controls should be implemented and in place prior to, or as soon as possible, following the removal of vegetation
- traffic should be confined to defined roads and access tracks to minimise soil disturbance
- infrastructure, parking and laydown areas should be located at sites with minimal slope grade
- hardstands should be constructed out of erosion resistant material
- erosion and sediment control measures should be installed on disturbed slopes to minimise erosion and sediment released into waterways. This is especially important for soils with sandy topsoil or dispersive subsoils
- water runoff should be directed around or away from disturbed areas using diversion bunds and catch drains as appropriate
- run-off from disturbed areas should be directed to sedimentation basins
- exposed soils should be revegetated as soon as practical after works have been completed. Soils on Light Forests LRA and Cypress Pine LRA will need to be revegetated with low water tolerant plants, or have soil amelioration measures to increase the water holding capacity of the soil
- disturbed and rehabilitated land should be retained with a rough surface (as opposed to a smooth surface) to slow overland water flow
- the reinstated landsurface should be shaped to ensure that rain water is not channelised, but is allowed to disperse over a large area
- all soil stockpiles should be bunded. Short term stockpiles may be bunded by sediment fencing, while long term stockpiles should have measures such as earthen bunds. Drainage works installed to divert overland flow from upslope of the longterm stockpile areas away from and around the stockpiles. Sediment traps or similar features will need to be installed downslope of stockpiles to present eroded sediment entering waterways
- erosion should be remediated as soon as practicable. This may include levelling the eroded area, capping with non-dispersive topsoil, application of seed and applying erosion control measures to prevent water impacting the site.
- any soil conservation measures, such as contour banks, that are disturbed during works should be reinstated following construction

- watering trucks should be used during windy conditions for dust suppression
- vegetation clearing (including grass cover) should be limited to the minimal amount required for Project works
- where appropriate, long-term (greater than three months) stockpiles of topsoil will be planted with vegetation to minimise entrainment of soil particles into the air and minimise erosion through raindrop impact
- exposed soils should be revegetated as soon as practical after works have been completed
- exposure of alkaline or sodic subsoils (e.g. all soils other than Kinnoul, Chinchilla, Davy and Minnabilla) should be avoided where possible, and should be limited to the minimal amount of time practicable
- alkaline or sodic subsoils should not be left exposed on the surface, and should be covered with topsoil or other material
- fill around the proposed pipeline should be compacted to at least the density of the surrounding soil material, and the filled trench left slightly higher than the natural landsurface to minimising ponding or infiltration around the pipe
- all dispersive soils along the corridor should be fully capped with at least 0.2 m of non-dispersive topsoil. Deeper topsoil depths have the potential to store rainwater and reduce infiltration into dispersive subsoils
- the final landsurface should be managed to prevent the ponding of water on Teviot soils, to reduce the potential for infiltration into subsoils
- regular (e.g. weekly or fortnightly) monitoring for erosion should be conducted during construction, including the trench and water management infrastructure
- erosion monitoring should continue until the vegetation cover has become fully established
- monitoring for the development of tunnel erosion should be undertaken 3 monthly for 12 months following the completion of construction
- the topsoil of Teviot is saline and generally should not be used as a topsoil layer in rehabilitation. Where suitable supply of other topsoil is available, this should be used in preference to Teviot, or Teviot soil mixed with this soil. Salt tolerant vegetation species may be required for rehabilitation on Teviot topsoils
- the subsoils of Cheshire, Teviot, Poplar Box Flat Plains soils, Bogandilla and Tara are saline and should be buried below the rooting depth plants and crops
- soils that will be trafficked or compacted during construction should have water control and sediment containment measures installed to minimise potential erosion and sediment entering into waterways
- previously compacted areas that are to be rehabilitated should be remediated by ripping the top layer of soil. Ripping the top layer of soil breaks down the soil structure, and as a result protection of these areas from re-compaction (i.e. vehicles or grazing animals) after ripping is required to allow the soil structure to reform
- existing soil conservation measures should be retained and or reinstated following construction works where they currently exist

- compaction of topsoil can be reduced by selection of appropriate earthmoving machinery for these soils (i.e. light weight vehicles with large wheel/track size)
- topsoil should be stripped separately to lower soil and stockpiled during clearing for reuse in site rehabilitation
- topsoil should be stored in stockpiles no more than 3 m high to retain seed germination potential
- topsoil should be stored for the shortest period practicable, and where possible reused within six months of stripping to maximise the retention of the seed bank in the soil
- topsoil should be reused in the general area from which it was stripped
- during site rehabilitation works topsoil should be spread to a depth of approximately 0.2 m
- control measures such as fencing should be installed on newly topsoil areas to exclude vehicle or stock access until a vegetation cover has established
- topsoil should be stripped to depth shown in Table 9-1.

Table 9-1: Topsoil stripping depths and potential constraints for reuse

Soil type	Surface soil composition	Topsoil stripping depth (m)	Potential constraints
Brigalow uplands LRA			
Cheshire	light clay	0.4	▪ highly alkaline and saline subsoil ▪ dispersive subsoil
Downfall	Clay	0.15	▪ shallow topsoil depth ▪ dispersive subsoil
Kinnoul	Clay	0.3	▪ low nutrient availability in topsoil ▪ dispersive subsoil ▪ shallow soil depth
Rolleston	Clay	0.2	▪ alkaline ▪ topsoil may be dispersive ▪ dispersive subsoil
Teviot	Clay	0.2	▪ dispersive subsoil ▪ moderately alkaline and saline
Rugby	Loam	0.4	▪ sodic lower subsoil
Glenhaughton forest			
Texture contrast soils	sandy loam	-	▪ stone and gravel ▪ very low pore available water capacity (soil water storage capacity) ▪ low nutrient availability ▪ susceptible to wind erosion following disturbance

Soil type	Surface soil composition	Topsoil stripping depth (m)	Potential constraints
Poplar box flat plains			
Braemar	sandy loam	0.15	▪ very low pore available water capacity (soil water storage capacity)
Weranga	loamy sand	0.05	▪ very low pore available water capacity (soil water storage capacity) ▪ sodic and dispersive subsoils ▪ highly saline lower subsoils ▪ impermeable subsoil ▪ low nutrient availability
Cypress pine sands			
Chinchilla	sandy loam	0.3	▪ low pore available water capacity (soil water storage capacity) ▪ susceptible to wind erosion following disturbance
Davy	sandy loam	0.4	▪ low pore available water capacity (soil water storage capacity) ▪ low nutrient availability ▪ susceptible to wind erosion following disturbance
Combidiban	sandy loam	0.3	▪ very low pore available water capacity (soil water storage capacity) ▪ variable topsoil depth ▪ susceptible to wind erosion following disturbance
Bogandilla	clay loam	0.1	▪ strongly sodic and dispersive subsoil ▪ highly saline lower subsoil ▪ low pore available water capacity (soil water storage capacity)
Brigalow plains			
Tara	light clay	0.4	▪ sodic subsoils ▪ low to medium pore available water capacity (soil water storage capacity) ▪ gilgai (stripping difficulties)
Light forests			
Minnabilla	sandy clay loam	0.1	▪ very low pore available water capacity (soil water storage capacity) ▪ very shallow profile depth ▪ stone and gravel

Soil type	Surface soil composition	Topsoil stripping depth (m)	Potential constraints
Binkey	sandy loam	0.3	▪ very low pore available water capacity (soil water storage capacity) ▪ stone and gravel ▪ acidic throughout ▪ low nutrient availability ▪ strongly sodic and dispersive subsoil
Ironbark/bull oak forest			
Braemar	sandy loam	0.15	▪ very low pore available water capacity (soil water storage capacity)
Cutthroat	loamy sand	0.3	▪ sodic lower subsoil ▪ very low pore available water capacity (soil water storage capacity) ▪ low nutrient availability
Channing	sandy loam to loam	0.15	▪ acidic throughout ▪ sodic and saline subsoil ▪ low pore available water capacity (soil water storage capacity)

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Attachment A

Land suitability criteria

Attachment A – Land suitability criteria

Table A-1: Suitability criteria for rainfed broadacre cropping

Limitation	Land suitability class				
	1	2	3	4	5
Water availability	PAWC >150 mm	PAWC 125-150 mm	PAWC 100-125 mm	PAWC 75-100 mm	PAWC <75 mm
Nutrient deficiency	Bicarbonate P >10 ppm	Bicarbonate P 5-10 ppm and Exchangeable K >0.3 meq. %	Bicarbonate P 5-10 ppm and Exchangeable K ≤0.3 meq. % or pH <5 60-90 cm below surface or pH >9 60-90 cm below surface	Bicarbonate P <10 ppm and Exchangeable K ≤0.3 meq. %, and Exchangeable Ca <3 meq.%, or pH <5 30-60 cm below surface, or pH >9 30-60 cm below surface	pH <5 within 30 cm of surface or pH >9 within 30 cm of surface
Soil physical factors	Cracking clays with very fine self-mulch (peds <2 mm), or Rigid soils with a loose, soft or firm surface when dry	Cracking clays with fine self-mulch (peds 2-10 mm)	Cracking clays with coarse self-mulch (peds 10-20 mm) or Rigid soils with a hard setting surface when dry	Cracking clays with coarse peds at the surface (≥20 mm)	
Soil workability	Friable cracking clays (indicated by very fine self-mulch), or Rigid soils with a loose, soft or firm surface when dry	Firm cracking clays (indicated by fine self-mulch) or Rigid soils with a hard setting surface when dry	Stiff cracking clays (indicated by coarse self-mulch with peds>10 mm, crusting or hard setting surface)		
Salinity	Rootzone EC <0.15 mS/cm or Rootzone Cl <300 ppm	Rootzone EC 0.15 -0.3 mS/cm or Rootzone Cl 300-600 ppm	Rootzone EC 0.3-0.9 mS/cm or Rootzone Cl 600-900 ppm	Rootzone EC 0.9-1.2 mS/cm, or Rootzone Cl 900-1,500 ppm	Rootzone EC >1.2 mS/cm or Rootzone Cl ≥1,500 ppm

Limitation	Land suitability class				
	1	2	3	4	5
Rockiness	<10% coarse surface gravel (>6 cm diam.) and rock outcrop	10-20% coarse surface gravel and rock outcrop	20-50% surface cobble (6-20 cm diam.)and rock outcrop	50-90% surface cobble and rock outcrop, or 20-50% stone and boulders (>20 cm diam.)	>90% surface cobble and rock outcrop, or >50% stone and boulders and rock outcrop
Microrelief	No melonholes (semi-circular depressions <30 cm deep and usually surrounded by mounds)	Melonholes 30-60 cm deep cover <20% surface area or Melonholes >60 cm deep cover <10% surface area	Melonholes 30-60 cm deep cover 20-50% of surface area or Melonholes >60 cm deep cover 10-20% surface area	Melonholes 60-100 cm deep cover 50% surface area	Melonholes at least 100 cm deep cover 50% surface area
Wetness	Undulating terrain or elevated plains	Low-lying level plains with melonholes covering <25% surface area, or Rigid soils with sodic subsoil (ESP 6-14) within 60 cm of the surface, or Non-sodic rigid soils with coarse pale grey and yellow mottles within 75 cm of the surface	Low-lying level plains with melonholes covering 25-50% surface area, or Rigid soils with strongly sodic subsoil (ESP≥15) within 60 cm of the surface, or Non-sodic rigid soils with coarse pale grey and yellow mottles within 50 cm of the surface	Seasonal swamps and lowlying run-on areas	Permanent swamps and lakes
Topography	No gully dissection	Occasional deep gullies impede cultivation slightly	Many deep gullies reduce arable area by <33% or require major changes to cultivation practices	Many deep gullies make the arable areas too small to cultivate	Abundant deep gullies prevent any practical cultivation

Limitation	Land suitability class				
	1	2	3	4	5
Water erosion	Slopes <0.5% on cracking clays without melonholes, or Slopes <1% on melonhole clays, or Slopes <1% on nonsodic rigid soils, or Slopes <0.5% on sodic rigid soils	Slopes 0.5-1% on cracking clays without melonholes or Slopes 1-3% on melonhole clays, or Slopes 1-2% on non-sodic rigid soils, or Slopes 0.5-1% on sodic rigid soils	Slopes 1-3% on cracking clays without melonholes or Slopes 2-4% on non-sodic rigid soils or Slopes 1-2% on sodic rigid soils	Slopes 3-5% on all cracking clays or Slopes 4-6% on non-sodic rigid soils or Slopes 2-3% on sodic rigid soils	Slopes >5% on all cracking clays or Slopes >6% on nonsodic rigid soils or Slopes >3% on sodic rigid soils
Flooding	No flooding	Rare flooding (only during abnormal 1 in 50 to 100 year events)	Infrequent flooding (inundation occurs <half the times that stream flow increases)	Occasional flooding (inundation occurs ≥half the times that stream flow increases)	Regular flooding (inundation occurs whenever stream flow increases)

Table A-2: Suitability criteria for beef cattle grazing

Limitation	Land suitability class				
	1	2	3	4	5
Water availability	PAWC >125 mm	PAWC 100-125 mm	PAWC 75-100 mm	PAWC 50-75 mm	PAWC ≤50 mm
Nutrient deficiency	Brigalow, gidgee, blackwood or softwood scrub soils and former scrub soils with Bicarbonate P >10 ppm	Eucalypt vegetation and downs with Bicarbonate P >10 ppm	Other soils with Bicarbonate P 5-10 ppm except Sands and loams at least 75 cm deep or overlying rock at shallow depth	Sands and loams at least 75 cm deep or overlying rock at shallow depth, with Bicarbonate P 5-10 ppm, or Bicarbonate P ≤4 ppm	

Limitation	Land suitability class				
	1	2	3	4	5
Soil physical factors	Cracking clays with very fine self-mulch (peds <2 mm), or Rigid soils with a loose, soft or firm surface when dry	Cracking clays with fine self-mulch (peds 2-10 mm), or Rigid soils with a hard setting surface when dry	Cracking clays with coarse peds (peds ≥10 mm) or crust on the surface		
Salinity	Rootzone EC < 0.15 mS/cm or Rootzone Cl <300 ppm	Rootzone EC 0.15-0.3 mS/cm or Rootzone Cl 300-600 ppm	Rootzone EC 0.3-0.9 mS/cm or Rootzone Cl 600-900 ppm	Rootzone EC 0.9-1.2 mS/cm or Rootzone Cl 900-1500 ppm	Rootzone EC >1.2 mS/cm or Rootzone Cl ≥1500 ppm
Rockiness	<20% coarse surface gravel (>6 cm diam.) and rock outcrop	20-50% coarse surface gravel and rock outcrop	50-90% surface cobble and rock outcrop	>90% surface cobble and rock outcrop	Rock outcrop and surface coarse fragments cover total area
Microrelief	Melonholes cover <20% surface area (semi-circular depressions at least 30 cm deep and usually surrounded by mounds)	Shallow melonholes (30-60 cm deep) cover 20-50% surface area	Deep melonholes (>60 cm deep) cover 20-50% of surface area		
pH (1:5)	5.6-6.6	6.6-8.0 5.0-5.6	8.0-9.0 4.5-5.0	9.0-10.0 4.0-4.5	>10.0 < 4.0
ESP (10 cm)% Exchangable Sodium Percentage	<5.0	5-10	10-15	15-30	>30

Limitation	**Land suitability class**				
	1	**2**	**3**	**4**	**5**
Wetness	Undulating terrain or elevated plains	Low-lying level plains , or Rigid soils with strongly sodic subsoil (ESP≥15) within 60 cm of the surface, or Non-sodic rigid soils with coarse pale grey and yellow mottles within 50 cm of the surface	Shallow seasonal and permanent swamps		Permanent lakes and deep swamps
Topography				Many deep gullies make cultivation for sowing pastures impractical, or Slopes >15% make cultivation along contours impractical	Strongly dissected terrain over ≥75% of the area preventing adequate herd management
Water erosion	Slopes <1% on sodic rigid soils or Slopes <3% on all other soils	Slopes 1-3% on sodic rigid soils or Slopes 3-6% on cracking clays, or Slopes 3-12% on non-sodic rigid soils	Slopes 3-6% on sodic rigid soils or Slopes 6-9% on cracking clays, or Slopes 12-20% on nonsodic rigid soils	Slopes 6-12% on sodic rigid soils or Slopes 9-15% on cracking clays or Slopes 20-45% on non-sodic rigid soils	Slopes >45%
Flooding	No flooding	Periodic flooding (from once in 50 years to whenever stream flow increases)			

Limitation	**Land suitability class**				
	1	**2**	**3**	**4**	**5**
Vegetation regrowth (management limitation)	Softwood, brigalow, gidgee or blackwood scrub without melonholes , or Queensland bluegrass grasslands, or Mountain coolabah, bloodwood and ironbark open woodlands	Brigalow, gidgee or blackwood scrub with melonholes, or Box and ironbark woodlands without wattle understorey, or Coolabah woodlands on flooded country		Eucalypt woodlands with wattle understorey or Broad-leaved teatree woodlands	

Table A-3: Suitability assessment for beef cattle grazing

	Brigalow uplands						Glenhaughton Forest
	Cheshire	**Downfall**	**Kinnoul**	**Rolleston**	**Teviot**	**Rugby**	**Texture contrast soils**
Water availability	2	1	1	2	2	2	3
Nutrient deficiency	2	2	2	2	2	1	2
Soil physical factors	1	1	1	2	2	2	2
Salinity	1	1	1	1	1	2	1-2
Rockiness	2	1	2	1	1	1	1-2
Micro relief	1	1	1	1	1	1	1
Ph	2	2	2	2	2	2	1
Esp	2	1	1	1	1	2	2
Wetness	1	2	1	1	1	1	1
Topography	1	1	1	1	1	1	1
Water erosion	2	1	2	1	1	1	2
Flooding	1	2	1	1	1	1	1
Vegetation regrowth	1	1	1	1	1	1	2
Land suitability class	**2**	**2**	**2**	**2**	**2**	**2**	**3**

Table A-3: Suitability assessment for beef cattle grazing (continued)

	Poplar box flat plains		Cypress pine sands				Brigalow plains	Light forests	
	Braemer	**Weranga**	**Chinchilla**	**Davy**	**Combidiban**	**Bogandilla**	**Tara**	**Minnabilla**	**Binkey**
Water availability	5	5	3	3	5	4	3	5	5
Nutrient deficiency	2	2	2		2	1	1		
Soil physical factors	1	1	1	1	1	1	2	1	1
Salinity	3	1	1	1	1	2	1	1	1
Rockiness								2	
Micro relief	1	1	1	1	1	1	2	1	1
Ph	1	1	2	1	1	3	1	3	3
Esp	3	3	1	1	1	1	2	1	1
Wetness	1	1	1-2	1-2	2	2	1	1	1
Topography	1	1	1	1	1	1	1	2	2
Water erosion	2	2	1	1	1	1	1	3	3
Flooding	2	2	2	2	2	2	2	1	1
Vegetation regrowth	2	2	2	2	2	2	2	4	4
Land suitability class	**5**	**5**	**3**	**3**	**5**	**4**	**3**	**5**	**5**

Table A-3: Suitability assessment for dry land cropping

	Brigalow Uplands						Glenhaughton Forest
	Cheshire	**Downfall**	**Kinnoul**	**Rolleston**	**Teviot**	**Rugby**	**Texture contrast soils**
Water availability	3	2	2	3	3	3	4
Nutrient deficiency	3	4	3	4	3	2	2
Soil physical factors	1	2	1	1	2	3	3
Workability	2	2	2	2	2	2	2
Salinity	1	1	1	1	1	2	1
Rockiness	2	1	2	2	1	1	1-3
Microrelief	1	1	1	1	1	1	1
Wetness	1	2	1	1	1	1	1
Topography	2	2	2	2	2	2	2
Water erosion	4	3	4	3	3	3	2
Flooding	1	2	1	1	1	1	1
Land suitability class	**4**	**4**	**4**	**4**	**3**	**3**	**4**

Table A-4: Suitability assessment for dry land cropping (continued)

	Poplar box flat plains		Cypress pine sands				Brigalow plains	Light forests	
	Braemer	**Weranga**	**Chinchilla**	**Davy**	**Combidiban**	**Bogandilla**	**Tara**	**Minnabilla**	**Binkey**
Water availability	5	5	4	4	5	5	4	5	5
Nutrient deficiency	2	2	2	3	1	1	2		3
Soil physical factors	1	1	1	1	1	1	2	1	1
Workability	1	1	1	1	1	1	2	1	1
Salinity	3	1	1	1	1	2	1	1	1
Rockiness									
Microrelief	1	1	1	1	1	1	2	1	1
Wetness	1	1	2	2	2	2	2	1	1
Topography	1	1	1	1	1	1	1	3	3
Water erosion	3	3	2	2	2	2	2	3	3
Flooding	2	2	3	3	3	3	3	1	1
Land suitability class	**5**	**5**	**4**	**4**	**5**	**5**	**4**	**5**	**5**