Australia Pacific LNG Project

Volume 5: Attachments

Attachment 5: Geology, Topography, Geomorphology and Soils Assessment - Gas Fields



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Executive Summary

An assessment was undertaken to identify the existing values and characteristics of soils, geology, topography and geomorphology within the gas field portion of the Australia Pacific Liquefied Natural Gas (LNG) Project. The purpose of this assessment was to identify potential impacts of the proposed Australia Pacific LNG gas field development on land-based environmental values. Where appropriate, mitigation measures that would ameliorate potential impacts were to be identified.

The assessment was carried out through a desktop study supplemented by field investigations within the gas field area involving terrain observations and intrusive soil sampling. The field assessment was followed by laboratory testing on soil samples retrieved.

Topography, geology and geomorphology

The desktop review and field studies have indicated that the gas fields study area is predominantly flat, with gentle undulations and rises (with slopes generally between 1% and 10%), as well as plateaus, low sandstone hills and lateritic scarps. Hills are generally in the order of 10% slope, and in some instances up to 20%. The gas fields study area is also transected by numerous water courses of varying channel size. To maintain the existing landform functions, the capacity of drainage lines should be maintained through implementation of progressive construction techniques, water diversion, sediment and erosion control and revegetation. Large structures requiring significant site levelling works such as water storage facilities should be selectively located in flatter areas to mitigate changes to topography. Construction material sources, mainly in the form of borrow pits, are likely to be required within the tenements. While these will cause local changes to topography, many pits could be returned to a natural landform unless there is a need to retain them in the future as a material source for community benefit. Vehicle and pipe crossings of water courses should incorporate erosion protection measures to minimise damage to stream banks.

The geological review indicated that ground conditions are likely to be suitable for the construction of the gas fields Project and significant development constraints are not foreseen in this regard. Detailed investigation should be undertaken to quantify the environmental impact (such as potential for increased dust, noise and vibration) at site-specific excavations. Within most areas (approximately two thirds) within the tenements, excavations up to 2m depth are likely to largely encounter soils, with localised areas of rock. It is anticipated most materials can be reused. Rock excavated can be broken down for erosion protection or crushed for rip-rap.

The geological review also indicated that the site is located in an area of low earthquake risk. Significant structures should still need to be designed according to AS1170.4 and structure-specific earthquake requirements.

A review of extractive resources in the region indicated that most existing quarries have a low production output (generally <80,000tpa). Although this assessment did not identify the material reserves associated with existing quarries, expansion of these quarries and new quarries (both operated by others) may be required to meet the demands of this and other CSG projects. To meet the demand of the Australia Pacific LNG Project, any new quarry would be required to undergo an impact assessment as part of gaining a separate development approval prior to commencing the activity.

Soils

The soils assessment revealed a range of soil types within the gas fields study area. Predominant soils were identified as shallow texture contrast soils (Sodosols, Kurosols and Chromosols) with

significant areas of deep, dark cracking and non-cracking clays (Vertosols and Dermosols). The shallow texture contrast soils are predominantly used for grazing on improved and native pastures while shallow soils with a predominance of stone are used for forestry activities or rough grazing on native pastures. The cracking and non-cracking clays (particularly of alluvial origin) are the most productive soils in the region and are used for dry land and irrigated cropping and improved pasture. The texture contrast soils in particular were identified as commonly having highly sodic and dispersive subsoil.

Minimising erosion associated with Project construction will be a significant issue to be addressed further in planning and design, particularly where facilities are to be developed in areas of shallow dispersive texture contrast soils on steeper grades, particularly above 8% slope. This study has identified the erosion risk across the gas fields study area. Intensive erosion control measures with controls specified within sediment and erosion control plans should be implemented at development areas identified as having a high to severe erosion risk (approximately 2% [8864ha] of the tenements). On-going maintenance and monitoring of erosion levels and the effectiveness of erosion control measures should also be incorporated.

Due to the nature of soils within the study area, good topsoil segregation and handling procedures should be established. Topsoil depth is highly variable and site specific topsoils assessments should be undertaken. The high level of erosion risk in many areas of the tenements reinforces the need for the implementation of sound sediment and erosion control and thorough rehabilitation and revegetation.

Good quality agricultural land

Approximately 58% (331,187ha) of the tenement area has been identified as good quality agricultural land (GQAL). The best agricultural land (Class A) is mainly associated with the deep dark clay soils identified above and is located mainly on the alluvial plains formerly associated with Brigalow vegetation. The overall project intent has been to minimise the loss of GQAL, however some GQAL (classes A, B and C1) will potentially be directly impacted by the gas fields' construction (approximately 23,726ha). The implications of this aspect are addressed in the separate Land Use and Planning Report. Proposed rehabilitation measures in GQAL areas should include the reinstatement of the original landform and soil profile so as to minimise productivity losses and to maintain cropping efficiency. It is anticipated that there will be some loss of GQAL due to structures that are to be retained during operations, however this area will be relatively small (approximately 4,319ha or 0.75% of the Project area).

Dust

Dust has been identified as an issue in the study area, especially the potential generation of bulldust. Appropriate dust management should be incorporated including construction of gravel access roads on the main haul routes, controls on vehicle speeds as well as dust suppression with water trucks or Dustmag on unsealed roads.

Overview

In summary, a significant potential adverse impact associated with the Australia pacific LNG gas fields development, without mitigation measures would be excessive soil erosion. This has the potential to result in scarring of the landscape, gullying of local drainage lines and adverse water quality impacts in downstream areas. Land within the tenements likely to experience the greatest impact would be the substantial areas of shallow texture contrast soils with sodic and dispersive subsoils (ie. the Solodic / Sodosol soil types), particularly where slopes exceed 3%. Areas where slopes exceed 8% would have

very high to severe levels of erosion risk. The development, implementation and on-going monitoring of sediment and erosion control plans will be critical in ensuring that impacts in this regard are minimised to acceptable levels.

There may also be issues with the source and availability of suitable extractive material sources for Project construction. Further assessment is required into the likely demands of the construction phase in this regard.

No significant construction issues or impacts are foreseen in terms of the requirements for excavation in rock. Similarly, seismic issues are not expected to be significant.

While the project infrastructure is likely to disturb a substantial area of GQAL, the majority of the area impacted in this regard will be able to have the original landform and agricultural values reinstated following cessation of activities.

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1. Introduction

An investigation was undertaken to identify the existing values and characteristics of soils, geology, topography and geomorphology within the gas field portion of the Australia Pacific Liquefied Natural Gas (LNG) Project. These are known as the Walloons gas fields and are located within the Surat and Bowen Basin in Central Queensland. The gas fields study area encompasses a number of land tenements, which stretch from Wallumbilla to Millmerran on the Darling Downs (refer Figure 1.1). These land tenements occupy the area on which gas wells will be drilled (approximately 10,000 over the life of the project) and from which coal seam gas (CSG) will be extracted. From west to east, the names of the tenements are as follows: Combabula, Ramyard, Woleebee, Carinya, Condabri, Talinga, Orana, Dalwogan, Kainama and Gilbert Gully.

The purpose of this study is to identify potential impacts of the proposed Australia Pacific LNG gas field development (refer Figure 1.1) on land-based environmental values by investigating existing site geophysical conditions through the collection and evaluation of local soil and terrain data.

This assessment will provide a basis for establishing development parameters to minimise land degradation and maximise rehabilitation opportunities. In this regard, it addresses potential construction constraints for the development of the proposed gas fields in terms of soil management.

1.1 Legislative framework

The following describes the main pieces of legislation application to the planning, approval, construction and operation of the pipeline in relation to landform, soils and soil management.

1.1.1 Environmental Protection Act 1994

The primary objectives of the EP Act is to protect environmental values and human health whilst allowing developments that improve the total quality of life both now and in the future in a way that maintains ecological processes. The requirements of the EP Act are administered by the Department of Environment and Resource Management (DERM); formerly the Environmental Protection Agency (EPA).

1.1.2 Petroleum and Gas (Production and Safety) Act 2004

The purpose of this Act is to facilitate and regulate the carrying out of responsible petroleum activities and the development of a safe, efficient and viable petroleum and fuel gas industry. It also has provisions to carry out activities on land within and outside the area of authority in order to allow access. This includes access to conduct environmental investigations such as soil sampling.

1.1.3 Soil Conservation Act 1986

The *Soil Conservation Act 1986* allows for the approval of soil conservation property plans to ensure the co-ordination of runoff to control erosion. Although there are no approvals required under the *Soil Conservation Act 1986*, the Project will need to comply with any Project Plans, Property Plans, run-off coordination notices and soil conservation notices that have been issued under the Act.

1.1.4 Environmental Protection (Water) Policy 2009

The *Environmental Protection (Water) Policy* 2009 aims to support the *Environmental Protection Act 1994* with a range of water management guidelines. This policy develops a framework for identifying

environmental values, developing water quality objectives, managing the intent for waters and developing management plans.

1.1.5 State Planning Policy 1/92

State Planning Policy 1/92 states that Good Quality Agricultural Land (GQAL) has a special importance and should not be built on unless there is an overriding need for the development in terms of public benefit and no other site is suitable for the particular purpose (DPI/DHLGP 1992). As defined by *Planning Guidelines: The Identification of Good Quality Agricultural Land* (DPI, 1993). GQAL is "…land which is capable of sustainable use for agriculture, with a reasonable level of inputs, and without causing degradation of land or other natural resources".

DPI/DHLGP also define agricultural land "...as land used for crop or animal production, but excluding intensive animal uses such as feedlots, piggeries, poultry farms and plant nurseries based on either hydroponics or imported growth media". GQAL classes for the study area are described in Section 5.3.

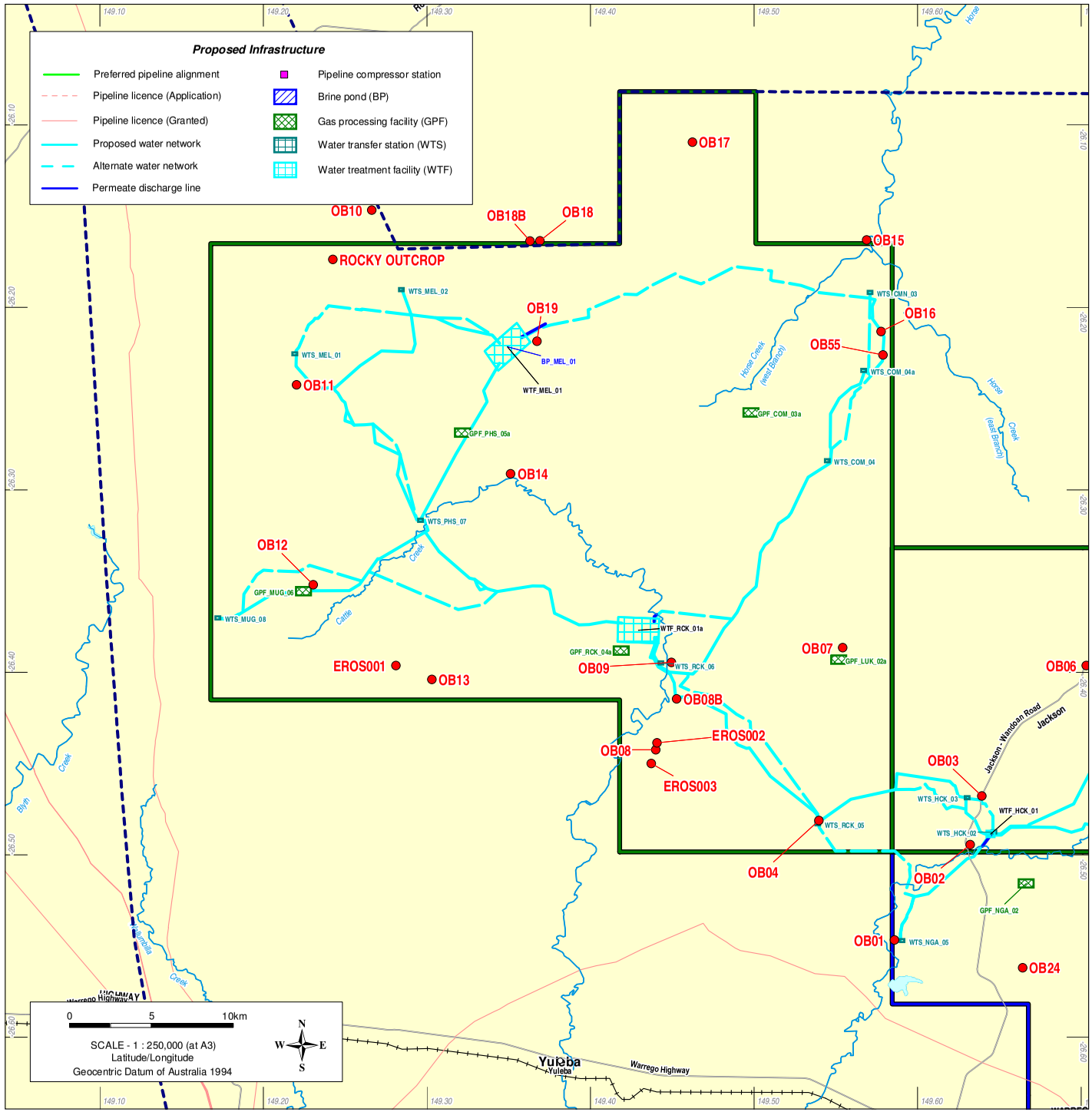
1.1.6 State Planning Policy 2/02

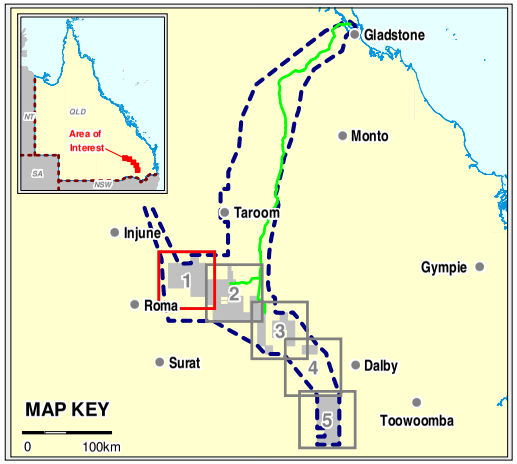
In Queensland, the State Planning Policy (SPP) 2/02 sets out the State's interest concerning development involving acid sulfate soils (ASS) in low-lying coastal areas. The SPP 2/02 has effect under the *Sustainable Planning Act 2009* (SPA) and applies to all land, soil and sediment at or below 5mAHD where the natural ground level is less than 20mAHD (Queensland Government 2002). Within this area, the SPP2/02 applies to all development involving excavating or removing 100m^3 or more of soil or sediment, or filling of land involving 500m^3 or more of material with an average depth of 0.5m or greater.

DERM (previously known as NR&M) has published comprehensive guidelines for ASS management, sampling and analysis. These guidelines also provide technical and procedural advice to avoid environmental harm and achieve best practice environmental management. They include:

- Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland 1998, version 4.0 (Ahern et al. 1998)
- Queensland Acid Sulfate Soil Technical Manual – Soil Management Guidelines, 2002, version 3.8 (Dear et al. 2002).

Methodology for this assessment is guided by the above policies and is presented in Section 2 below.





LEGEND

- Observation location
- Town
- Existing infrastructure
- Major drainage
- Road
- Study area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

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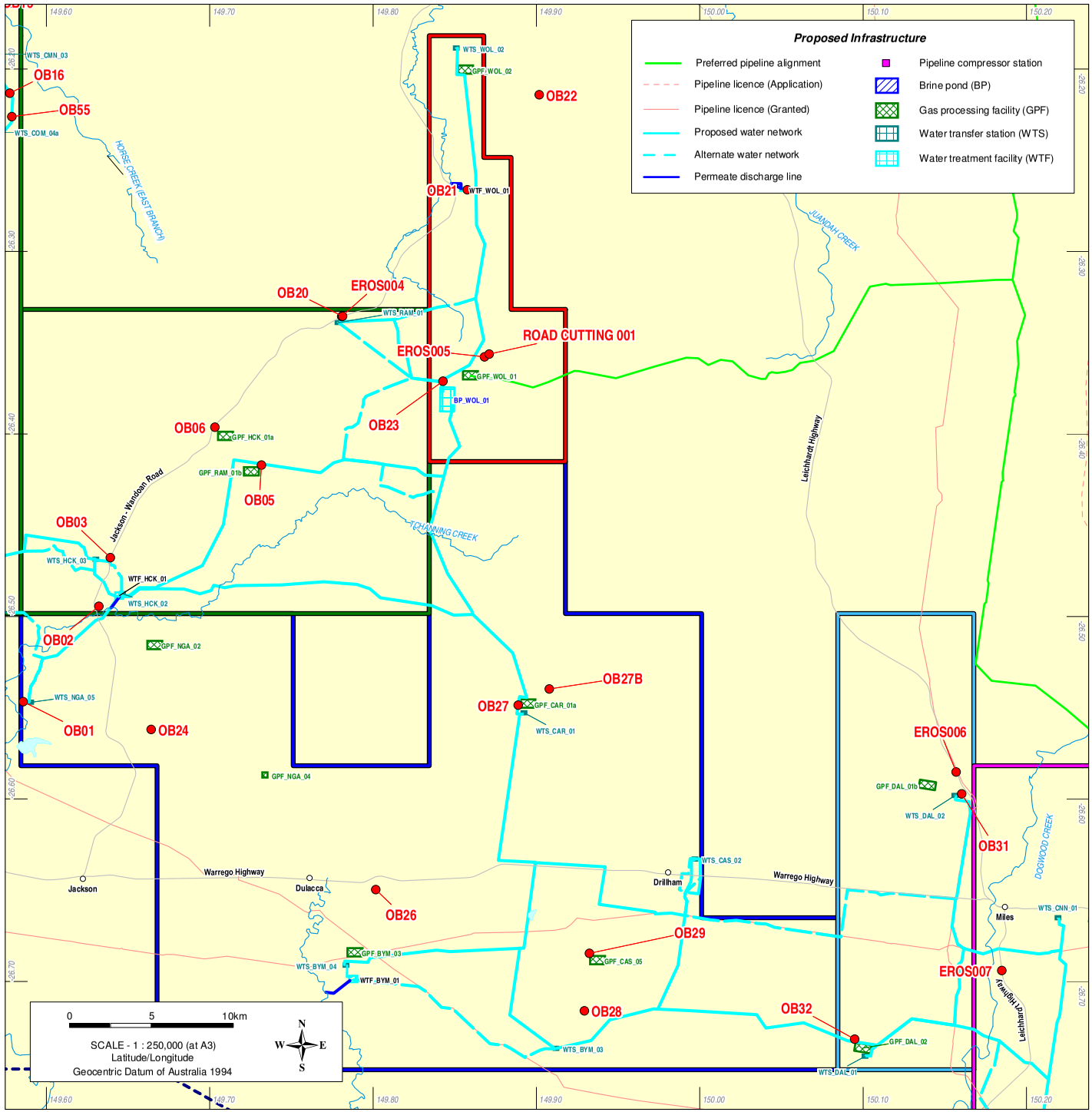
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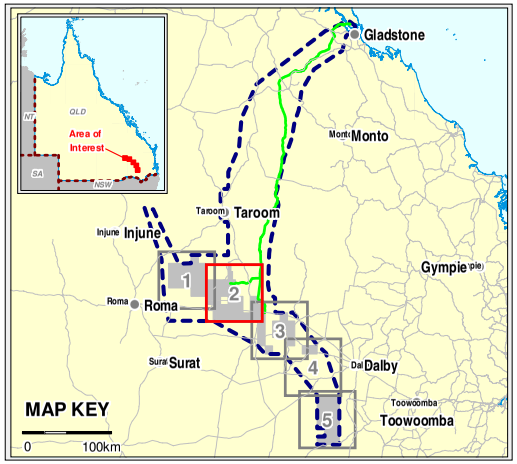
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Figure 1.1 Study Area and Observation Locations Map 1 of 5

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LEGEND

- Observation location
- Town
- Existing infrastructure
- Major drainage
- Road
- Study area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

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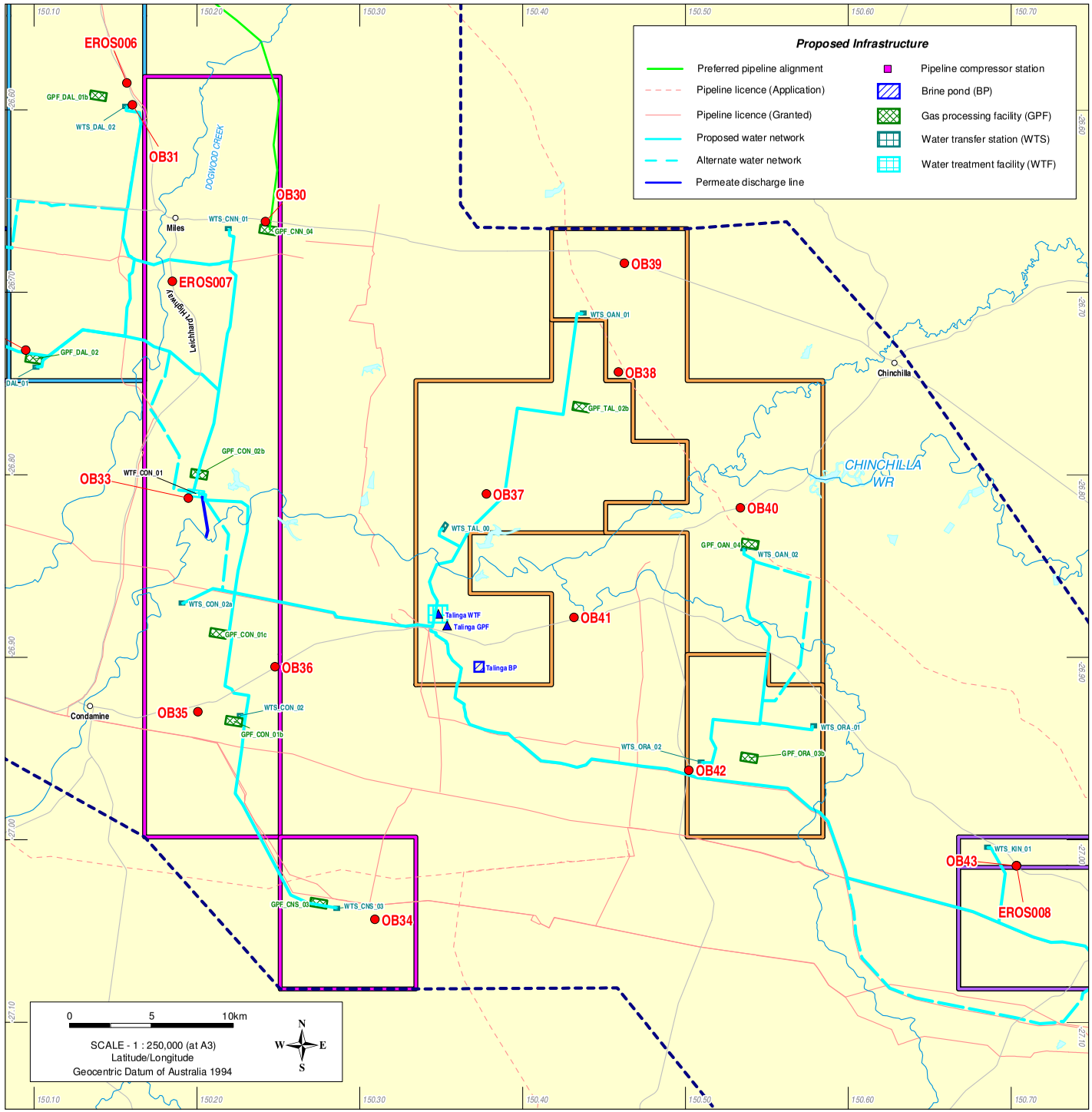
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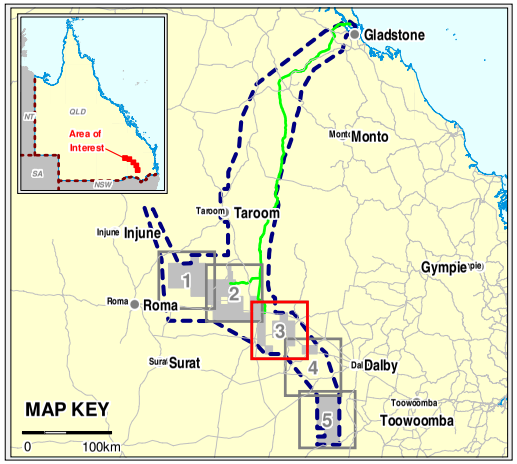
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LEGEND

- Observation location
- Town
- Existing infrastructure
- Major drainage
- Road
- Study area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
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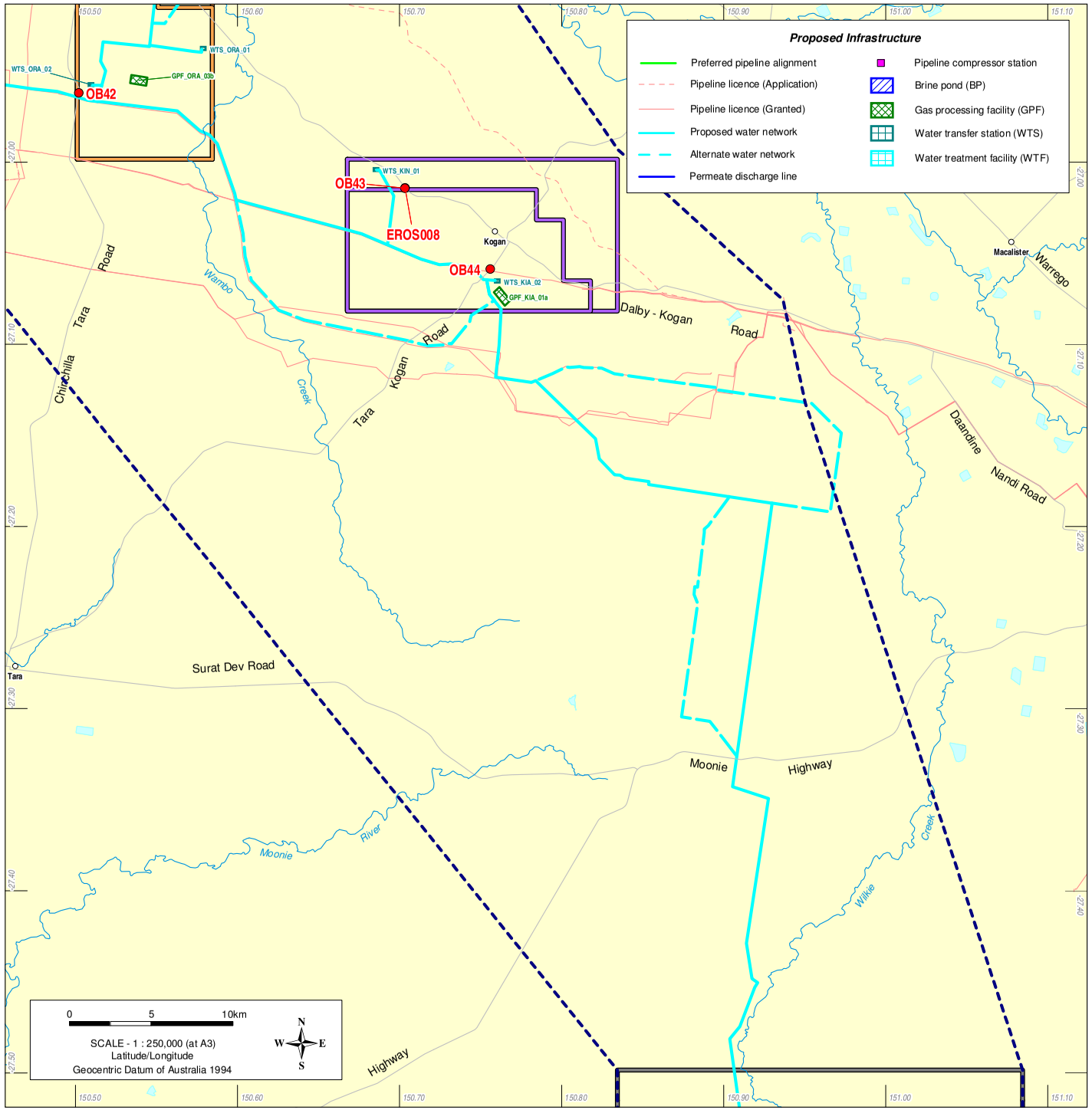
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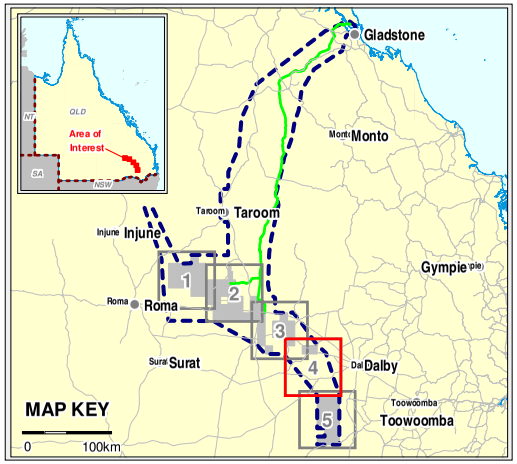
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LEGEND

- Observation location
- Town
- Existing infrastructure
- Major drainage
- Road
- Study area

Walloons Gas Fields Development Areas

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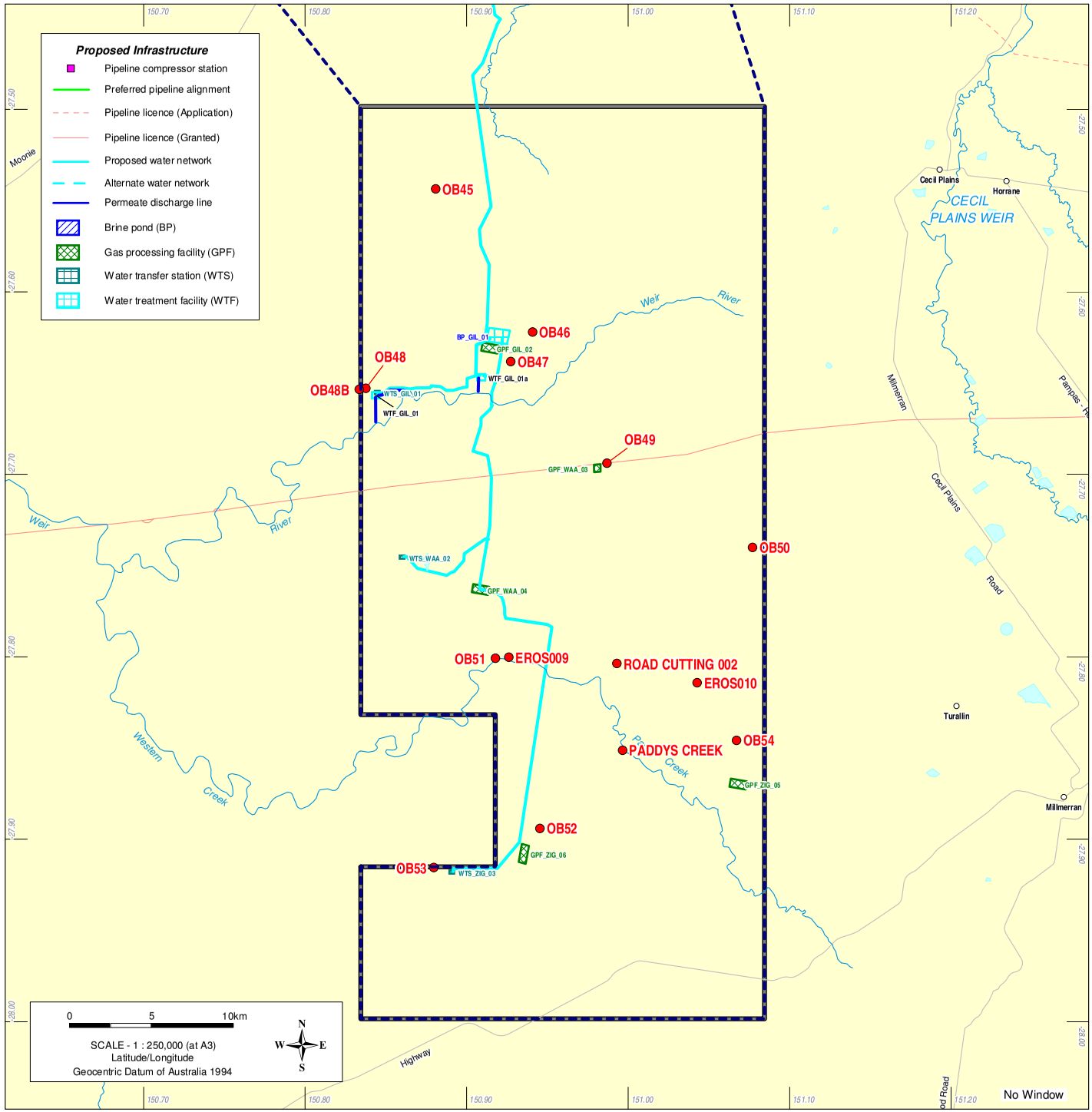
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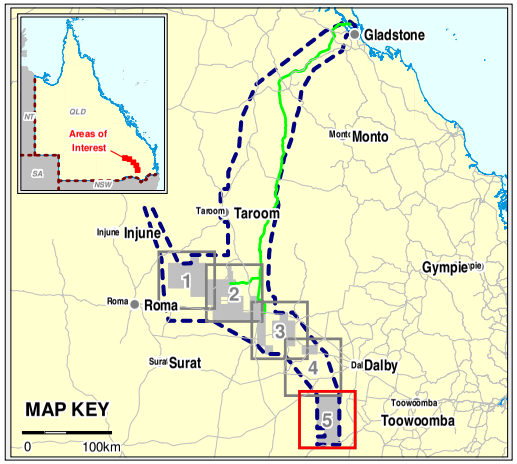
AUSTRALIA PACIFIC LNG PROJECT
Figure 1.1 Study Area and Observation Locations
Map 4 of 5

Project No: 301001-00448	Figure: 00448-00-EN-DAL-0202	Rev: 1

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LEGEND

- Observation location
- Town
- Existing infrastructure
- Major drainage
- Road
- Study area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

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0	14/11/2009	Issued for use	JB	DH		RB

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AUSTRALIA PACIFIC LNG PROJECT
Figure 1.1 Study Area and Observation Locations Map 5 of 5

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2. Methodology

2.1 Geology

The geology of the study area (refer Figure 3.1) was assessed using the Geological Survey of Queensland (GSQ) Geoscience Datasets (2008) and GSQ regional mapping of the Bowen Basin and Surat Basin as shown on the 1:250,000 Geological Series Chinchilla (SG56-9), Roma (SG55-12) and Dalby (SG 56-13) map sheets. This dataset has been used to describe the regional and study area geology to enable assessment of:

- Potential construction constraints
- Location of geologic structures and faults
- Potential impacts to local extractive resources which may be required for project development.

Geological mapping has also been used in combination with topographic data provided in Section 4 to produce a geological profile of the study area. This is illustrated as Figure 3.2.

2.2 Topography and Geomorphology

The terrain characteristics of the study area have been assessed in terms of topography (surface form and slope) and geomorphology (landform).

The assessment was undertaken in two parts:

a) Desktop review was conduced of major topographic features within the study area. This was carried out using the 25m Digital Elevation Model (DEM) supplied by DERM to provide a basis for the assessment of slope class. This data was used in conjuction with the following land system mapping to identify and assess landform:

   i) Maher, JM (ed), Land Resource Areas – Murilla and Chinchilla Shires, 1:250,000 Department of Primary Industries (DPI) 1995.

   ii) Department of Primary Industries (DPI), 1995. Land Resource Areas – Tara Shire, 1:250,000.

   iii) Commonwealth Scientific and Industrial Research Organisation (CSIRO) – Division of Land Research, 1974. Land Systems – Balonne-Maranoa Area, Queensland Australia, 1:500,000.

   iv) Commonwealth Scientific and Industrial Research Organisation (CSIRO) – Division of Land Research 1968, Land Systems – Dawson - Fitzroy Area, Queensland Australia, 1:500,000.

   v) Queensland Department of Natural Resources (DNR), 1998, Land Resource - Central Darling Downs, 1:250,000.

   vi) MacNish, S. (cd), 1987. Roma District Land Management Field Manual Queensland Department of Natural Resources and Mines (DNRM).

Digital data for the purposes of mapping land systems and soil types have been derived predominantly from the above datasets.

b) A field assessment was carried out across the study area classifying terrain and slope at each observation location.

2.3 Soils

The soils assessment was undertaken in two parts:

a) Desktop review of existing information pertaining to the study area such as land system, land resource and soils mapping

b) A field assessment including soil sampling and classification and erosion categorisation.

2.3.1 Desktop

Land system and land resource maps provide useful soils and landform data across wide areas throughout Queensland. A land system map generally presents areas of discrete landscapes based on a combination of geology, landform, soils and natural vegetation characteristics. Such maps should not be regarded as detailed soils maps, as they indicate the general soil characteristics of an area at a sufficient level to be able to define management issues and constraints. They also provide reliable background data that would otherwise be impracticable to obtain through a comprehensive field survey.

The Project Area (tenement area) is approximately 570,000ha and is spread across six mapped land system areas which were used to identify potential soil types within the study area. These land systems are described in Section 2.2.

The land system maps presented in each of these studies were combined and trimmed to fit within the study area and a standardised key to soil types within the study area was developed (refer Figure 5.1 and Section 5.1).

2.3.2 Field investigation

The field investigation of the study area was undertaken from 24-31 August 2009 and consisted of testing soils for physical and agronomic parameters at 39 observation locations and inspecting 19 waterway locations (refer Figure 1.1) in proximity to proposed significant infrastructure sites initially selected by Australia Pacific LNG. All observation locations were initially inspected by cultural heritage monitors to identify the potential presence of artefacts and relocate borehole locations, if necessary.

Soil observation locations were selected by focussing on those areas required for gas processing facilities and where access was available. The water crossing observations were selected based on the proximity of proposed water treatment facilities; water transfer stations, gas treatment facilities to waterways. Note that the location of gas wells was excluded from the observation selection process as specific well locations were unknown. Observation locations were adjusted in the field based on permissible land access and cultural heritage constraints. This methodology and sampling intensity of approximately one location (observation) every 1044ha (construction footprint [40717ha – refer Table 6.1]) was considered adequate to represent soils within the study area (in conjunction with existing land suitability information) and provide sufficient information to correlate encountered soils with land system data.

Soil observations comprised hand augering to a depth of between 0.2m to 1.0m below ground level (BGL), depending on hardness of subsurface material and presence of coarse fragments. A summary of field data is provided in Appendix B. Soil samples were collected for laboratory analysis of physical and agronomic constituents.

2.3.3 Soil Descriptions

Soils at each borehole location were described in accordance with the Australian Soil and Land Survey Field Handbook (McDonald et al, 1990) and Australian Soil Classification (Isbell, 1996). Soil characteristics were described at all 39 soil observation locations and photographed to show the soil profile and the surrounding adjacent environmental setting (refer Section 2.3.3). This included soil horizon and landscape information provided in Table 2.1, while a summary of field data is provided in Appendix B.

Table 2.1 Soil horizon and landscape information

Soil horizon descriptions	Landscape information
Subgroup classification	Terrain (slope class)
Horizon name	Predominant slope
Depth	Slope position
Colour (matched to the Munsell Colour Chart paint chip)	Existing erosion
Texture	Drainage
Structure	Aspect
Consistence	Approximate water table depth
Coarse fragments	Universal Transverse Mercator (UTM) coordinates of Zone 55
Mottles	Vegetation (canopy / understorey)
Presence of carbonates and/or salts	Land use
Rooting description	

2.3.4 Soil sampling methods

Field sampling procedures conformed to WorleyParsons Quality Assurance / Quality Control (QA/QC) protocols to minimise potential for cross contamination and preserve the sample integrity. The following sections provide a brief description of the testing methods used, while Table 2.2 provides a summary of the soil sampling activities.

Table 2.2 Soil sampling methods

Activity	Details
Borehole locations	Borehole locations were recorded using a Garmin 76 hand held Ground Positioning System (GPS) unit which has an accuracy of ±4m.
Soil coring	Borehole coring was undertaken using an 82mm manual hand auger by WorleyParsons staff members and extended to a maximum depth of 1m BGL.
Abandonment	Boreholes were backfilled to the existing natural ground level using soil retrieved during soil coring.
Soil logging	Soil profiles were logged based on the subsoil brought to the surface.

Activity	Details
Soil sampling	Soil samples were obtained directly from the auger or borehole using new disposable nitrile gloves. Samples to be tested for agronomic parameters were then placed into resealable plastic bags and stored in eskies for dispatch to laboratory.
Labelling	Sample containers were labelled with the date, the abbreviated project title (Origin) and the location / depth. For instance a sample collected at OB03 at a depth of 0.9 to 1.0mBGL was labelled as follows: ORIGIN 25/08/09 OB03/0.9-1.0
Dispatch	Samples were stored in eskies and transported to BioTrack for analytical testing following the completion of field works.

2.3.5 Soil sampling and laboratory analysis

Sampling for physical and agronomic parameters included the collection of discrete soil samples within the topsoil (typically surface to 0.2m) and subsoil horizons (typically 0.2m to 1.0m). A total of 39 topsoil and 30 subsoil samples were collected and analysed.

Soil samples were dispatched to BioTrack Laboratory in Brisbane for Emerson Dispersion testing and analysis of pH, electrical conductivity (EC), available nutrients [total Kjeldahl nitrogen (TKN) and phosphorus (P)], cation exchange capacity (CEC) and exchangeable cations. The laboratory analysis plan is presented in Appendix B.

3. Existing geology

3.1 Regional geology

3.1.1 Stratigraphy – Bowen Basin

The Bowen Basin was formed during the Early Permian to Middle Triassic and occupies an area of around 160,000 square kilometres which extends in a north-south trending belt from the vicinity of Townsville, Queensland, southwards into central northern New South Wales, near Moree. Deposition of the Bowen Basin was concentrated in two depocentres, the Taroom Trough on the eastern edge of the basin, and Denison Trough along its western edge. The deposition commenced in the Early Permian and extended through to the Middle Triassic. Early phases of deposition in the Taroom Trough consisted of fluvial and lacustrine sediments and volcanics, while in the Denison Trough deposition consisted of a thick succession of coals and non-marine clastic sediments. Following rifting (pulling apart of Earth's crust), a subsidence phase extending from the Early to Late Permian allowed deposition of deltaic and shallow marine, predominately clastic sediments as well as extensive coal measures. A period of accelerated subsidence followed during the Late Permian, resulting in the deposition of a very thick succession of marine and fluvial clastics, consisting of Early to Middle Triassic fluvial and lacustrine clastic sediments and further coal. The deposition was terminated by a Middle to Late Triassic contraction of the surface.

3.1.2 Stratigraphy – Surat Basin

The Early Jurassic to Early Cretaceous Surat Basin overlies the southern half of the Bowen Basin, and extends from the southern part of central southern Queensland in the vicinity of the Expedition Range southward to central northern New South Wales, near the Warrumbungle Range.

The deposition in the Surat Basin commenced during the Early Jurassic, comprising mostly fluviolacustrine deposition. By the Middle Jurassic coal swamp environments predominated over much of the basin, except in the north where fluvial sedimentation continued. By the end of the Middle Jurassic, fluvial deposition again predominated and continued until the Early Cretaceous when a period of marine transgression followed, depositing paralic and marine sediments. The subsequent regression caused a fairly abrupt return to fluvial, lacustrine and paludal environments before sedimentation ceased in the Early Cretaceous.

3.2 Study area geology

The geology mapped within the study area (refer Figure 3.1) predominately comprises Early Cretaceous mudstones, Jurassic arenites and mudstones and Tertiary sedimentary rocks.

Quaternary alluvium and associated soil occur in lower lying areas and adjacent to waterways throughout the Bowen and Surat basins and generally overlies the older Tertiary sediments and Cretaceous and Jurassic materials. As mapped in the GSQ Geoscience Datasets (2008), several of the geological mapping units identified have similar characteristics in terms of age and rock type. To simplify the mapping process, these mapping units have been combined and re-defined as geological units. The geological units and map symbols that have been adopted as a basis for terrain mapping are described in Table 3.1.

Table 3.1 Geological unit summary

Geological unit	Age	Lithology summary	Dominant rock	Map symbol
Late Cainozoic floodout and residual sand, soil and gravel	CAINOZOIC	Sand, soil and gravel	MISCELLANEOUS UNCONSOLIDATED SEDIMENTS	Cz, Czg
Quaternary alluvium and lacustrine deposits	QUATERNARY	Sand, silt, mud and gravel	ALLUVIUM	Qa, Qs, Qpc
Palaeocene-Oligocene sediments	TERTIARY	Sandstone, mudstone, conglomerate	SEDIMENTARY ROCK	Tl, T,Tpc
Wallumbilla Formation	EARLY CRETACEOUS	Mudstone and siltstone with calcareous concretions	MUDSTONE	Kl, Klg, Kls, Kld, Klc
Bungil Formation, Gubberamunda Sandstone, Hooray Sandstone, Kumbarilla beds, Longsight Sandstone, Mooga Sandstone, Orallo Formation, Southlands Formation	JURASSIC - CRETACEOUS	Glauconitic, labile to quartzose, siltstone, mudstone; sandstone, minor conglomerate, siltstone; coal	ARENITE	JKk, Jug, Juo, Kly, Klm, Klk, Kln, Kli
Injune Creek Group, Mulgildie Coal Measures, Walloon Subgroup	JURASSIC	Sandstone, siltstone, mudstone, coal, conglomerate	SEDIMENTARY ROCK	Ji, Jw

3.3 Geological structural features and faults

The structural features and faults identified within the Bowen and Surat basins are predominately north to south or north-north west to south-south east trending, with moderate sized folds and faults resulting from regional compression towards the west-south-west during the end of the Permian to the Middle Triassic Periods (refer Figure 3.3). These structural features may potentially comprise zones of weakness in the upper crust that may be subject to differential movement during a significant seismic event in the region. Limited information is available regarding the movement of the identified faults, however traditionally in Queensland, no active faults have been observed in recent times. Similarly, no earthquakes since 1958 have been recorded within the gas fields study area.

Standards Australia have produced earthquake loading maps to provide engineers with design coefficients for earthquake risk, based upon a 10% probability of exceedance in 50 years. Using these maps, the Hazard Factor (Z), (equivalent to Peak Ground Acceleration in ms^{-2}) for the study area varies between 0.04-0.07, depending upon the location. A value of 0.05 indicates that in any 50-year period, there is a 10% chance that the peak ground acceleration will exceed 0.05.

3.3.1 Induced seismicity

Extraction or injection of material below ground has the potential to trigger small earthquakes. This phenomenon is known as induced seismicity.

In oil and gas extraction in general, small seismic events have been known to result from stress changes in the ground during and following removal of pore fluid, such as water or oil. Steps such as re-injecting water back into the ground can reduce the effects of induced seismicity.

Seismic events have been also been known to occur with large lagoon and dam construction due to the increased stress on the ground over a widespread area.

In general, induced seismic events resulting from engineered activity are of low magnitude and of minimal consequence, in terms of public risk.

3.4 Location and quality of CSG resource

Australia Pacific LNG has the largest portfolio of independently-certified CSG reserves and resources in Australia. The gas fields' component of the Project covers an area of approximately 570,000 hectares (refer Figure 1.1).

In situ gas quality will vary between the fields, with the produced gas being predominantly methane with very low concentrations of nitrogen, carbon dioxide and ethane. Australia Pacific LNG's reserves and resource position in accordance with Society of Petroleum Engineers guidelines include 7,265PJ of 2P reserves, 12,627PJ of 3P reserves and 15,869PJ of Contingent Resources as at 30 June 2009. Further detail is provided in EIS volume 2, Chapter 3 – Project Description.

3.5 Extractive resources

The construction of Project infrastructure (i.e. gas processing and water treatment facilities, and underground pipelines) will require extractive materials such as rock, sand and gravel for use as bedding, creation of hardstand areas, access tracks, fill, sediment and erosion control and rehabilitation (i.e. rock armouring for waterways). Furthermore, a source of cement for concrete and bentonite for grouting is also likely to be required.

The quantities of extractive materials that would be required for the development of the Australia Pacific LNG gas fields and other potential projects within the area have not been fully calculated, nor has the quality and type of materials required or the location where they will be required been determined. These calculations and factors are determined during Front-End Engineering and Design (FEED) phases of a project and involve conceptualisation and feasibility of design.

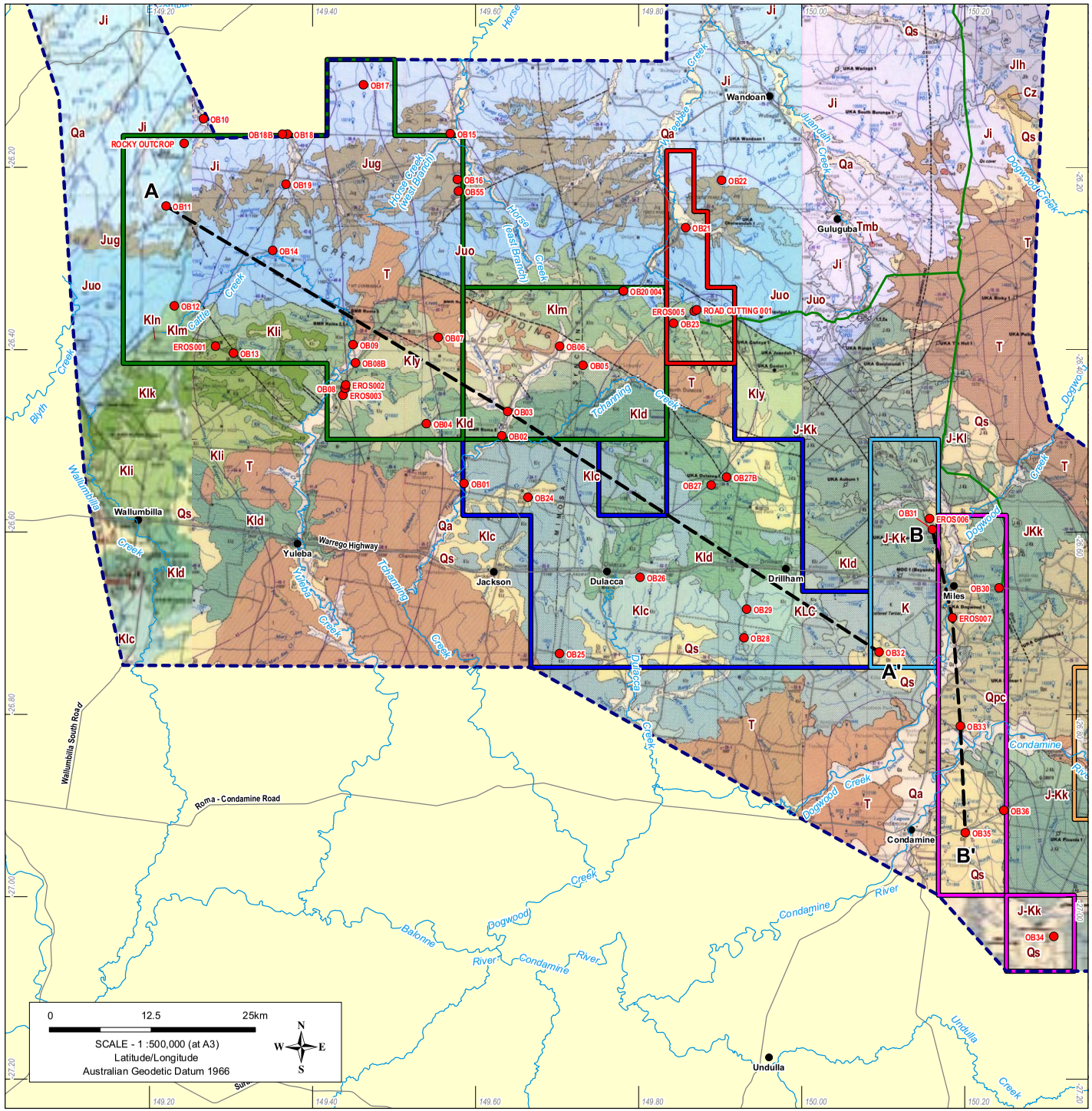
As part of this assessment, a search for existing quarries around and within the Australia Pacific LNG gas field study area was conducted and the results provided in Table 3.2. This search indicated that most existing quarries currently have a low production rate (generally <80,000 tpa) and generally provide extractive materials exclusively to the local councils and communities for road maintenance and upgrades and building construction. Although this assessment did not identify the material reserves associated with existing quarries, expansion of existing operations and new quarries may be required to meet the demand of this Project and other CSG projects.

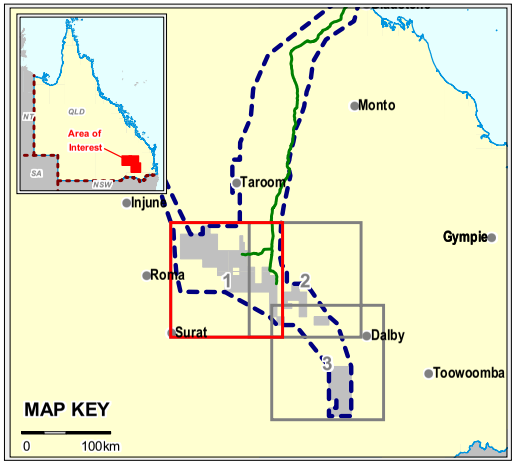
Table 3.2 Existing extractive resources

Quarry name	Operator	Status	Production rate (refer notes)	Local authority (pre 2008 boundaries)	Operation type	Descriptive locality
Blackswamp Pit	Chinchilla Shire Council	Operating	low	CHINCHILLA	Hard rock	Cnr North Kogan/Warra Kogan Rds
Chandlers Quarry	Millmerran Shire Council	Operating	low	MILLMERRAN	Hard rock	30 km south of Millmerran, via Bringalily on Millmerran-Inglewood Road
Colls Pit	N & J Bobcat Hire	Operating	low	CHINCHILLA	Sand	Monmouth Bridge Rd (Redhill Rd) West Shire
Hunter Road Pit	Neville Colls	Operating	low	CHINCHILLA	Sand	Hunter Road via Chinchilla, "Monmouth Park"
Jimbour	Wambo Shire Council	Operating	high	WAMBO	Hard rock	about 20 km along Dalby/Bell (Bunya Highway) rd on left just after Jimbour Quarry Road T/O
Juandah Creek	Richards Concrete	Suspended	-	TAROOM	Sand	Juandah Creek
Lavelle Road	Millmerran Shire Council	Operating	low	MILLMERRAN	Hard rock	
Newton's	GCM Mining Pty Ltd	Operating	low	WAMBO	Hard rock	
Warra-Kogan	Chinchilla Shire Council	Operating	low	CHINCHILLA	Hard rock	Warra - Kogan Rd, Condamine South

Quarry name	Operator	Status	Production rate (refer notes)	Local authority (pre 2008 boundaries)	Operation type	Descriptive locality
Warrians	Boral Resources (Qld) Pty Ltd - Country	Operating	low	BUNGIL	Hard rock	35km up Roma - Taroom Rd
Yuleba	Yuleba Minerals Pty Ltd	Suspended	-	BENDEMERE	Sand & Gravel	6km south Yuleba on Yuleba-Surat Rd

Note: Extractive industry information obtained for the Australia Pacific LNG gas fields from the Department of Mines and Energy, QRock Database.
Low Production (<80,000 tpa) Medium Production (80,000 – 200,000 tpa) High Production (>200,000 tpa)





LEGEND

- Observation location
- Town
- Road
- Preferred pipeline alignment
- Major drainage
- A — A' Cross-Section
- Reservoir
- Study area

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A full description of geology is provided in Table 3.1.

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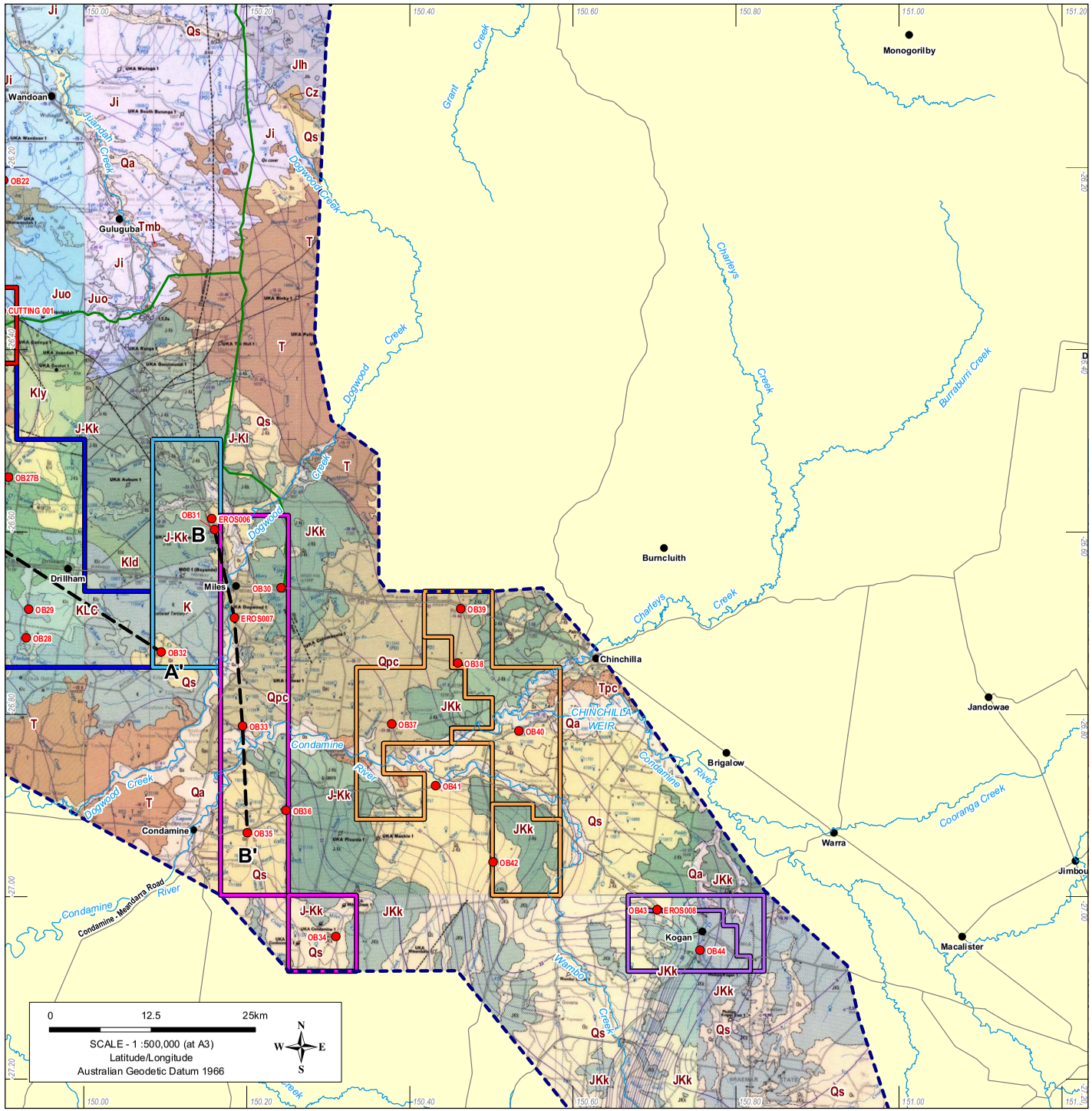
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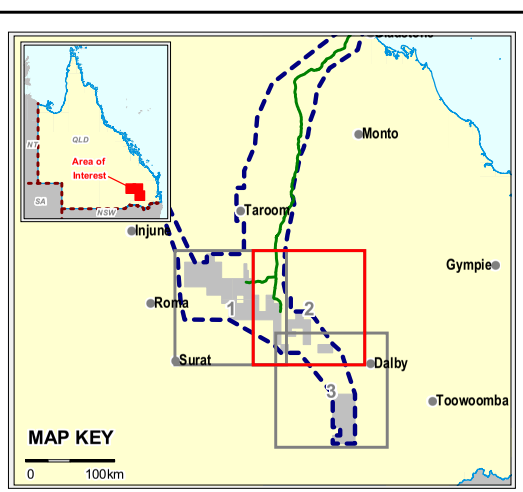
AUSTRALIA PACIFIC LNG PROJECT
Figure 3.1 Study Area Geology and Cross Section Profile Locations
Map 1 of 3

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LEGEND

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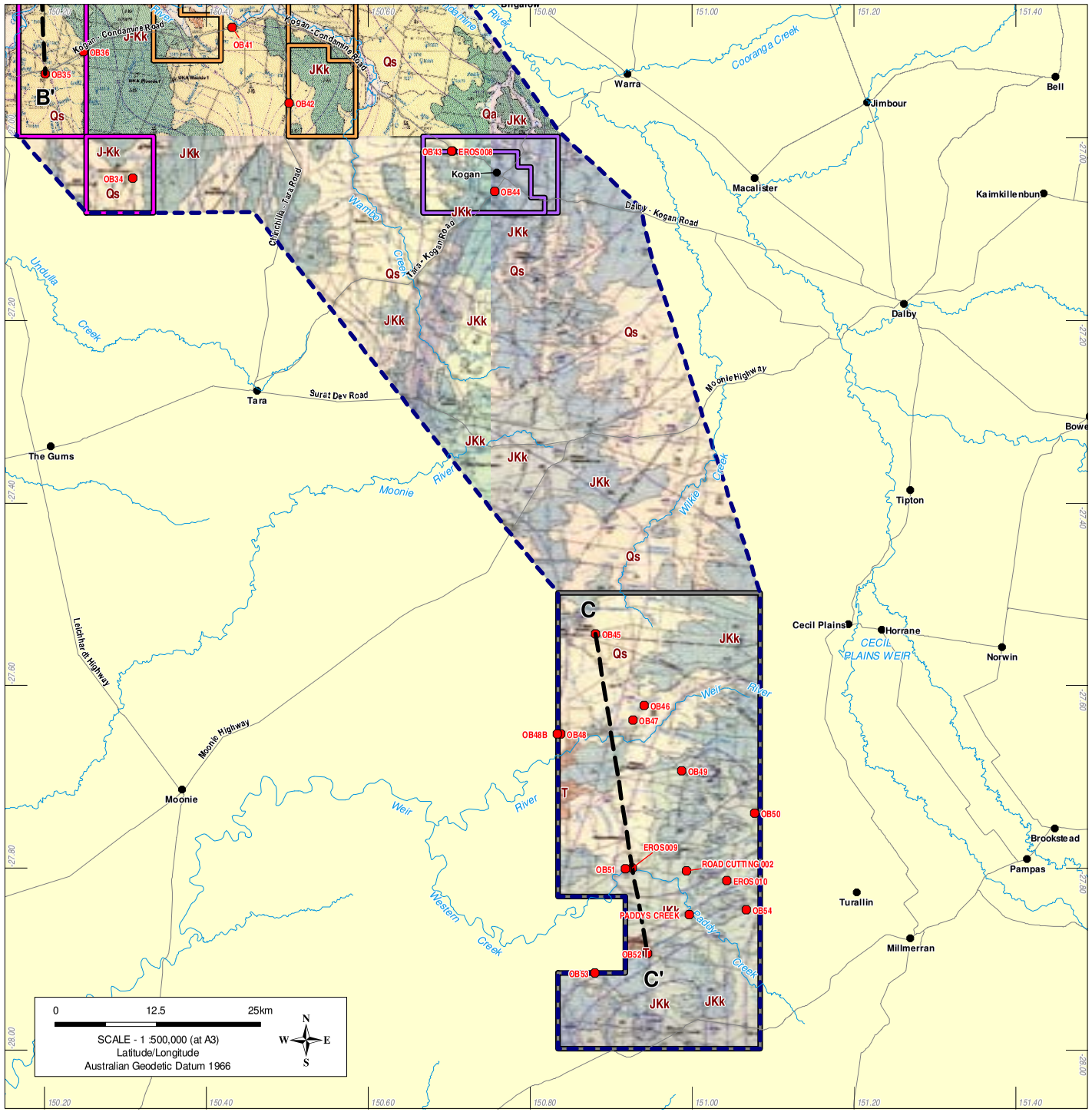
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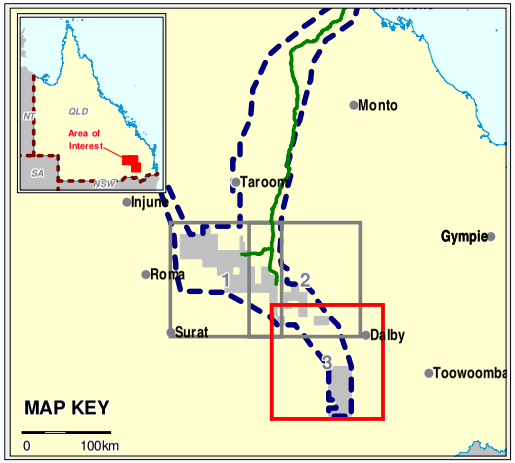
AUSTRALIA PACIFIC LNG PROJECT
Figure 3.1 Study Area Geology and Cross Section Profile Locations
Map 2 of 3

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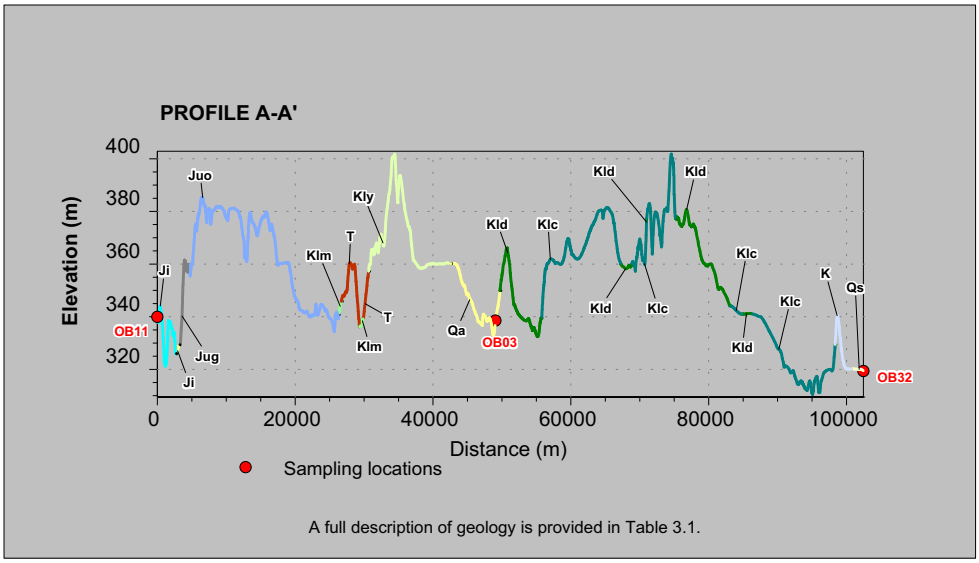
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Figure 3.1 Study Area Geology and Cross Section Profile Locations
Map 3 of 3

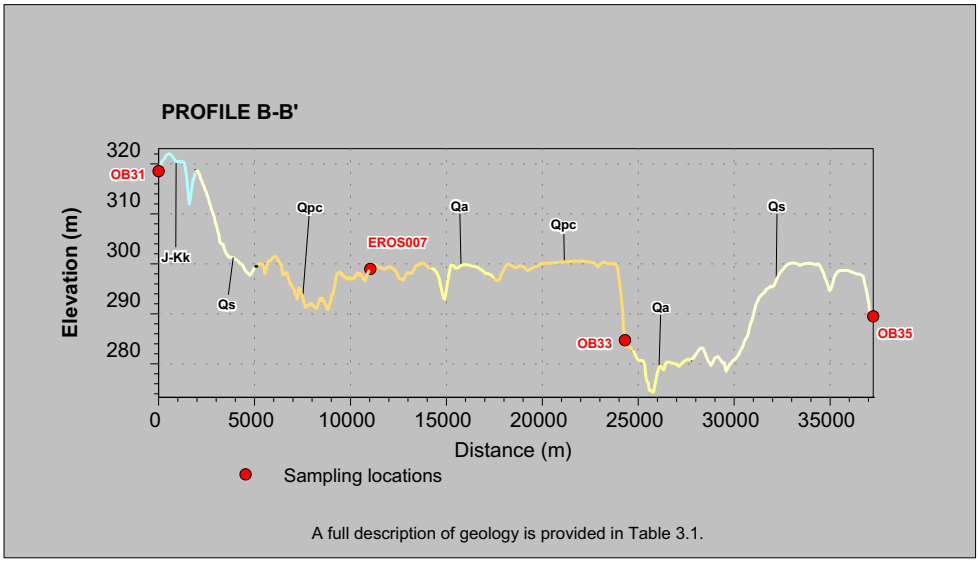
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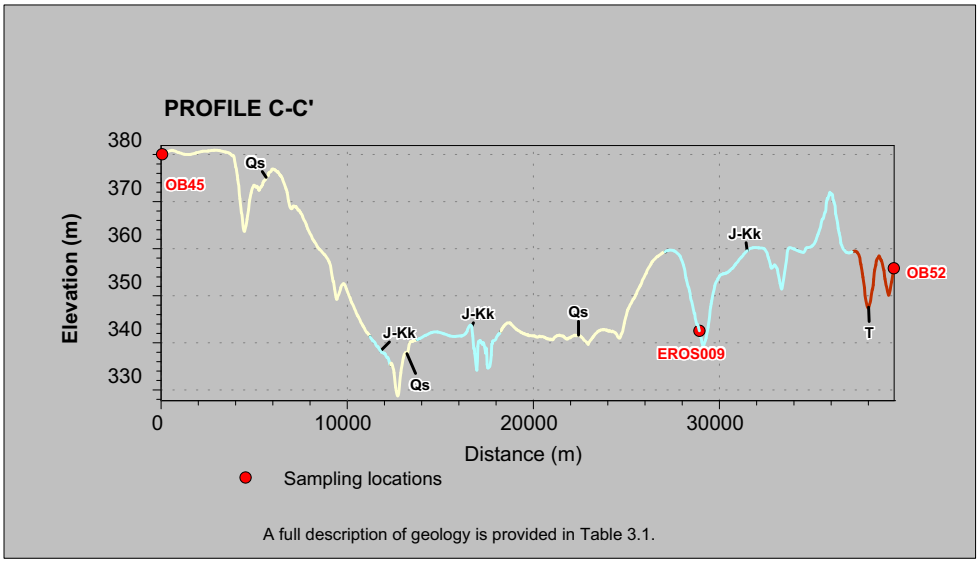
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A full description of geology is provided in Table 3.1.



A full description of geology is provided in Table 3.1.



A full description of geology is provided in Table 3.1.

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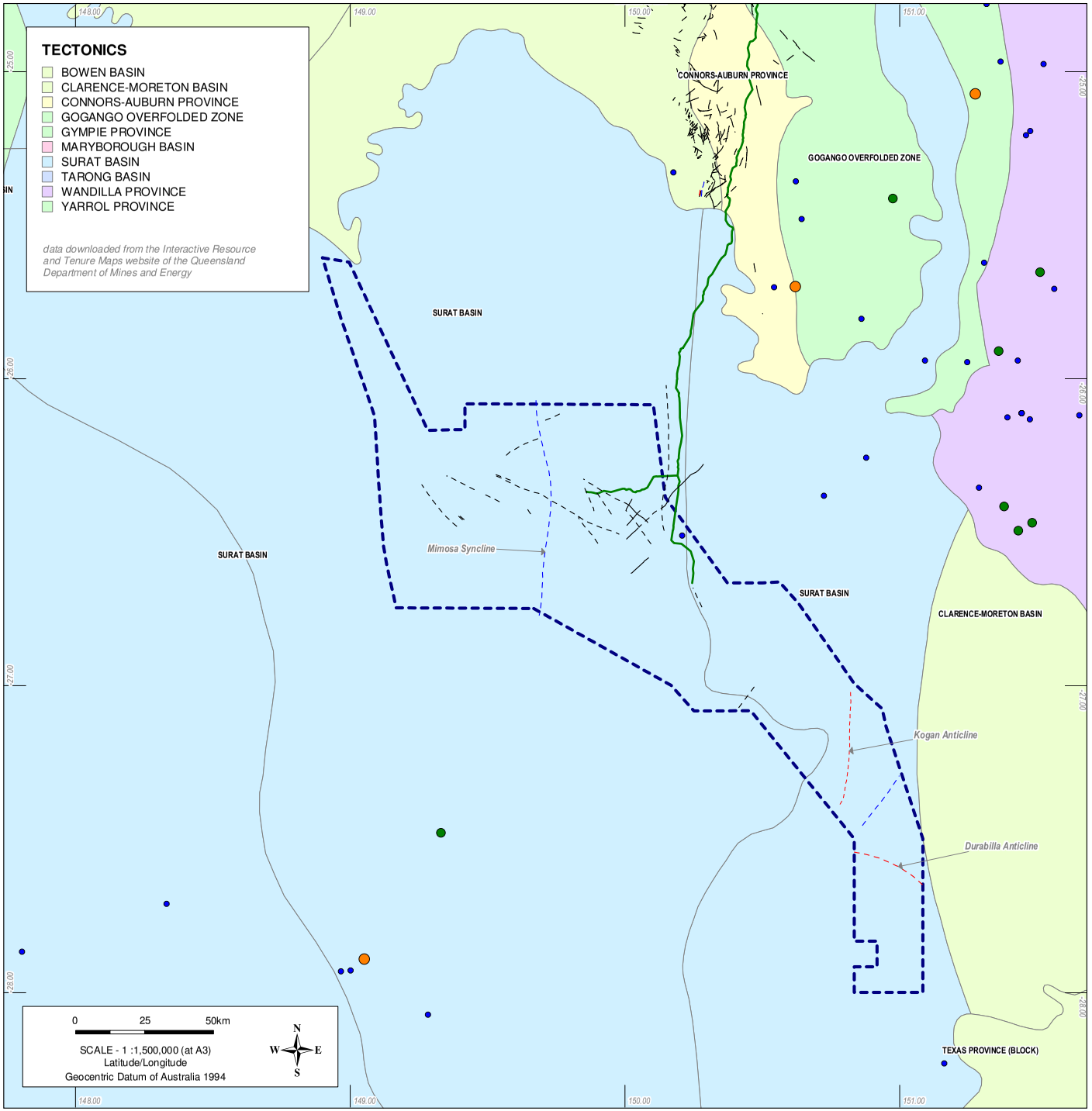
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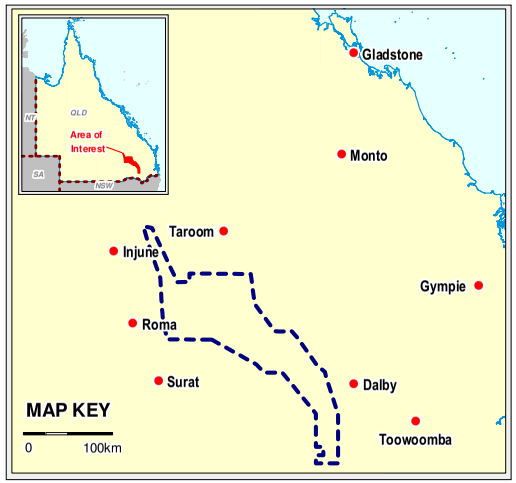
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Figure 3.2 Study Area
Geological Cross Sections

Project No: 301001-00448	Figure: 00448-00-EN-DAL-0186	Rev: 0

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LEGEND

- Earthquake magnitude > 2
- Earthquake magnitude > 3
- Earthquake magnitude > 4
- Earthquake magnitude > 5
- Preferred pipeline alignment
- Faults accurate
- Faults approximate / concealed / inferred
- Anticlines accurate
- Anticlines approximate / concealed / inferred
- Synclines accurate
- Synclines approximate / concealed / inferred
- Dykes or veins
- Gas Fields study area

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Earthquake data courtesy of the U.S. Geological Survey

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Figure 3.3 - Historical earthquakes 1958 onwards and tectonic boundaries - Gas Fields

Project No: 301001-00448	Figure: 00448-00-EN-DAL-0410	Rev: 0

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4. Existing Topography and Geomorphology

Terrain characteristics of the study area have been assessed in terms of topography (surface form and slope) and geomorphology (landform).

4.1 Desktop Topography Review

The topography across the study area is predominantly flat, with gentle undulations and rises, as well as plateaus, low sandstone hills and lateritic scarps. There are also broadly spaced minor water courses within this area (refer EIS Chapter 11 for further information on the water courses). Hills are generally in the order of 10% slope, and in some instances up to 20%.

Generalised landform information specific to each of the tenements is provided in Table 4.1, while Figure 4.1 illustrates terrain and slope of the study area. Figure 4.2 illustrates study area landform based on categories generated from the digital slope analysis (refer Figure 4.1) and landform descriptions provided in Table 5.1. These categories are as follows:

- Mountains and hills
- Dissected plateaus
- Plateaus
- Plateaus and low hills
- Low hills and rises
- Rises and undulating plains
- Level to gently undulating plains and low hills
- Level to gently undulating plains.

Figure 4.2 indicates that the predominant landforms are level to gently undulating plains and low hills.

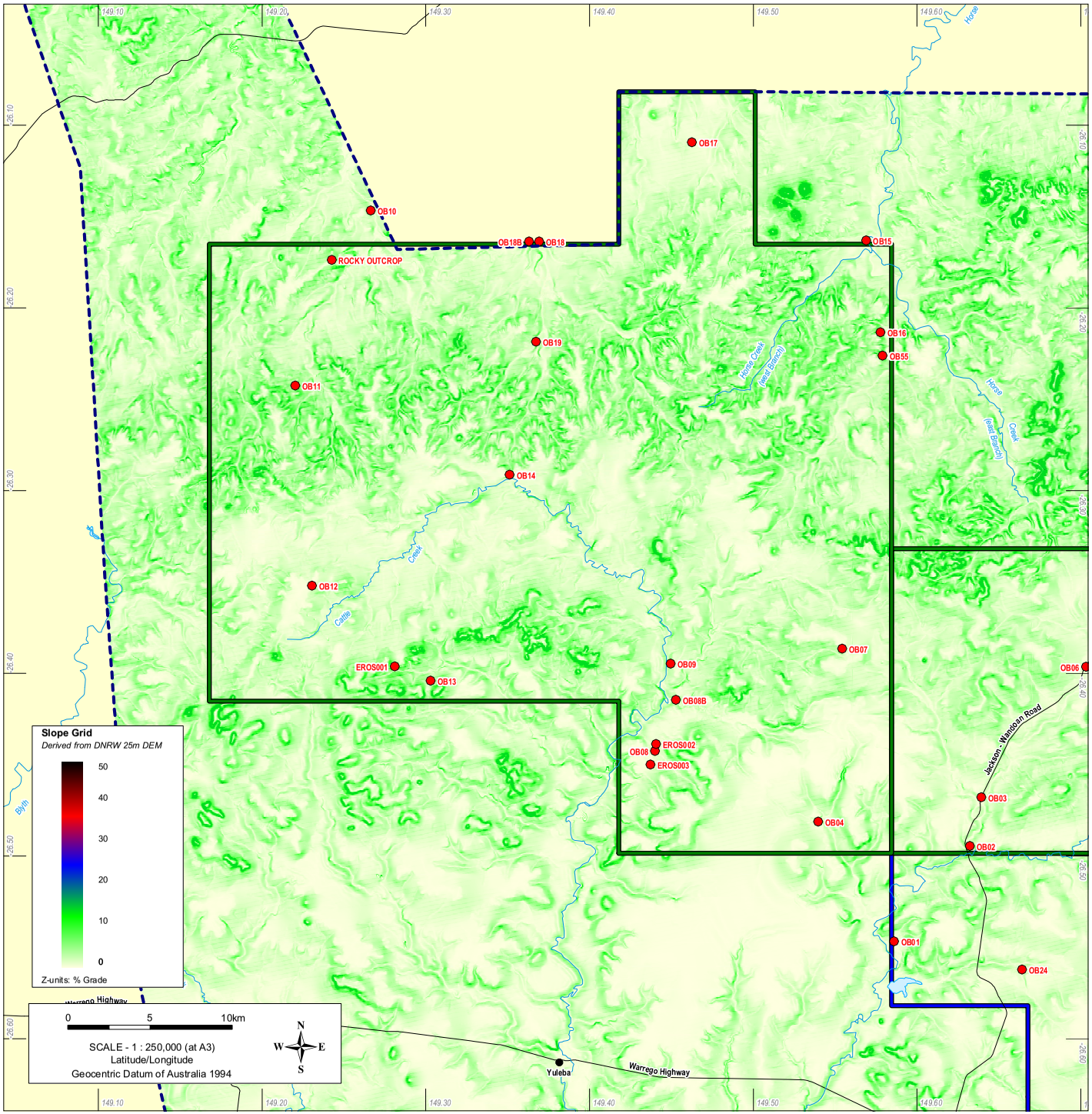
The High Pressure (HP) gas and water networks extend outside the tenements to the north-west and south-west of Combabula and between the Condabri, Talinga and Gilbert Gully tenements. This portion of the topography is also described within Table 4.1

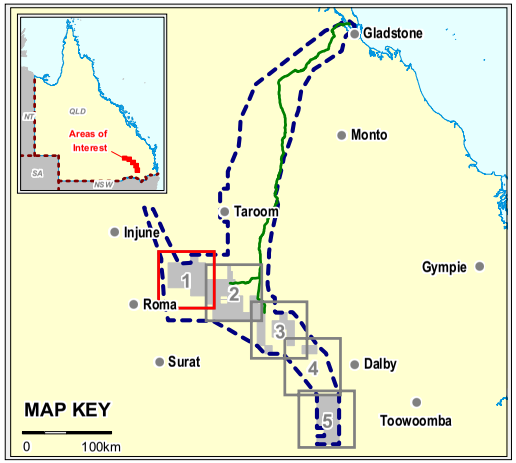
Table 4.1 Study area landform

Land Tenement (refer Figure 1.1)	Land System Project Area (source: refer Section 2.2)	Soil Grouping (refer Section 5)	Landform
Land north-west and adjacent to Combabula tenement boundary	Balonne-Maranoa (south-west portion of study area) Dawson-Fitzroy (north-west portion of study area)	1a/1b 2a/2b/2c/2d 3b 4b 5a/5b/5b(m)	This area will be traversed by a portion of the proposed HP gas and water pipeline network. The north-west portion of this area is characterised by gentle slopes, low hills and undulating plains in the west leading into fluvial plains south of Eurobah Creek. Slopes are generally less than 5%, however one area of 15% exists adjacent to and north of Roma-Taroom Road. North of this creek, hills and dissected tablelands exist. The south-west portion of this area can be generally characterised by rolling and undulating terrain with slopes up to 10% directly west of the Combabula tenement. However, this merges into lowlands predominately comprised of slopes less than 5% followed by rises and low hills adjacent to and west of Yuleba Creek up to 10% slope. Undulating lowland terrain with slopes less than 1% exists to the east of Yuleba Creek with only some fringes occurring up to 10%.
Combabula / Ramyard	Dawson-Fitzroy: (northern portion of tenement) Balonne-Maranoa: (southern portion of tenement) Murilla and Chinchilla/Tara (southeast portion of tenement)	1a/1b 2b/2c/2d 3b 4b 5a/5b/5b(m)	The Combabula / Ramyard tenement is characterised by gentle slopes, low hills and undulating plains. Lateritic scarps and sandstone hills are common throughout the tenement. A belt of undulating lateritic scarp, with slopes in the area up to 10%, is present across the north portion of the tenement. This is accentuated in the far north-east corner with slopes up to 20%. The southern portion of the tenement is comprised of broad undulating plains and lowlands with patches of low sandstone hills and lateritic scarps. Some tributary fluvial plains are present in the north-west corner and on the eastern boundary.
Woleebee	Dawson-Fitzroy	1b 2a/2b/2c 4b 5b/5b(m)	Undulating plains and flat clay plains characterise the northern portion of the Woleebee tenement while flat alluvial plains are present near Woleebee Creek. In the southern portion of this tenement, tributary fluvial plains are present, as well as plateaus, undulating plains and low sandstone hills with a slope up to 20%.Lateritic scarps are common throughout.

Land Tenement (refer Figure 1.1)	Land System Project Area (source: refer Section 2.2)	Soil Grouping (refer Section 5)	Landform
Carinya	Balonne-Maranoa: (north-west corner of tenement) Murilla and Chinchilla/Tara (throughout tenement)	1a/1b 2a/2b/2c/2d 5a/5b/5b(m)	An array of different land forms are present within the Carinya tenement, however it is predominantly uniform and level. It is comprised of undulating lowlands and rises (mainly Jurassic mudstone and siltstone), as well as some sandstone hills, plateaus and plains, most with slope less than 10% but up to 20% in some places. Flat plains and stream terraces of shale and sandstone alluvium are found at the ephemeral headwaters of Dulacca Creek and Dogwood Creek. Flat clay pans with moderately deep to deep Gilgai microrelief are found in the north-west corner of the tenement. Lateritic scarps are also present throughout.
Dalwogan	Murilla and Chinchilla/Tara	1b 2a/2b 5b(m)	Flat to gently undulating plains, plateaus and low sandstone hills characterise much of the Dalwogan tenement. Lateritic scarps are also common. Flat clay pans with moderately deep to deep gilgai microrelief (ephemeral pondage) are also found at the northern and southern extremities of the tenement.
Condabri	Murilla and Chinchilla/Tara	1a/1b 2a/2b/2c 5a/5b/5b(m)	In general, the Condabri tenement is comprised of flat to gently undulating plains derived from weathered sandstone with some rises associated with the edges of the Brigalow plains or the dissected, lateritised sandstone remnants in the northern portion of the tenement. Flat clay pans with gilgai microrelief varying from shallow to deep are found at the northern and southern ends of the tenement. Where Dogwood Creek traverses the tenement, flat to gently undulating sandy alluvial plains are present.
Study area between Condabri and Talinga	Murilla and Chinchilla/Tara	1a/1b 2a/2b/2c 5a/5b/5b(m)	This area will be traversed by a portion of the proposed HP gas and water pipeline network. The northern portion of this area is comprised of plateaus and low sandstone hills to undulating plains with slopes no greater than 2%.Just south of the Condamine River this area changes to flat to gently undulating plains with fringes of 5% slopes.
Talinga / Orana	Murilla and Chinchilla/Tara	1a/1b 2a/2c/2d 5a/5b/5b(m)	The Talinga / Orana tenement is comprised largely of flat to gently undulating clay pans with shallow to deep Gilgai, as well as plateaus and low sandstone hills to undulating plains. Lateritic scarps are also common throughout. Terraces, channels and associated alluvial plains are found where the Condamine River passes through the tenement and flat to gently undulating sandy alluvial plains are

Land Tenement (refer Figure 1.1)	Land System Project Area (source: refer Section 2.2)	Soil Grouping (refer Section 5)	Landform
			present where Charleys Creek and Wambo Creek join the Condamine River. Slopes throughout these landforms are up to 10%.
`Kainama	Murilla and Chinchilla/Tara	1a/1b 2a/2b/2d 5b	Flat to gently undulating plains, some of weathered sandstone are present throughout the tenement, as well as plateaus and low sandstone hills. The majority of slopes throughout the tenement are less than 10%. Several areas of flat to gently undulating sandy alluvial plains enter the north portion of the tenement with ephemeral headwaters of a tributary to the Condamine River.
Study area between Talinga, Kainama and Gilbert Gully	Central Darling Downs Murilla and Chinchilla/Tara	1a/1b 2a/2b/2c/2d 4b 5b	This area will be traversed by a portion of the proposed HP gas and water pipeline network. The terrain south-west of the Kainama tenement and along Wambo Creek is comprised of flat to gently undulating plains with slopes less than 1%.Further south-west of this area, plateaus and low sandstone hills to undulating plains exist. Slopes here are generally less than 5%. Adjacent to and south of Kainama tenement, gently undulating to flat plains (slopes less than 1%) exist. Further south again plateaus and low sandstone hills with slopes ranging from less than 1% up to 15% (at lateritic scarps) exist. The HP networks traverse closer to the Kainama tenement in order to avoid these steeper slopes in the south. To the north of the Gilbert Gully and the southeast of Kainama tenements there are gently undulating plains with rises and some laterised sandstone. Slopes are generally less than 1%, but some isolated areas occur up to 3%.
Gilbert Gully	Central Darling Downs Murilla and Chinchilla/Tara	1b 2a/2b/2c/2d 4b 5b	On the east portion of the tenement, plateaus, low sandstone hills, undulating plains and lateritic scarps are common with slope grade up to 20% in parts. Similar topography is less prevalent throughout the west portion, with flat to undulating plains and rises being more common. Slopes are generally up to 10%. Flat to gently undulating sandy alluvial plains are present where Weir River and Paddy Creek traverse the tenement.





LEGEND

- Observation Locations
- Towns
- Road
- Preferred pipeline alignment
- Major Drainage
- Reservoir
- Study Area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

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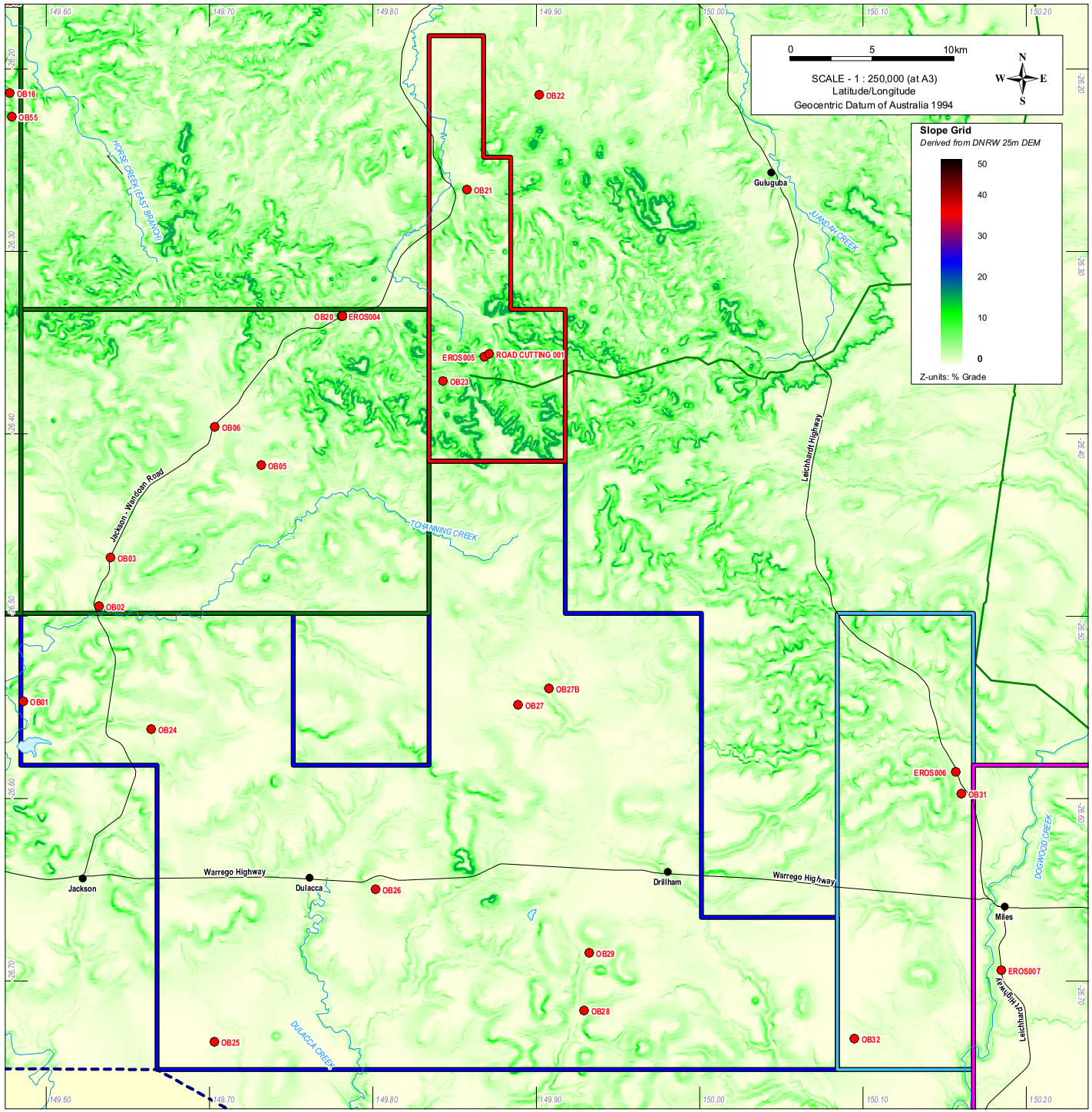
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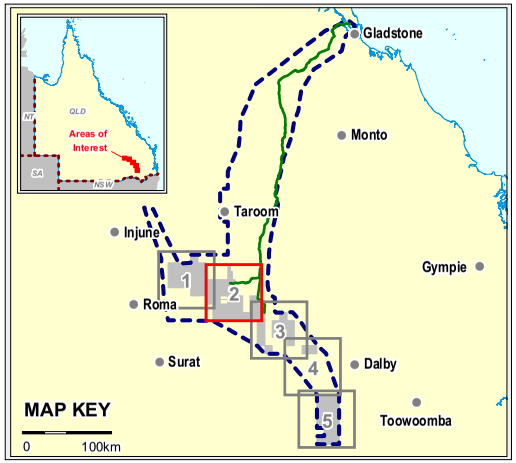
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Figure 4.1 Study Area Digital Slope Analysis
Map 1 of 5

Project No: 301001-00448	Figure: 00448-00-EN-DAL-0215	Rev: 0

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LEGEND

- Observation Locations
- Towns
- Road
- Preferred pipeline alignment
- Major Drainage
- Reservoir
- Study Area

Walloons Gas Fields Development Areas

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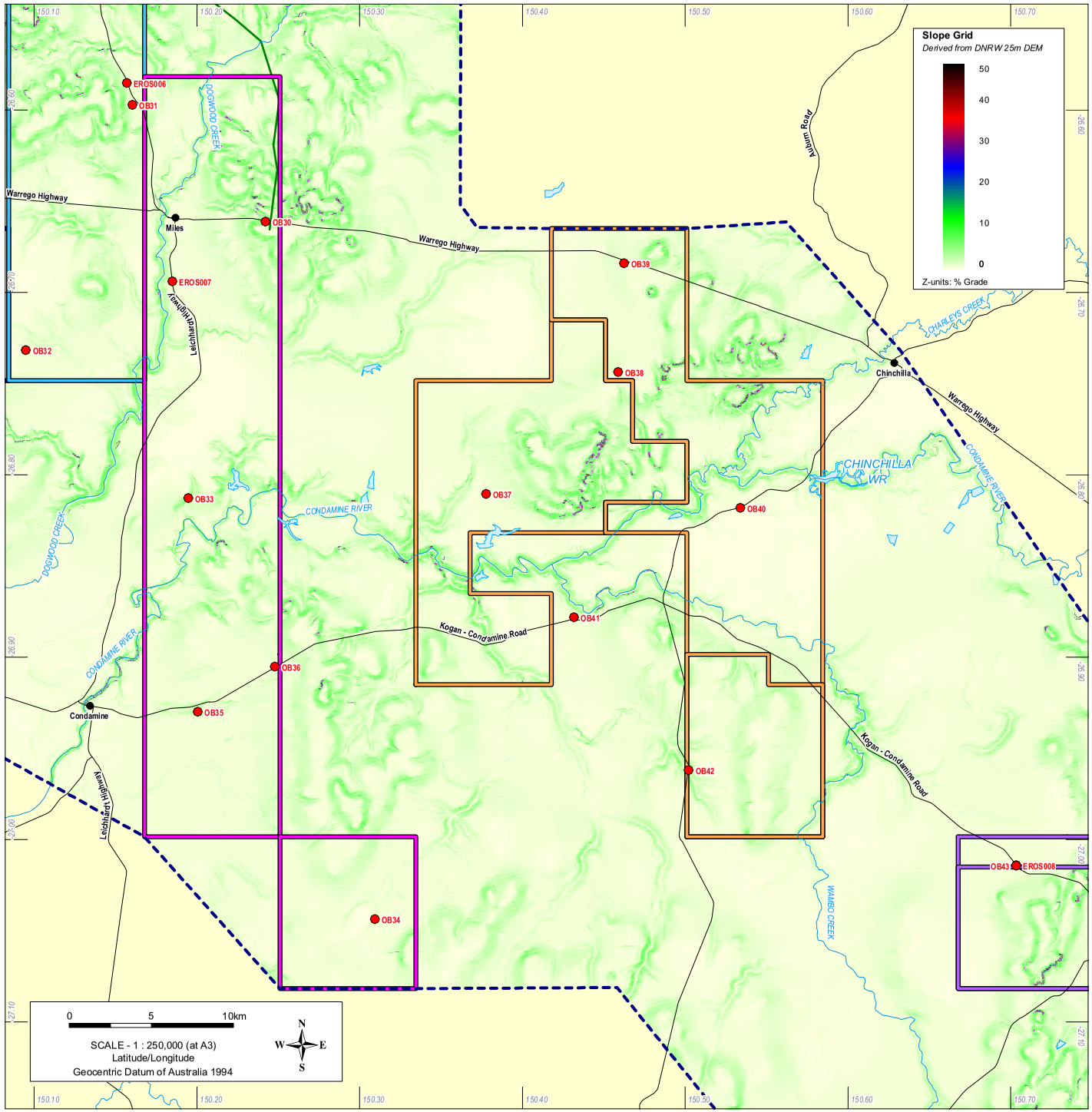
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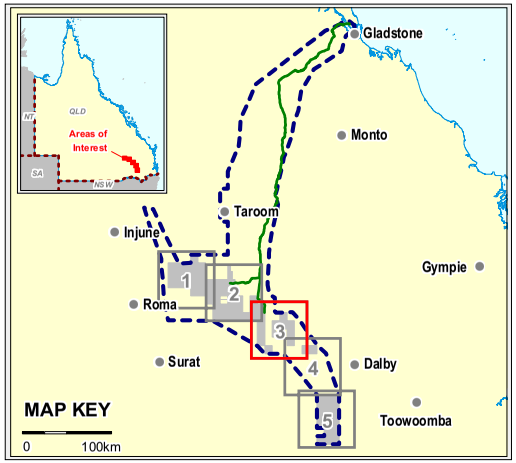
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Figure 4.1 Study Area Digital Slope Analysis Map 2 of 5

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LEGEND

- Observation Locations
- Towns
- Road
- Preferred pipeline alignment
- Major Drainage
- Reservoir
- Study Area

Walloons Gas Fields Development Areas

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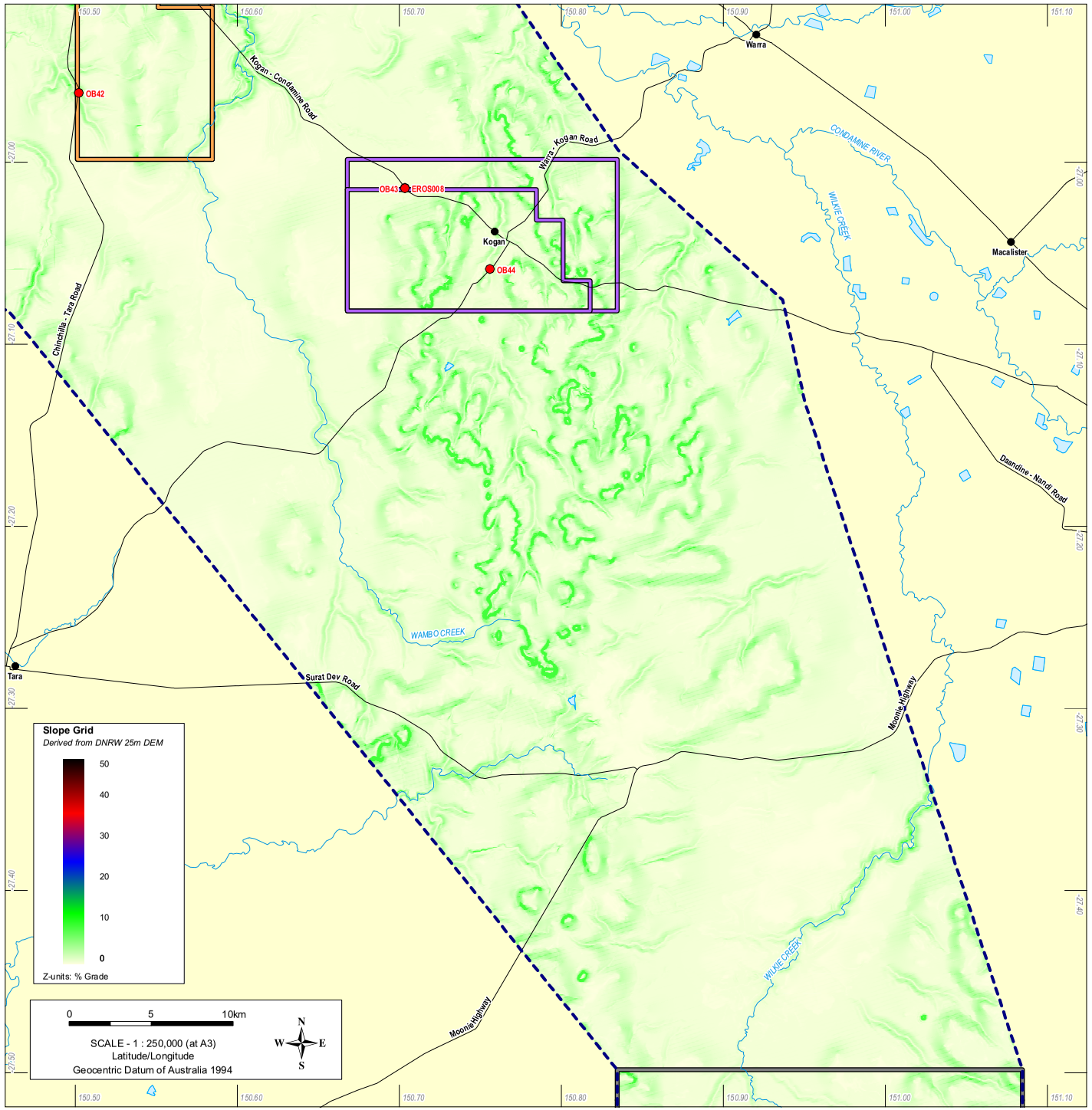
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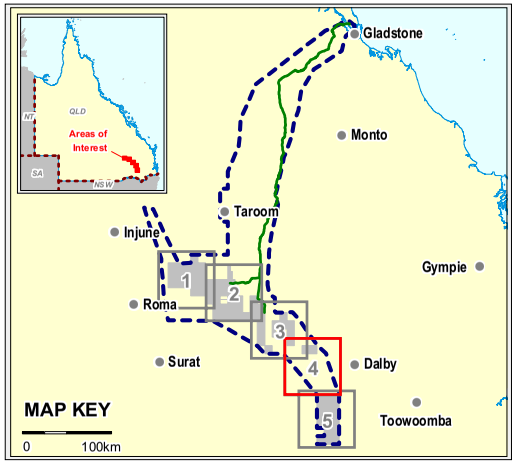
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Figure 4.1 Study Area Digital Slope Analysis
Map 3 of 5

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LEGEND

- Observation Locations
- Towns
- Road
- Preferred pipeline alignment
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- Reservoir
- Study Area

Walloons Gas Fields Development Areas

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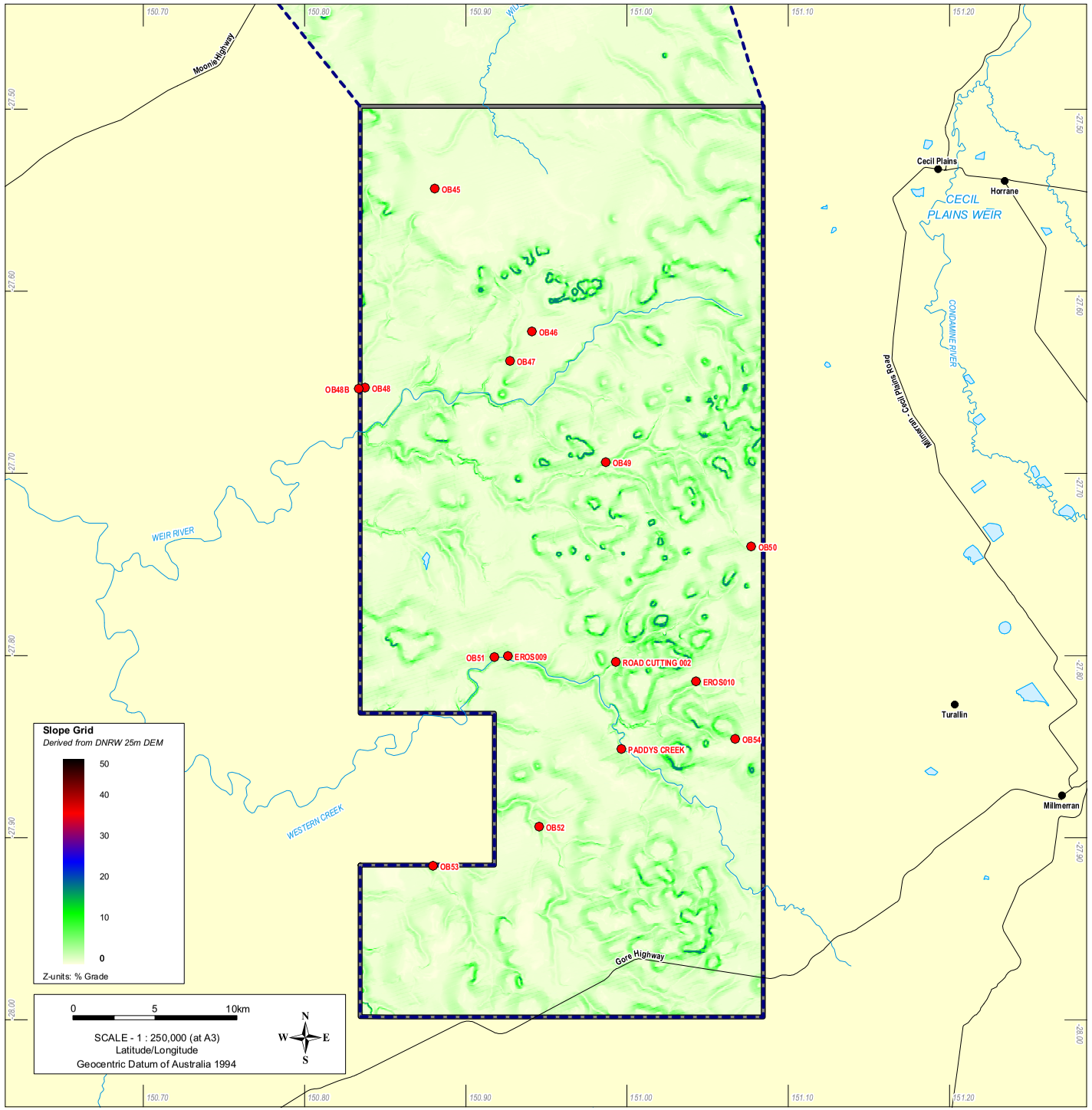
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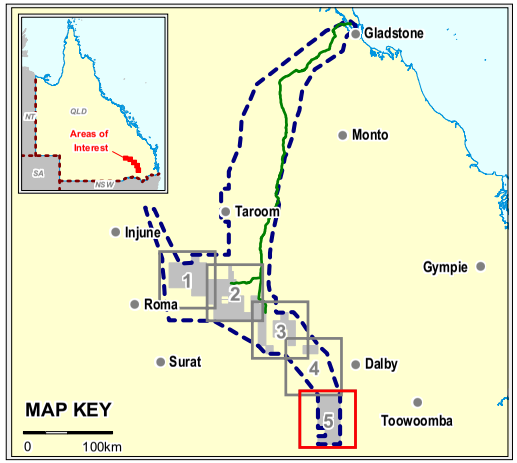
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Figure 4.1 Study Area Digital Slope Analysis
Map 4 of 5

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LEGEND

- Observation Locations
- Towns
- Road
- Preferred pipeline alignment
- Major Drainage
- Reservoir
- Study Area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

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Figure 4.1 Study Area Digital Slope Analysis
Map 5 of 5

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4.2 Field topography assessment

This section describes topography and landform according to observations made during the fieldwork assessment undertaken from 24-31 August 2009. Terrain assessments were made in conjunction with the soils investigation (refer Section 5) at 58 locations observed within the study area (refer Figure 1.1). At each location, topography was classified according to the specific location, terrain and slope.

Terrain was broadly classified using the following descriptions:

- Low: The terrain is flat to gently undulating with slopes generally less than 10%. This unit generally has broadly spaced, mostly shallow, incised drainage channels or gullies.
- Medium: The terrain is dissected land with local relief up to about 50m between crests and adjacent valleys, with surface slopes typically in the range of 11-32%.
- High: The terrain is dissected and/or hilly lands. The local relief is in the range 50m to150m between ridge and spur crests and adjacent valley or gully floors, with steep valley side slopes up to 32% or greater.

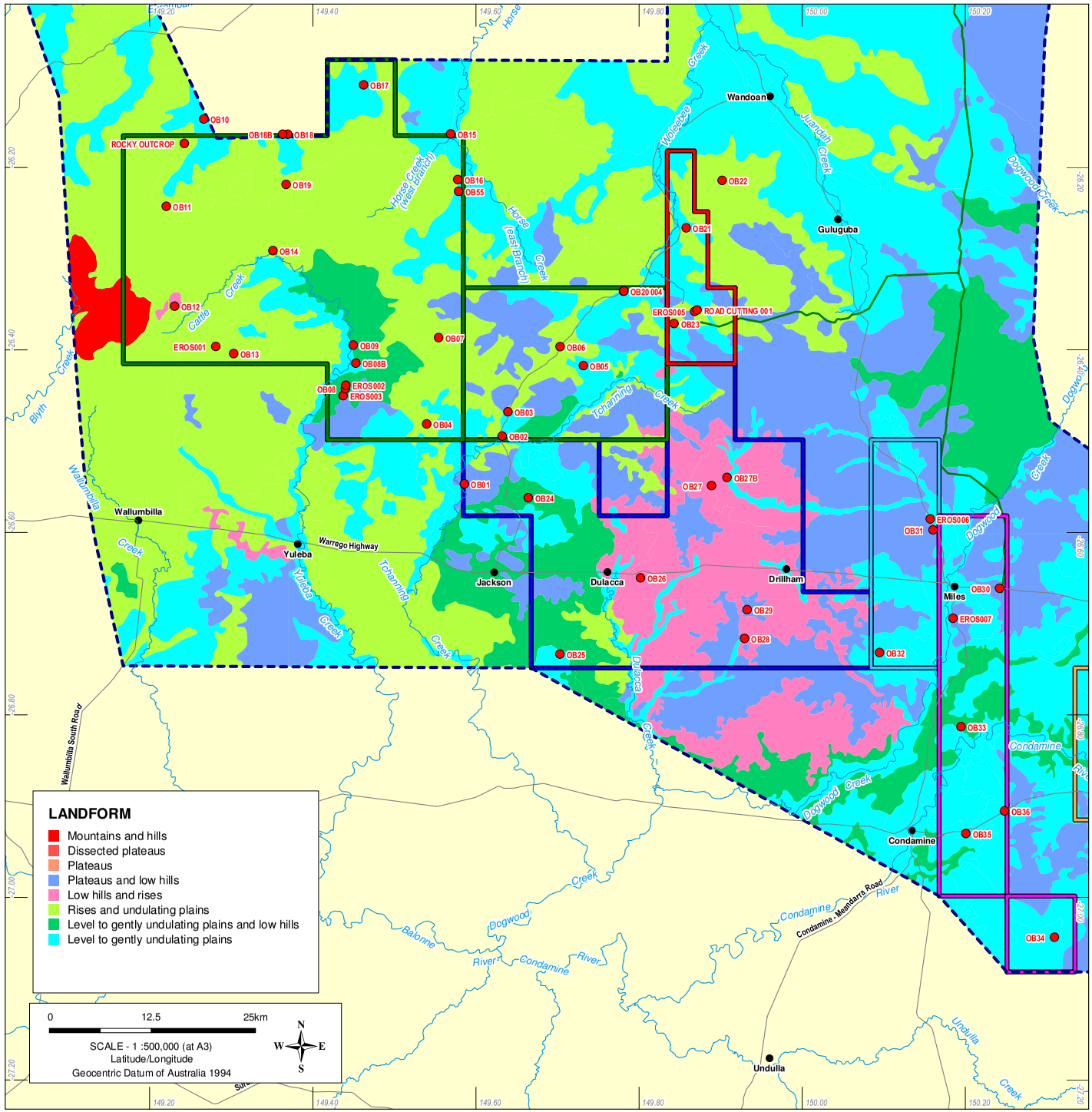
Predominant slopes were classified as follows:

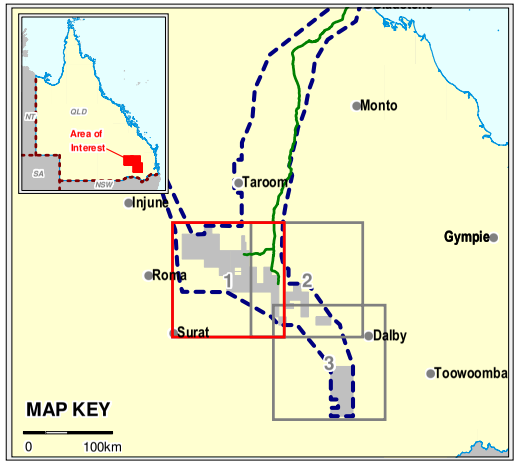
- Flat: <2 %
- Gentle: 2-5%
- Low slope: 5-10%
- Moderate slope: 10-25%
- Steep slope: 25-50%
- Very steep: >50%.

In summary the observed topography and geomorphology were generally consistent with the desk-top assessment. Table 4.2 describes the terrain and predominant slope classifications as noted during fieldwork at each borehole location.

Table 4.2 Field terrain and slope analysis

Observation Location	Terrain	Predominant slope
OB01, OB02, OB03, OB04, OB05, OB06, OB07, OB08, OB08B, OB12, OB15, OB17, OB18, OB24, OB25, OB26, OB27, OB31, OB32, OB34, OB35, OB36, OB37, OB38, OB39, OB41, OB42, OB43, OB44, OB45, OB46, OB47, OB49, OB50, OB51, OB52, OB54, OB55	Low	Flat
OB09, OB13, OB14, OB22, OB23, OB28,	Low	Gentle
OB11	Low	Low
OB10, OB20, OB27B, OB29, OB30, OB48, OB48B, OB53,	Medium	Gentle
OB18B	Medium	Low
OB16	High	Low





LEGEND

- Observation location
- Town
- Road
- Preferred pipeline alignment
- Major drainage
- Study area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

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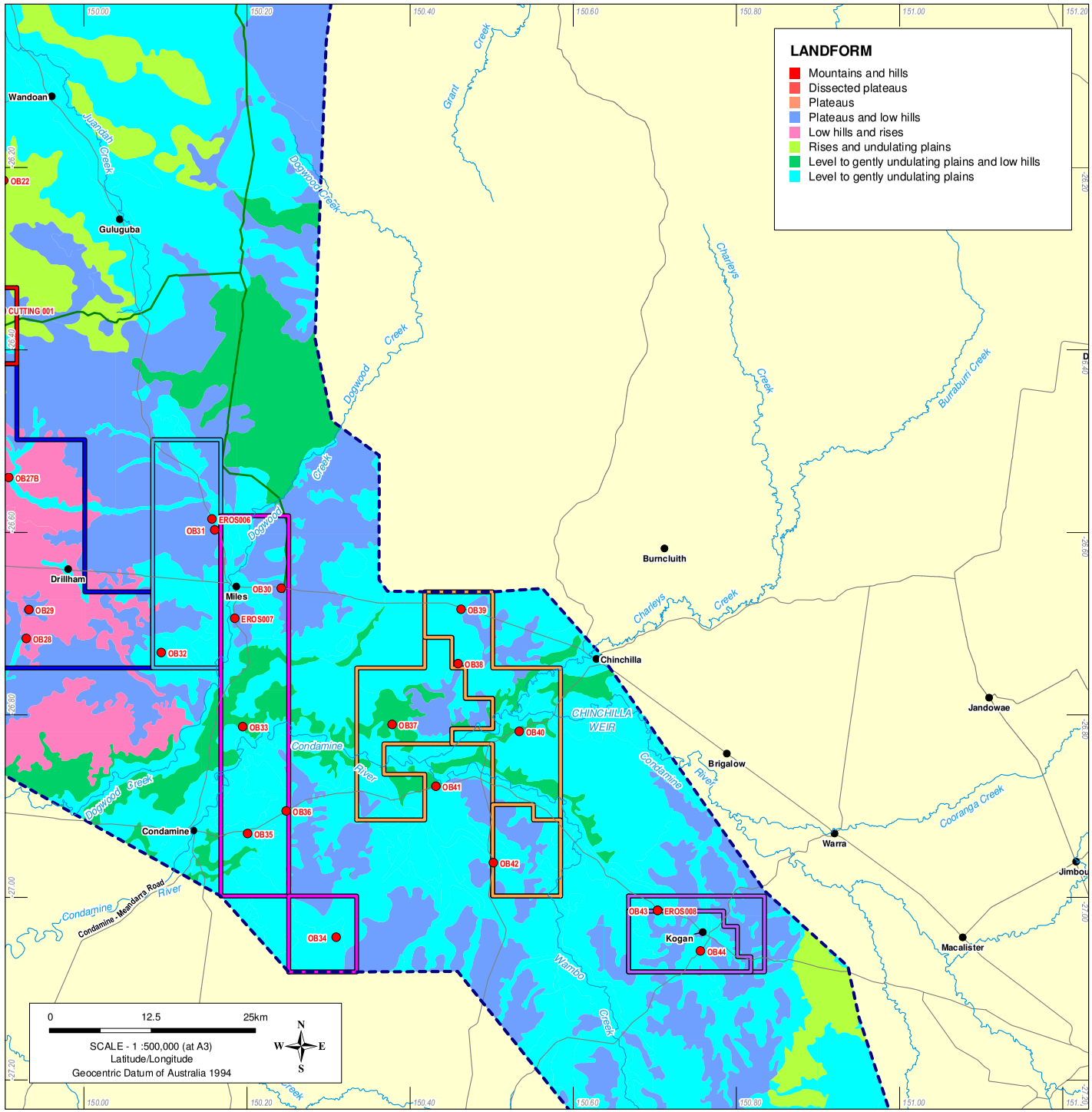
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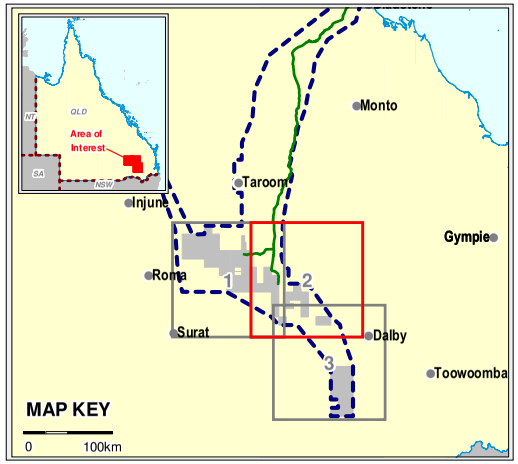
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Figure 4.2 Study Area Landform
Map 1 of 3

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LEGEND

- Observation location
- Town
- Road
- Preferred pipeline alignment
- Major drainage
- Study area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
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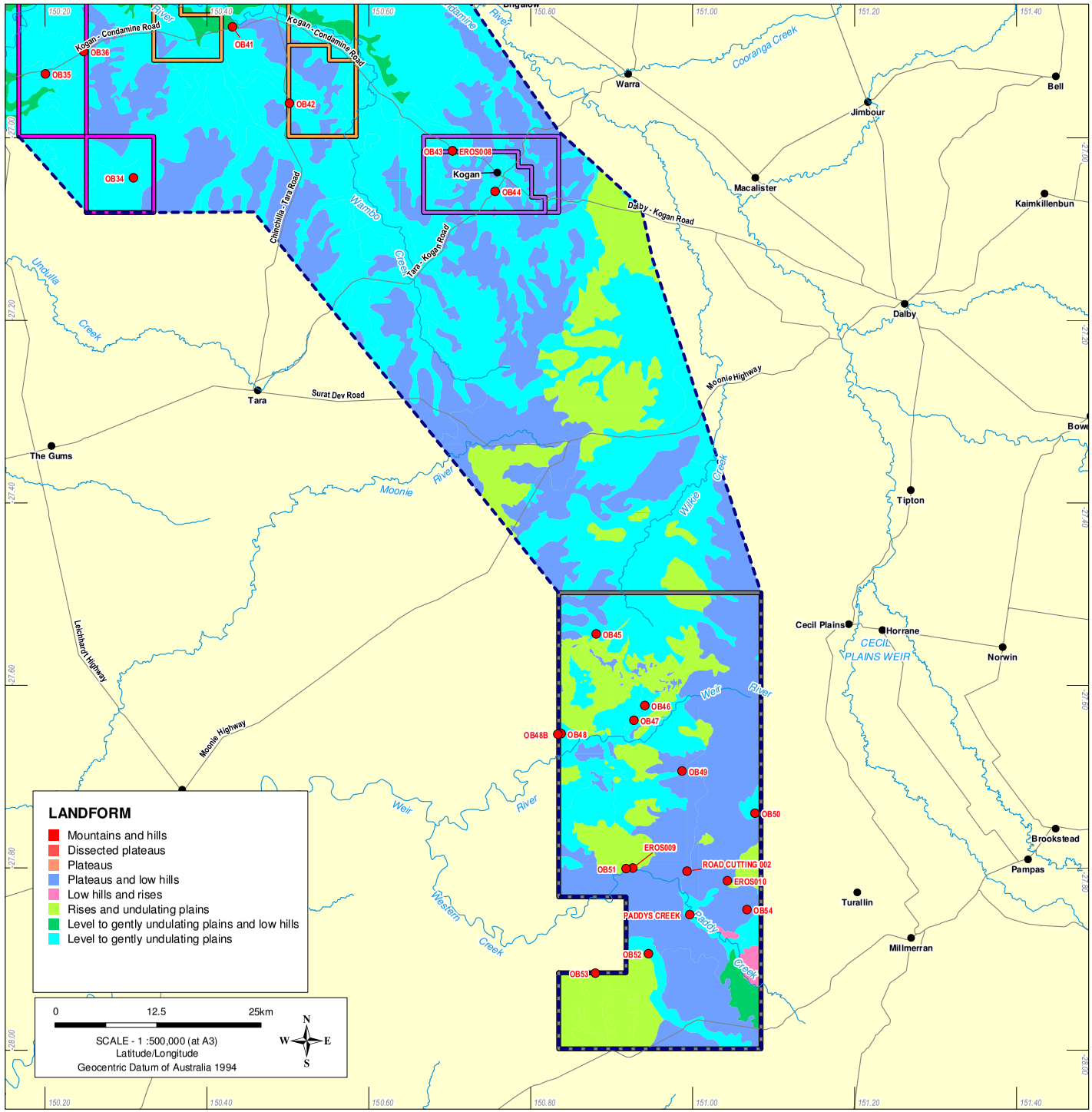
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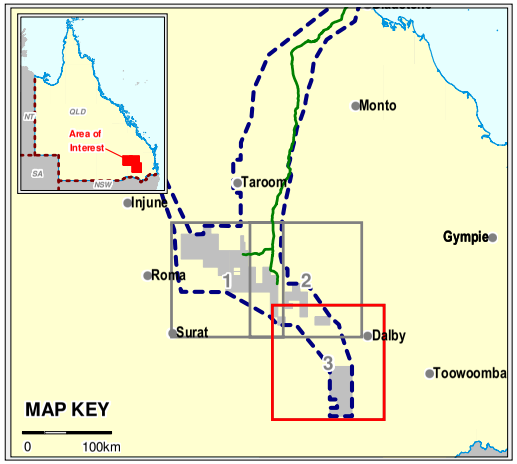
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Figure 4.2 Study Area Landform
Map 2 of 3

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LEGEND

- Observation location
- Town
- Road
- Preferred pipeline alignment
- Major drainage
- Study area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
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Figure 4.2 Study Area Landform
Map 3 of 3

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5. Existing soils

5.1 Soil desktop assessment

5.1.1 Soil types and occurrence

The study area occurs across six land system mapping areas (as mapped in DPI, DNR, CSIRO and DNRM reports) as described in Section 2.2. Table 5.1 presents a summary of the land systems present within the study area. This table indicates the associated landform character, most common soil types, and typical native vegetation characteristics (where intact). This table also indicates the 'good quality agricultural land' classification for each land system. This aspect is further assessed in Section 5.3 and within EIS, Volume 2, Chapter 6 - Land Use and Planning. The soils classification refers to the soil types in Figure 5.1 and Table 5.2.

For the purposes of this report, the soil types / soil mapping units described within each of the land system reports that cover the study area (refer Table 5.1) have been assessed and grouped to enable a common description of soil characteristics and management issues of relevance to the Australia Pacific LNG Project. This standardised soil key for the study area is presented in Table 5.2, while Figure 5.1 illustrates the combined soil groups according to this standardised soil key. Mapped soil groups were correlated against soil types encountered during the field assessment to refine soil mapping and provide background data on soil constraints (refer Section 5.2.1).

Table 5.1 Study area land systems

Map code	Land system	Landform	Geology	Soils*	Vegetation	GQAL Classification (Based on SPP1/92 Guidelines)
Land systems – Dawson - Fitzroy Area, Queensland Australia, 1:500,000 (CSIRO 1968)						
W	Wandoan	Undulating plains	Erosional upper slopes and depositional lower slopes	Cracking clays, and dark brown and grey-brown clays (5b/4b)	Brigalow and softwood scrubs	A
K	Kiddell	Undulating plains	Extensive depositional lower slopes	Cracking clays, and dark brown and grey-brown clays (5b/4b)	Brigalow scrub with scrub grass and blue grass grasslands	
E	Eurombah	Undulating plains	Mesozoic shale, locally capped with Tertiary basalt	Moderately deep to deep cracking clays, and dark brown and grey-brown clays (5b/4b)	Softwood and Brigalow scrubs	
O	Oakleigh	Low hills and undulating plains	Subhorizontal Cretaceous sandstone -	Dark brown and grey-brown clays, cracking clays and texture-contrast soils (5b/2c)	Softwood and Brigalow scrubs, and high forest	B
J	Juandah	Mainly stable plains	Deposits derived from less weathered rocks -	Deep texture-contrast soils (2a)	Grassy woodland, eastern mid-height grass	
Ci	Conloi	Undulating plains	Weathered, subhorizontal sandstone	Shallow to moderately deep texture-contrast soils (2b)	High forests and grassy woodlands, forest grass and eastern mid-height	C

Map code	Land system	Landform	Geology	Soils*	Vegetation	GQAL Classification (Based on SPP1/92 Guidelines)
					grass	
We	Woleebee	Tributary fluvial plains	Erosional slopes on Mesozoic shale and sandstone	Texture-contrast soils (2b/3c)	Grassy woodland, eastern mid-height grass and three-awn grass	
Y	Yebna	Hills	Flat-lying Mesozoic sandstone -	Deep texture-contrast soils and very shallow undifferentiated soils (2b/1b)	High forests and grassy woodlands, and eastern mid-height grass	D
Du	Duaringa	Closely dissected low tablelands	Lateritised Tertiary sedimentary rocks	Red earths and texture-contrast soils (3a/2b)	Shrub woodlands, three-awn Grass	
Mo	Montana	Tributary fluvial plains	Extensive erosional slopes on flat-bedded Mesozoic shale and sandstone -	Shallow to moderately deep texture-contrast soils (2b/2d)	Grassy woodland, eastern mid-height grass	
Land systems – Balonne-Maranoa Area, Queensland Australia, 1:500,000 (CSIRO 1974)						
4	Fresh or little - weathered labile sediments (ShSw)	Hills and escarpments	-	Brown and grey-brown soils (4b)	Softwood scrub	A
3	Fresh or little - weathered quartz and quartzose sandstone (QrCp)	Flat to gently undulating plains and low hills	Weathered subhorizontal sandstone. Lateritic scarps are common -	Uniform sandy soils and duplex soils with thick sandy surface horizons (2b)	Open forest of bull oak, bull oak and cypress pine, or bull oak and narrow-leaved ironbark, partly cleared or narrow-leaved	B

Map code	Land system	Landform	Geology	Soils*	Vegetation	GQAL Classification (Based on SPP1/92 Guidelines)
					ironbark, spotted gum and rusty gum open forest.	
11	Resistant weathered sediments [(S)rNi]	Rises and low hills	-	Shallow stoney massive earths (3a)	Narrow-leaved ironbark woodland with shrub	C
16	Moderately resistant weathered sediments [(S)uX]	Undulating lowlands	-	Massive earths and duplex soils (3b)	Poplar box woodland usually with few shrubs	C
18	Moderately resistant weathered sediments [(S)uBu]	Undulating lowlands	-	Duplex soils (2d)	Bull oak and poplar box woodland	C
20	Unresistant weathered sediments [(S)uXB]	Low hills and undulating plains	Subhorizontal Cretaceous sandstone and hills and dissected tablelands on flat lying Jurassic rocks	Duplex soils and cracking clays with some Gilgai (2c/5b)	Poplar box and Brigalow woodland or Belah open forest	C
21	Unresistant weathered sediments [(S)uBl]	Low hills and undulating plains	Subhorizontal Cretaceous sandstone and hills and dissected tablelands on flat lying Jurassic rocks	Duplex soils and cracking clays with some Gilgai (2c/5b)	Poplar box and Brigalow woodland or Belah open forest	C
30	Alluvial sands, silts and mixed fine sediments (AX)	Flat to gently undulating	Sandy alluvial plains	Duplex soils (2a)	On the sandier soils cypress pine, tumbledown gum and rough barked apple predominate, with	C

Map code	Land system	Landform	Geology	Soils*	Vegetation	GQAL Classification (Based on SPP1/92 Guidelines)
					poplar box and Belah or bull oak woodland on the heavier soils	
19	Unresistant weathered sediments [(S)hY]	Plateaus and low sandstone hills to undulating plains, lateritic scarps are common	-	Skeletal and brown and grey-brown soils (1b)	Layered open forest of ironbarks and wattles	D
Land Resource Areas – Murilla, Tara and Chinchilla Shires, 1:250,000, (DPI 1995a and 1995b)						
1a	Clay alluvial plains	Older, elevated alluvial plains	-	Black and grey cracking clays and bleached sands over brown or black clays (5a/1a)	Poplar box open-grassland	A
1b	Clay alluvial plains	River terrace, channels and associated alluvial plains subject to periodic flooding	-	Black and grey cracking clays and bleached sands over brown or black clays (5a/1a)	Coolabah, river red gum open forest and woodland fringe on drainage lines, Poplar box grassy woodland on the plains	
4a	Brigalow plains	Flat to gently undulating clay plains with very shallow to moderately deep gilgai	-	Grey or black cracking clays (5b)	Extensively cleared Brigalow, belah, Wilga forest	
4b	Brigalow plains	Flat clay plains with	-	Grey cracking plains	Extensively cleared	

Map code	Land system	Landform	Geology	Soils*	Vegetation	GQAL Classification (Based on SPP1/92 Guidelines)
		moderately deep to deep gilgai		(5b/5b(m))	Brigalow, Belah, Wilga forest	
5a	Brigalow rises	Gently undulating rises and plains	Sandstone and shale	Brown or grey, occasionally black, cracking clays (5b)	Extensively cleared Brigalow, Belah, Wilga forest	
5b	Brigalow rises	Undulating rises	-	Brown or grey, occasionally black, cracking clays (5b)	Extensively cleared Brigalow, Belah, Wilga forest	
5c	Brigalow rises	Undulating to steep, low	Sandstone hills and rises	Red non-cracking clays and grey or black cracking clays (4b/5b)	Softwood scrub and Brigalow forest, partly cleared	
2a	Poplar box flat plains	Flat plains or stream terraces	Shale and sandstone alluvium	Bleached clay loams or sands over black or grey clays (1a/2a)	Poplar box shrubby woodland to open forest, or poplar box and false sandalwood shrubby woodland	B
3a	Cypress pine sands	Flat to gently undulating	Sandy alluvial plains	Deeps sands, deep bleached sands over mottled, yellow or grey clay and bleached clay loams over black or grey clays (2a)	Cypress pine, tumbledown gum, rough-barked apple on sandy soils, with poplar box or bull oak on heavier soils	C

Map code	Land system	Landform	Geology	Soils*	Vegetation	GQAL Classification (Based on SPP1/92 Guidelines)
3b3b	Cypress pine sands	Flat sand plains raised above the level of surrounding clays	-	Deep sands and deep bleached sands over mottled, yellow or grey clays (2d)	Cypress pine, tumbledown gum on deep sands, poplar box, cypress pine or tumbledown gum on texture contrast soils	
7a	Ironbark / bull oak forest	Flat to gently undulating plains	Weathered sandstone	Bleached sands over mottled, yellowish brown or brown and red clays (2b)	Bull oak, cypress pine, and narrow-leaved ironbark open forest	
7c	Ironbark / bull oak forest	Dissected, undulating sandstone rises with low hills	Sandstone rises with low hills	Bleached sands over mottled, yellowish brown or brown and red clays (2b)	Ironbark, cypress pine, wattle and rusty gum layered open forest	
8a	Poplar box rises	Gently undulating plains to rises associated with the edges of Brigalow plains or the dissected, lateritised sandstone remnants – includes some local creek alluvia	Dissected, lateritised sandstone remnants – includes some local creek alluvia	Bleached loams or sands over brown, black or red clays, or mottled yellowish-brown clays (2c)	Poplar box, false sandalwood shrubby woodland	
8b	Poplar box rises	Gently undulating plains to undulating rises on	Sandstone	Bleached loams or sands over brown or mottled,	Poplar box, false sandalwood and myall	

Map code	Land system	Landform	Geology	Soils*	Vegetation	GQAL Classification (Based on SPP1/92 Guidelines)
		sandstone		grey and brown clays (2c)	layered forest and shrubby woodland	
9a	Light forests	Undulating plains and rises, often lateritised	-	Very shallow, gravely, red soils, bleached sands over mottled, yellowish brown clays, and shallow or deep sands or loams grading to red loams or clays (2b)	Ironbark and wattle layered open forest	
9b	Light forests	Plateaus and low sandstone hills to undulating plains, lateritic scarps are common	Sandstone hills	Very shallow, gravely, red soils and shallow, gravely texture contrast soils (1b/2b)	Ironbark, spotted gum, rusty gum and cypress pine open forest	
10a	Granite hills	Undulating to steep granite hills	Granite hills	Sands over yellow, brown or red clays (1c/2b)	Ironbark and Queensland blue gum woodland, extensively cleared	D
Roma District Land Management Field Manual, 1:500,000 (DNRM1987)						
1	Rolling downs – open downs	Rolling downs and gently undulating plains with slope 1-3%	Fresh and slightly weathered siltstones, mudstone and labile sandstone	Uniform, fine textured cracking clays, with some poorly developed linear gilgai. Some quartz cobbles may be present (5b)	Mitchell grass, Queensland blue grass, white spear grass open grassland	A

Map code	Land system	Landform	Geology	Soils*	Vegetation	GQAL Classification (Based on SPP1/92 Guidelines)
22	Undulating plains – Brigalow uplands	Undulating plains (2-3%) and short footslopes (to 8%) associated with low hills and ridges	Weathered sandstones and shale	Cracking and non-cracking grey, brown and red clays; minor red brown earth and other texture contrasts (5b/4b)	Brigalow open forest in association with Belah or poplar box bauhinia	
4	Undulating plains – Coogoon	Gently undulating plains (1-2%) and short slopes to 5% associated with ridges and crests	Weathered quartzose, sandstones and ferruginised sediments	Red and red-brown earths – solodic intergrades. Some skeletal soils, texture contrast and massive earths occur (2b/3a)	Poplar box, silver-leaved ironbark grassy open woodland. Scattered belah, Brigalow and Moreton Bay ash may also occur	B
8	Flat alluvial plains and levees – Maranoa	Plains to 1%) and some sandy leaves	Predominantly sandy alluvia	Sand texture contrast soils and deep sands (2a/1a)	Silver-leaved ironbark, poplar box and belah open forest to open woodland	C
9	Dissected residuals – Yuleba	Moderately steep plains to 5%, low hills and scarps	Quartzose sandstones, lithic sandstones, minor mudstones	Skeletal soils and shallow stony texture contrast soils; minor areas of grey and brown cracking and non-cracking clays (1b/2b)	Poplar box, bulloak, cypress pine and yapunyah open-forest	D
1111	Dissected residuals – Straun	Moderately sloping plains to 4%, low hills and	Quartzose and lithic sandstones	Shallow to moderately steep, hard setting	Poplar box, ironbark and mulga open forest and	

Map code	Land system	Landform	Geology	Soils*	Vegetation	GQAL Classification (Based on SPP1/92 Guidelines)
		scarps		massive red earths and skeletal soils (3a/1b)	woodlands	
1212	Dissected residuals – Merivale	Undulating valley floors (1-5%) and rolling to steep dissected hills and scarps	Slightly weathered mudstones, silt-stones and quartzose sandstones	Stony skeletal soils, texture contrast soils and sands. Minor areas of grey and brown cracking clays (1b/2b)	Stringybark, narrow-leaved ironbark, silver-leaved Ironbark, cypress pine, bloodwood and spotted gum layered woodland and open forest	
Land Resource - Central Darling Downs, 1:250,000 (DNR, 1998)						
6d	Brigalow uplands	Gently undulating to undulating rises and plains on fine grained sediments and clay sheets	Walloon coal measures	Grey and brown cracking clays with grey-brown loams over brown clays (5b/4b)	Brigalow, belah, open forest with box or poplar box open woodland	A
9a	Poplar box Sodosols	Gently undulating plains on sandstone	Marburg subgroup	Bleached sands and loams over brown and grey clays (2b)	Poplar box and gum-topped box open-woodland	B
10a	Ironbark / Bull Oak sodosols	Gently undulating plains on sandstone	Quaternary sands	Bleached sands to loams over mottled, grey or yellow grey clays (2b/2c)	Narrow-leaved ironbark, bull oak, cypress pine, rusty gum and poplar box open forest	C
11a	Cypress pine stands	Flat to gently undulating	Quaternary sands	Deep sands and deep	Cypress pine, rough-	

Map code	Land system	Landform	Geology	Soils*	Vegetation	GQAL Classification (Based on SPP1/92 Guidelines)
		sandy alluvial plains		bleached sands over mottled, yellow or grey clays (2a)	barked apple, blue gum, rusty gum open forest	
12a	Sandstone forests	Rises and undulating plains on sandstone, often lateritised	Kumbarilla beds	Bleached sands to loams over mottled, grey or yellow grey clays (2b/2c)	Narrow-leaved ironbark, bull oak, cypress pine, rusty gum and poplar box open forest	
12b	Sandstone forests	Plateaus and low sandstone hills to undulating plains; lateritic scarps are common	Kumbarilla beds	Shallow, gravely sands to loams, deep sands or bleached sands over mottled, grey or yellow clays (2b)	Narrow-leaved ironbark, spotted gum and rusty gum open forest, or cypress pine, bull-oak, rusty gum and ironbark open forest	
13a	Granite hills	Steep granite with rock outcrops	Granite	Gritty sands over natural, impermeable hardpan or coloured sands (1c)	New England Blackbutt, tumbledown gum, ironbark and Stringybark woodland	D

Notes: * Australia Pacific LNG Project soil groups (described below) are presented in bracket

For the purposes of this report, the soil types / soil mapping units described within each of the land system reports that cover the study area (refer Table 5.1) have been assessed and grouped to enable a common description of soil characteristics and management issues of relevance to the Australia Pacific LNG Project. This standardised soil key for the study area is presented in Table 5.2, while Figure 5.1 illustrates the combined soil groups according to this standardised soil key. Mapped soil groups were correlated against soil types encountered during the field assessment to refine soil mapping and provide background data on soil constraints (refer Section 5.2.1). Note that Acid Sulfate Soils (ASS) do not occur within the Project area and are generally associated with low-lying coastal areas, such as tidal mud flats and estuary marine deposits, predominately below 5mAHD. These soils are discussed within the Chapter 5 of volumes 3 and 4 of this EIS.

Table 5.2 Study area soil group

Order		Description	
1	Skeletal soils (mainly Rudosols)	a	Alluvial – deep sands
		b	Shallow stony loams derived from sediments
		c	Shallow stony loams derived from mixed sources (metamorphic, intrusive or volcanic parent material)
2	Texture contrast soils (Chromosols / Sodosols / Kurosols)	a	Alluvial – predominantly moderately deep to deep
		b	Shallow mainly sandy surface: neutral to acid subsoil (Chromosols / Kurosols) neutral to alkaline subsoil (Sodosols)
		c	Shallow mainly loamy surface: neutral to acid subsoil neutral to alkaline subsoil
		d	Moderately deep to deep sands / loams
3	Red/yellow earths (Kandosols / Tenosols)	a	Shallow earths – derived from sediments
		b	Deep earths – derived from sediments
		c	Shallow/ deep earths derived from mixed sources
4	Brown/ grey non-cracking clays (Dermosols)	a	Alluvial – predominantly flood plain sediments
		b	Derived from Jurassic / Tertiary sediments
		c	Derived from mixed sources (mainly intrusives / volcanics)
5	Brown/grey/dark cracking clays (Vertosols)	a	Alluvial
		b	Derived from Jurassic / Tertiary sediments (mainly clay plains)
		c	Derived from intrusives / volcanics
		(m)	Melonhole clays

Figure 5.1 illustrates the five soil groups for the study area. Descriptors below generally include the broad Great Soil Group (GSG) and Australian Soil Classification (ASC) category (the latter in italics below). Within each soil group, there are numerous soil mapping units, each with different management implications for Project development.

a) Lithosols / *Rudosols* – Mainly shallow stony soils or deep structureless sands. This group has been divided into three units as follows:

i) Alluvial – deep sands: These are generally deep infertile soils associated with the floodplains of the major streams. Due to their landscape position and low gradient, they present few management constraints in terms of project development with the possible exception of stream bank erosion control.

ii) Shallow stony loams derived from sedimentary material: These soils are generally associated with the steeper hilly lands within the tenements and are derived mainly from mixed sedimentary rocks. The characteristics of these soils (which are prevalent in the north west tenement areas) are as follows:

- A shallow surface soil with abundant gravel or stone and with little profile development.
- Significant rock, often competent, may be found at a shallow depth, often within 15cm of the surface. Rock outcrops may be present.
- Nutrient levels are very low and are usually acid soils.
- The topsoil is generally very thin with constraints to stripping for subsequent use for vegetative rehabilitation. Topsoils are generally less than 5cm deep.

iii) Shallow stony loams derived from mixed sources, mainly igneous and metamorphic rocks, generally of the Permian period or older. There are few locations with this unit within the study area. Characteristics are similar to b) but present greater constraints for excavation due to rock. There is often a conspicuous bleached layer between the surface ‘‘topsoil’[1] and the rock layer. The implications of these soils (1b and 1c) for project development are:

- There will only be a thin layer (or complete absence) of topsoil suitable for stripping for rehabilitation.
- Trenching/excavation may be difficult due to a predominance of rock at a shallow depth.
- Due primarily to the landscape position, these soils are often highly prone to erosion. However, the high proportion of gravel or rock within the surface material may, in many circumstances, tend to protect or mitigate the erosion severity, especially in regard to the potential for gully erosion.

b) Texture contrast soils / *Chromosols* / *Sodosols* / *Kurosols* – This group has been divided into four mapping units as follows:

i) Alluvial soils – the alluvial texture contrast soils may be either *Chromosols* or *Sodosols*. (For the *Chromosols*, the topsoil can be quite deep (often >60cm). General characteristics of both these types are described below – however, the lower slopes and

[1] In the context of this report, ‘topsoil’ refers to the surface profile of the soil that is darkened due to organic matter accumulation and/or with a structure generally conducive to use for vegetative rehabilitation (often termed the A1 horizon).

depth of topsoil may limit the propensity for erosion with the exception of stream channels).

ii) Shallow mainly sandy surface

iii) Shallow mainly loamy surface

iv) Moderately deep to deep sands/loams (non- alluvial).

These can be further divided into i) neutral to acid subsoil (Chromosols / Kurosols) and ii) neutral to alkaline subsoil (Sodosols). These soils in the plains and upland areas are derived mainly from fine and coarse grained sedimentary material of mainly Jurassic or Tertiary sedimentary origin.

Solodics / Sodosols can be classified into the following types, as interpreted from the various land system reports.

- Shallow gravely texture contrast soils: These surface soils range from deep, loose sands to shallow hard setting loams, and their clay subsoils form well-structured, friable permeable types to coarsely-structured, tough ones of low permeability. In nearly all of these soil types, the more clayey subsoil causes some, and often severe impedance of internal drainage, and the hard-setting loamy surface soils lead to excessive runoff from high intensity rainfall. Where the natural cover is reduced by clearing or overgrazing, significant gully erosion can result.
- Texture contrast soils on plains with bulloak and cypress pine: These soils generally have a thin sandy or loamy surface soil (commonly <30 cm), brown to grey-brown in colour, over brown, yellowish brown or reddish brown light to medium clay subsoils. The subsurface soils are commonly lighter in colour and sometimes sporadically or conspicuously bleached. The surface soils are usually slightly acid and there is generally a gradual increase to a strongly alkaline or acid reaction in the subsoils. Structure at the surface is massive and angular blocky, occasionally columnar, in the subsoils where small to moderate amounts of carbonate may be present. The surface soils set hard when dry and subsoil consistence is commonly hard to very hard. These soils occur mainly on very gentle, intermediate or lower slopes.
- Sandy texture contrast soils dominated by poplar box: These soils have a thin loamy sand or sandy loam surface soil (generally<15cm) with an acid surface and neutral to alkaline subsoil that is commonly brownish grey or light yellowish brown. Subsoils are commonly strongly sodic and the deep subsoils can be highly saline. They are very dispersible and prone to gully and tunnel erosion.

Bierenbroodspot and Thew, 1982 present general management strategies for solodic soils. Due to the prevalence of these soils in inland areas of southern Queensland, appropriate methods of handling these soils have become well-established in the gas infrastructure and pipeline construction industry. In almost all cases, these soils are characterised by the following:

- The topsoil is low in organic matter and hard-setting.
- Nutrient levels in the surface soils are low to very low.
- There is usually a moderate to conspicuous bleach between the surface soil and subsoil.
- The depth of topsoil (that is, above the bleach) can be quite variable (some can be over 60cm).
- The subsoils are usually strongly sodic and highly dispersive as is evidenced by soil sampling undertaken for this project (refer Section 5.2.3). All sampling of soils in this group indicated a very high / extreme level of dispersion (Emerson Dispersion Class 1), very high levels of sodicity (Na% levels commonly higher than 16%) and low calcium to magnesium ratio (also indicating a

propensity for dispersion). Only two 'non-dispersive' subsoils were indicated from field investigations in the texture contrast soils areas of the study area.

- They are very prone to gully and tunnel erosion with a surface soil that is prone to sheet erosion.

Key management issues with these soils within the gas field study area are as follows:

- The topsoil depth is quite variable but the layer suitable for stripping is often between 10cm and 20cm. The topsoil layer is usually readily able to be identified in the field.
- Extreme care should be undertaken with the highly sodic subsoils with careful segregation from the topsoil piles (refer Section 7.3.2 later for handling methods) as these soils are prone to dispersion.
- The very low nutrient levels will necessitate some fertilisation to achieve an acceptable rehabilitation standard.
- Ongoing monitoring will be required following rehabilitation due to ensure the continued integrity of the rehabilitation works.

The Chromosols / Kurosols key characteristics are as follows:

- These are mainly shallow sandy loam or loamy surface soils, often gravely.
- A bleached A2 horizon is not common.
- Nutrient levels are low.
- Subsoils are generally red, brown or yellow clay with a blocky structure and often moderately permeable. Lateritic layers can occur.
- Subsoils are usually acid to neutral, non-sodic and non-dispersive to moderately dispersive.
- They commonly intergrade with the gradational soils described below or the Solodic / *Sodosol* soils described previously.

Implications of these soils for project development are similar to those described for the solodic / sodosols above, albeit, in many cases, with a lower propensity for tunnel and gully erosion due, in most circumstances, to the more stable subsoils. Key constraints include:

- The topsoil is of variable depth for stripping but is generally 10cm to 30cm and readily discernible in the field.
- Topsoil may require fertilisation.
- While subsoils require segregation from the topsoils, they present no special handling constraints due to their relative stability. However, such soils generally occur on steeper terrain requiring intensive erosion control works to control runoff.

c) Red / yellow earths / *Kandosols* / *Tenosols* – These soils have a coarse to medium texture and with a uniform or gradational profile. This group has been divided into:

   i) Shallow earths – derived from sediments

   ii) Deep earths – derived from sediments

   iii) Shallow / deep earths derived from mixed sources (only minor areas of this type are present within the study area).

Characteristics of these soils include:

- Topsoil of medium depth (typically 15cm to 30cm).
- Generally acid throughout
- Usually low to very low fertility levels
- Significant gravel content in shallow earths (3a), often with rock outcrop or broken rock
- Loose surface, prone to sheet erosion
- Quick profile drainage and low moisture holding capacity
- Relatively stable subsoils, making them less susceptible to gully erosion than the texture contrast soils.

The main management implications for these soils are the presence of stone and their rapid drying. The latter issue may limit vegetative rehabilitation success in some areas.

d) Brown and grey non-cracking clays / *Dermosols* – This soil group has been divided into:

i) Alluvial soils – found along the terraces associated with most major watercourses (These can be prone to flooding.) Such soils are commonly used for dry land and irrigated crop production in the region.

ii) Soils in upland areas or plains derived from sediments (mainly from Jurassic and Tertiary sources) – common in northern areas of the tenements.

iii) Soils derived from mixed sources (mainly intrusives / volcanics) – only minor areas of this type are present within the study area.

Key characteristics and management implications of this soil group are as follows:

- They have relatively deep topsoil (often up to 50cm deep) that merges gradually into medium clayey subsoil. However, clay levels in the surface may be high and limit topsoil stripping opportunities.
- The differentiation between the topsoil and subsoil material can be moderately obscure.
- Surface and subsoil profiles are generally moderately permeable.
- Subsoils are usually moderately sodic and dispersive (based on the results undertaken for this report).
- Fertility levels are generally low to moderate. Fertilisation for rehabilitation purposes would be beneficial.
- They are comparatively stable, particularly 4a. However, the significant clay content in the surface soil can result in compaction issues if excessively handled and thus affect rehabilitation success.

e) Brown/grey/dark cracking clays / *Vertosols*: This soil group has been divided into:

i) Alluvial soils – found along the terraces and floodplains of some larger watercourses including the Condamine River floodplain. These soils are generally very deep and present few physical constraints aside from possible flooding issues. They are the most valuable soils in the region in terms of agricultural productivity and, in many areas, are heavily utilised for dry land and irrigated crop production, including cotton farming.

ii) Soils derived from sediments (as for 4b)

iii) Soils derived from mixed sources (intrusives/ volcanics).

The cracking clay soils in non-alluvial locations (that is, 5b and 5c) are generally of medium depth, have friable surface horizons and a moderately high nutrient status. The phosphorus content, although variable, is usually moderate to high. Although large areas of these soils have previously been used for annual cropping, especially in the area to the south west of Wandoan, the low and highly variable rainfall, high evaporation and unavailability of suitable irrigation water limit their long term cropping potential and many areas are now mainly under improved pasture.

The deep grey and brown cracking clays occur chiefly as grassland plains adjacent to some of the major streams and as small areas of gently undulating plains of older clay sediments. In some areas, there are deep 'melonhole' gilgai on the plains with moderate linear gilgai common on gentle slopes. Deep melonhole areas (as identified in the land system mapping) have been mapped as 5b(m). These soils have moderate to high water holding capacity, but agricultural potential is often limited due to their impeded drainage. Nevertheless, many formerly gilgaied soils have been subjected to significant land levelling to improve their suitability for annual cropping.

Typical characteristics of these soils are as follows:

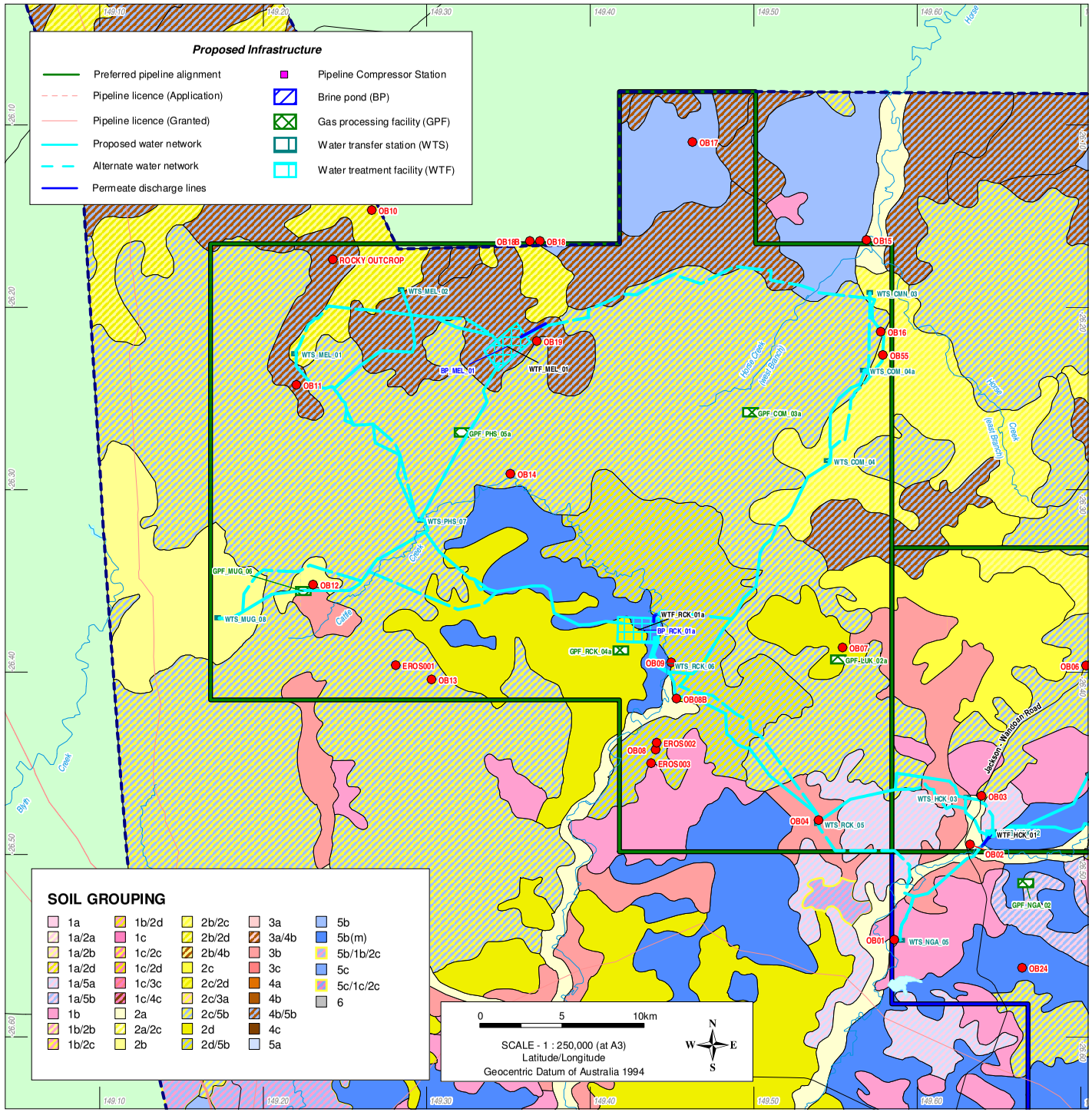
- Their finely structured surface may form a weak surface.
- Gilgai may or may not be present – where developed, some variation in profile characteristics and surface condition may be seen, e.g. gilgai mounds can be reddish and depressions grey; the depth to carbonate layers and acid subsoils is usually greater in depressions than on mounds.
- Management of these soils may be aided by a fine, friable surface and well structured upper subsoil.
- Lower subsoils are generally strongly sodic with very high salinity levels. Dispersion levels are variable. Sampling conducted for this report indicated highly dispersive levels in most cracking clay soil areas.
- Subsoils shrink and swell and may develop large vertical cracks when dry. This shrink/swell characteristic may have implications for pipeline establishment (refer Section 6.1.4).
- Soil pH is generally neutral to alkaline at the surface, usually becoming strongly alkaline at around 30cm. It may become strongly acid below 100cm.
- Plant available water capacity (PAWC) in the root zone of gilgai mounds is low (50mm-100mm); gilgai depressions have higher PAWC levels.
- Fertility levels are usually medium to high (pasture).

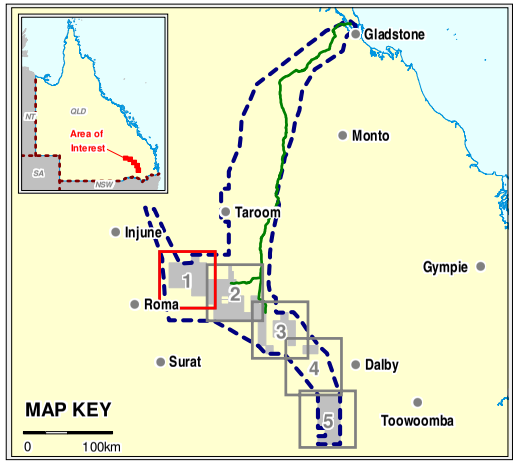
Implications for project development are:

- Careful segregation of the (often shallow) topsoil from the dispersive subsoil may be necessary. Stripping depths may need to be quite shallow (around 10cm) or some soils may not be conducive to stripping and therefore a site specific topsoil assessment may be required.
- The visual differentiation of topsoil from subsoil can be difficult. The high clay content may limit the use of this topsoil for rehabilitation purposes.
- Very careful segregation and handling of the subsoil may be required. Excessive handling and compaction of topsoil may result in destruction of soil structure and affect rehabilitation success.

- Due to the relatively high fertility levels, fertilisation may not be necessary for rehabilitation purposes.

Stripping of surface soil where the gilgai is pronounced may prove a significant operational constraint for some machinery, especially graders due to surface undulations which may be up to 1m deep. Management of surface soils for successful rehabilitation may need to be carefully monitored – some surface material suitable for rehabilitation may need to be 'borrowed' from other areas.





LEGEND

- Observation location
- Town
- Existing infrastructure
- Major drainage
- Road
- Study area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

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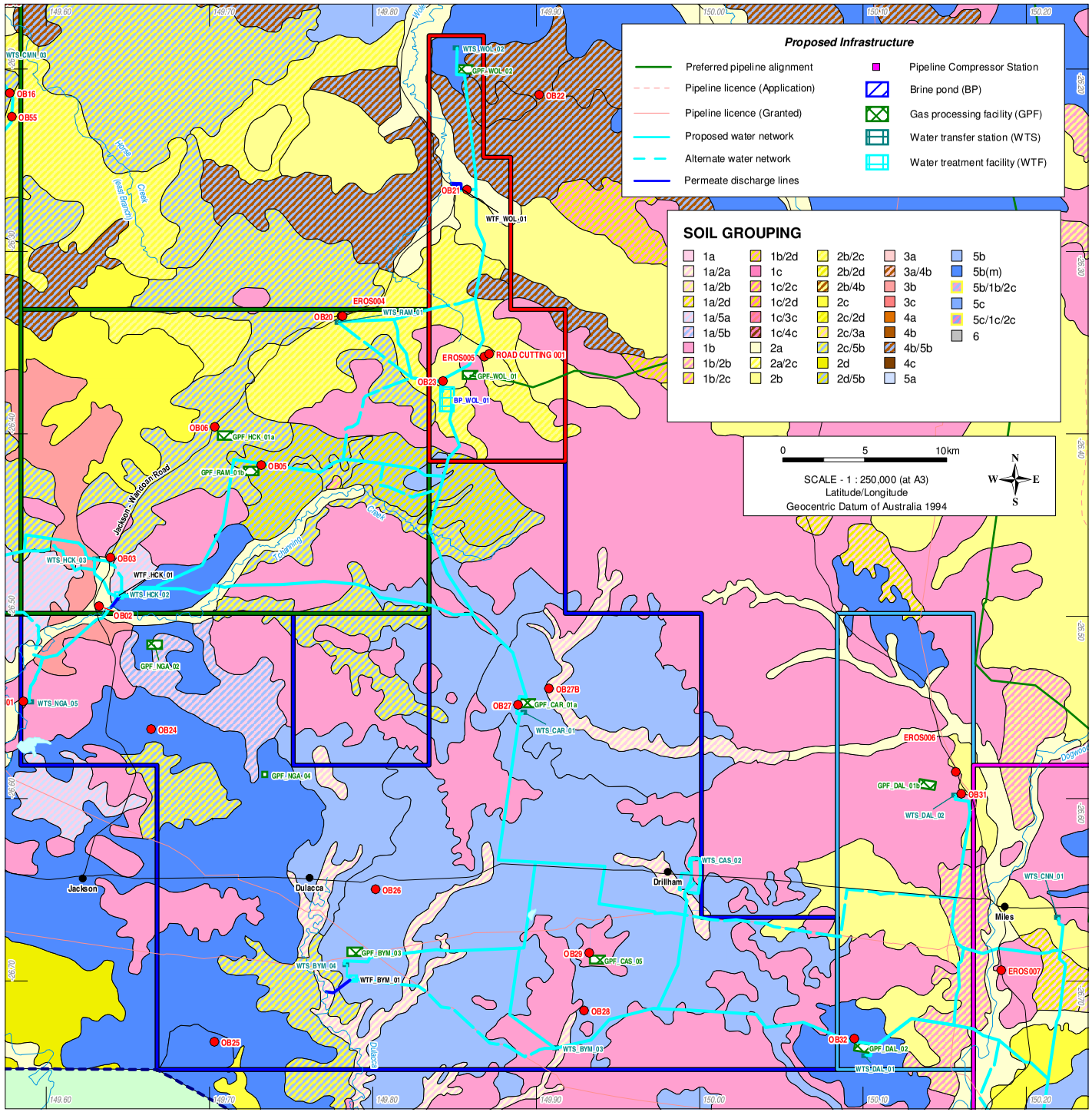
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Figure 5.1 Study Area Soil Types
Map 1 of 5

Project No: 301001-00448	Figure: 00448-00-EN-DAL-0220	Rev: 0

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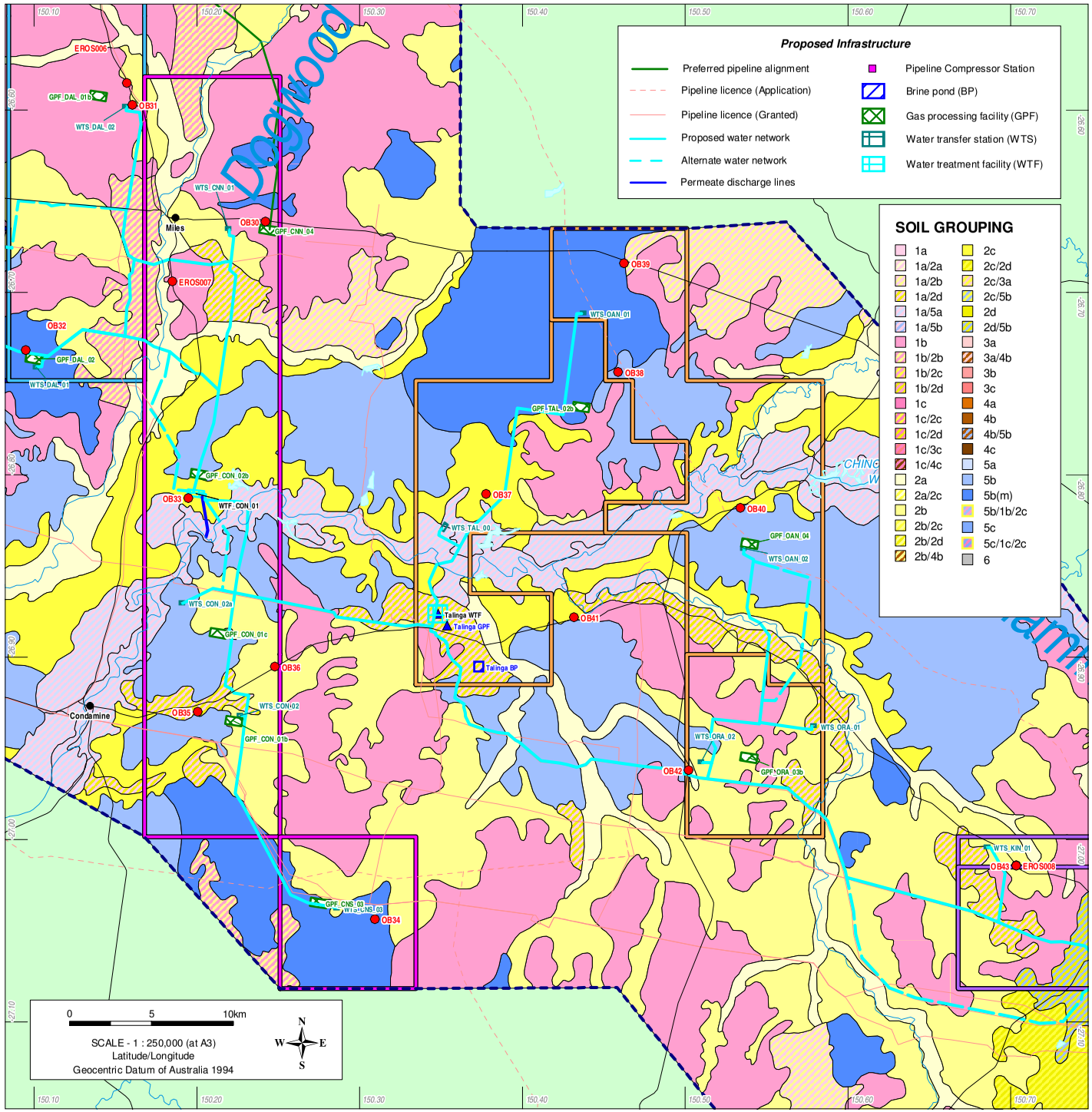
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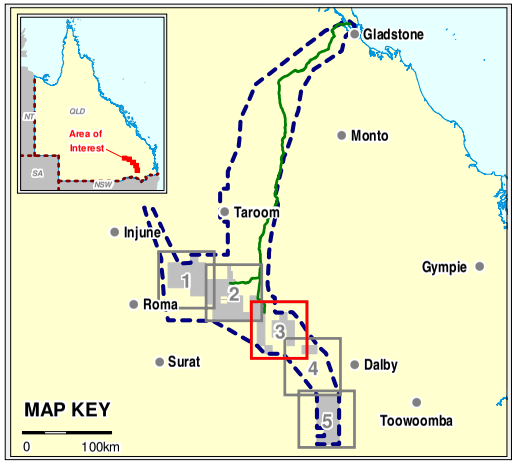
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Figure 5.1 Study Area Soil Types
Map 2 of 5

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LEGEND

- Observation location
- Town
- Existing infrastructure
- Major drainage
- Road
- Study area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

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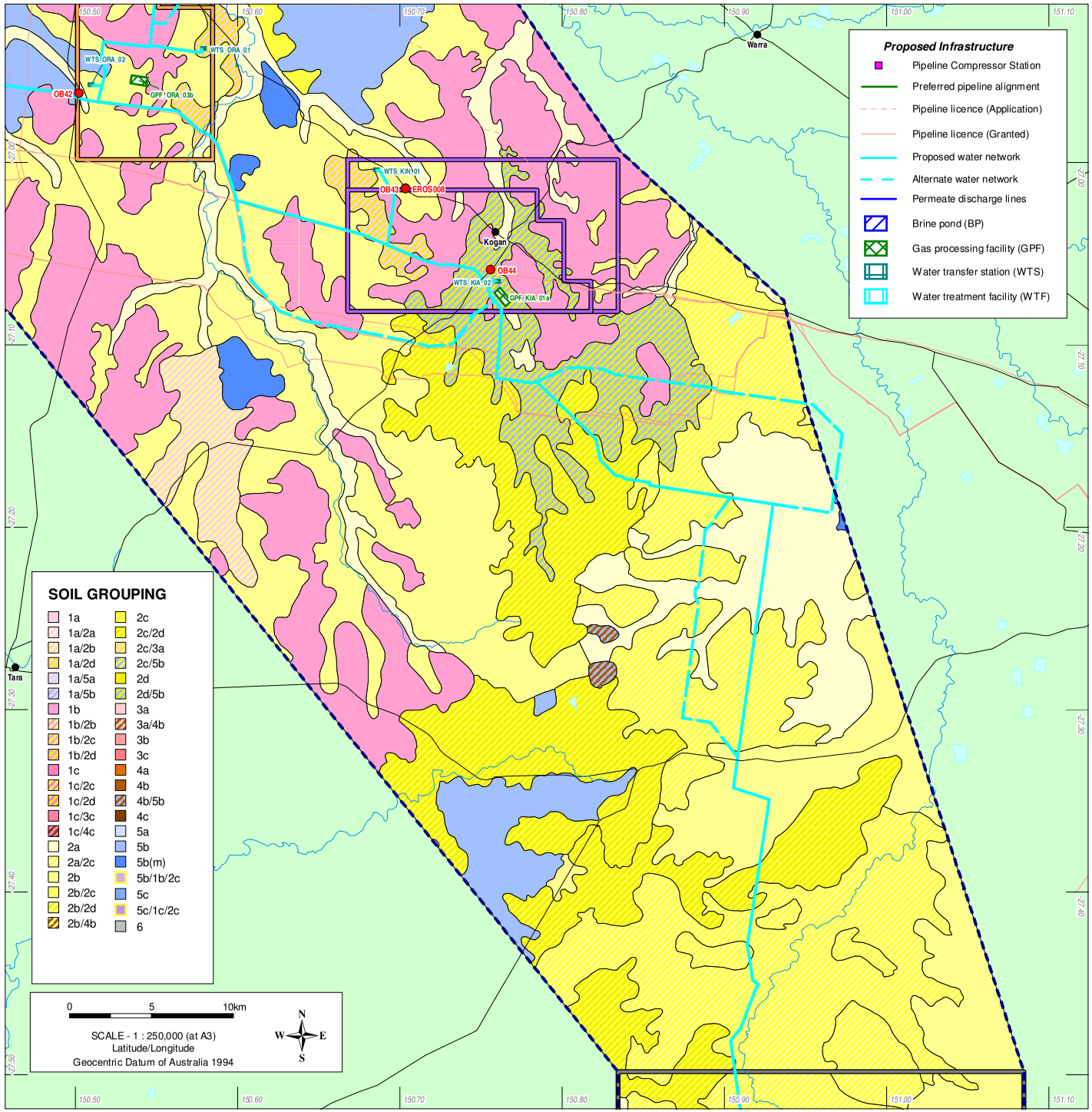
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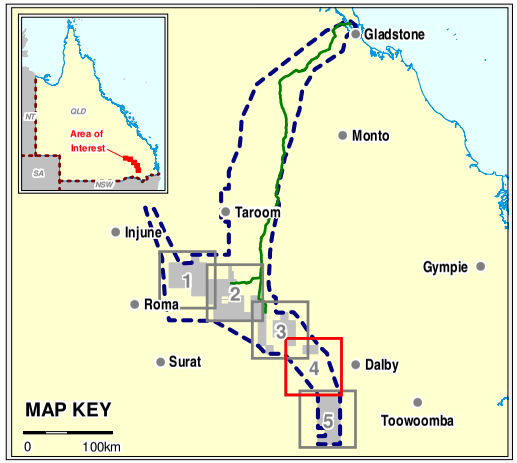
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Figure 5.1 Study Area Soil Types
Map 3 of 5

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LEGEND

- Observation location
- Town
- Existing infrastructure
- Major drainage
- Road
- Study area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
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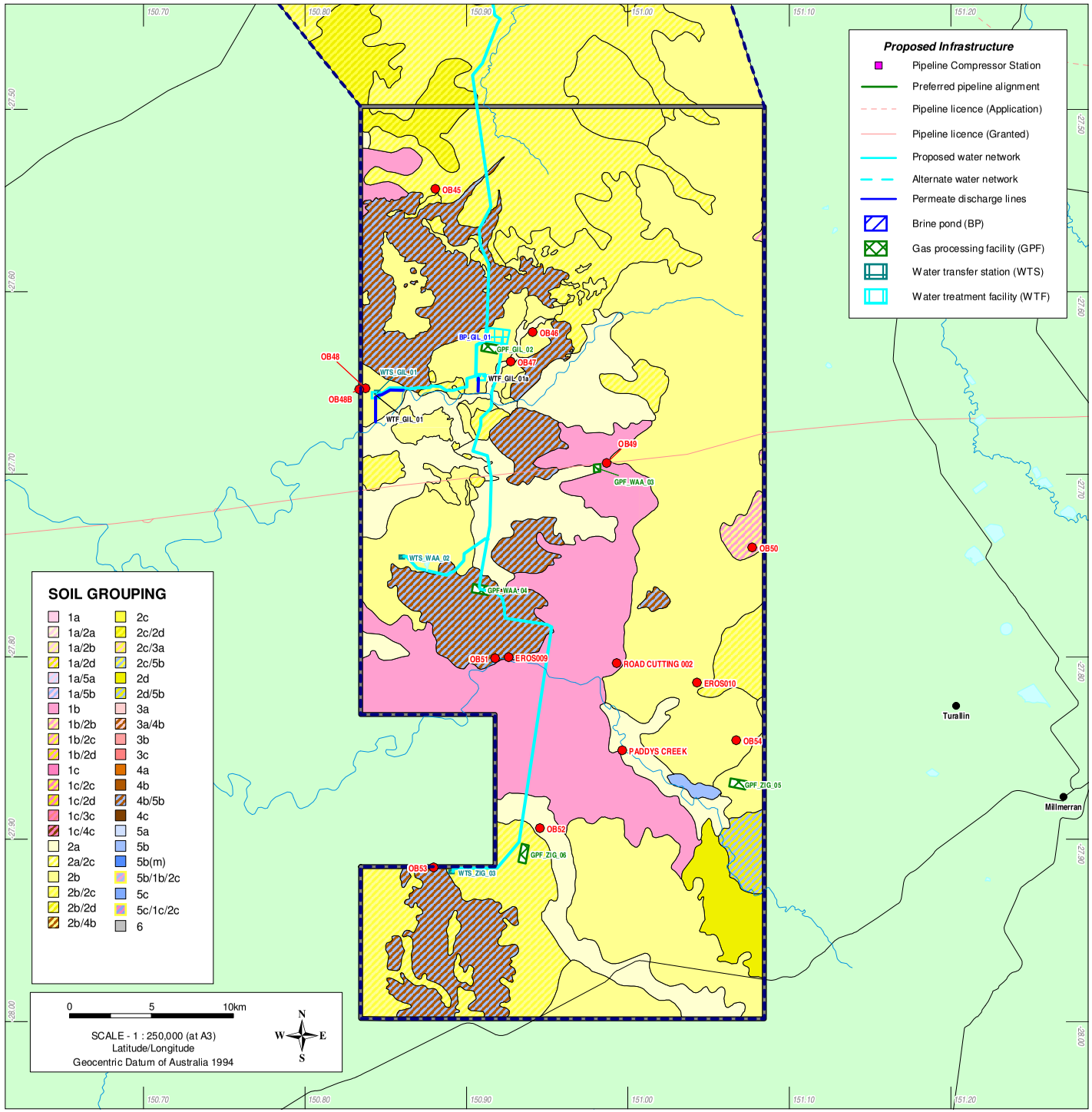
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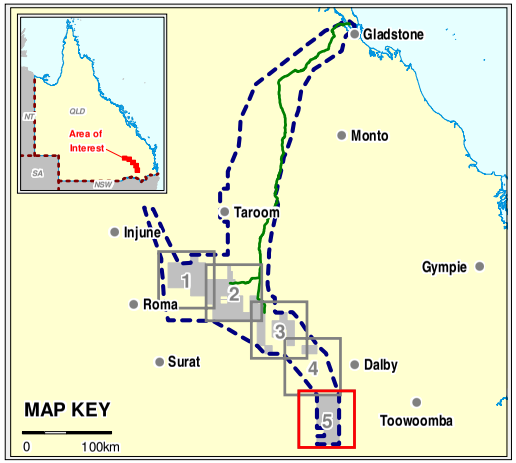
AUSTRALIA PACIFIC LNG PROJECT
Figure 5.1 Study Area Soil Types
Map 4 of 5

Project No: 301001-00448	Figure: 00448-00-EN-DAL-0223	Rev: 0

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LEGEND

- Observation location
- Town
- Existing infrastructure
- Major drainage
- Road
- Study area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

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Soil groupings combined and interpreted from Department of Natural Resources Land Resources Area maps by WorleyParsons October 2009.

Rev	Date	Revision Description	ORIG	CHK	ENG	APPD
0	14/11/2009	Issued for use	JB	DH		

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Figure 5.1 Study Area Soil Types
Map 5 of 5

Project No: 301001-00448	Figure: 00448-00-EN-DAL-0224	Rev: 0

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5.2 Soils field assessment

5.2.1 Soil types and occurrence

Soils at 39 locations within the study area were described in accordance with the Australian Soil and Land Survey Field Handbook (McDonald et al 1990) and Australian Soil Classification (Isbell 1996) [refer Table 1 Appendix B], the majority of which generally correlated to mapped soil types (refer Section 5.1.1 and Table 1, Appendix B). 'A' horizon field description for OB09, OB16, OB25, OB31, OB32 and OB43 were extrapolated using mapped soil types as the subsoil profiles at these locations could not be examined due to refusal near the surface. Discrete soil samples were collected at all 39 locations. Table 5.3 provides a description of the soils encountered against the mapped soil types (refer Table 5.2) in which they occur (refer Figure 5.1).

Table 5.3 Soil group descriptions

Mapped soil group (refer Table 5.2))	Occurrence*	Field description (ASC)
1a	OB35 (1a/2d)	Arenic (AO), RU
1b	OB29	Brown (AB), KA
	OB30	Colluvic (HI), Clastic (HH), RU
	OB31	Lutic (GV), RU
	OB49	Hypernatric (CR), Brown (AB), SO
1c	Not encountered	-
2a	OB42	Mottled-Hypernatric (FP), Brown (AB), SO
	OB47	Hypernatric (CR), Brown (AB), SO
	OB52	Mottled-Hypernatric (FP), Brown (AB), SO
2b	OB12	Epipedal (GS), Brown (AB), VE
	OB23	Crusty (BH), Brown (AB), VE
	OB36	Hypernatric (CR), Grey (AD), SO
	OB43	RU
	OB45 (2b/2c)	Hypernatric (CR), Brown (AB), SO
	OB46	Hypernatric (CR), Brown (AB), SO
	OB54	Mottled-Hypernatric (FP), Brown (AB), SO
	OB55 (2b/2c)	Hypernatric (CR), Grey (AD), SO
2c	OB14 (2c/5b)	Grey (AD), SO
	OB16 (2c/5b)	RU
	OB37	Crusty (BH), Brown (AB), VE
	OB41	Self-mulching (EI), Brown (AB), VE

2d	OB05 (2d/5b)	Dystrophic (AF), Red (AA), CH
	OB07	Episodic-Endoacidic (GG), Epipedal (GS), Brown (AB), VE
	OB09 (2d/5b)	RU
3a	Not encountered	-
3b	OB04	Crusty (BH), Brown (AB), VE
3c	Not encountered	-
4a	Not encountered	-
4b	OB11 (4b/5b)	Sodic (EO), Petrocalcic (DZ), Brown (AB), DE
4c	Not encountered	-
5a	Not encountered	-
5b	OB03 (2c/5b)	Episodioc-Endoacidic (GG), Crusty (BH), Brown (AB), VE
	OB17	Epipedal (GS), Brown (AB), VE)
	OB26	Self-mulching (EI), Brown (AB), VE
	OB27	Duric (BJ), Crusty (BH), Brown (AB), VE
	OB38	Crusty (BH), Grey (AD), VE
	OB40	Brown (AB), VE
5c	Not encountered	-
5b(m)	OB25	Crusty (BH), Brown (AB), VE
	OB32	Crusty (BH), Brown (AB), VE
	OB34	Lutic (GV), RU
	OB39	Hypernatic (CR), Brown (AB), SO
1b / 2b	OB50	Crusty (BH), Brown (AB), VE
2c / 5b	OB13	Mesotrophic (AG), Brown (AB), KA
4b / 5b	OB51	Hypernatric (CR), Brown (AB), SO
5b / 5b(m)	OB24	Epipedal (GS), Brown (AB), VE

NOTES: HY – Hydrosols, RU – Rudosols, TE – Tenosols, SO – Sodosols, CH – Chromosols, VE – Vertosols, SO – Sodosols, DE – Dermosols, KA – Kandosols

* combined soil group as mapped

Field classifications indicate the majority of soils encountered within the study area are either texture contrast soils (Sodosols), brown cracking clays (Vertosols) or skeletal soils (Rudosols).

5.2.2 Topsoil thickness

Within this report, topsoil refers to the surface layer of soil which generally contains organic material and is classified as the A1 horizon within Table 1, Appendix B. Using the A horizon thickness classification provided in the Australian Soil Classification (Isbell 1996) for Chromosols, Kurosols and Sodosols (refer Table 5.4), topsoil thicknesses within the study area has been rated and is presented in Table 5.5. This should be regarded as indicative only as there can be marked variation, even within very short distances due to origin, formation processes, pedological issues, slope, erodibility and land use effect. The topsoil depths for all borehole locations are provided in Table 1, Appendix B.

Table 5.4 Topsoil thickness classification

Horizon thickness (m)	A horizon thickness rating
<0.1	Thin
0.1-0.3	Medium
0.3-0.6	Thick
>0.6	Very thick

Table 5.5 Study area topsoil thickness

Soil type	A horizon thickness rating	Typical thickness
1a	Medium	Thick
1b	Thin – medium	Thin
1c	Not encountered	Thin
2a	Thin – medium	Thick – very thick
2b	Thin – medium	Thin – medium
2c	Thin	Thin – medium
2d	Thin – medium	Thick – very thick
3a	Not encountered	Thin – medium
3b	Medium	Medium – thick
3c	Not encountered	Thin – thick
4a	Not encountered	Thin – very thick
4b	Thin	Medium – thick
4c	Not encountered	Thin – thick
5a	Not encountered	Medium – thick
5b	Thin – thick	Medium – thick
5c	Not encountered	Medium – thick
5b(m)	Medium	Medium – thick

Based on field classifications, topsoil was generally thin to medium in thickness throughout the study area, with only one occurrence of thick topsoil noted within a Vertosol at OB27. However, as mentioned previously, due to significant variations in origin, formation processes, pedological issues, slope, erodability and land use, a site specific assessment will be required prior to disturbance to ascertain the appropriate depth of topsoil to be stripped and segregated from subsoil.

5.2.3 Sodic soils and dispersion

Sodicity

Sodicity is a measure of exchangeable Na in relation to other exchangeable cations and leads to clay dispersion in the soil (Hazelton and Murphy 2007). Sodic soils can cause severe surface crusting, have low infiltration and hydraulic conductivity, become very hard and are highly susceptible to gully and tunnel erosion (Hazelton and Murphy 2007). Sodicity can be rated by calculating the proportion of exchangeable Na cations to the sum of all exchangeable cations, which is referred to as Cation Exchange Capacity (CEC). This proportion is known as the Exchangeable Sodium Percentage (ESP):

ESP = Exchangeable Na / CEC

Table 5.6 provides sodicity ratings in Australia, which have been applied to the soil results presented in Table 2, Appendix B.

Table 5.6 Sodicity and ESP ratings (Hazelton and Murphy 2007)

Sodicity rating	ESP's proposed for Australian soils (%)
Non-sodic	0-6
Marginally sodic to sodic	6-14
Strongly sodic	>14

Calculated ESP levels ranged from 1.6% (OB23/0.0-0.1) to 54.5% (OB36/0.9-1.0). This indicates that subsoils ranged from non-sodic to strongly sodic with the majority of results indicating sodic or strongly sodic levels.

Due to the ESP calculation (exchangeable Na as a percentage of CEC) some samples which reported elevated sodicity are not necessarily dispersive. For instance, where exchangeable Na concentrations are relatively low compared to other exchangeable cations (Ca, Mg, K) and salts (such as sulphate), sodicity will not be a major issue. Where this is the case, such as at OB11, OB14 and OB27, salinity issues may be more prominent.

Sodic to strongly sodic ratings calculated for coarser textured soils (that is, OB49) are likely to be the result of the small fraction of finer textured material within these soils. They are still likely to erode, (refer Section 5.2.4) not because of clay dispersion, but rather due to lack of soil structure and organic material and higher slopes.

Sodic to strongly sodic fine textured subsoils (that is, mainly within soil groups 2, 4 and 5) will require careful management and should be kept separate from non-sodic soils if excavated. Additionally, sodic to strongly sodic coarse textured soils (that is, mainly within soil groups 1, 2 and 3) will also require careful management and separation of the subsoil.

Emerson Dispersion results reported for samples collected and analysed within the study area range from non-dispersive (6) to very dispersive (1), with the majority of results reported as very dispersive despite noting negligible erosion during field work at most locations. With the exception of non-sodic

samples OB05/0.9-1.0, OB13/0.6-0.7 and OB27/0.4-0.5, Emersion Dispersion Class results correlate well with ESP data reported.

Sodium adsorption ratio

Sodium Adsorption Ratio (SAR) describes the activity of the Na ion relative to that of Ca and Magnesium [Mg] (Hazelton and Murphy 2007).It is an indirect measurement of sodicity and is calculated as follows:

$$SAR = Na^{+} \Big/ \left(Ca^{2+} + Mg^{2+}\right)^{1/2}$$

SAR values of less than 0.01 meq/100g were calculated for a number of samples within the study area while the highest calculated SAR value was 3.94 meq/100g for sample OB41/0.9-1.0 (refer Table 2, Appendix B). This range is considered low to high. Similarly, the central tendency of data (0.62 meq/100g to 2.5 meq/100g) indicates sodicity in soils throughout the study area is variable. Notably, the highest SAR values calculated were for Sodosols, Vertosols and a single Dermosol, Kandosol and Rudosol, while the lowest were calculated for Chromosols, Kandosols, Rudosols and only some Vertosols.

This data indicates sodium activity within the Sodosols and Vertosols is high and therefore correlates well with the ESP data above. As a result, clay dispersion in these soils, with the exception of soils encountered at OB11, OB14 and OB27 and coarse textured soils encountered at soil groups 1, 2 and 3, will require additional focus in terms of erosion control and rehabilitation.

5.2.4 Soil erodibility

The assessment of erosion potential for an area of land needs to take into account the particular soil properties that may induce or inhibit erosion. It is a function of the soils structural stability and its capacity to absorb rainfall and minimise runoff. Some factors which contribute to erosion are vegetation clearing, topsoil removal, soil disturbance, poor drainage management and concentration of runoff. Soils within the study area were assessed according to the classification system described in Table 5.7.

Table 5.7 Erosion potential classification

Field observation	1 – Nil or minor erosion associated with land use	1 or 2 – Little erosion, surface slope wash features	2 – Little erosion, surface slope wash features	2 or 3 – Slope wash, rill, tunneling and gully erosion	3 – Slope wash, rill, tunneling and gully erosion
Emerson dispersion class	Class 5 - 8 soils are slightly or non-dispersible. Aggregates disperse at a water content intermediate between field capacity and that of a	Class 4 soils are slightly or non-dispersible. Do not disperse after remolding, but contain minerals such as calcite or gypsum. Not highly	Class 3 means soils are slightly dispersible. After remoulding, show dispersion. Soils are generally stable. Gypsum application can	Class 2 means soils are moderately dispersible. Aggregates slake and partly disperse. Indicate some degree of tunneling	Class 1 means soils are very dispersible. Aggregates slake and disperse completely leaving only sand grains in a cloud of clay.

	suspension. Not highly susceptible to erosion.	susceptible to erosion.	reduce crusting.	susceptibility	Indicate high tunneling susceptibility.
Salinity (μS/cm)	< 70 – 150 (sand soils) to 150 – 300 (clays Very low-to-low salinity rating. Sensitive to moderately sensitive crops	150 – 340 (sandy soils) to 300 – 700 (clays) Medium soil salinity rating. Moderately tolerant crops	340 – 630 (sands) to 700 – 1180 High salinity rating. Tolerant crops	630 – 930 (sands) to 1180 – 1870 (very high salinity rating). Very tolerant crops.	> 930 (sands) to > 1870 (clays) Extreme salinity rating. Generally too saline for crops
Erosion potential classification based on field observations and Emerson Dispersion Class	1 – nil / slight potential	1 or 2 – sheet / wind / small scalds may develop	2 – sheet / wind / small scalds may develop	3 – gully or sheet and significant scalds may develop or 4 major gullies may develop	4 – gully or sheet and significant scalds may develop or 4 major gullies may develop

According to this system, the erosion potential for each soil sample submitted for analysis has been assessed and is shown in Table 5.8 and illustrated in Figure 5.2. Laboratory reports are presented in Appendix D. It should be noted that other soil properties also affect soil erodibility including soil coherence, infiltration and permeability, topsoil depth and texture (including presence of stone). These factors have generally been taken into account in Section 5.2.5.

Table 5.8 Soil erosion parameters

Sample Location	Sample	Mapped Soil Group	Field ASC	Field Slope Class	Emerson Value	Current landuse	ECe	Erosion potential (field observations)	Erosion potential if area disturbed (i.e vegetation removed)
OB03	0.9-1.0	2c/5b	VE	1	1	Road reserve / grazing	13674	1	4
OB05	0.9-1.0	2d/5b	CH	1	2	Road reserve / grazing	230	1	2
OB07	0.9-1.0	2d	VE	1	1	Road reserve / grazing	8100	1	4
OB11	0.7-0.85	4b/5b	DE	1	3	Road reserve / grazing	9374	1	2
OB12	0.9-1.0	2b	VE	1	1	Road reserve / grazing	6880	1	4
OB13	0.6-0.7	2c/5b	KA	1	2	Road reserve / grazing	570	1	2
OB14	0.7-0.85	2c/5b	SO	1	3	Private property / grazing	4472	1	3
OB17	0.6-0.7	5b	VE	1	3	Road reserve / grazing	9116	1	3
OB23	0.9-1.0	2b	VE	1	2	Road reserve / grazing	7076	1	3
OB24	0.8-0.9	5b / 5b[m]	VE	1	1	Road reserve / grazing	8004	1	4
OB26	0.9-1.0	5b	VE	1	2	Road reserve / grazing	9600	1	4
OB27	0.4-0.5	5b	VE	1	6	Private property / grazing	30900	1	2
OB29	0.4-0.5	1b	KA	2	5	Road reserve / grazing	475	1	2
OB30	0.7-0.8	1b	RU	2	3	Road reserve / grazing	2380	2	2
OB36	0.9-1.0	2b	SO	1	1	Road reserve / grazing	4830	1	4
OB37	0.9-1.0	2c	VE	1	1	Road reserve / grazing	5394	1	4
OB38	0.5-0.6	5b	VE	1	1	Road reserve / grazing	3975	1	4
OB39	0.9-1.0	5b[m]	SO	1	1	Easement / grazing	2838	1	4
OB40	0.6-0.7	5b	VE	1	2	Road reserve / grazing	3096	1	3
OB41	0.9-1.0	2c	VE	1	1	Road reserve / grazing	2030	1	4
OB42	0.9-1.0	2a	SO	1	1	Road reserve / grazing	1290	1	4
OB45	0.9-1.0	2b/2c	SO	1	1	Private property / regrowth	1634	1	4
OB46	0.9-1.0	2b	SO	1	1	Road reserve / grazing	9430	1	4
OB47	0.9-1.0	2a	SO	1	1	Road reserve / natural	6440	1	4
OB49	0.9-1.0	1b	SO	1	2	Road reserve / state forest	1380	1	3
OB50	0.9-1.0	1b/2b	VE	1	1	Private property / grazing	2250	1	4
OB51	0.9-1.0	4b/5b	SO	1	1	Road reserve / grazing	3680	1	4
OB52	0.9-1.0	2a	SO	1	2	State forest	2070	1	3
OB54	0.9-1.0	2b	SO	1	2	State forest	860	1	4
OB55	0.9-1.0	2b/2c	SO	1	3	Road reserve / grazing	3680	3	4

The above table indicates that at most locations where soils were sampled there was a low existing erosion potential (due mainly to existing ground cover and land use). However, with disturbance, the potential is substantially increased.

Based on the classification system provided in Table 5.7, field observations (including texture classifications), Emerson Dispersion test results, sodicity ratings and photography have been used to generate the erosion potential classifications provided in Table 5.8. Where vegetative cover has been removed (for development), soils with a classification of 3 or 4 will require focussed management as they are highly susceptible to subsurface erosion. Soils with an erosion classification of 2 or lower are less likely to erode as a result of non-sodic or high salinity concentrations which limit dispersion.

5.2.5 Overall erosion hazard

The soil erosion potential classification provided in the last column of Table 5.8 has been used to determine the overall erosion risk for the gas fields study area (refer Section 5.2.1). These are provided in Table 5.9 and illustrated on Figure 5.2.

This table is based on the principle that the more susceptible a soil is to erosion and the steeper the slope, the greater the overall erosion hazard.

Table 5.9 Soil group erosion ratings

Soil group	Soil erodibility ranking*	Slope category				
		1 (0-2%)	2 (2-8%)	3 (8-15%)	4 (15-30%)	5 (30%+)
1a	2	L	N/A	N/A	N/A	N/A
1b	1-2	VL	L	M	H	VH
1c	1-2	VL	L	M	H	VH
2a	2	L	N/A	N/A	N/A	N/A
2a(i)	1	L	N/A	N/A	N/A	N/A
2a(ii)	2	M	N/A	N/A	N/A	N/A
2b	4	M	H	S	S	N/A
2b(i)	3	M	H	VH	VH	N/A
2b(ii)	4	H	VH	S	S	N/A
2c	4	M	H	S	S	N/A
2c(i)	3	M	H	VH	VH	N/A
2c(ii)	4	H	VH	S	S	N/A
2d	2	M	H	VH	N/A	N/A
2d(i)	1	M	H	VH	N/A	N/A
2d(ii)	2	M	H	VH	N/A	N/A
3a	2-3	L	M	H	VH	S
3b	1-2	VL	L	M	N/A	N/A
3c	2	L	M	H	VH	S
4a	1	VL	N/A	N/A	N/A	N/A
4b	2	L	M	H	VH	N/A
4c	2	VL	L	M	H	N/A
5a	1	VL	N/A	N/A	N/A	N/A
5b	1-2	VL	L	M	N/A	N/A
5c	1-2	VL	L	M	H	N/A
5b(m)	1	VL	L	N/A	N/A	N/A

Notes

Soil erodibility: 1: low 2: moderate 3: high 4: very high

Erosion hazard: VL: very low L: low M: moderate H: high VH: very high S: severe

N/A: Soil group unlikely to occur on such slopes

Based on the erosion ratings provided in Table 5.9, soil groups 2b and 2c have the highest erosion rating. However, where slope is a factor, the erosion hazard for most soil groups increases. This is particularly notable in the coarser textured soil groups 1, 2 and 3 where there is little structure and organic matter to help bind the soil and resist erosion. This also contributes to the lower (i.e. more dispersible) Emerson Dispersion test results for soils tested within these soil groups. Examples of this erosion were observed throughout the study area (refer Plate 5.1 to Plate 5.10). Notably, these examples occur where vegetation had been cleared for agriculture or infrastructure development purposes (for example, adjacent to roads, fences and creeks) and stabilisation and / or rehabilitation was either unsuccessful or not implemented. Specific measures (refer Section 7.3.3) to minimise soil erosion in areas disturbed by Project development should be implemented to prevent such erosion.



Plate 5.1 EROS001: Soil Group 2c (dispersive soils)



Plate 5.2 EROS002: Soil group 2c (erosive soils)



Plate 5.3 EROS003: Soil group 1b (erosive soils)



Plate 5.4 EROS004: Soil group 2b (dispersive soils)



Plate 5.5 EROS005: Soil group 2b (erosive soils)



Plate 5.6 EROS006: Soil group 2b (erosive soils)



Plate 5.7 EROS007: Soil group 1b (erosive and dispersive soils)



Plate 5.8 EROS008: Soil group 2b (erosive soils)



Plate 5.9 EROS009: Soil group 5b (dispersive soils)



Plate 5.10 EROS010: Soil group 2b (erosive and dispersive soils)

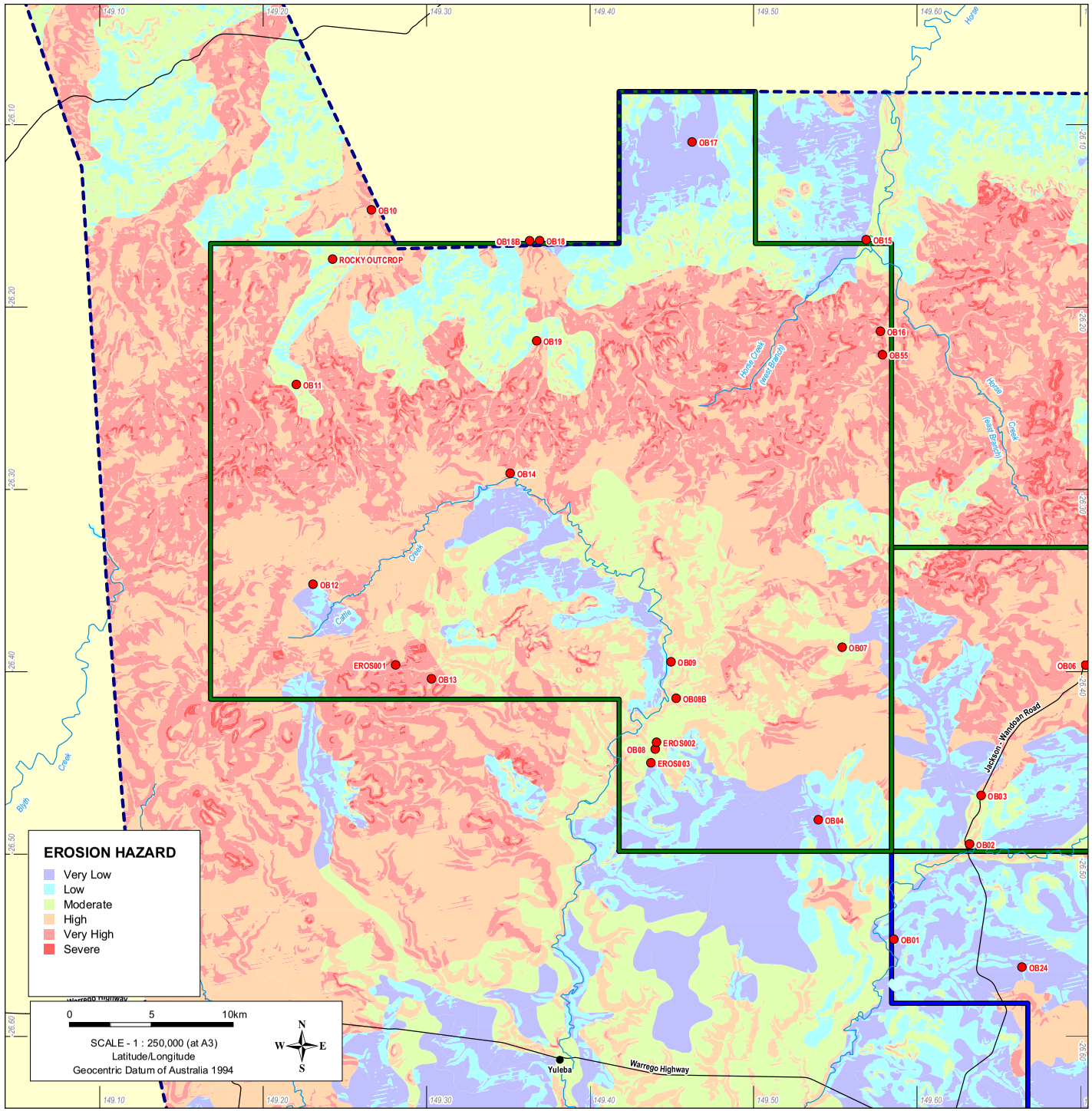
Based on the assessment presented in Figure 5.2, the following table presents the overall erosion hazard of each of the tenements.

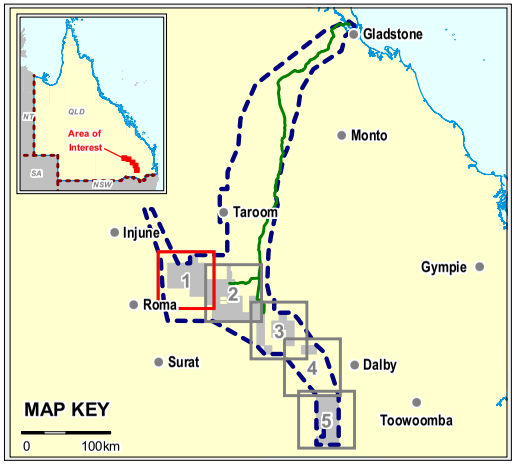
Table5.10 Tenement erosion hazard

Tenement	Area (ha)					
	Very low	Low	Moderate	High	Very high	Severe
Combabula-Ramyard	19,946.22	21,107.99	27,728.46	59,252.57	50,488.00	5,945.86
Carinya	71,608.13	20,679.93	6,660.97	7,658.00	839.99	19.34
Woleebee	1,188.34	2,366.42	2,895.16	2,717.51	4,310.82	1,298.03
Dalwogan	8,796.04	5,193.60	1,005.56	7,068.26	962.66	1.56

Tenement	Area (ha)					
	Very low	Low	Moderate	High	Very high	Severe
Condabri	17,069.50	5,066.31	5,816.70	16,156.42	1,853.90	7.20
Talinga-Orana	21,742.90	8,040.01	6,907.33	12,974.54	2,089.91	41.51
Kainama	4,760.04	2,402.69	3,967.83	3,857.23	292.17	14.96
Gilbert Gully	14,190.79	19,857.70	16,116.63	57,150.93	20,336.65	1,535.39
Total	159,301.96	84,714.65	71,098.64	166,835.46	81,174.10	8,863.86
% of total Project Area(tenements)	28%	15%	12%	29%	14%	2%

Each level of erosion hazard – that is, from very low to severe – requires a different level of project planning and management, particularly during the construction phase. Clearly, areas designated with a very high to severe rating will require focused infrastructure planning, erosion protection measures and rehabilitation strategies. General mitigation measures, described in Section 7, include topsoil and subsoil management (stripping, stockpiling, respreading), sediment and erosion control and slope and drainage line management.





LEGEND

- Observation location
- Town
- Road
- Preferred pipeline alignment
- Major drainage
- Reservoir
- Study area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

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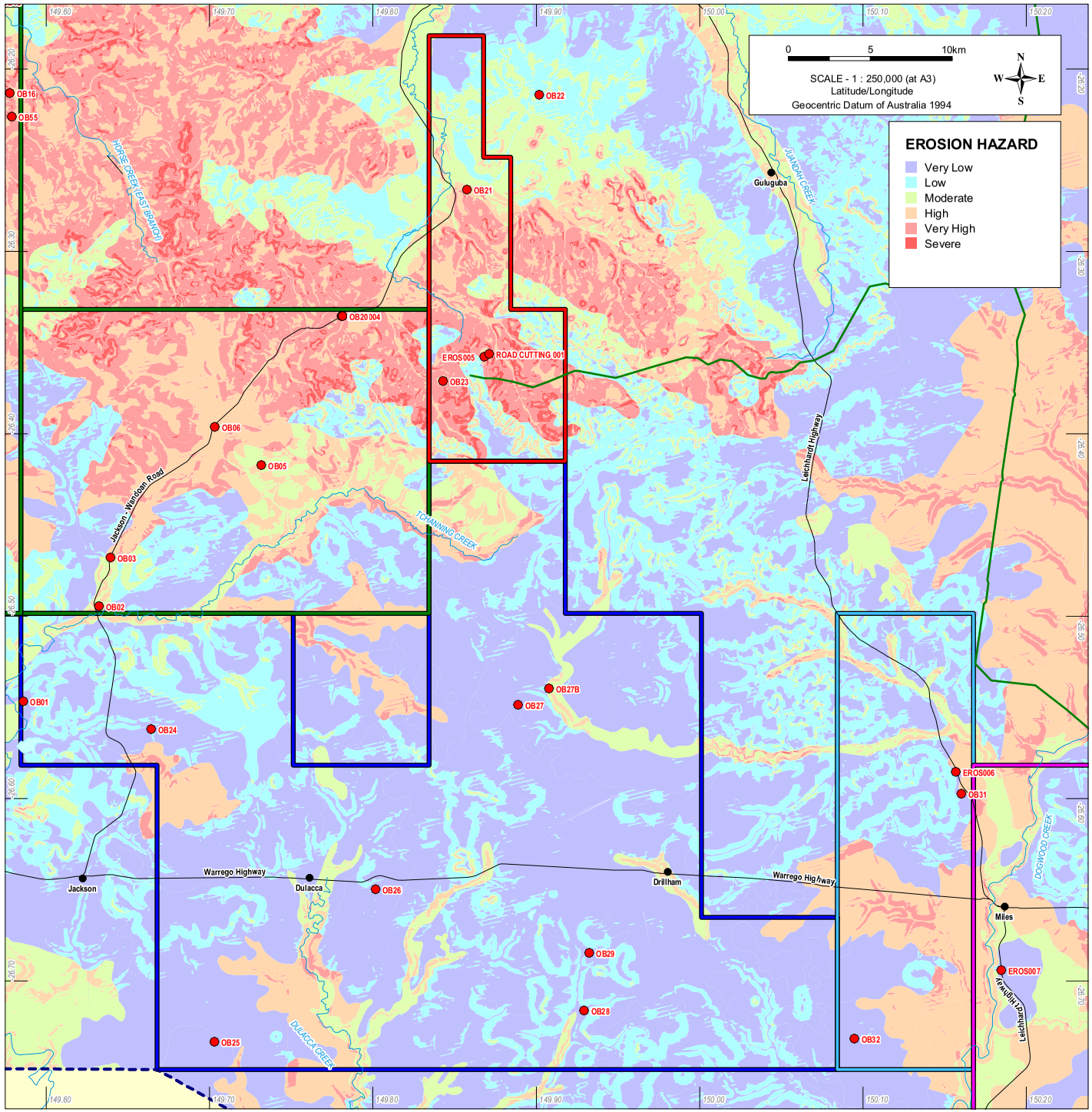
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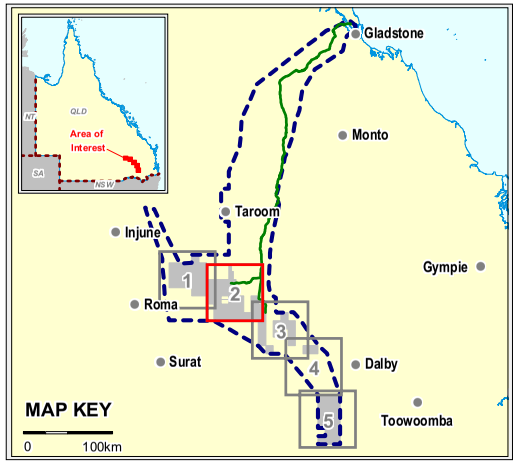
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Figure 5.2 Study Area Erosion Hazard
Map 1 of 5

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LEGEND

- Observation location
- Town
- Road
- Preferred pipeline alignment
- Major drainage
- Reservoir
- Study area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

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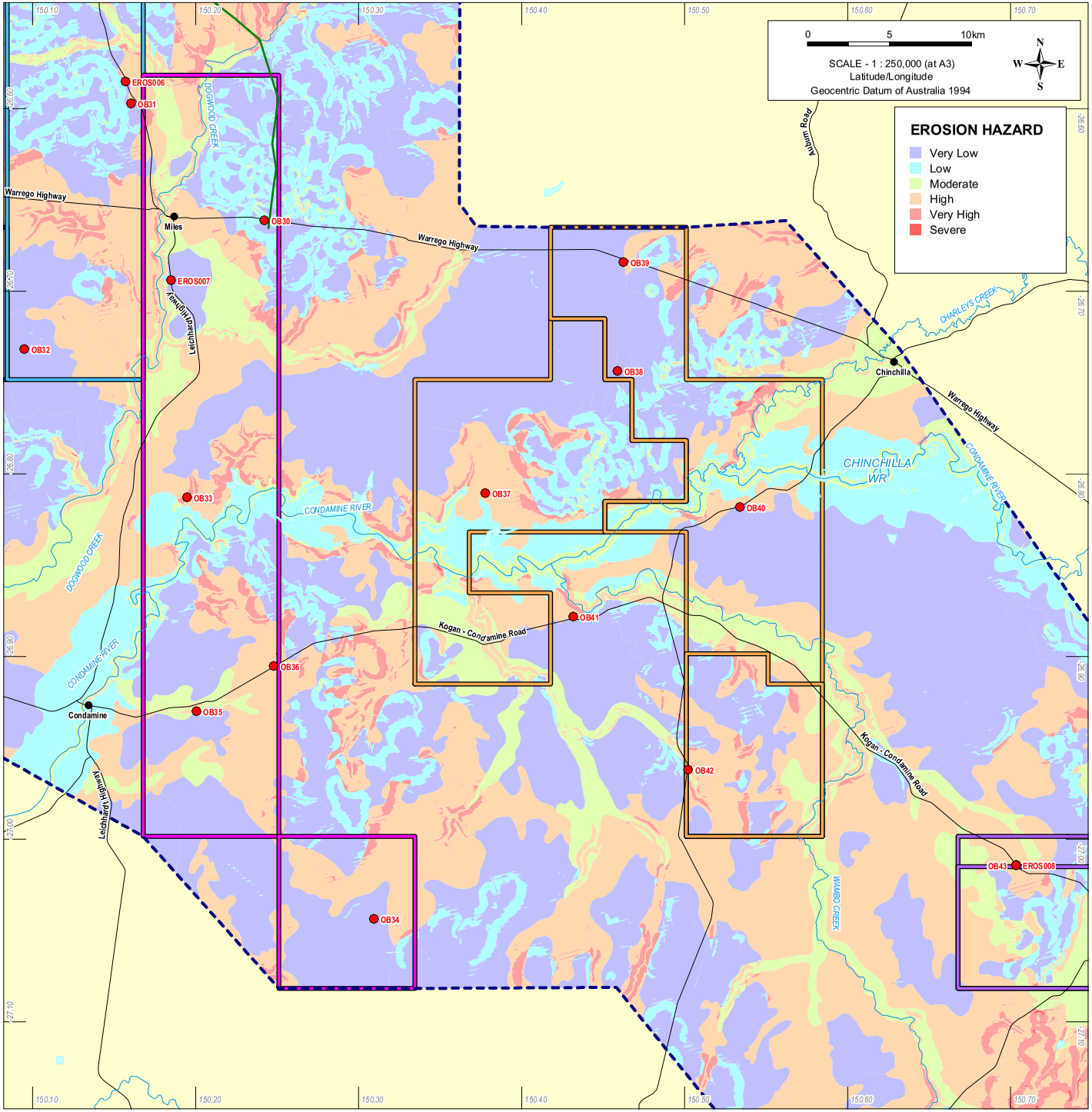
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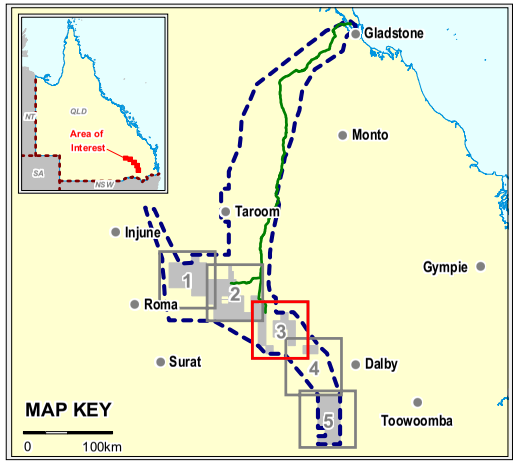
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Figure 5.2 Study Area Erosion Hazard
Map 2 of 5

Project No: 301001-00448	Figure: 00448-00-EN-DAL-0205	Rev: 0

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LEGEND

- Observation location
- Town
- Road
- Preferred pipeline alignment
- Major drainage
- Reservoir
- Study area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
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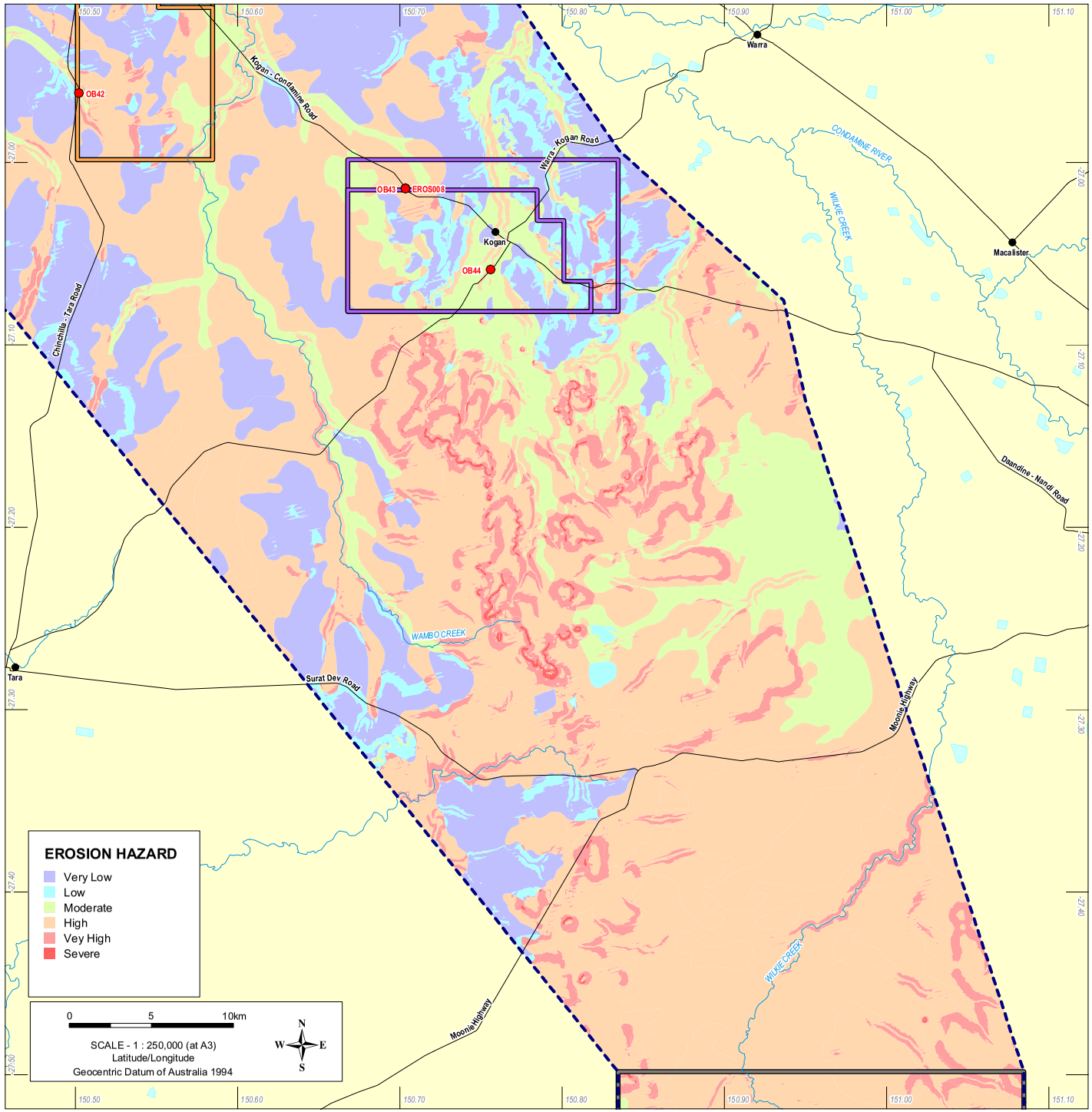
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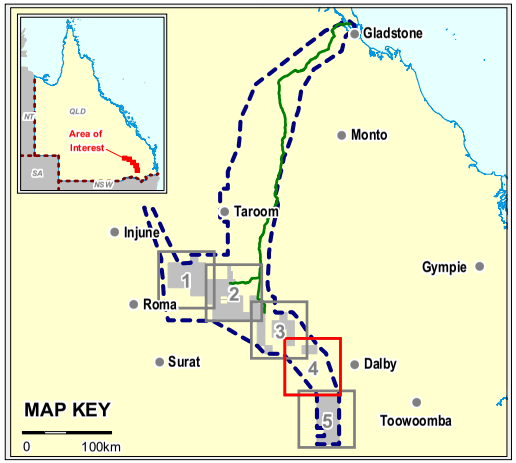
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Figure 5.2 Study Area Erosion Hazard
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Project No: 301001-00448	Figure: 00448-00-EN-DAL-0206	Rev: 0

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LEGEND

- Observation location
- Town
- Road
- Preferred pipeline alignment
- Major drainage
- Reservoir
- Study area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
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- Condabri
- Talinga / Orana
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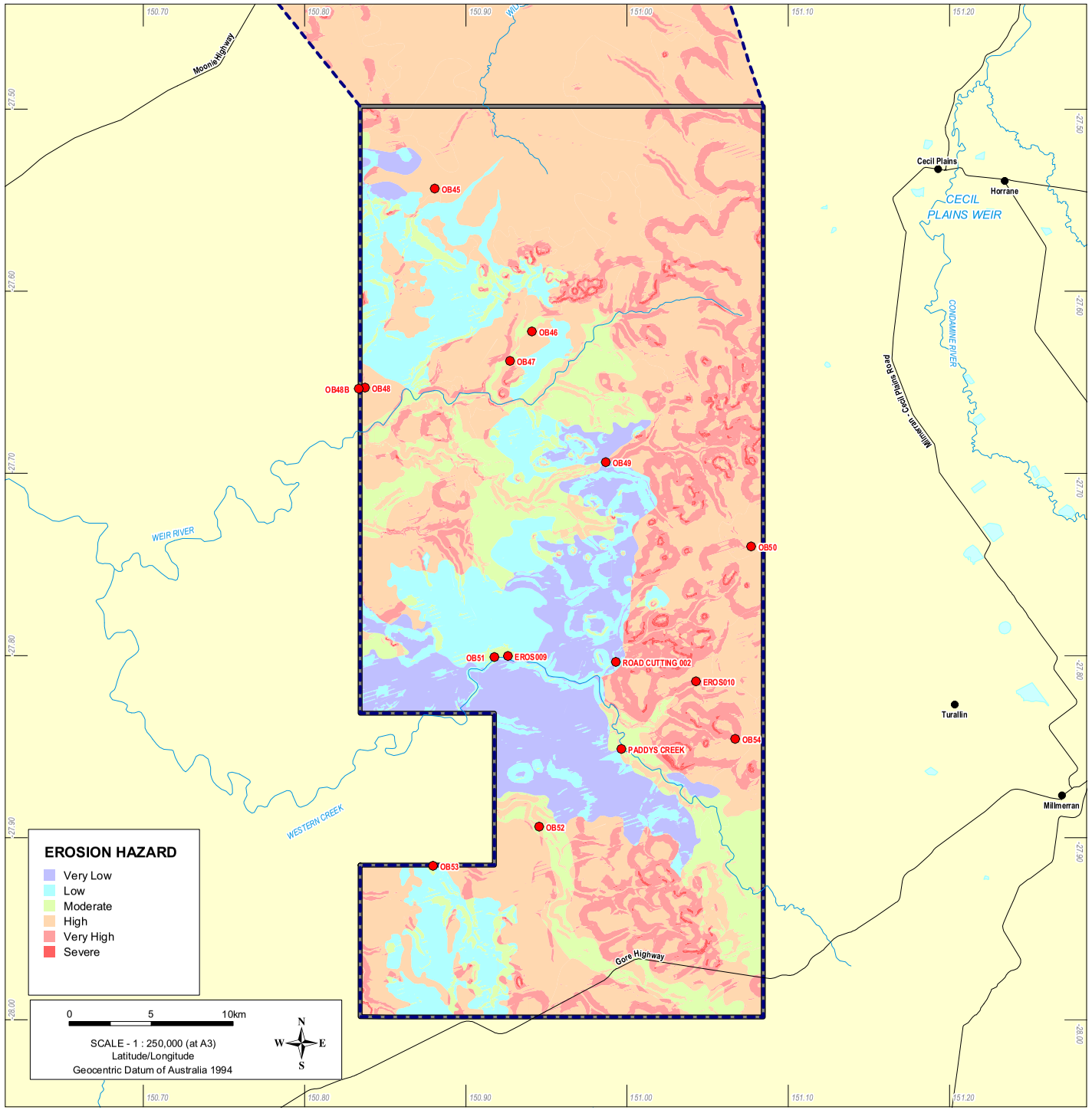
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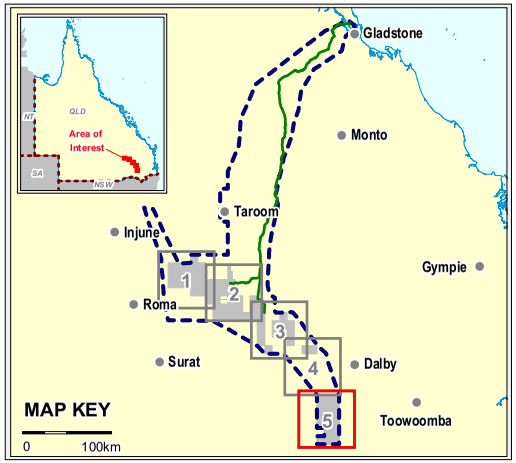
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Figure 5.2 Study Area Erosion Hazard
Map 4 of 5

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LEGEND

- Observation location
- Town
- Road
- Preferred pipeline alignment
- Major drainage
- Reservoir
- Study area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
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Figure 5.2 Study Area Erosion Hazard
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5.2.6 Soil pH

Soil pH can be used as an indicator of the chemical processes that occur in a soil (that is, indicate certain nutrient deficiencies and toxic effects) (Hazelton and Murphy 2007), which may have implications for soil management and rehabilitation measures. Table 5.11 presents pH classification ratings used to assess results, while a summary of all results is presented in Table 2, Appendix B.

Table 5.11 pH classification (Hazelton and Murphy 2007)

pH	Rating
> 9.0	Very strongly alkaline
9.0 – 8.5	Strongly alkaline
8.4 – 7.9	Moderately alkaline
7.8 – 7.4	Mildly alkaline
7.3 – 6.6	Neutral
6.5 – 6.1	Slightly acid
6.0 – 5.6	Moderately acid
5.5 – 5.1	Strongly acid
5.0 – 4.5	Very strongly acid

For samples collected within the study area, pH ranged from 5.5 (OB03/0.9-1.0 and OB07/0.9-1.0) to 8.2 (OB27/0.0-0.1). This indicates that soils are very strongly acid to moderately alkaline. The central tendency of pH data ranged from 6.6 to 7.3 (neutral) and indicates that most soil pH was within the range considered acceptable to plant growth (5 to 7).

Only soil samples OB03/0.0-0.1, OB03/0.9-1.0 and OB07/0.9-1.0 were rated as strongly acidic. Of these samples, only OB07/0.9-1.0 has a high concentration of aluminium (Al) [400meq/100g] which correlates with strongly acidic pH.

This data does not indicate significant constraints. However, if disturbed (that is, during excavation or filling), soils classified as strongly acid and very strongly alkaline should be kept separate from other soils and may require pH amelioration to render them conducive for further use (refer Section 7.3). Note that acid sulfate soils are unlikely to be present in the gas fields study area.

5.2.7 Salinity

Salinity is the presence of soluble salts in or on soils [mainly Na, but also K, Ca, Mg, sulfate (SO_4) and chloride (Cl)]. High salinity levels in soils may result in reduced plant productivity including the elimination of native vegetation and may increase erosion (Hazelton and Murphy 2007). Table 5.12 presents salinity ratings for soil used to classify results once laboratory EC (1:5) values were converted to ECe which is the electrical conductivity of extract obtained from a saturated soil paste which is the standard soil salinity measure used to assess plant salt tolerance. A summary of all results is presented in Table 2.

Table 5.12 Salinity ratings for soil based on ECe (Hazelton and Murphy 2007)

Rating	Electrical conductivity (ECe) (μS/cm)
Non-saline	<2,000
Slightly saline	2,000-4,000
Moderately saline	4,000-8,000
Highly saline	8,000-16,000
Extremely saline	>16,000

Salinity reported for samples collected within the study area ranged from <10 μS/cm (OB49/0.01-0.1 and OB55/0.0-0.1) [non-saline] to 30,900 μS/cm (OB27/0.4-0.5) [extremely saline] with the central tendency of salinity ranging from non-saline to moderately saline. Highly saline concentrations were reported for only eight samples (OB03/0.9-1.0, OB07/0.9-1.0, OB11/0.7-0.85, OB17/0.6-0.7, OB24/0.8-0.9, OB26/0.0-0.1, OB26/0.9-1.0 and OB46/0.9-1.0) while a single extremely saline concentration was reported for OB27/0.4-0.5.

With the exception of OB07/0.9-1.0, high to extremely high saline results were associated with high concentrations of sulfate (S), which ranged <1 meq/100g to 23,647 meq/100g in these samples, the majority of which were clay textured soils. Samples which reported moderate salinity had higher concentrations of Ca, Mg, K and Na. Sand textured soils (which still contain a clay fraction) [that is, OB42] which were generally non-saline to slightly saline, also had high sulfate concentrations. This may be attributable to the clay fraction which would retain the majority of salts within these profiles.

Although moderate to high salinity was reported within subsoil samples, accumulation of salts is an important issue whether at or near the surface. A likely cause of this accumulation of salts is lack of leaching due to low rainfall, or elevated salinity in fluctuating near surface groundwater. The field investigation did not identify any significant areas of salinisation or extensive scalding. However, due to the elevated salinity levels in many subsoils (notably the 2b, 2c and 5b soil groups), careful management will be required, particularly for rehabilitation purposes (refer Section 7.3).

5.2.8 Fertility

Soil fertility is a function of:

a) The soil's capacity to attract and release exchangeable ions, which is influenced by the amount and type of organic matter and clay

b) The presence of nutrients which are available for plant growth, or can be available in the future.

In this assessment, Cation Exchange Capacity (CEC), exchangeable ions, Total Kjeldahl Nitrogen (TKN) and phosphorus (P) were measured as indicators of soil fertility.

Cation Exchange Capacity (CEC)

CEC is a measure of a soil to hold and exchange cations (Hazelton and Murphy 2007). A soil which has a high CEC has the ability to buffer the effects of changes in pH, available nutrients and structure. High CEC can also indicate a soil's fertility. Table 5.13 and Table 5.14 present the classification of CEC and exchangeable cations which are used to assess soils within the study area, while Table 5.15 presents the fertility results. A summary of all results is presented in Table 2, Appendix B.

Table 5.13 CEC ratings (Hazelton and Murphy 2007)

CEC (meq/100g)	Rating
< 6 (soils low in fertility)	Very low
6 – 12	Low
12 – 25	Moderate
25 – 40	High
> 40	Very high

Table 5.14 Exchangeable cations classification (Hazelton and Murphy 2007)

Cations	Very low	Low	Moderate	High	Very high
Units			(meq/100g)		
Na	0 – 0.1	0.1 – 0.3	0.3 – 0.7	0.7 – 2.0	> 2
K	0 – 0.2	0.2 – 0.3	0.3 – 0.7	0.7 – 2.0	> 2
Ca	0 – 2	2 – 5	5 -10	10 – 20	> 20
Mg	0 – 0.3	0.3 – 1.0	1 - 3	3 – 8	> 8

Ranges of exchangeable ions reported for samples collected within the study area are presented in Table 5.15:

Table 5.15 Exchangeable ions ranges

Analyte (meq/100g)	CEC	Na	K	Ca	Mg	S	Fe	Al
Value	1.8 – 189.7	0.4 – 11.7	0.1 – 1.9	0.1 - 160	0.3 – 20.6	<1 – 23,647	<1 – 18	<1 - 519
Rating	Very low to very high	Moderate to very high	Very low to high	Very low to very high	Very low to very high	-	-	-
Central tendency of data	Low to high	High to very high	Low to moderate	Very low to high	High	-	-	-

CEC concentrations from low to high indicate variable fertility within study area soils. Notably, however, lower concentrations were reported for sandy and loamy textured soils (Chromosols, Kandosols and Rudosols), while higher concentrations were reported from clay textured soils, predominately Vertosols. These results indicate that sandy and loamy textured soils are less fertile than clayey textured soils. The application of soil additives for fertility, pH or structure amelioration will most likely be required in the sandy texture contrast soils (soil groups 2a – 2d).

Exchangeable cations

Sodium (Na) concentrations were rated as high to very high within study area soils. These values reflect the data reported for ESP and SAR (refer: Section 5.2.3).

Potassium (K) concentrations were rated as low to moderate within study area soils.

Calcium (Ca) concentrations were from very low to high within study area soils. Ca concentrations usually decline with depth in the profile. This was the case in most soils. However, in some cases Ca concentrations increased. Where increases in Ca concentrations were reported, calcite (denoted by K within field data: Table 1, Appendix B) was usually noted at depth within the profile (that is, at OB03, OB17 and OB37.

Magnesium (Mg) concentrations were rated as high within study area soils and were generally higher in concentration within subsoils. This is expected as Mg concentrations usually increase with depth in the profile. This data correlates well with pH data which indicates exchangeable Mg should be high as it generally becomes available to plants at pH levels greater than 5.

Exchangeable anions

Exchangeable iron (Fe) concentrations ranged from <1 mg/kg to 18 mg/kg, while the central tendency of data ranged from 3 meq/100g to 9 meq/100g, which is considered low. Soils are generally negatively charged. Therefore, low concentrations of anions (such as Fe) are expected.

Exchangeable aluminium (Al) concentrations ranged from <1 mg/kg to 519 mg/kg, while the central tendency of data ranged from 3 mg/kg to 69.75 mg/kg. High concentrations of Al were reported at OB05, OB07, OB29 and OB34. Although laboratory pHs reported for these soils were generally neutral, all had strongly acidic field pH. This is expected as Al generally increases with lower pH. Furthermore, anions concentrations (such as Al) generally increase within weathered or sandy textured soils where cation concentrations are lower.

Both exchangeable cation and anion results are indicative of the soil sampled.

Nutrients

Table 5.16 presents Total Kjeldahl Nitrogen (TKN) and P ratings which are used to assess nutrient levels, while a summary of all results is presented in Table 2, Appendix B.

Table 5.16 Soil nutrient level ratings

Analyte	Very low	Low	Moderate	High	Very high
Nitrogen (total) (N) (% weight)	0.05	0.05 – 0.15	0.15 – 0.25	0.25 – 0.5	> 0.5
Phosphorus (P) (mg/kg)	5	5 – 10	10 – 17	17 – 25	> 25

Only topsoil samples were analysed for nutrients TKN and P. These concentrations were as follows:

- Concentrations of TKN ranged from <0.1% (OB55/0.0-0.1) [very low] to 0.11% (OB23/0.0-0.1) [low], while the central tendency of data was also very low to low (0.03% to 0.055%). These concentrations were reported for both coarse and fine textured soils. As a significant portion of total soil N is stored within organic matter, it may be used as an indicator for organic matter in soil. These results indicate there is only minor organic matter in study area topsoils.
- Concentrations of P ranged from <1mg/kg (OB42/0.0-0.1) [very low] to 37mg/kg (OB23/0.0-0.1) [very high], while the central tendency of data ranged from 2mg/kg (very low) to 7.5mg/kg (low). These results indicate study area topsoils (both coarse and fine textured) are deficient in P and therefore may require the addition of P fertiliser to support plant growth during revegetation.

These results indicate topsoils sampled within the study area ranged in fertility from very low to low.

5.2.9 Bulldust

Bulldust formation is common in arid areas and is more likely to occur in soils with high silt and fine sand content as well as those with high calcium carbonate content. Bulldust will generate wind blown dust and cause dry bogging of vehicles and equipment. Once a soil turns into bulldust it is very difficult to manage. Following generation of bulldust, final rehabilitation and revegetation may be difficult because the soil structure has been destroyed.

Significant levels of bulldust were not observed within the study area. However, this does not preclude its development. Loamy soils, particularly soils located within soil groups 1, 2 and 3 are prone to generate bulldust if vegetation is cleared and topsoil heavily trafficked through project development. Soils located at OB11, OB13, OB14, OB17, OB23, OB26 and OB27 (which ranged in texture from sandy loams to clayey loams) contained appreciable concentrations of Ca which may exacerbate bulldust generation.

As most surface layers of soil within the study area have generally loamy textures, bulldust generation is expected to be widespread if appropriate dust mitigation is not implemented throughout project construction and operation (refer Section 7.3.7).

5.3 Agricultural land capability

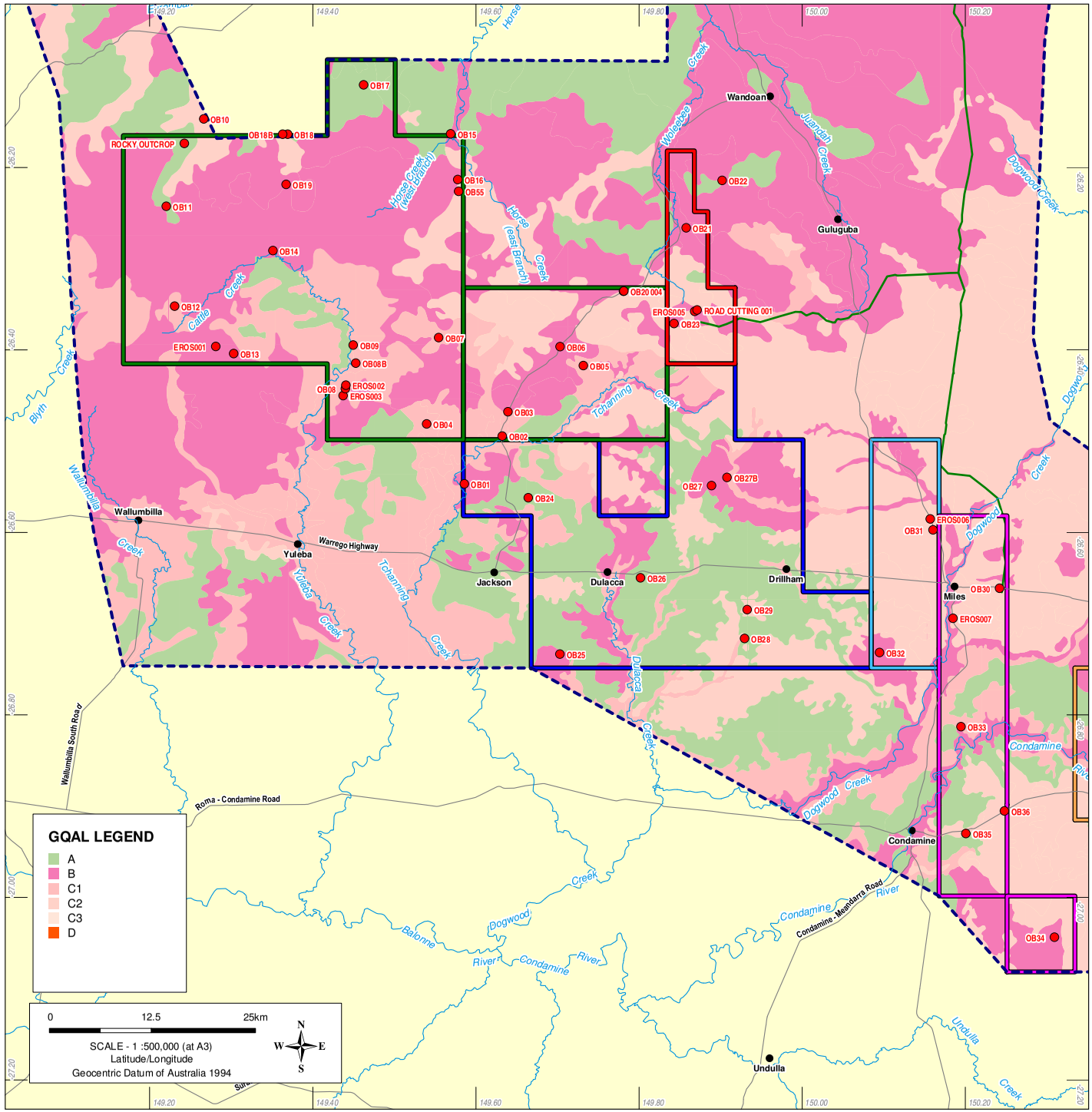
Land systems mapping produced by those reports described in Section 5.1.1, have been used as the basis for determining what areas are considered to be GQAL as per State Planning Policy 1/92 (refer Section 1.1.5). This DERM mapping is presented as Figure 5.3. Table 5.1 presents the GQAL classification for each of the land systems within the study area.

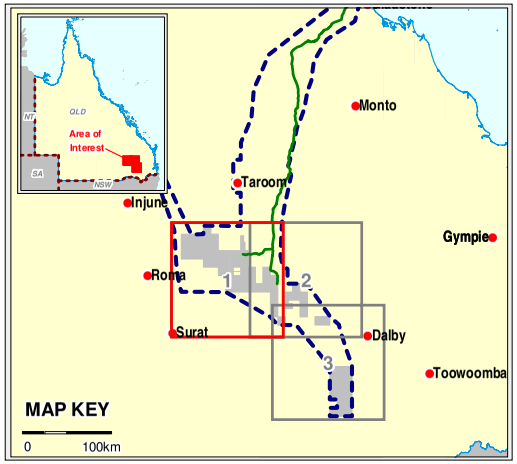
Agricultural land has been classified into four groups as described in Table 5.17.

Table 5.17 Agricultural land classes (source: DHLGP 1993)

Class	Description
A	Crop land Land that is suitable for current and potential crops with limitations to production which range from none to moderate levels. There are two sub-classes of crop land: A1 – Crop land suitable for rainfed cropping A2 – Crop land suitable for horticulture All crop land is considered to be GQAL.
B	Limited crop land Land that is marginal for current and potential crops due to severe limitations; and suitable for pastures. Engineering and/or agronomic improvements may be required before the land is considered suitable for cropping. Land marginal for particular crops of local significance is considered to be GQAL.
C	Pasture land Land that is suitable only for improved or native pastures due to limitations which preclude

Class	Description
	continuous cultivation for crop production; but some areas may tolerate a short period of ground disturbance for pasture establishment. In areas where pastoral industries are the major primary industry, land suitable for improved or high quality native pastures may be considered to be GQAL. There are three sub-classes of pasture land: C1 – Land suitable for sown pastures with moderate limitations C2 – Land suitable for sown pastures with severe limitations C3 – Land suitable for light grazing for native pastures in inaccessible areas C1 may be considered to be GQAL (depending on the respective local authority planning provisions).
D	Non-agricultural land Land not suitable for agricultural uses due to extreme limitations. This may be undisturbed land with significant habitat, conservation and/or catchment values or land that may be unsuitable because of very steep slopes, shallow soils, rock outcrop or poor drainage. These limitations preclude any interference with land or biological resources for the production of agricultural goods.





LEGEND

- Observation location
- Town
- Road
- Preferred pipeline alignment
- Major drainage
- Study area

Walloons Gas Fields Development Areas

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AUSTRALIA PACIFIC LNG

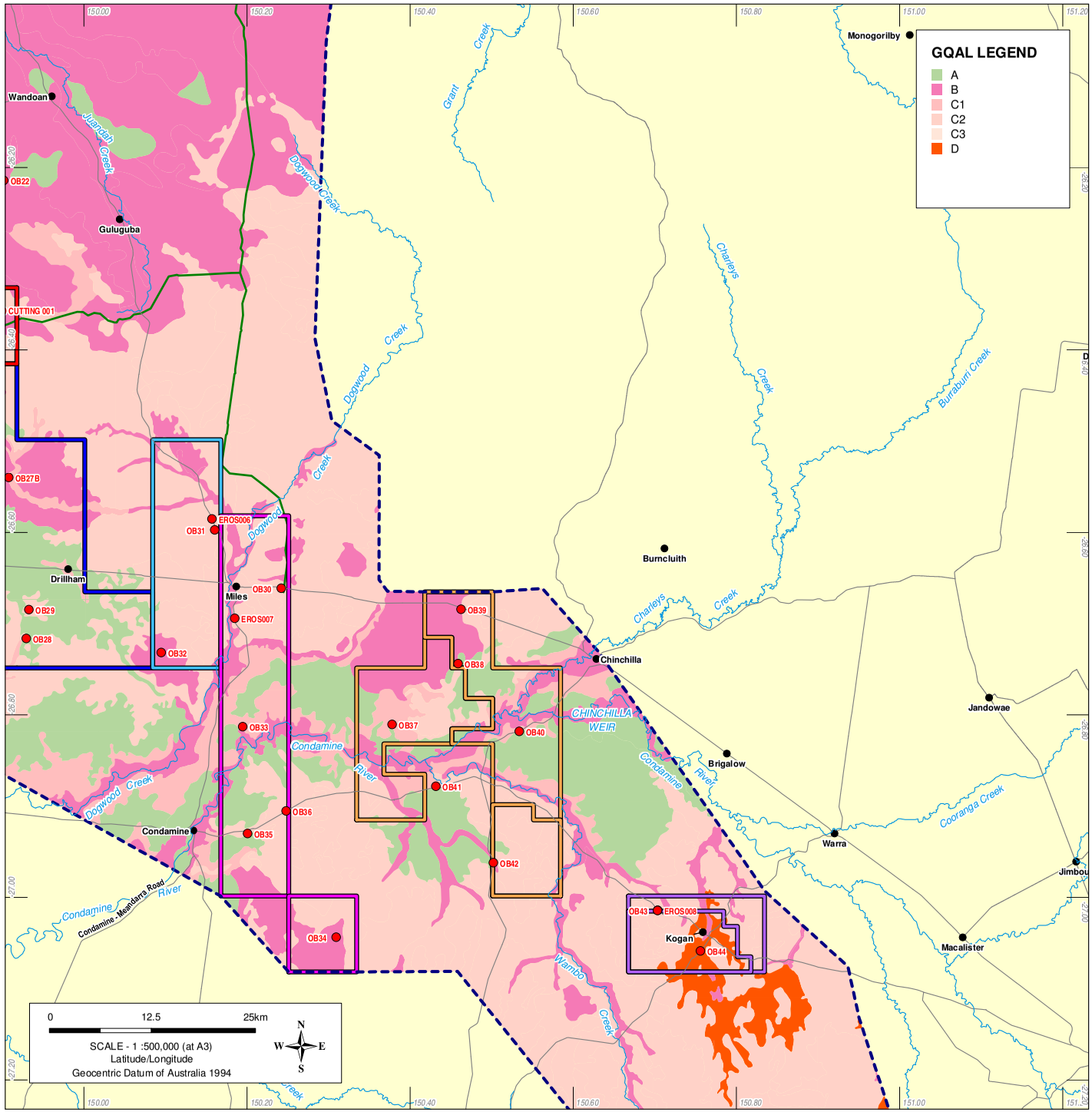
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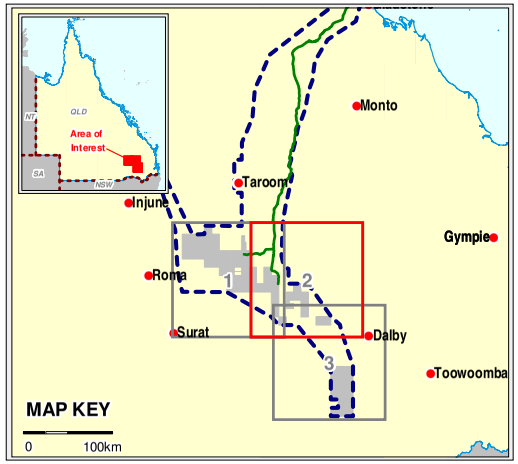
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Figure 5.3 Study Area Good Quality Agricultural Land - Map 1 of 3

Project No: 301001-00448	Figure: 00448-00-EN-DAL-0212	Rev: 0

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LEGEND

- Observation location
- Town
- Road
- Preferred pipeline alignment
- Major drainage
- Study area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

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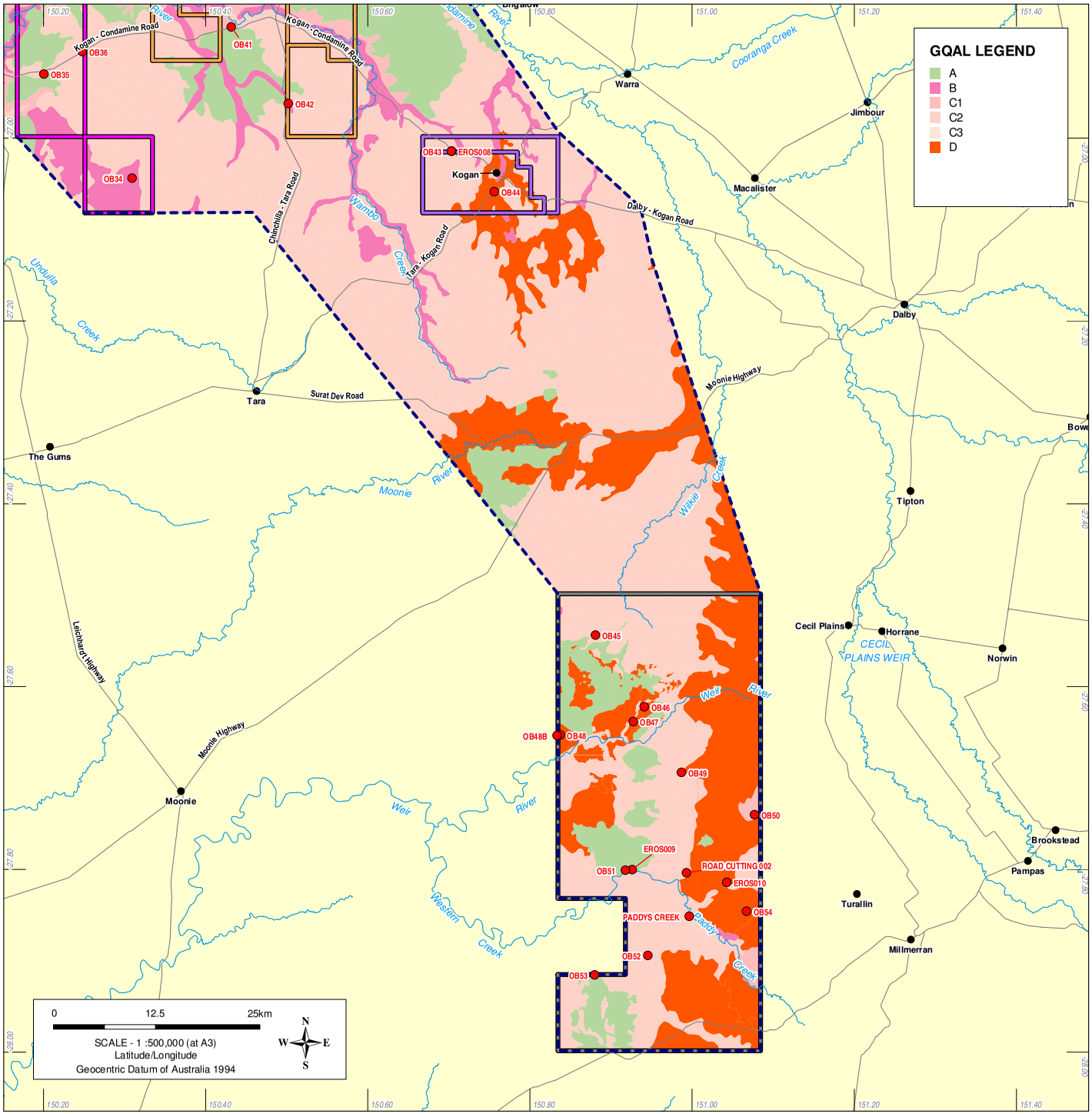
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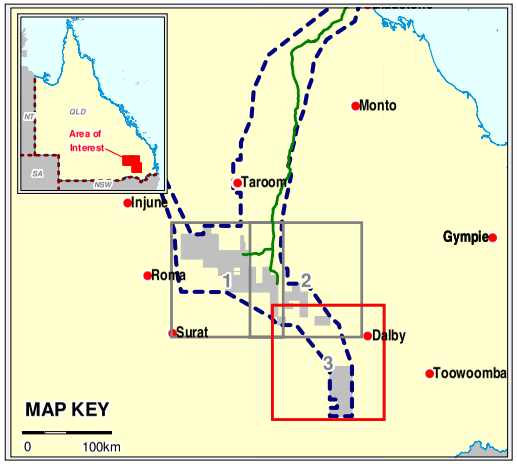
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Figure 5.3 Study Area Good Quality Agricultural Land - Map 2 of 3

Project No: 301001-00448	Figure: 00448-00-EN-DAL-0213	Rev: 0

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LEGEND

- Observation location
- Town
- Road
- Preferred pipeline alignment
- Major drainage
- Study area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

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Figure 5.3 Study Area Good Quality Agricultural Land - Map 3 of 3

Project No: 301001-00448	Figure: 00448-00-EN-DAL-0214	Rev: 0

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Based on this mapping, the percentages of GQAL within the study area have been calculated and provided in Table 5.18.

Table 5.18 Project area GQAL

Class	Total area of GQAL within Project area (ha)	Percent GQAL within Project area (%)	Total area of GQAL within study area (ha) [incl Project area]	Percent GQAL within study area (%) [incl Project Area]
A	111,846	19.6	263,169	18
B	148,727	26.0	395,722	27
C1	70,614	12.3	195,423	13
C2	188,756	33.0	517,653	35
C3	-	-	9,427	1
D	52,045	9.1	86,521	6
TOTAL	571,989	100	1,467,916	100

The location of GQAL is required to understand the existing status of the land resource likely to be affected by the project and provide a standard of which rehabilitation should return the land. GQAL is considered to be comprised of classes A, B and, depending on the planning intent of the respective local authority, Class C1. For the purposes of this study, Class C1 has been considered to be GQAL. When combined, the total GQAL within the Project Area is 58%.

Based on mapping, GQAL class A occurs within all tenements with the exception of Woleebee, Dalwogan, and Kainama. Notably, the highest percentage of GQAL class A occurs within the Carinya tenement. GQAL class B also occurs throughout the entire Project Area, with the highest portion occurring within the Combabula tenement. GQAL class C1 occurs throughout most of the Project Area.

GQAL class C2 and below is not considered to be GQAL and comprises 33% of the Project Area. The highest portion of non-GQAL occurs within Gilbert Gully, the majority of which is comprised of State Forest land.

GQAL mapping correlates well with soil group mapping. Generally speaking, areas mapped as soil groups 4 and 5 (i.e. the deep, dark cracking and non-cracking clay soils) are commonly also mapped as GQAL class A or B. Soil groups 1, 2, and 3 are generally mapped as GQAL class C2 or D and, to a lesser extent, Class C1.

6. Potential Impacts

The Australia Pacific LNG gas field's development will involve the construction and operation of a number of facilities including gas wells, gas processing plants, water transfer stations, waste treatment facilities and brine and water storage ponds. These facilities are likely to occur at isolated locations and may be linked to others by a network of roads, pipelines and cables which form the gathering network for the LNG resource. The construction footprints / disturbance areas of the proposed infrastructure are presented in Table 6.1.

Using the information provided in the above existing land resource assessment, this section discusses the associated impacts of Australia Pacific LNG gas fields development to land; specifically existing geology, topography and geomorphology and soil resources.

Table 6.1 Proposed project disturbance areas

Footprints *(Australia Pacific LNG supplied)*	**Construction** Land area initially cleared (ha)	**Operational** Sterilised land area (ha)
Gas wells	10118	228
Gas and water gathering lines - ROW	18000	Nil - Returned to land use
Scraper stations - HP network	12	12
Gas fields temporary accommodation facility	138	0
Gas fields permanent accommodation facility	138	138
Access tracks	4388	4388
WTS	792	198
HP gas network #	4000	480
HP water network ##	1100	132
GPF	1150	1150
WTF	24	24
Feed pond - WTF_MEL_01 or WTF_RCK_01a	20	20
Feed pond - WTF_HCK_01	5	5
Feed pond - WTF_BYM_01	10	10
Feed pond - WTF_WOL_01	10	10
Feed pond - WTF_GIL_01 or WTF_GIL_01a	20	20
Feed pond - Talinga WTF	20	20
Feed pond - WTF_CON_01	20	20
Brine pond - BP_WOL_01	175	175
Brine pond - BP_GIL_01 or BP_GIL_01a	140	140
Brine pond - BP_Talinga	210	210
Brine pond - BP_RCK_01 or BP_MEL_01	140	140
Pipeline temporary accommodation facilities and lay down area	83	0
Telecommunication towers	4	4
TOTALS	***40717***	***7524***

NOTES: HP – High pressure WTF: Water transfer facility GPF: Gas processing facility ROW: Right of way
assumes all rehabilitated except for 6m vehicle access track; ## assumes 800km co-location with gas

6.1 Geology

Geological data indicate that the Project Area is suitable for proposed development without significant ground improvement or without the need for large-scale blasting. The soils and rock will generally be suitable for the support of structures.

6.1.1 Excavation

An assessment has been undertaken based on the geological and terrain models for the Walloons CSG fields to establish the potential constraints and associated impacts relating to the excavation of materials that nominally occur within 2m depth of the natural ground surface level. An excavation rating assessment was carried out, based on the following broad definitions

Rating 1 (low): Deep soil profile; some low strength extremely weathered to highly weathered soft rock with soil like properties may occur at low levels. Few excavation problems are envisaged. It is anticipated that most materials will be able to be reused for engineered fill or in the backfill of trenches.

Rating 2 (medium): Shallow to medium depth soil profile or gravelly soils, underlain by medium strength, highly weathered to moderately weathered rock, including closer jointed closely fractured / jointed high strength rock. Rocky soils, including cobbles and small to medium size boulders, may occur and present more difficult excavation conditions. A larger sized excavator may be needed to expedite excavation works in rock. The excavator may require a hydraulic rock breaker attachment. It is expected most materials will be able to be reused for engineered fill or in the backfill of trenches. Boulders and rocky soils may not all be reused unless placed through a crusher.

Rating 3 (high): Rock outcrops or skeletal to shallow depth soil profile underlain by high strength moderately weathered to fresh rock, including wider jointed medium strength rock. High strength rock-breaking capability or rock drilling and blasting may be necessary for rock removal. Rock may be unsuitable for reused unless blasts are designed to sufficiently break up rock or material is put through a crusher.

Based on these criteria and with reference to the geological (refer Figure 3.1) and terrain models (refer Figure 4.1), an indicative assessment of the excavation conditions (including probability of rock outcrops) likely to be encountered within the upper 2.0m depth below natural ground surface level was conducted and is described in Table 6.2.

Table 6.2 Study area excavation and environmental impact to geology rating

Geology	Geology unit	Excavation rating	Probability of rock outcrops
Quaternary alluvium and lacustrine deposits	Qa	Rating 1	Unlikely
Palaeocene-Oligocene sediments	Tl	Rating 2	Likely
Wallumbilla Formation	Ku	Rating 2	Likely
Bungil Formation, Gubberamunda Sandstone, Hooray Sandstone, Kumbarilla beds, Longsight Sandstone, Mooga Sandstone, Orallo Formation, Southlands Formation	JKb	Rating 2	Most likely
Injune Creek Group, Mulgildie Coal Measures, Walloon Subgroup (Moreton Basin)	Ji	Rating 2	Most likely
Quaternary alluvium and lacustrine deposits	Qa	Rating 1	Unlikely
Palaeocene-Oligocene sediments	Tl	Rating 2	Most likely
Bungil Formation, Gubberamunda Sandstone, Hooray Sandstone, Kumbarilla beds, Longsight Sandstone, Mooga Sandstone, Orallo Formation, Southlands Formation	JKb	Rating 2	Most likely
Injune Creek Group, Mulgildie Coal Measures, Walloon Subgroup (Moreton Basin)	Ji	Rating 2	Likely
Late Cainozoic floodout and residual sand, soil and gravel	Czs	Rating 1	Unlikely
Quaternary alluvium and lacustrine deposits	Qa	Rating 1	Unlikely
Palaeocene-Oligocene sediments	Tl	Rating 2	Likely
Wallumbilla Formation	Ku	Rating 2	Likely
Bungil Formation, Gubberamunda Sandstone, Hooray Sandstone, Kumbarilla beds, Longsight Sandstone, Mooga Sandstone, Orallo Formation, Southlands Formation	JKb	Rating 2	Most likely
Late Cainozoic floodout and residual sand, soil and gravel	Czs	Rating 1	Unlikely

Geology	Geology unit	Excavation rating	Probability of rock outcrops
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Bungil Formation, Gubberamunda Sandstone, Hooray Sandstone, Kumbarilla beds, Longsight Sandstone, Mooga Sandstone, Orallo Formation, Southlands Formation	JKb	Rating 2	Most likely
Late Cainozoic floodout and residual sand, soil and gravel	Czs	Rating 1	Unlikely
Quaternary alluvium and lacustrine deposits	Qa	Rating 1	Unlikely
Bungil Formation, Gubberamunda Sandstone, Hooray Sandstone, Kumbarilla beds, Longsight Sandstone, Mooga Sandstone, Orallo Formation, Southlands Formation	JKb	Rating 2	Most likely
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Palaeocene-Oligocene sediments	Tl	Rating 2	Likely
Bungil Formation, Gubberamunda Sandstone, Hooray Sandstone, Kumbarilla beds, Longsight Sandstone, Mooga Sandstone, Orallo Formation, Southlands Formation	JKb	Rating 2	Likely

This assessment indicates that approximately two thirds of the geologic units within the study area have a likely probability of rock outcrops to occur. This is despite only noting minor occurrences during the field investigation (refer Figure 3.1). Where there is a likelihood of rock outcrops to occur, excavation difficulties will increase. As this assessment indicates that geology within the study area has an excavation rating of 1 to 2, only some excavation difficulties are envisaged. Investigations (refer Section 7.1.1) will still be required to quantify the environmental impact (such as potential for increased dust, noise and vibration) at site-specific excavations. Further detail is provided in EIS volume 2 chapters 13 and 15 – air quality and noise and vibration respectively.

In summary, the presence of rock is not expected to be a significant impediment to project development and associated impacts relating to rock extraction and handling are expected to be manageable. This review also revealed a range of materials are potentially available. As a result, trenching equipment is expected to able generate bedding for pipelines using some of these materials, however some importation of bedding materials may still be required.

6.1.2 Geologic structural features and faults

Identified faults could potentially comprise zones of weakness in the upper crust that may be subject to differential movement during a significant seismic event in the region. However there have been no recorded earthquakes within the gas fields study area since 1958. This suggests the earthquake risk within the gas fields study area is low.

Should an earthquake occur during the life-cycle of Project development, damage to infrastructure may occur. An indication of potential levels of public nuisance and damage to infrastructure for the approximate range of earthquake magnitude recorded in Queensland is presented in Table 6.3.

Table 6.3 Indicative levels of damage from Earthquakes

Modified Mercalli scale		Level of damage	Richter Scale
1-4	Instrumental to moderate	No damage	</= 4.3
5	Rather strong	Damage negligible. Small, unstable objects displaced or upset; windows rattle, felt by some people.	4.3 - 4.8
6	Strong	Damage slight; windows, dishes, glassware broken,, door swing, felt by everyone	4.9 - 5.4
7	Very strong	Damage slight to buildings with plaster cracking and brick falling	5.5 - 6.1
8	Destructive	Cause much building damage and houses move on foundations. Bridges twist, wall fracture, masonry building collapse. Most buildings collapse from 7.4 to 7.9. When greater than 8, total damage with waves seen on the ground surface and object thrown in the air	6.2 - > 8

Source: http://www.ga.gov.au/urban/factsheets/20010919_15.jsp

The table suggests that structural damage could occur during earthquakes of Richter 4.9 or higher. In such an instance, damage to LNG infrastructure could result. A ‘worst case scenario’ would be that an earthquake was of significant magnitude or duration to rupture pipes within the gathering network and

cause a release of contaminant into the ground and/or atmosphere. Whilst such an occurrence may be statistically remote, the potential seismic risk should be appropriately addressed during design.

It has been noted earlier (Section 3.3.1) that a seismic event could also arise as a result of gas extraction or construction of a large lagoon. However no deep lagoons or dams are proposed to be developed as part of the gas fields and therefore surcharge loading on the earth is not expected to be significant. The risk of seismic events caused by construction of a lagoon is thus considered to be negligible. With regard to the potential for seismic activity to be caused by gas extraction (particularly during initial well development), the depth of extraction is such that surface impacts are likely to be minimal, with the potential for only very localised ground vibrations.

6.1.3 Extractive resources

The identified potential impacts on extractive resources associated with the development of the Australia Pacific LNG gas fields are as follows:

- New quarries and expansions to existing quarries (operated by others) may be required with development of the Australia Pacific LNG gas fields and changes to land and road use would potentially occur as a result. To meet the demand of the Australia Pacific LNG Project, any new quarry would be required to undergo an impact assessment as part of gaining a separate development approval prior to commencing the activity.
- While not specifically addressed within this report, the environmental effects of any future quarry developments will require consideration and will need to include the cumulative effects associated with the resource demands of other possible CSG projects in the region. Such effects may include alteration of topography, drainage, leaching of chemical / minerals, removal of vegetation and changed dust, noise and vibration levels. Extractive industry operations would, however, need to comply with DERM and local council operational conditions including compliance with relevant emission levels.

The potential constraints and opportunities relating to demands by the Australia Pacific LNG Project and other proposed CSG projects on the available (or additional sources of) extractive resources in the region requires further investigation by project proponents during FEED.

6.1.4 Reactive Soils

Vertosols (cracking clays - 5b and 5b[m]) encountered within the Australia Pacific LNG study area as described and mapped in Section 5.1.1 are generally expansive dark brown / grey cracking clays. The potential impacts with construction in areas where Vertosols are encountered may include:

- Cracking clays are usually highly reactive to moisture variations and can generally lead to extensive subsidence and in turn cause damage to the proposed buildings and roads.
- Potential damage to pipeline infrastructure (i.e. damage to protective coating) in areas of expansive cracking clays.
- Traversing through areas of where Vertosols occur may become very difficult when wet.

6.1.5 Sterilisation of resources

There are areas of the gas fields where there are a number of permits that have overlapping tenure for coal mining or extraction of coal seam gas. The extraction of gas could potentially impact other

permits for gas, however extraction of gas from coal seams does not impact the ability to mine the coal. In fact, degassing the coal can assist in any future underground coal mining.

Australia Pacific LNG is also working with government to manage the tenure overlaps and sterilisation of resources. In February 2009 the Queensland Government released its Underground Coal Gasification (UCG) policy, which guides the management of such overlaps. Australia Pacific LNG is represented on the UCG Industry Consultative Committee, which was established to advance the policy and is addressing issues such as potential resource impacts or sterilisation.

Given that the extraction of gas is a tenurial issue in this case (i.e. not an environmental matter), this issue has not been considered further in this report.

6.2 Topography and geomorphology

Development of the gas fields will involve construction of numerous facilities – gas wells, gas plant facilities, water transfer stations, waste treatment facilities, brine and water storage ponds – and associated handling infrastructure – pipelines and access roads – across and between all tenements. Construction will involve vegetation clearing and earthworks, resulting in destabilisation of soils.

Overall, the potential impacts of the project on terrain are likely to be low with the main issues relating to soil erosion risk and control, aspects which are addressed in detail in Section 7.3.3. The study area landform may be altered locally through changes to existing natural drainage patterns and may involve slope changes and diversion of stormwater around facilities.

If not managed, changes to natural drainage patterns and destabilisation of soils may contribute to erosion which, if not mitigated may scar the land and contribute to downstream water quality degradation. The destabilising of soils may also lead to slope instability due to the increased water infiltration or loss of vegetation. The assessment of erosion susceptibility and likely project impacts is presented in Section 5.2.4 and 6.1.4 respectively. Land clearing, altered landform and changes to land use may have other associated impacts, including the potential loss of GQAL and visual amenity (refer Section 5.3 and Landscape and Visual Amenity EIS Chapter 7, respectively).

There are also numerous water courses that traverse the tenements. Trafficking and pipelines across these water courses can cause erosion and affect embankment stability which can in turn increase the potential for erosion and increase sediment load (further impacts are considered in Chapter 11 of the EIS, Surface water and watercourses).

6.3 Soils and land resources

This section discusses potential impacts to soil resources within the study area from the construction and operation of approximately 10,000 gas extraction wells and associated infrastructure based on the soil assessment detailed above, the construction footprints / disturbance areas of which are presented in Table 6.1.

6.3.1 Topsoil

Topsoil protects dispersive subsoils, is critical to erosion control and is important for revegetation and weed management. Construction of project infrastructure will impact topsoils if they are not stripped and stockpiled separately to subsoils and vegetation, resulting in soil inversion (replacement of topsoils with subsoils on the soil surface and upper soil profile). If subsoils are exposed for extended periods, excessive erosion may occur. Operational impacts could result from poor rehabilitation and drainage management leading to topsoil and subsoil erosion.

Based on field classifications, topsoil varied in thickness from thin to medium throughout the study area. As topsoil is generally removed down to the subsoil, site specific assessments will be required pre-disturbance to determine the appropriate removal depth and handling / stockpiling arrangements. A shortage of topsoil is inevitable in some areas, particularly in shallow stoney soils (soil group 1), shallow texture contrast soil (soil group 2) and those within soil groups 4 and 5 where clay content is significant in surface material. Additional topsoil may therefore need to be removed from areas with substantial topsoil depths to overcome this possible shortfall. A site specific topsoil assessment should take this into account.

Fertility of topsoils (both fine and coarse textured) within the study area was rated as very low to low. As a result, additional nutrients (specifically N and P) / conditioner may be required during stockpiling and rehabilitation to improve topsoils, stabilise subsoils and support vegetation regrowth.

6.3.2 Erosion

There is the potential for construction of Project infrastructure to have a significant adverse impact on soils resulting in excessive soil erosion and sedimentation levels with consequent adverse effect on water quality in the main watercourses. Failure to effectively control erosion may have continuing adverse consequences during operational and decommissioning stages of the Project. The degree of impact will relate strongly to the effectiveness of methods employed for land clearing, grading, earthworks and infrastructure establishment.

Potential follow on effects may include, but are not limited to, undermining of structures, pipeline exposure, furrowed landscape, upstream bank erosion (incision of a stream into its banks), downstream sedimentation, decline in fertility through loss of soil structure, increased dust generation and loss of GQAL.

Based on erosion ratings (refer Section 5.2.4), soil groups 2b and 2c have the highest erosion rating. This is particularly notable in the coarser textured soil groups where there is little structure and organic matter to assist in binding soil and resist erosion. However, where slope increases, so too does the erosion hazard. Most soil groups were generally highly erodible if disturbed when the site slope is more that about 8%. Finer textured soil groups (4 and 5) have a low to moderate erosion rating. However, most were reported as sodic to strongly sodic and will erode where vegetation has been removed due to clay dispersion.

There is the potential for construction of the project to have a significant adverse impact on soils resulting in excessive soil erosion and sedimentation levels with consequent adverse effect on water quality in the main watercourses. Failure to effectively control erosion may have continuing adverse consequences during the operational and decommissioning stages of the project. The degree of impact will relate strongly to the effectiveness of methods employed for land clearing, grading, earthworks and infrastructure establishment.

Previous erosion assessments undertaken within the study area have indicated that conventional stormwater control through runoff diversion and concentration combined with scour protection has had mixed success, particular in highly dispersive soil areas. In certain circumstances, practices have increased erosion through channelled runoff flows leading to gully development and increased sedimentation. This is not only attributable to stormwater control constraints but inherent soil erodibility constraints also, particularly where the subsoils are highly dispersive. Detailed sediment and erosion plans (as identified later) will be necessary to designate effective control measures, especially in areas designated as having a high to severe erosion hazard.

Concentrated discharge of reverse osmosis treated gas well groundwater ('product') to waterways is likely to be required during the Project's operational phase. Lined management ponds will be used to store a portion of treated 'product' water for reuse at other project components (that is, power plants). Based on a 'worst case scenario', the volume of product discharge to waterways will total 235ML/day during peak production. As precise discharge locations are unknown at this stage of the Project, it has been assumed that proportions of this total volume will be discharged to waterways adjacent to Water Treatment Facilities (WTF). Based on this assumption, the soil erodibility rankings determined in Table 5.9 have been used to indicate the erosion hazard of soil resources which line the receiving waterways (refer Table 6.4).

Table 6.4 Erodability ranking of soil at treated water discharge points

WTF name	Mapped soil types	Soil erodibility ranking (no disturbance) [Table 5.9]
WTF_BYM_01	5b	1
WTF_CON_01	2c	4
WTF_GIL_01	2b	4
WTF_GIL_01a (alternative)	2b	4
WTF_HCK_01	1a/5a	2
WTF_MEL_01	4b/5b	2
WTF_RCK_01a (alternative)	2d	2
WTF_WOL_01	2a	2
Talinga WTF (existing)	1a/5a	2

Notes
Soil erodibility: 1: low 2: moderate 3: high 4: very high

Where concentrated flow is proposed (including diversion of stormwater around construction areas), the greatest erosion impact will occur in unprotected (un-vegetated), coarse textured soils and dispersive fine textured soils (refer Figure 5.2). Where large volume concentrated flows are likely to occur, there is the potential to:

- Exacerbate gully erosion
- Cause notch erosion resulting from reduced variability of flows downstream of discharge points.
- Increased bank instability (stream bank erosion).
- Exacerbate meander migration.
- Increase entrainment of bed sediments, resulting in redistribution downstream (refer Aquatic ecology – EIS, Volume 2, Chapter 9).

Hydrostatic testing of the HP gas network and gas and water gathering pipelines will be required using water sourced locally. Following the completion of testing, this water may have high concentrations of turbidity, iron and sodium bisulphate and will require disposal (refer Chapter 12 of EIS Associated Water Management report). The preferred method of disposal will be discharge to land owner dams for irrigation. However, where this option is unavailable, sheet flow land irrigation will be undertaken. Impacts in relation to 'worst case' scenario (irrigating to land) are expected to be similar to the erosion

hazards described above. Furthermore, there is the potential for follow-on effects where this water contains contaminant concentrations, such as heavy metals, raised dissolved salt concentrations and (possibly) hydrocarbons. Therefore, hydrotest water should not be released without treatment or an assessment of the water quality and receptors at the release. As a minimum, any discharge to land should meet specific quality criteria outlined by environmental authorities. This aspect is addressed in a separate report (refer Chapter 12 of EIS Associated Water Management report).

6.3.3 Salinity

Salinity levels ranging from non-saline (electrical conductivity (EC) levels <2000µS/cm) to moderately saline (4000-8000µS/cm) was reported for soils encountered within the study area. Eight samples were highly saline (8000-16000µS/cm), while an additional one was extremely saline (16000µS/cm). The highly saline samples were clays classified as Vertosols, Dermosols and Sodosols. The high and moderate levels of salinity reported for fine and coarse textured soils respectively was attributed to high concentrations of sulphate. Moderate salinity reported in the majority of remaining samples was attributable to high concentrations of exchangeable cations (Ca, Mg, K, Na). All samples which reported moderate to high salinity ratings were collected within land currently utilised for grazing and not considered GQAL.

Vegetation has varying tolerance to salinity with only several species able to tolerate EC levels greater than 8000µS/cm. As a result, moderate to highly saline soils will require special management as they may be corrosive to civil structures and present challenges for revegetation. Several Australian standards, such as Australian Standard AS3600 for concrete design and AS2159 for piling design, include requirements for buried concrete and steel depending on soil chemistry. However, further specific geotechnical investigations will be required to assess suitable corrosion protection requirements. Additionally, suitable subsoil handling and progressive rehabilitation shall be undertaken to minimise potential blending between non-saline and highly saline soils.

Dry land salinity associated with parent soils is present in some locations within the study area. The Projects activities such as vegetation clearing and management of surface water have the potential to contribute to further salinisation of soils. However, given the relatively fragmented nature of proposed clearing of intact vegetation for the project, the nature of drainage patterns and existing occurrences of salinisation with the region, the risk of the project causing a significant outbreak of dry land salinity is considered to be low. Nevertheless, there remains the possibility that localised salt outbreaks/scalds could occur in certain areas. Salinisation caused by irrigation and other water management strategies associated with the project (i.e. Groundwater extraction, water containment and disposal) has been addressed in other reports (refer Groundwater Assessment, Volume 5, Attachment 22).

Over the lifetime of the Project, approximately 10,000 gas wells will be drilled. The drilling process inherently generates saline (>16000µS/cm) fine material which will be isolated in a sump, which is covered with original topsoil and rehabilitated after the wellhead has been established.

Gas wells are dewatered to extract the Coal Seam Gas (CSG). This water has a higher dissolved salt content than fresh water and is described as brackish. Untreated, this water has a limited use and therefore is treated via reverse osmosis which produces clean water suitable for a number of uses. It does, however, produce an extremely saline (approximately 60g salt/L) effluent which will initially be stored in management (brine) ponds for evaporation. The preferred option is to inject the brine back into geologically suitable aquifers at depth if deemed feasible.

6.3.4 Bulldust

Loamy soils, particularly soils located within soil groups 1, 2 and 3, are prone to generate bulldust if vegetation is cleared and topsoil heavily trafficked throughout the Project.

As there is a high proportion of soils with generally loamy textured surface layers, bulldust generation is expected to be widespread if appropriate dust mitigation is not implemented throughout construction and operation.

6.3.5 Land capability reinstatement

A total of 58% of the study area is comprised of GQAL (classes A, B and C1). This land will be impacted through construction and operation of various project components, which could cause a minor loss of agricultural production (reduced cropping area) in a regional context through:

- Interference with overland flow through the modification of runoff controls
- Increase in soil compaction through heavy trafficking, reducing water infiltration
- Decrease in fertility
- Increase in erosion
- Disruption to farming operations with respect to the timing of operations and restrictions on land use.

Given the scale of the Australia Pacific LNG development, the impact on the productive value of land may have an intermediate impact in the short-term until such time as infrastructure is implemented and suitable rehabilitation measures are completed. This impact may have a cumulative impact with other concurrent CSG projects, although these would be in neighbouring regions.

The short term impact to GQAL (during construction) is estimated as 23,726ha. Following the implementation of suitable rehabilitation measures (refer Section 7), the estimated total area of GQAL which will be sterilised during gas fields operation is 4,319ha (0.75% of the tenement area).

Individual facility construction and operational footprints within GQAL have been discussed in EIS Volume 2, Chapter 6 – Land use and Planning. These estimates are based on data presented in Table 6.1.

7. Mitigation Measures

7.1 Geology

7.1.1 Excavation

The excavation ratings provided in Table 6.2 correspond with the increasing levels of potential environmental impacts including the likely extent of clearing, the construction methods and types of equipment required to undertake the work. Such impacts include increased noise and dust levels, handling / stockpiling of rock and rehabilitation constraints. Other impacts relate to the strength and amount of rock likely to be encountered and the suitability of the excavated spoil for backfill purposes.

Wherever practicable, clearing of existing natural vegetation should be confined to within the proposed construction disturbance footprint (refer Table 6.1). Where additional clearing is required to permit access for larger equipment, clearing should be kept to the minimum necessary to complete the work.

Based on these excavation ratings provided in this assessment, it was concluded that in most locations excavation to 2m is likely to be possible with conventional plant. However the use of hydraulic rock breakers may be required in some areas as boulders and rock in these locations may not be suitable for backfill. Nonetheless, FEED phases of the Project should quantify and qualify the type of equipment required for excavation and therefore qualify the potential associated environmental impacts.

If rock breaking and / or drilling and blasting is required for rock removal, the works should be undertaken to minimise the effects of noise and vibration on the surrounding environment (refer EIS Chapters 13 and 15 – air quality and noise and vibration respectively). Blasting should be carried out in accordance with relevant local authority guidelines and AS2885.1: Gas and Liquid Petroleum Guidelines.

Rock spoil, where encountered, should be reused on the construction site or removed from the site and used for erosion control rip-rap, or disposed of in alternative approved locations, wherever practicable. If there is a deficiency of trench backfill material, suitable material (certified weed and disease free) should be imported. Any excess of suitable material should be used for rehabilitation purposes or removed from the site to an approved disposal area.

7.1.2 Geologic structural features and faults

There area a number of moderately sized faults and folds which occur within the study area, however there are no recorded earthquakes since 1958. Nonetheless the design of structures should be undertaken in line with Australian Standard AS1170.4:2007 or other standards that consider the effect on a structure against related earthquake phenomena such as settlement, slides, subsidence, liquefaction or faulting.

7.1.3 Extractive resources

Extractive industry operations that supply material to Australia Pacific LNG Project would be expected to implement mitigation measures to ensure compliance with their operating licence conditions and undertake rehabilitation of extraction areas when extraction is completed. The operation and management of the extractive industry is outside the direct control of Australia Pacific LNG. Australia Pacific LNG intends to work with industry to align with its sustainability principals (refer EIS volume 1,

Chapter 3 - Sustainability). The use of borrow material within the Project area will necessitate remediation and rehabilitation of treatments. This should include the re-establishment of stable landforms.

To minimise the impacts associated with the extractive resources, the following mitigation measures are proposed:

- FEED phases of the Project should quantify and qualify the need for extractive materials prior to construction, as well as identifying the quality and type of materials required and the location at which it will be required.
- The Australia Pacific LNG has not planned to directly develop new quarries as part of the Project. Businesses which choose to meet the demand for extractive materials for the Project and other developments within the region would be required to follow an approvals process in accordance with applicable legislation. The need for borrow pits and associated approvals will be assessed during FEED phases of the Project
- Selected existing resources should be assessed during the Project's FEED phases to determine the size and local demand. This would enable an informed assessment to be made regarding adequate resources to service gas field requirements as well as existing community demands.
- Mobile crushers should be considered for use on the Project where practicable so that excess rock that has been excavated can be utilised, minimising the need for quarry materials.
- Construction is to be carried out progressively, with remediation of areas scheduled so that rock for construction platforms and temporary access roads can be recycled to minimise the need for quarry materials.

It is probable that development approvals will be necessary for other extractive resources on land held by private operators. These would be the subject of a separate approvals process undertaken by others.

For any extractive activities undertaken by others on behalf of the Project, the environmental issues associated with the extraction of resources should be mitigated through the development of environmental management and operation plans.

Once operations have concluded, finishing earthworks and revegetation should be carried out with all equipment, structures and imported materials removed. Remediation and rehabilitation of any contaminated areas, grading and revegetation of the quarry/borrow pits should be undertaken in accordance with regulatory approval conditions.

7.1.4 Reactive Soils

Soils with a significant shrink/swell characteristic (termed reactive soils) (ie.5b and 5b[m]), occur throughout the Project area. To minimise construction constraints associated with these soils, the following mitigation measures are proposed:

- Where construction is proposed for major infrastructure within soil group 5b[m], site specific geotechnical investigations, such as those undertaken during FEED phases, should be undertaken to assess the potential movement caused by these cracking clays. These investigations will also identify the potential infrastructure protection (that is pipeline coatings resistant to stresses from clay movement) required. The potential movement due to the

cracking clays will be considered in the design of all buildings, roads and other structures, where located on these soils

- Substantial pipelines are anticipated to be constructed mainly within the lower section of the shrink/swell profile and are thus unlikely to be exposed to the full extent of the movement. At these depths the shrinking, swelling and heaving (Gilgai's) of these cracking clays are unlikely to affect the integrity of a welded steel pipeline. However, it may affect the protective coating of the pipeline. An alternative protective coating may be considered in the areas where these cracking clays are encountered, but this need can be assessed following geotechnical investigations.
- Construction in reactive soil areas should be limited to dry weather conditions as far as practicable. The construction of gravel access tracks and working platforms may be warranted to prevent rutting and damage to soil resource as these soils are of significant agricultural value.

7.2 Topography and Geomorphology

Clearing and earthworks will have the greatest impact on existing landform through the alteration of drainage paths, soil destabilisation and loss in GQAL. It is noted that requirements for changes in landform will also be subject to input from flood studies (refer: Chapter 11 of EIS, Surface Water) and soil characteristics (refer Section 5).

The general mitigation measures listed below should be addressed throughout the project to minimise potential impact on water quality of downstream sites due to erosion, and improve the stabilisation of soils to prevent potential erosion and sediment runoff which will assist in minimising landscape impact. Further requirements for water diversion, sediment and erosion control are provided in Section 7. These sections provide detailed mitigation measures which are also addressed in the Environmental Management Plan (EM Plan) (Chapter 24 of EIS).

Mitigation measures which should be adopted include, but are not limited to, the following:

- Redirect / divert surface water runoff from disturbed areas (that is, cleared sites and stockpiles), but ensure it is managed to minimise concentrated flows, uncontrolled channelling or impedance of flow or cause nuisance to landholders downstream and / or adjacent to the site (also Chapter 11 of EIS, Surface Water).
- Implementation of sediment and erosion control measures, such as installation of sediment dams, traps and fences to dissipate the velocity of stormwater which runs across the site (refer Section 7.3.3 and the EM Plan in Chapter 24 of the EIS, volume 2). Where practicable, any vegetation cleared should be mulched and placed as a protective layer on disturbed areas to assist in fertility retention and sediment and erosion control.
- In areas of site levelling works, proposed formation levels should be set to reduce the need for significant cut and fill areas.
- Reuse of construction materials should be implemented to minimise the volume required from borrow pits.
- Pipeline backfill and compaction of the fill should be controlled to minimise subsidence and the need for excessive temporary soil mounding.
- Progressive clearing should only be undertaken immediately prior to construction to ensure the minimum amount of bare soil remains on site at any one time.

- Undertake progressive rehabilitation of disturbed areas such as temporary diversion drains, cleared sites and stockpile areas.
- Structures requiring substantial earthworks (that is, gas plant facilities, water transfer stations, waste treatment facilities, brine and water storage ponds) should be sited on relatively level sites for ease of landform rehabilitation following Project completion.
- If it is necessary to carry out clearing works and construct structures on steep or very steep slopes (generally >25%) then an assessment should be carried out by a geotechnical engineer as to the overall slope stability as well as a site-specific water diversion, erosion, sediment and revegetation plan be prepared for the site.
- Where there is to be a vehicular or pipe trench crossing of a water course, the crossing should be reinstated to it previous state following cessation of use. Measures given in Section 7.3.5 should be adopted for watercourse crossings.
- At the completion of the project, equipment, structures and imported materials should be removed and landform reinstatement and rehabilitation undertaken. This may involve remediating and rehabilitating any contaminated areas, and subsequently grading and revegetating the site, returning it to a condition as close to its original state as practicable. This also includes the re-establishment of original landform and drainage (including pre-existing erosion management structures) and remediation of soil fertility and structure (refer Section 7.3.8).

7.3 Soils

Mitigation measures in regard to soil disturbance and rehabilitation should focus on avoidance and reinstatement. Where practicable, major development facilities on intensive agricultural production areas should be avoided and the reuse of existing disturbed areas, such as tracks, maximised. Where avoidance is not practicable, suitable placement of gas wells and associated infrastructure within areas likely to cause the least impact to land resources should be selected (that is, along paddock boundaries and away from overland flow paths).

7.3.1 Land capability

There is potential for sterilisation of GQAL (classes A, B and C1 [in some areas]) throughout project construction. However the long term impact can be mitigated through progressive rehabilitation of gas well sites, HP gas and water networks and gas and water gathering lines as a portion of the construction area will rehabilitated (refer Table 6.1 and Section 6.3.5). However there is expected to be a net loss in GQAL due to the operational footprint (approximately 0.75% of 571,989ha = 4,319ha) which will remain for other Project facilities.

To minimise the impact during construction and operational periods, drill pads, access tracks, pipelines, temporary accommodation facilities, ponds and communication towers should be located on areas which will have the least impact on the productive capacity and drainage of the land and cause the least changes to landholder operations. Such areas include fence lines, existing access tracks, road reserves and other areas deemed appropriate by the land owner.

Good topsoil management is also important to facilitate restoration of GQAL which should involve rehabilitation to vegetation types consistent with the surrounding environment (refer Section 7.3.2.) Additional measures such as good quality fencing to restrict stock movement between neighbouring properties, minimising productive soil exposure and installing appropriate signage (that is, on fencing

not within paddocks) should be incorporated during construction. Where pipelines are to be established in croplands, particularly where deep ripping may be used, additional depth of cover will be required as determined by design engineers and validated by the AS2885 Safety Management Study. This will also be the subject of consultation with affected landholders.

Land Capability impacts can also be mitigated through good management of associated water (refer Chapter 12 of EIS, Managing associated water). Associated water without appropriate treatment should not be used without consideration of soil salinity and impact of other contaminants. Similarly Waste Management is also important to not contaminate GQAL (refer EIS Chapter 16, Waste).

Sediment and erosion control and careful revegetation of GQAL is also important to mitigate loss of GQAL (refer subsequent sections).

7.3.2 Topsoils and subsoil management

The following section outlines topsoil and subsoil management strategies to be implemented during and following the construction of various project components in all land areas to be disturbed. During the operations phase of the project, management should largely include monitoring of rehabilitation and further rehabilitation as required, which is outlined within the construction EM Plan (refer Chapter 24 of EIS). Post lease rehabilitation should involve the decommissioning and removal of project facilities (refer Section 7.3.8).

Topsoil stripping

Prior to the commencement of topsoil stripping, areas should be cleared of vegetation. Timing of clearing should be coordinated with respective landowners to ensure that where GQAL disturbance is unavoidable, minimal disruption to farming operations will occur. Vegetation clearance should be minimised where practicable to reduce the potential for soil erosion and exposure of dispersive soils, particular when clearing has not been timed according to seasonal rainfall (that is early to mid summer – December to March). Vegetation clearance should take place as close as practicable to construction activity and undertaken progressively.

Vegetation which is removed should be stockpiled separately. There should be a distinct break of at least 1m between the vegetation and soil stockpiles, but additional storage space must be accounted for as the subsoil displaced during construction (particularly for underground infrastructure such as pipes) is substantial. Further information regarding vegetation management is contained within the Terrestrial Ecology technical report or Chapter 8 of the EIS.

Topsoil should then be stripped. Any excess displaced spoil must be prevented from mixing with topsoil as the cost of extra storage space is minor compared with the rehabilitation of soil inversion areas which limit nutrient availability, biomass and productivity. Soil inversion can also affect a soil's permeability and water holding capacity. Terrestrial Ecology technical or Chapter 8 of the EIS

Soil stripping should be undertaken in consultation with information provided in this report and subsequent detailed soil assessments, including designation of optional topsoil stripping depths. In areas where both the topsoil and subsoil are to be removed, they should be stripped and stockpiled separately and be located as to minimise loss of material from water and wind erosion. This is necessary to prevent blending of different stockpiled material (that is, during rain events) as this may impact the success of rehabilitation.

Soils should ideally be replaced close to where they are sourced. The separation of coarse textured soils (mainly groups 1, 2 and 3) from fine textured soil groups (4 and 5) at soil type boundaries should be undertaken. Coarse textured soils are often more erosive and generally less fertile than fine

textured soils which are generally dispersive. As a result, coarse textured soils will involve differing nutrient / conditioner requirements to that of fine textured soils. It is therefore preferable to reinstate close to the source so that existing conditions are retained as much as practicable.

Vegetation which is cleared and chipped may be used to provide a thin surface mulch to improve the topsoil productivity and mitigate erosion. If any vegetation burning is proposed (subject to operational conditions), remaining ash may be incorporated with the topsoil during the topsoil stripping operations.

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

Stockpiling

Where practicable, topsoil material should be respread directly from stripped areas onto areas being rehabilitated. Where this is not practicable, topsoil shall be stored in stockpiles. Stockpiles should be located in areas that are outside the site disturbance area and at least 50m away from main drainage lines or significant overland flow paths. Drainage from higher areas should be diverted around stockpiles to prevent erosion, while sediment controls should be installed downstream of the stockpiles to collect any washed sediment.

Topsoil stockpiles should not exceed 2m in height, particularly to minimise damage to topsoil and maintain fertility. Where multiple stockpiles are required, gaps should be left every 50m to allow for drainage, and permit the movement of vehicles and wildlife. This is particularly necessary during the construction of pipelines. Stockpiles exposed for extended periods should be deep ripped and sown with seed stock compatible with local conditions in order to keep the soil healthy and maintain biological activity and prevent weeds from growing. Topsoil stockpiles should be clearly sign-posted for easy identification and to avoid any inadvertent losses. Establishment of weeds on the stockpiles should also be monitored and controlled. Rocky surface materials should be removed and stockpiled separately from other material. Information regarding management of weeds is included within the Terrestrial Ecology technical report or Chapter 8 of the EIS.

Surface stabilisers may be used on soils which have been classified as erosive or dispersive and exposed for prolonged periods.

Respreading

Upon completion of construction, wastes should be removed, temporary access tracks should be closed and soils should be replaced in the order in which they were excavated. If subsoil cannot be reused, then suitable certified backfill material from a registered quarry should be imported. Excess soils should be disposed of appropriately – for example, stockpiled for use in future rehabilitation or respread elsewhere in consultation with landowners avoiding admixing. During the removal of soil from stockpiles, upper and lower sections of the stockpiles should be mixed to spread seed stock and microfauna.

Topsoil application should only take place following initial reinstatement of the subsoil, construction of contour banks on steep slopes and compaction and crown development (micro-relief) of subsoils to account for subsidence. Topsoils that have been stockpiled for long periods should be re-analysed before reusing to assess whether fertility levels are optimum and if required, conditioners should be added. Topsoils should be respread over watered and scarified / ripped subsoils in even layers at a

thickness appropriate for the intended land use of the area to be rehabilitated, however they should be tapered on slopes to account for downward movement (that is, 100mm at the top of slope to 75mm at the bottom).

Topsoil should be compacted firmly but left slightly rough to provide a suitable seed bed and revegetation undertaken as soon as practicable after topsoil respreading. Cross ripping of topsoils may be undertaken to encourage rainfall infiltration and minimise runoff. On steep slopes hydroseeding and hydromulching should be used. Vehicle movement should be restricted to permit vegetation to become re-established. In areas where access tracks were utilised, re-profiling to original or stable contours, re-establishing surface drainage lines and other land features should be completed. Other considerations should include:

- Balancing required rehabilitation topsoil quantities against stored stockpile inventories.
- Planning the source of topsoil material to maximise direct respreading from stripping areas and to minimise the length of time the material is stored in stockpiles.

Rehabilitation of disturbed areas should be consistent with surrounding conditions (refer Section 5.3 and restoration requirements in the Terrestrial Ecology technical report or Chapter 8 of the EIS Volume 2) unless developmental conditions are required to be maintained as an approval condition or land owners. Where GQAL has been disturbed, rehabilitation should be to a standard negotiated with the respective landowner. This includes the re-establishment of original topography and drainage (including erosion and water management structures, such as contour banks) and remediation of soil fertility and structure (refer Section 7.3.8). Specific Project rehabilitation measures include the isolation (in sumps) of drilling fines generated from gas well drilling and the encapsulation or reinjection or removal and disposal of saline solids from brine ponds.

7.3.3 Water diversion, sediment and erosion control

All soils which are to be disturbed should have sediment and erosion controls measures adopted throughout construction and rehabilitation. This is required for environmental, structural, rural land management and aesthetic reasons. The following measures are suggested:

- Divert water around the construction site. Within the site, divert water around excavations and stockpiles.
- Where water diversion involved construction of diversion drains, the preferred method is placing a mound of soil on the uphill side of the excavation from which it was sourced. The mound of soil should be compacted. This method results in water flowing over undisturbed ground.
- Construct sediment fences on the downhill side of the excavation areas.
- Construct sediment fences around the stockpile areas.
- Sediment fences should comprise filter fabric anchored into a 200mm deep trench and extend maximum height of fence above ground: 700mm.
- Maximum post spacing: 2m without wire mesh backing.
- Allow at least 2m between fence and a stockpile.
- Where tracks go down slopes, contour banks should be used at appropriate intervals to produce sheet flow rather than concentrated flow and directed to discharge at multiple locations at low velocities and volumes.

- Sediment and erosion control measures should be inspected on a regular basis, replaced where damaged and emptied following rainfall events if required.
- Clear vegetation progressively, so as to maximise the area of soil protection.
- Create stable slopes and revegetate soon after disturbance.
- Topsoil stockpiles should be seeded (refer Section 7.3.2).
- Stockpiles and / or exposed soil areas, such as unsealed access tracks, which are exposed for prolonged periods or have been identified as problem soils (erosive / dispersive) should be treated with chemical surface stabilisers or physical alternatives (crushed rock).
- Diversion sediment and erosion control devices should be put in place prior to construction commences. These should remain in place at rehabilitated areas until the area has completely re-established.
- Roads and tracks should ideally go across slopes. Where tracks go down slopes contour banks should be used at intervals appropriate to the slope to control the flow of surface water so as to minimise erosion.
- Where pipes go down slopes, trench breakers should be installed in the backfill at intervals appropriate to the steepness of the slope to prevent water tunnelling along the buried pipe. On surface contour banks should be used to divert water off the disturbed areas.
- There should be a sediment basin constructed on the downhill side of the major infrastructure facilities on the uphill side of sensitive water courses (Refer Chapter 11 of EIS, Surface water and watercourses).
- If any water is required to be discharged off-site it should be done so through silt fences to prevent erosion.
- In the vicinity of natural watercourses, routine water quality monitoring of pH, electrical conductivity, dissolved oxygen, redox, temperature and turbidity should also be considered to ensure that water quality is maintained.

A comprehensive soil erosion, control and monitoring plan (detailing the measures described above) should be provided in the construction EM Plan (refer Chapter 24 of EIS).

7.3.4 Slope management

As described in Section 5.2.4, soil erodibility increases for all soil types when slope increases, particularly when steeper than around 8%. Where the slope is more than 2% soil and surface stability controls should be constructed and maintained at all times. These measures includes shaping the ground surface where required to maintain slope stability, with intensive erosion control works to be established for disturbed areas over 8% slope, as well as installing temporary sediment and erosion control (contour banks, diversion drains and silt fences) and maintaining until final construction clean-up and rehabilitation and re-establishment is completed.

Where clearing slopes adjacent to drainage lines is required, sediment and erosion control (such as water diversion banks, sediment fences and a sediment basin at the base of the hill) should be incorporated prior to clearing where practicable. A series of earth banks should be installed at an appropriate spacing depending on gradient and soil types immediately following clearing activities and should be constructed across the entire disturbed width of the working area. They should be directed to frequently spaced vegetated or sediment fence discharge points to minimise scouring. They should

be maintained to be effective at all times until rehabilitation and re-establishment of the site is completed. Earth banks should be high enough to collect water but not so high that they are dangerous to drive over on steep slopes. Clearing in the area immediately adjacent to water courses below slopes should be delayed until construction at the drainage line is imminent.

7.3.5 Drainage line management

Several significant drainage lines are located throughout the study area (refer Chapter 11 of EIS - Surface water and watercourses). As dispersive and erosive soils are located adjacent to drainage lines in many areas, appropriate management of these soils is required in order to minimise erosion, soil loss, sediment laden runoff and downstream impacts and maximise creek bank stability. Several pipeline crossings and it is therefore expected several vehicle crossings will be required for the installation of a number of project facilities including the high pressure gas network and water and gas gathering lines.

Where these crossings are required and geologic constraints permit, a 20m buffer of vegetation adjacent to the drainage line should be retained until construction across the drainage line is imminent. When such time arises, trees may be chain sawed and felled away from the drainage line. Clearing shall aim to retain the maximum amount of root stock within the construction area.

Where there is to be a vehicular crossing of a water course, the crossing should be reinstated to it previous state following the vehicle crossing's use. If there is water to be flowing or the potential for water to flow during the period of the crossing being in use, there should be an access road constructed and a strategy prepared for management of the water so that the water will not flow outside its natural course. This could involve culverts or pipes placed through the road embankment suitable for the water flows likely or else water pumped from one side of the road embankment to the other (only suitable when water flows <1000l/s). Any water pumping which may require offsite discharge during construction should be done so through geotextile, sediment fences or gravel outlets to prevent erosion. Further advice is contained in Chapter 11 of the EIS, Surface water and watercourses.

Where the pipeline is to cross a water course, the pipe trench should be excavated perpendicular to the direction of the water flow. There should be a trench breaker the full height of the trench on either side of the water course and the pipe trench backfill should be carefully compacted, and compaction plant used in the upper layers of the pipe trench backfill. If the bank is topsoiled, topsoil should be respread over the area from which it was removed and areas of disturbance seeded.

In areas where rapid water flows are likely rock armour should be used to cover the area of the trench. Where original drainage lines had a surface layer of cobbles and coarse gravel overlaying finer material, it should be removed and stockpiled separately so that it may be replaced during rehabilitation. If this material is not reinstated to its original profile, the bed substrate may erode sufficiently to cause indirect effects such as bank collapse. Where the original material cannot be reused, rock armouring can be adopted. Where this is adopted a maximum bank slope of 2 horizontal : 1 vertical should be prepared. The rock should generally extend 2m up the bank from the toe and across the drainage line floor. Rock armour should be placed to an average thickness of 300mm and pressed into the soil base with an excavator.

Trench crossings should be carried out when the water course is dry. If there is water in the water course at the time of trench construction, then there should be a dam upstream and downstream and water diverted through suitably designed culverts or pipes through the dams or water pumped around (for flows up to 1000l/s). Any water pumping which may require offsite discharge during construction w should be done so through geotextile, sediment fences or gravel outlets to prevent erosion. Further a

geotechnical engineer should carry out an assessment of the trench stability as trenches often unstable in the presence of water which is a risk to personnel safety, river bank stability and sediment load in the creek. More specific advice including the required depth of the pipe below the water-bearing layers is given in Chapter 11 of the EIS, Surface water and water courses.

Routine and following high or extreme rainfall events, inspections of soils at the crossings should be conducted. These inspections should aim to visually monitor erosion immediately at the crossing and evidence of sediment runoff downstream. For larger watercourses, that is for those of Stream Order 4 or greater, routine water quality monitoring of pH, electrical conductivity, dissolved oxygen, redox, temperature and turbidity should be conducted upstream and downstream of the crossing to identify trends and water quality degradation. A detailed monitoring plan should be provided in the EM Plan.

The restoration of the drainage line should be to the original state or natural slope with any sheer banks battered back. Stockpiled timber from clearing activities may also be utilised by spreading the timber randomly over the construction area leading down to the drainage line. Sandbag, gabion or other means of scour protection may be applied and should be placed to conform with existing natural contours, as appropriate, with topsoil respread over the sandbags or gabions. Where required by proximity to grazing stock or other threats, access should be prevented to sites (for example, using fencing or barriers) to assist site recovery.

Water used for hydrostatic testing may be provided to farm dams or for irrigation. However in the absence of definite alternatives, discharge to grade in the local area should be assumed, Prior to discharge, locations should be negotiated with land owners and spent hydrostatic testing water should be analysed for contaminants (for example heavy metals and nutrients) to ensure safe discharge.

In the absence of precise information, the ‘worst case’ scenario of 235ML/day has been assumed for proportional discharge at waterways adjacent to Water Treatment Facilities during project operation. In terms of land, this volume, and potential high velocity discharge is likely to exacerbate gully, notch and stream bank erosion and exacerbate meander migration and redistribution of sediments downstream within waterways. In order to minimise erosion, discharge must be located within a geomorphically stable waterway reach and bank stabilisation measures and riparian management plans (including monitoring) implemented (refer Chapter 9 of EIS - Aquatic Ecology).

Additional engineering controls such as scour protection and flow velocity limits may be required.

7.3.6 Revegetation, revegetation species and weed control

Revegetation issues are addressed within the Terrestrial Ecology technical report or Chapter 8 of the EIS.

7.3.7 Access roads and dust mitigation

When soils are subjected to vehicular traffic, the soil structure diminishes and the soils are more prone to generate dust. This is particularly notable in soils with poorly structured A or B horizons (notably in soil group 2). Dust generation is likely to cause ongoing problems as a result of increased traffic during construction. Similarly on existing road, once there has been substantial traffic flow and subgrade failure occurs, it is difficult to reconstruct roads by backfilling potholes because there will be poor subgrade drainage into potholes and reworking of the structure of the soils in the subgrade.

Appropriate traffic routes should be therefore be assessed. Existing roads should be then assessed for suitability for the anticipated traffic and upgraded if required. Consideration should be given to concurrent CSG activities and activities coordinated if practicable, so that roads are maintained or improved for local residents.

In areas where new access roads are proposed there should be vegetation removal and the stripping and stockpiling of the topsoil layer. Where there are new access roads, the road should be sheeted with a material appropriate for the subgrade and for the traffic proposed.

Where roads are to be temporary and remain unsealed, the construction methods should aim to reduce the exposure periods for non-vegetated areas and undertake revegetation as soon as practical after construction. Vegetation removal should be limited to the immediate construction area to minimise soil resource degradation (assist in retention of soil moisture and nutrients).

Material being transported should be covered at all times and speed limitation should be adopted to minimise dust creation. Excessive dust should be controlled through the use of spraying water from water trucks. Water should be applied to exposed soils as required to prevent dust generation. Water supplies should be of an appropriate water quality and should not lead to soil contamination (e.g. saline groundwater or contaminated waste water).

On routes which are to be maintained throughout the construction period, and dust is of concern the adoption of specialised additives such as *Dustmag* can be used in order to minimise dust emissions. *Dustmag* is an additive that may be added to the water trucks to help suppress dust if normal measures are not adequate. It is a biodegradable, magnesium chloride preparation, which draws water from the air at night and forms a stabilised compacted surface. The additive may only be required once (generally lasts 3 months) although repeat applications may be required in high use areas. Some watering may be required in extremely dry periods and in problem areas it may be appropriate to remove additional soil layers down to the harder subsoils.

Dust generated from soil stockpiles should be minimised by ensuring exposure time is minimised, seeding with local stock or addition of mulch, applying water, covering stockpiles with protective materials (e.g. Hessian, tarpaulins), applying soil additives on stockpiles or exposed slope batters.

Where bulldust occurs on access roads, where it is necessary to retain an access road suitable sheeting material should be used to resurface the road. Where it is practicable to divert traffic, the area should be stripped of bulldust, the topsoil respread, fenced and revegetated.

If all available methods of dust stabilisation fail to suppress dust and it continues to result in unacceptable impacts, construction activities in the affected area may need to be modified while the situation is rectified.

7.3.8 Post-lease rehabilitation

Based on information provided by Australia Pacific LNG, rehabilitation programs will include the decommissioning of: gas wells (steel pipes made safe: purged with water or compressed air and left *in situ* to corrode and connecting pipelines flooded, purged and vented), Gas Processing Facility, Water Treatment Facility, gas and water gathering lines and associated infrastructure such as buildings, tanks and ponds. Roads, drains, fences, material, equipment, wastes and hardstands will be removed and disposed (if required) offsite.

When all equipment, structures and imported materials have been removed there should be assessment and remediation and rehabilitation of any contaminated areas, then subsequently grading and revegetating the site returning it to a condition as close to its original state as practicable. This includes the re-establishment of original topography and drainage (including pre-existing erosion management structures) as far as practical and remediation of soil fertility and structure.

Areas which are not returned to pre-development conditions are those which are to be maintained by either land owners or others upon agreement. These areas should be assessed and determined prior to decommissioning.

It has been assumed that Australia Pacific LNG will base future rehabilitation programs on previous successful programs as a minimum. These programs should incorporate comprehensive rehabilitation monitoring and not declared completed until the area is approved by the land owner.

8. Summary of environmental values, sustainability principles, potential impacts and mitigation measures

A summary of the environmental values, sustainability principles, potential impacts and mitigation measures in relation to terrain and soil management is presented below in Table 8.1.

In addition, Table 8.1 includes the residual risk levels for land management. A risk assessment has been undertaken to identify the potential risks, causes and consequences to land from the LNG plant development. Mitigation measures to reduce the risk have been nominated and the residual risk has been calculated. Further details on the risk assessment methodology are provided in Volume 1 Chapter 4.

Table 8.1 Summary of environmental values, sustainability principles, potential impacts and mitigation measures

Environmental values	Sustainability principles	Potential impact	Possible cause(s)	Mitigation measures	Residual risk rating
Existing finite resources to be sourced for construction material	Minimising adverse environmental impacts and enhancing environmental benefits associated with our activities, products or services; conserving, protecting, and enhancing where the opportunity exists, the biodiversity values and water resources in our operational areas. Using resources efficiently, reducing the intensity of materials used and implementing programs for the reduction and reuse of waste. Identifying, assessing, managing, monitoring and reviewing risks to our workforce, our property,	Alteration of topography, drainage, leaching of chemical / minerals, removal of vegetation, changes to land and road use and changed dust, noise and vibration levels	Demand on local resources for gas fields development Development of new and / or expansion of existing quarries	FEED phases will quantify the need for extractive materials prior to construction, and identify the quality, volume and type of materials required, and the location at which these will be required. Extractive businesses which choose to meet the demand for extractive materials for the Project would be required to follow approvals process in accordance with applicable legislation. FEED phases will identify size and local demand of existing extractive resources. Reuse materials on site where practicable. Mobile crushers may be used to minimise the need for quarry materials from external sources. Maintain private and public road conditions. Extraction operations (where undertaken by Australia Pacific LNG) will be mitigated through environmental management and operation plans and comply with operational conditions including compliance with relevant emission levels.	Low

Environmental values	Sustainability principles	Potential impact	Possible cause(s)	Mitigation measures	Residual risk rating
Existing landform character and stability	the environment and the communities affected by our activities.	Change to topography Destabilisation of soils Change to drainage Short term loss of GQAL Degraded downstream water quality Slope instability Visual amenity	Landform modification through stormwater diversion, vegetation clearing and earthworks	Implement sediment and erosion control and manage runoff to minimise concentrated flows. Construction materials should be reused where practicable. Compaction of fill should be controlled to minimise soil mounding or settlement. Progressive clearing and rehabilitation. Structures should be sited on relatively level sites where practicable. Undertake a geotechnical slope analysis. Stabilise water crossing following construction, Rehabilitation to a condition as close to the gas fields area's original state as practical or to a condition which is consistent with the surrounding environment.	Medium
Existing soil resource (including values for agricultural productivity)		Loss of topsoil quality and quantity	Incorrect stripping, prolonged exposure and erosion Soil inversion (replacement of topsoils with subsoils) Poor rehabilitation and drainage management	Vegetation clearance should be minimised as far as practicable. Undertake site-specific topsoils assessment. Undertaken progressive clearing and rehabilitation. Separate stockpiling of vegetation and soil groups.	Low

Environmental values	Sustainability principles	Potential impact	Possible cause(s)	Mitigation measures	Residual risk rating
				Account for additional stockpile storage. Addition of nutrients / conditioner or suitable seed stock. Training with earthmoving staff to ensure correct handling. Topsoil stockpiles should be limited to 2m in height to maintain fertility and vegetated if stockpiled for extended periods. Rocky material should be removed during stripping, where practicable Monitoring of weeds should be undertaken. Implement sediment and erosion control. Rehabilitation of disturbed areas should be consistent with surrounding conditions.	
		Increased salinity leading to poor rehabilitation and corrosion of civil structures	Poor soil handling (removal, stockpiling and respreading) leading to soil inversion Blending of non-saline and highly saline soils Inadequate monitoring of rehabilitation	Undertake geotechnical investigations to assess suitable corrosion protection for civil structures. Implement suitable subsoil handling which minimises blending of non-saline and highly saline soils and soil inversion. Minimise vegetation clearing and stockpile topsoils separately from subsoils. Isolation (in sumps) and rehabilitation of drilling	Low

Environmental values	Sustainability principles	Potential impact	Possible cause(s)	Mitigation measures	Residual risk rating
				fines. Removal of remaining saline solids from brine ponds. Adoption of EM Plan which incorporates monitoring of rehabilitated areas.	
		Soil erosion – soil destabilisation Poor rehabilitation and drainage management Sedimentation of downstream areas Undermining of structures (roads, buildings, fencing) where soil has been wash away through runoff	Vegetation clearing Poor drainage management Concentrated flow discharge Improper sediment and erosion controls Inadequate earthworks contractor training and supervision	Implement sediment and erosion control plan which includes redirection and management of runoff to minimise concentrated flows should be developed and implemented. Sediment fences and/or sediment detention structures should be constructed on the downhill side of excavated areas and around stockpiles. Conduct regular inspections of sediment and erosion control measures and areas receiving concentrated flows. Undertake progressive clearing and rehabilitation and creation of stable slopes. Stabilise erosive / dispersive areas which are exposed for extended periods. Sediment and erosion control devices should be installed prior to construction and retained until the area is stabilised. Access tracks should be constructed across	Medium

Environmental values	Sustainability principles	Potential impact	Possible cause(s)	Mitigation measures	Residual risk rating
				slopes, or have contour banks at appropriate intervals where access tracks go down slope. Trench breakers will be installed in the backfill at interval appropriate to slope steepness. Sediment basins will be constructed on the downhill side of facilities when they are near sensitive receptors. Water to be discharged from construction sites will be done so through silt fences or other erosion control measures if required. Conduct routine (and following severe rain events) inspections of natural watercourses. Pipe trenches at watercourses should be excavated perpendicular to direction of water flow and backfilled carefully Where practicable, construction through creeks will be carried out when dry. Existing water will be dammed or diverted around construction Creek rehabilitation will be consistent with surrounding environment and contours of the channel at the time of construction and protected with fencing where required Determination of suitable discharge locations in consultation with landowners and relevant authorities will be undertaken.	

Environmental values	Sustainability principles	Potential impact	Possible cause(s)	Mitigation measures	Residual risk rating
				Point discharges from water treatment facilities should be into stable waterways and / or drainage lines and engineering controls such as scour protection and flow velocity limits implemented.	
		Reduced agricultural production area (loss of GQAL) Modification of overland flow Increased soil compaction Decreased fertility Increased erosion Disruption of farming operations	Construction and operation of gas fields infrastructure	Where practical locate gas field facilities on areas which will not impinge on the productive capacity and drainage of the land and cause the least changes to landholder operations. When operating on properties which maintain livestock, ensure gates are kept closed to prevent livestock moving between properties. Install good quality fencing (steel gates on driver side) to restrict stock movement between neighbouring properties, minimising productive soil exposure and installing appropriate signage (that is, on fencing not within paddocks). Incorporate additional depth of cover for pipelines where deep ripping may be used. Undertake rehabilitation of construction areas. Remove wastes as per a waste management plan to be prepared for the gas fields (refer Volume 2 Chapter 16). Rehabilitate disturbed areas to vegetation	Medium

Environmental values	Sustainability principles	Potential impact	Possible cause(s)	Mitigation measures	Residual risk rating
				types consistent with the surrounding environment.	
Existing qualities of the air environment including the life, health and well-being of the community		Degradation of soil structure Dust creation	Clearing of vegetation and increased traffic	Assess appropriate on-site traffic routes. Vegetation and topsoil will be removed where new tracks are required. On-site access roads will be surfaced with gravel and/or geotextile or surface additives. Revegetation should be undertaken as soon as practical. Use watering truck to control dust where required. Apply speed limitations. Where bulldust occurs, consider application of crushed rock, diversion of traffic and rehabilitation of this area.	Low

9. Limitations and assumptions

This assessment of soil conditions within the study area was based on government supplied information and a suitably scaled field assessment. It does not constitute a detailed investigation that would be used for engineering design purposes. The information provided in this assessment is directly relevant only to the points in the ground where they were obtained at the time of the assessment, considered indicative of field conditions and appropriate to the scale of the Project. The precision with which conditions are indicated depends largely on the frequency and the method of sampling and the uniformity of conditions, and is considered indicative of field conditions.

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Appendix A Abbreviations and Glossary

Abbreviations

AASS	Actual acid sulfate soil
ASS	Acid sulfate soil
Ca	Calcium
CEC	Cation exchange capacity
Cl	Chloride
DERM	Department of Environment and Resource Management
DNR	Queensland Department of Natural Resources
DNR&W	Queensland Department of Natural Resources and Water
DNRM	Queensland Department of Natural Resources and Mines
DPI	Queensland Department of Primary Industries
EC	Electrical conductivity
EHS	Extremely high strength
EPA	Environmental Protection Agency
ESP	Exchangeable sodium percentage
Fe	Iron
FEED	Front end engineering and design
GQAL	Good quality agricultural land
HW	Highly weathered
K	Potassium
LS	Low strength
Mg	Magnesium
MS	Medium strength
MW	Moderately weathered
Na	Sodium
P	Phosphorus
PASS	Potential acid sulfate soils
PAWC	Plant available water capacity
SAR	Sodium adsorption ratio
SO_4	Sulfate
SW	Slightly weathered

TAA	Titratable actual acidity
TKN	Total Kjeldahl Nitrogen
UTM	Universal Transverse Mercator
VHS	Very high strength
XW	Extremely weathered

Glossary

A horizon	The original top layer of mineral soil divided into A_1 (typically from 5 to 30 cm thick; generally referred to as topsoil with a high content of organic matter, dark colour and maximum biological activity) and A_2 horizons (usually 5 – 70 cm thick; similar texture to A_1 but paler in colour, poorer in structure and less fertile).
acid soil	Any soil with a pH of less than 6.5.
aggregate (soil)	A unit of soil structure consisting of primary soil particles held together by cohesive forces or by secondary soil materials such as iron oxides, silica or organic matter. Aggregates may be natural, such as *peds*.
alkaline soil, alkalinity	Alkaline soils have laboratory measured pH values >8.5. Alkalinity may inhibit the growth of plants.
alluvial terrace	Former floodplain which either no longer floods or rarely floods due to deepening or enlargement of the stream channel.
alluvium	Sediment deposited from the transport by channelled stream flow or over-bank stream flow.
andesite	Fine-grained volcanic rock composed of andesine (plagioclase) with one or more mafic constituents.
apedal	In the moderately moist to moist state, none of the soil material occurs in the form of peds; it is massive or single-grained and when disturbed, separates into fragments or primary particles.
ASC	Australian Soil Classification—It is a multi-category scheme with classes defined on the basis of diagnostic horizons or materials and their arrangement in vertical sequence as seen in an exposed soil profile.
available soil water	That part of the water in the soil that can be absorbed by plant roots that can be held between field capacity and the moisture content at which plant growth ceases.
available water holding capacity	The ability to hold that part of the water in the soil that can be absorbed by plant roots. Available water is the difference between field capacity and permanent wilting point.
B horizon	The layer of soil below the A horizons, usually of finer texture (i.e., more clayey), denser and stronger in colour. Thickness ranges from 10 cm to 2 m thick and is divided into B_1 and B_2 horizons.
bolus	A small handful of soil which has been moistened and kneaded into a soil ball which just fails to stick to the fingers.

boundaries (soil)	The boundary between soil horizons defines the nature of the change from one horizon to that below. It is specified by two terms—one a measure of the width of the transition zone between the two horizons, the other a description of its shape.
C horizon	Layers below the B horizon which may be weathered, consolidated or unconsolidated parent material little affected by biological soil-forming processes.
Cainozoic	Geological period 65 million years ago to present.
Chromosol	ASC Soil Order classification—Soils with a clear or abrupt textural B horizon where the major half of the B_2horizon is not strongly acid (i.e. >pH5.5) and non-sodic (can be sodic at depth).
clastic	Rocks built up from fragments of pre-existing rocks generated by weathering and erosion and transported to a point of deposition.
colluvium	Unconsolidated soil and rock material transported largely by gravity (i.e., mass movement: landslide, mudflow, creep or sheetflow), deposited on a lower slope and/or at the base of a slope. Does not have bedding structure such as alluvium and is has more variable grain size.
Cretaceous	Period of geological time, 144 – 65 million years before present.
deltaic	Sediments deposited at the mouth of a river where it enters a lake or the sea.
Dermosol	ASC Soil Order classification—Other soils with B_2horizons that have structure more developed than weak throughout the major part of the horizon, generally non-sodic subsoil, generally gradational textured soils (gradual boundaries).
Devonian	Geological period 395 – 345 million years ago.
Ferrosol	ASC Soil Order classification—Soils with B_2 horizons in which the major part has a free iron oxide content greater than 5% Fe in the fine earth fraction (<2 mm). Soils with a B_2horizon in which at least 0.3 m has vertic properties are excluded.
fluvial	Material deposited by rivers and streams.
fore-arc	A forearc is a depression in the sea floor located between a subduction zone and an associated volcanic arc.
fossiliferous	Fossil containing rock formations.
gilgai	Microrelief associated with soils containing shrink-swell clays.
granite	A granular igneous rock composed chiefly of felspar (orthoclase) and quartz, usually with one or more other minerals, as mica, hornblende, etc.
granodiorite	Plutonic rock consisting of potassium felspar, quartz, plagioclase, biotite and hornblende. Granodiorite is an intermediate between quartz, monzonite and quartz diorite.
gravel	The amount (visual abundance estimate) of gravel-sized (>2 mm) materials that occur on the surface and in the A_1 horizon and include hard (when moist), coarse fragments and segregations of pedogenic origin.
gravely	Over 60% of surface cover consists of gravel (2 - 60 mm).
GSG	Great Soil Groups of Australia (as defined by Stace *et al* 1968), described in terms of

	morphology, genesis and land use.
Holocene	Present geological epoch which commenced 10 000 years ago.
Horizon	A layer within the soil profile with morphological characteristics and properties different from layers below and/or above it.
Jurassic	Geological period 295 - 135 million years ago.
Kandosol	ASC Soil Order classification—Other soils that are lacking a strong texture contrast and (i) have well-developed B_2 horizons in which the major part is massive or has only a weak grade of structure, *and* (ii) have a maximum clay content in some part of the B_2 horizon which exceeds 15%.
Kurosol	ASC Soil Order classification—Soils with a clear or abrupt textural B horizon and in which the major part of the upper 0.2 m of the B_2 horizon (or the major part of the entire B_2 horizon if less than 0.2 m thick) is strongly acid (i.e. pH<5.5).
lacustrine sediment	Sediment mass deposited from transport by waves and from sediment solution and suspension in still water in a closed depression on land.
Lithosol	GSG classification—A shallow soil showing minimal profile development and dominated by the presence of weathering rock and rock fragments. Lacking horizons other than an A_1 (one layer only).
loam	A medium, textured soil of approximate composition 10 - 25% clay, 25 - 50% silt and <50% sand.
melonhole	Irregularly distributed large depressions within soil surface, usually greater than 3m in diameter.
mottled horizon	A horizon in which mottle abundance is greater than 10% (visual abundance estimate) and contrast between colours is distinct and prominent.
mottling	The presence of more than one soil colour in the same soil horizon, not including different nodule or cutan colours.
oolitic	Sedimentary rock consisting of ooids
Palaeocene	Period of geological time, 65 – 54.8 million years before present.
paludal	Sediments that accumulated in a march environment.
paralic	Sedimentary basins developed in marginal marine environments, i.e. lagoons, littoral basins.
ped	An individual, natural soil aggregate.
Permian	Period of geological time, 290 – 248 million years before present.
Pleistocene	First epoch of the Quaternary period, from 2 million years ago to 10 000 years ago.
Quaternary	Period of geological time covering the Holocene plus the Pleistocene. Up to 2.6 million years ago.
red earths	GSG classification—Massive, reddish sandy profiles with a gradual increase in clay content with depth over a diffuse to gradual boundary.
Rudosol	ASC Soil Order classification—Soils with negligible pedologic organisation. They are

	usually young soils in the sense that the soil forming factors have had little time to pedologically modify parent rocks or sediments. The component soils can vary widely in terms of texture and depth.
sheet erosion	The removal of the upper layers of soil by raindrop splash and/or runoff.
silt	Fine soil particles in the size range 0.02 - 0.002 mm.
skeletal soils	Thin soils.
Sodosol	ASC Soil Order classification—Soils with strong texture contrast between A horizons and sodic B horizons which are not strongly acid.
solum	The upper part of a soil profile above the parent material in which current processes of soil formation are active. This is where the living roots and other plant and animal life characteristics are exhibited.
structure (soil)	Is concerned with the arrangement of all soil particles and refers to the distinctness, size, shape and condition of the peds.
Tertiary	Period of geological time, 2 – 65 million years before present.
texture	A measure of the behaviour of a small handful of soil when moistened and kneaded into a ball (bolus) and then pressed out between the thumb and forefinger.
topsoil	A part of the soil profile, typically the A_1 horizon, containing material which is usually darker, more fertile and better structured than the underlying layers.
Triassic	Period of geological time, 180 – 230 million years before present.
Vertosol	ASC Soil Order classification—Clay soils with shrink-swell properties that exhibit strong cracking when dry and at depth have slickensides and/or lenticular structural aggregates. Although many soils exhibit gilgai microrelief, this feature is not used in their definition.

Appendix B Summary of field data and results

General Information				*Soil Summary*										*Landscape Information*																			
General Location	Sample Assessment Location	Observation Type	Location Description Notes	Horizon and General Soil Description (depth mBGL)			Mapped Soil Group and Description	Field Classification (ASC)	Soil Description (texture, structure, consistence, coarse fragments, rooting)		Existing Erosion			Drainage						Terrain Class			Predominant Slope				Slope Position						Aspect				Watertable	GPS Coordinates		Vegetation	Comments
									Topsoil	*Subsoil*	*1*	*2*	*3*	*R*	*W*	*MW*	*I*	*P*	*VP*	*1*	*2*	*3*	*1*	*2*	*3*	*4*	*F*	*C*	*U*	*M*	*L*	*D*	*N*	*S*	*E*	*W*		*Southing*	*Easting*		
Carinya	OB01	Water	Observation within private property - predominately cleared grazing land	N/A			N/A	N/A	N/A	N/A	1						P			1			1				D					-		-	S26 32.800	E149 35.150	Observed vegetation: Poplar box regrowth Canopy 10m Understory: none Ground strata: short grasses	*Channel description* - Broad shallow channel approximately 39m and 1m deep - Main channel 2m in width - Bed substrate appears to be brown clay and short grass - Soil appears stable
Ramyard	OB02	Water	Observation within Road Reserve - predominately cleared cropping land	N/A			N/A	N/A	N/A	N/A		2					W			1			1				D					-		-	S26 29.665	E149 37.931	Observed vegetation: Blue Gum Woodland Canopy 20m Understory: none Ground strata: short grasses	*Channel description* - Wide channel approximately 30m and 3m deep - Bed substrate appears to be sand - Zone of deposition - Abundant debris and boulders - Banks appear stable with short grass and trees
Ramyard	OB03	Soil	Observation adjacent to Jackson Wandoan Road and within road reserve	A1 0.0 - 0.2 ZL B1 0.2 - 1.0 ZC			**(2c/5b)** Texture contrast soils (Chromosols / Sodosols / Kurosols) - Shallow mainly loamy surface (acidic or alkaline) and Brown/grey/dark cracking clays (Vertosols) - Derived from sediments (mainly clay plains)	Episodioc-Endoacidic (GG), Crusty (BH), Brown (AB), **VERTOSOL (VE)**	(10YR 4/3) ZL: D, VFI, C, many VF coarse fragments, few VF-M roots	(7.5YR 3/3) ZC: D, VFI, C, K			1				P			1			1				F					-		-	S26 28.067	E149 38.353	*Observed vegetation: Poplar box regrowth* Canopy: none Understory: none Ground strata: sparse short grasses	- Cleared grazing land
Combabula	OB04	Soil	Adjacent to unsealed road within road reserve	A1 0.0 - 0.2 CZL B1 0.2 - 0.4 ZC			**(3b)** Red/yellow earths (Kandosols/Tenosols) - Deep earths – derived from sediments	Crusty (BH), Brown (AB), **VERTOSOL (VE)**	(10YR 5/3) CZL: D, C, VFI, ST, few, F coarse fragments, abundant F-M roots	(10YR 2/2) ZC: D, STR, ST, PL, many VF roots			1				P			1			1				F					-		-	S26 28.867	E149 32.378	*Observed vegetation: Pasture grasslands* Canopy: none Understory: none Ground strata: sparse short grasses	- Cleared grazing land - Mostly bare soil
Ramyard	OB05	Soil	Observation adjacent to Jackson Wandoan Road and within road reserve	A1 0.0 - 0.2 ZfS A2 0.2 - 0.7 ZfS B1 0.7 - 0.9 ZfS B2 0.9 - 1.0 ZfS			**(2d/5b)** Texture contrast soils (Chromosols / Sodosols / Kurosols) - Moderately deep to deep sands/loams over Brown/grey/dark cracking clays (Vertosols) - Derived from sediments (mainly clay plains)	Dystrophic (AF), Red (AA), **CHROMOSOL (CH)**	(10YR 3/4) ZfS: D, LO, few VF roots @ 0.2 (10YR 5/6)	(5YR 5/6) ZfS: D, LO, few F coarse fragments @ 0.9 (10YR 6/5)			1				W			1			1				F			\		-		-	S26 25.024	E149 43.900	*Observed vegetation: Brigalow regrowth* Canopy: 10- 20m Understory: 3m Ground strata: sparse short grasses	- Cleared grazing land - some minor rill erosion evident
Ramyard	OB06	Water	Observation adjacent to Jackson Wandoan Road and within road reserve	N/A			N/A	N/A	N/A	N/A		2					W			1			1				D					-		-	S26 23.775	E149 42.189	*Observed vegetation: Blue gum woodland* Canopy: 20m Understory: None Ground strata: short grasses	*Channel description* - Narrow channel approximately 4m and 1.5m deep - Sandy bed substrate - Banks do not appear stable with steep eroded walls
Combabula	OB07	Soil	Observation adjacent to unsealed road within road reserve	A1 0.0 - 0.1 CZ A2 0.1 - 0.3 CZ B1 0.3 - 0.7 ZC B2 0.7 - 1.0 ZC			**(2d)** Texture contrast soils (Chromosols / Sodosols / Kurosols) - Moderately deep to deep sands/loams	Episodic-Endoacidic (GG), Epipedal (GS), Brown (AB), **VERTOSOL (VE)**	(10YR 4/3) CZ: D, LO, many F-C coarse fragments, many F-C roots @ 0.1 (10YR 5/2)	(2.5Y 3/2) ZC: D, FI, ST, PL, few F-M coarse fragments @ 0.7 (5YR 2.5/1)			1				P			1			1				F					-		-	S26 23.190	E149 33.253	*Observed vegetation: Ironbark - brigalow regrowth* Canopy: 10- 20m Understory: 5m Ground strata: sparse short grasses	- Cleared grazing land
Combabula	OB08	Water	Observation made at road crossing on Yeluba Taroom Road	N/A			N/A	N/A	N/A	N/A			1				MW			1			1				D					-		-	S26 26.544	E149 26.392	*Observed vegetation: Mixed eucalypt woodland* Canopy: 25m Understory: 10m Ground strata: sparse short grasses	*Channel description* - Broad shallow channel approximately 12m wide and 0.5m deep - Sandy bed substrate - Banks appear stable with established grass - Some surface debris - Grazing land cleared to creek bank - 6 x 1200mm culverts under road
Combabula	OB08B	Water	Observation made at road crossing on Yeluba Taroom Road	N/A			N/A	N/A	N/A	N/A		2					MW			1			1				D					-		-	S26 24.869	E149 27.159	*Observed vegetation: Blue gum* Canopy: 15-2m Understory: 3m Ground strata: tall grasses	*Channel description* - Narrow shallow channel approximately 1.5m wide and 1.5m deep - Sandy bed substrate with abundant boulders - Banks appear unstable - Grazing land cleared to creek bank
Combabula	OB09	Soil	Observation adjacent to bitumen road	A1 0.0 - 0.01 ZkSL A2 0.01 - 0.2 ZkSL			**(2d/5b)** Texture contrast soils (Chromosols / Sodosols / Kurosols) - Moderately deep to deep sands/loams over Brown/grey/dark cracking clays (Vertosols) - Derived from sediments (mainly clay plains)	**RUDOSOL**	(10YR 3/2) ZkSL: D, LO, abundant F-C roots @ 0.01 (10YR 4/1) ZkSL: D, LO, abundant F-S coarse fragments, many F-C roots @ 0.2 refusal on stones	-			1				MW			1			2				L					-		-	S26 23.671	E149 26.971	*Observed vegetation: Cypress pine woodland* Canopy: 10- 20m Understory: 5m Ground strata: abundant debris and very sparse short grasses	- State forest
Combabula	OB10	Water	Observation within private property	N/A			N/A	N/A	N/A	N/A			3				I			2			2				D					-		-	S26 08.799	E149 15.975	*Observed vegetation: Blue gum regrowth* Canopy: 10-20m Understory: None Ground strata: sparse short grasses	*Channel description* - Deep narrow channel approximately 5m wide and 3.5m deep - Sandy bed substrate - Banks do not appear stable with steep eroded walls - Abundant surface debris - Grazing land cleared to creek bank
Combabula	OB11	Soil	Observation adjacent to unsealed road within road reserve	A1 0.0 - 0.1 ZCL B1 0.1 - 0.85 ZC			**(4b/5b)** Brown/ grey non-cracking clays (Dermosols) - Derived from sediments and Brown/grey/dark cracking clays (Vertosols) - Derived from sediments (mainly clay plains)	Sodic (EO), Petrocalcic (DZ), Brown (AB),**DERMOSOL (DE)**	(10YR 4/4) ZCL: D, VFI, few F-M coarse fragments, abundant F-C roots	(10YR 5/4) ZC: D, VFI, NST, PL @ 0.85 refusal on strongly cemented pan			1				P			1			3				F					-		-	S26 14.545	E149 13.218	*Observed vegetation: Brigalow regroth* Canopy: 10- 20m Understory: 3m Ground strata: sparse short grasses	- Cleared grazing land
Combabula	OB12	Soil	Observation adjacent to unsealed road within road reserve	A1 0.0 - 0.1 ZCL A2 0.1 - 0.6 CZ B1 0.6 - 0.8 CZ			**(2b)** Texture contrast soils (Chromosols / Sodosols / Kurosols) - Shallow mainly sandy surface (acidic or alkaline)	Epipedal (GS), Brown (AB), **VERTOSOL (VE)**	(10YR 4/3) ZSL: D, LO, few F roots @ 0.1 (10YR 4/3) CZ: D, STR, few F roots	(10YR 4/3) CZ: D, STR			1				P			1			1				F					-		-	S26 21.118	E149 13.828	*Observed vegetation: Brigalow regroth* Canopy: 10- 20m Understory: None Ground strata: sparse short grasses	- Cleared grazing land
Combabula	OB13	Soil	Observation adjacent to unsealed road within road reserve	A1 0.0 - 0.05 L B1 0.05 - 0.7 ZL			**(2c/5b)** Texture contrast soils (Chromosols / Sodosols / Kurosols) - Shallow mainly loamy surface (acidic or alkaline) and Brown/grey/dark cracking clays (Vertosols) - Derived from sediments (mainly clay plains)	Mesotrophic (AG), Brown (AB), **KANDOSOL (KA)**	(7.5YR 3/4) L: D, STR, ST, abundant F-C roots	(7.5YR 3/3) ZL: D, STR, ST @ 0.7 abandoned			1				I			1			2				D					-		-	S26 24.231	E149 18.178	*Observed vegetation: Belah* Canopy: 10- 20m Understory: None Ground strata: sparse short grasses	- Cleared grazing land
Combabula	OB14	Soil	Observation adjacent to unsealed access track and private property fenceline	A1 0.0 - 0.1 CZL A2 0.1 - 0.3 CZL A3 0.3 - 0.5 CZkSL B1 0.5 - 0.85 CZkSL			**(2c/5b)** Texture contrast soils (Chromosols / Sodosols / Kurosols) - Shallow mainly loamy surface (acidic or alkaline) and Brown/grey/dark cracking clays (Vertosols) - Derived from sediments (mainly clay plains)	Grey (AD), **SODOSOL (SO)**	(10YR 4/1) CZL: D, C, abundant F-C coarse fragments, many F-C roots @ 0.1 (10YR 4/3) @ 0.3 (10YR 4/1) CZkSL: D, VFI, C, K, abundant F-C coarse fragments	(10YR 5/1) D, VFI, LO, few C coarse fragments			1				I			1			2				L					-		-	S26 17.468	E149 21.064	*Observed vegetation: Poplar box - Brigalow regrowth* Canopy: 10- 20m Understory: None Ground strata: sparse short grasses	- Cleared grazing land - Abundant scattered surface boulders / PGM
Combabula	OB15	Water	Observation adjacent to unsealed road within private property	N/A			N/A	N/A	N/A	N/A			1				P			1			1				D					-		-	S26 09.781	E149 34.134	*Observed vegetation:* Canopy: 15m Understory: 5-10m Ground strata: short grasses	*Channel description* - Narrow channel approximately 4m wide and 1.5m deep - Clay bed substrate with few scattered surface boulders - Banks appear stable with established grass - Tall grasses within channel - Grazing land cleared to creek bank

General Information				*Soil Summary*					*Landscape Information*											
General Location	Sample Assessment Location	Observation Type	Location Description Notes	Horizon and General Soil Description (depth mBGL)	Mapped Soil Group and Description	Field Classification (ASC)	Soil Description (texture, structure, consistence, coarse fragments, rooting)		Existing Erosion	Drainage	Terrain Class	Predominant Slope	Slope Position	Aspect	Watertable	GPS Coordinates		Vegetation	Comments
							Topsoil	*Subsoil*	*1 2 3*	*R W MW I P VP*	*1 2 3*	*1 2 3 4*	*F C U M L D*	*N S E W*		*Southing*	*Easting*		
Combabula	OB16	Soil	Observation adjacent to unsealed road within road reserve	A1 0.0 - 0.1 ZS A2 0.1 - 0.4 ZS	(**2c/5b**) - Texture contrast soils (Chromosols / Sodosols / Kurosols) - Shallow mainly loamy surface (acidic or alkaline) and Brown/grey/dark cracking clays (Vertosols) - Derived from sediments (mainly clay plains)	**RUDOSOL**	(10YR 4/4) ZS: D, LO, many F-M coarse fragments, abundant F-M roots @ 0.1 abundant F-S coarse fragments, many F-M roots @ 0.2 ZC lense: FI, ST, SPL, orange mottle @ 0.4 refusal	-	1	W	3	3	U	E	-	S26 12.795	E149 34.658	*Observed vegetation: Cypress Pine Woodland* Canopy: 20m Understory: 5m Ground strata: sparse short grass	- Scattered surface boulders
Combabula	OB17	Soil	Observation adjacent to unsealed road within road reserve	A1 0.0 - 0.1 ZSL A2 0.1 - 0.3 ZSL B1 0.3 - 0.7 ZC	(**5b**) Brown/grey/dark cracking clays (Vertosols) - Derived from sediments (mainly clay plains)	Epipedal (GS), Brown (AB), **VERTOSOL (VE)**	(10YR 3/3) ZSL: D, LO, many F-C roots @ 0.1 (10YR 3/3) ZSL: D, weak, few VF roots	(10YR4/3) ZC: D, FI, ST, SPL, K, few F-M coarse fragments @ 0.7 abandoned	1	I	1	1	F	-	-	S26 06.566	E149 27.742	Observed vegetation: Brigalow regrowth Canopy: 10-20m Understory: 3m Ground strata: short grass	- Partially cleared grazing land
Combabula	OB18	Water	Observation within private property	N/A	N/A	N/A	N/A	N/A	1	W	1	1	F	-	-	S26 09.812	E149 22.147	*Observed vegetation: Blue Gum Woodland* Canopy: 30m Understory: 5m Ground strata: sparse short grass	*Channel description* - Broad shallow channel approximately 65m wide and 2m deep - Main channel 15m wide and 1m deep - Sand bed substrate with abundant boulders - Banks appear stable with established grass - Grazing land cleared to creek bank
Combabula	OB18B	Water	Observation made at dam within private propety	N/A	N/A	N/A	N/A	N/A	1	P	2	3	D	-	-	S26 09.815	E149 21.780	*Observed vegetation: Blue Gum Regrowth* Canopy: 30m Understory: 5m Ground strata: short grass	*Channel description* - Wide deep channel approximately 20m wide and 7m deep - Clay bed substrate with abundant boulders - Banks appear stable with established grass - Grazing land cleared to creek bank - Dam was previously feed up natural spring
Combabula	OB19	Water	No Access	N/A	N/A	N/A	N/A	N/A	-	-	-	-	-	-	-	S26 13.110	E149 22.039	-	-
Ramyard	OB20	Water	Observation made at sealed road crossing along Jackson Wandoan Rd	N/A	N/A	N/A	N/A	N/A	3	P	2	2	D	-	-	S26 20.127	E149 46.881	*Observed vegetation: Pasture Grasslands* Canopy: 20m Understory: none Ground strata: long grasses	*Channel description* - Wide deep channel approximately 40m wide and 2m deep - Clay bed substrate with some coarse sand - Banks appear unstable with steepy eroded banks - Surrounding land use is grazing.
Wolsebee	OB21	Soil	No Access	-	-	-	-	-	-	-	-	-	-	-	-	S26 15.969	E149 51.458	-	-
Wolsebee	OB22	Water	Observation made at unsealed road crossing.	N/A	N/A	N/A	N/A	N/A	1	P	1	2	D	-	-	S26 12.847	E149 54.103	*Observed vegetation: Pasture Grasslands with Belah Regrowth* Canopy: 10m Understory: 2m Ground strata: short grasses	*Channel description* - Undefined channel approximately 30m wide and 0.5m deep - Banks appear stable with established grass - Surrounding land is mostly cleared for grazing.
Wolsebee	OB23	Soil	Observation adjacent to unsealed road within road reserve	A1 0.0 - 0.1 mC A3 0.1 - 0.4 hC B1 0.4 - 1.0 hC	(**2b**) Texture contrast soils (Chromosols / Sodosols / Kurosols) - Shallow mainly sandy surface (acidic or alkaline)	Crusty (BH), Brown (AB), **VERTOSOL (VE)**	(10YR 3/2) mC: D, C, STR, ST, PL, many F-M coarse fragments, abundant F-C roots @ 0.1 (10YR 2/2) hC: M, FI, VST, VPL, K, many F-M coarse fragments, many F roots	(10YR 2/2) hC: M, FI, VST, VPL, K, few F-M coarse fragments, few F roots @ 0.9 D, VFI	1	P	1	2	P	-	-	S26 22.262	E149 50.568	*Observed vegetation: Poplar Box Regrowth* Canopy: 20m Understory: none Ground strata: sparse short grasses	- Cleared grazing land
Carinya	OB24	Soil	Observation adjacent to unsealed road within road reserve	A1 0.0 - 0.1 L A3 0.1 - 0.3 ZhCL B1 0.3 - 0.9 ZhC	(**5b / 5b[m]**) Brown/grey/dark cracking clays (Vertosols) - Derived from sediments (mainly clay plains) [with or without Melonhole clays]	Epipedal (GS), Brown (AB), **VERTOSOL (VE)**	(10YR 4/3) L: D, WE, few VF roots @ 0.1 (7.5YR 3/2) ZhCL: D, FI, ST, SPL, few VF roots	(no colour) ZhC: D, STR, ST, SPL @ 0.9 abandoned	1	P	1	1	F	-	-	S26 33.715	E149 39.851	*Observed vegetation: Pasture Grasslands with Brigalow Regrowth* Canopy: 10m Understory: 2m Ground strata: short grasses	- Cleared grazing land
Carinya	OB25	Soil	Observation adjacent to unsealed road within road reserve	A1 0.0 - 0.2 ZL A2 0.2 - 0.4 ZC	(**5b[m]**) Brown/grey/dark cracking clays (Vertosols) - Derived from sediments (mainly clay plains) [Melonhole clays]	Crusty (BH), Brown (AB), **VERTOSOL (VE)**	(7.5YR 3/2) ZL: D, STR, C, many F-M roots @ 0.2 (7.5 YR 3/2) ZC: w some fS: S, STR, ST, PL, KC, few VF coarse fragments @ 0.4 Abandoned	-	1	P	1	1	F	-	-	S26 43.998	E149 42.175	*Observed vegetation: Belah Regrowth* Canopy: 10m Understory: 2m Ground strata: short grasses	- Cleared grazing land
Carinya	OB26	Soil	Observation adjacent to unsealed road within road reserve and minor drainage line	A1 0.0 - 0.3 ZhC A2 0.3 - 0.4 ZhC A3 0.4 - 0.8 ZhC B1 0.8 - 1.0 ZhC	(**5b**) - Brown/grey/dark cracking clays (Vertosols) - Derived from sediments (mainly clay plains)	Self-mulching (EI), Brown (AB), **VERTOSOL (VE)**	(10YR 3/1) ZhC: D, VFI, ST, VPL, abundant VF-C coarse fragments, abundant F-C roots @ 0.3 (10YR 3/4) @ 0.4 (10YR 4/6) many VF-C coarse fragments, few F roots.	(10YR 6/8) ZhC: D, WE, ST, VPL	1	P	1	1	D	-	-	S26 38.979	E149 48.101	*Observed vegetation: Cypress Pine Regrowth* Canopy: 10-20m Understory: none Ground strata: short grasses	- Cleared grazing land - Observation located within minor drainage line on bare soil - Some minor rill erosion
Carinya	OB27	Soil	Observation within private property	A1 0.0 - 0.4 L B1 0.4 - 0.5 ZhC	(**5b**) - Brown/grey/dark cracking clays (Vertosols) - Derived from sediments (mainly clay plains)	Duric (BJ), Crusty (BH), Brown (AB), **VERTOSOL (VE)**	(10YR 3/2) L: C, STR, C, abundant VF roots	(7.5YR 3/4) ZhC: D, STR, ST, PL, few VF roots @ 0.5 Abandoned	1	P	1	1	F	-	-	S26 32.917	E149 53.331	*Observed vegetation: Blue Gum Regrowth* Canopy: none Understory: none Ground strata: short grasses	- Cleared grazing land
Carinya	OB27B	Water	Observation made at sealed road crossing	N/A	N/A	N/A	N/A	N/A	2	P	2	2	D	-	-	S26 32.382	E149 54.472	*Observed vegetation: Blue Gum Regrowth* Canopy: 20m Understory: 3m Ground strata: short grasses	*Channel description* - Deep narrow U-shaped channel approximately 5m wide and 3m deep - Banks appear unstable with eroded steep banks - Bed substrate appears to be cracked clays - Surrounding land is mostly cleared for grazing.
Carinya	OB28	Water	Observation made at unsealed road crossing	N/A	N/A	N/A	N/A	N/A	2	MW	1	2	D	-	-	S26 42.967	E149 55.758	*Observed vegetation: Ironbark - Cypress Pine Regrowth* Canopy: 10-20m Understory: 5m Ground strata: short grasses	*Channel description* - Shallow narrow U-shaped channel approximately 5m wide and 1m deep - Banks appear unstable with eroded steep banks - Bed substrate appears to be sandy downstream and clay upstream - Surrounding land is mostly cleared for grazing.
Carinya	OB29	Soil	Observation adjacent to unsealed road within road reserve	A1 0.0 - 0.1 L A2 0.1 - 0.3 ZL A3 0.3 - 0.5 ZCL	(**1b**) - Skeletal soils (mainly Rudosols) - shallow stony loams derived from sediments	Brown (AB), **KANDOSOL (KA)**	(7.5YR 3/4) L: D, LO, ST, abundant VF-C coarse fragments, abundant VF-C roots @ 0.1 (7.5YR 3/3) ZL: D, LO, ST, abundant VF-S coarse fragments, many VF-C roots @ 0.3 (5YR 3/4) ZCL: D, LO, ST, PL, abundant VF-S coarse fragments, many VF-M roots @ 0.5 refusal on stones	-	1	I	2	2	M	W	-	S26 41.076	E149 55.946	*Observed vegetation: Poplar Box - Brigalow Regrowth* Canopy: 20m Understory: 3m Ground strata: short grasses	- Some clearing within road reserve - Abundant surface debris

| *General Information* | | | | *Soil Summary* | | | *Landscape Information* | | | |

General Information				*Soil Summary*							*Landscape Information*								
General Location	**Sample Assessment Location**	**Observation Type**	**Location Description Notes**	**Horizon and General Soil Description (depth mBGL)**	**Mapped Soil Group and Description**	**Field Classification (ASC)**	**Soil Description (texture, structure, consistence, coarse fragments, rooting)**		**Existing Erosion**	**Drainage**	**Terrain Class**	**Predominant Slope**	**Slope Position**	**Aspect**	**Watertable**	**GPS Coordinates**		**Vegetation**	**Comments**
							Topsoil	*Subsoil*	*1 2 3*	*R W MW I P VP*	*1 2 3*	*1 2 3 4*	*F C U M L D*	*N S E W*		*Southing*	*Easting*		
Gilbert Gully	OB45	Soil	Observation made on private property near Origin rig and camp clearing	A1 0.0 - 0.1 fSL A2 0.1 - 0.3 fSCL B1 0.3 - 1.0 SC	**(2b/2c)** Texture contrast soils (Chromosols / Sodosols / Kurosols) - Shallow mainly sandy surface (acidic or alkaline) and Shallow mainly loamy surface (acidic or alkaline)	Hypernatric (CR), Brown (AB), **SODOSOL (SO)**	(10YR 4/3) fSL: D, LO, NS, SPL, few F coarse fragments, many VF-M roots @ 0.1 (10YR 5/2) fSCL: D,LO ST, PL, abundant VF-C coarse fragments, few VF roots	(10YR 3/4) fSC: D, WE, SST, SPL, many F-C coarse fragments	1	I	1	1	F	-	-	S27 32.615	E150 52.848	*Observed vegetation: Poplar Box w Cypress Pine Regrowth* Canopy: 5-10m Understory: none Ground strata: patchy short grasses	- Regrowth vegetation - Observation made near vermin proof fence - Nearby unsealed vehicle tracks are exposed sandy clay where 200mm gravelly surface layer washed away
Gilbert Gully	OB46	Soil	Observation made within road reserve between sealed road and property boundary	A1 0.0 - 0.3 LIC (minor fS) A3 0.3 - 0.6 LfSLC B1 0.6 - 0.75 fSC B2 0.75 - 1.0 CmS	**(2b)** - Texture contrast soils (Chromosols / Sodosols / Kurosols) - Shallow mainly sandy surface (acidic or alkaline)	Hypernatric (CR), Brown (AB), **SODOSOL (SO)**	(10YR 3/3) LIC (minor fS): D, VFI, NS, SPL, many VF roots @ 0.1 (10YR 4/3) ST, PL, very few C roots @ 0.3 (10YR 3/4) LfSC: D, FI, ST, PL, many F coarse fragments, very few VF roots	(10YR 3/6) fSC: SLMO, WE, SST, PL, many F coarse fragments @ 0.75 (10YR 4/6) CmS: D, WE, SST, SPL, many F coarse fragments	1	I	1	1	F	-	-	S27 37.323	E150 56.452	*Observed vegetation: Poplar Box Regrowth* Canopy: 10-20m Understory: 5m Ground strata: sparse short grasses and debris	- Surrounding land cleared for grazing - Private property could not be accessed
Gilbert Gully	OB47	Soil	Observation made within road reseve and adjacent to private property boundary	A1 0.0 - 0.2 CmS A3 0.2 - 0.5 CmS B1 0.5 - 0.7 mSC B2 0.7 - 1.0 CmS	**(2a)** Texture contrast soils (Chromosols / Sodosols / Kurosols) - Alluvial – predominantly mod deep to deep	Hypernatric (CR), Brown (AB), **SODOSOL (SO)**	(10YR 4/3) CmS: D, LO, SST, SPL, few VF-M roots @ 0.2 (10YR 4/4) CmS: D, LO, ST, SPL, few VF-M roots	(10YR 3/6) mSC: MOi, FI, SST, PL, K @ 0.7 (10YR 3/3) CmS: MOi, FI, SST, SPL, K	1	P	1	1	F	-	-	S27 38.294	E150 55.640	*Observed vegetation: Blue Gum with Belah, Wilga Regrowth* Canopy: 20m Understory: 5-10m Ground strata: patchy short grasses and debris	- natural vegetation within road reserve - boundary of 2 soil types(cracking clays and sands)
Gilbert Gully	OB48	Water	Observation made within private property	N/A	N/A	N/A	N/A	N/A	2	MW	2	2	D	-	-	S27 39.171	E150 50.253	*Observed vegetation: Blue Gum Woodland* Canopy: 10-20m Understory: none Ground strata: short grasses and debris	*Channel description* - Undefined shallow narrow channel approximately 2m wide and 0.5-1m deep - Banks appear unstable with steep sides - Bed substrate appears to be sand - Surrounding land is mostly cleared for grazing.
Gilbert Gully	OB48B	Water	Observation made within private property at road crossing	N/A	N/A	N/A	N/A	N/A	2	P	2	2	D	-	-	S27 39.206	E150 50.011	*Observed vegetation: Poplar Box - Cypress Pine Woodland* Canopy: 10-20m Understory: none Ground strata: short grasses and debris	*Channel description* - Well defined wide and deep channel approximately 20m wide with banks 1-2m above water level - Banks appear stable with dense vegetation growth along sides - Bed substrate appears to be clay - Large debris within channel - Surface boulder evident - Road acts as weir (lower water level dowstream) - Surrounding land is mostly cleared for grazing.
Gilbert Gully	OB49	Soil	Observation made within road reseve	O 0.0 - 0.01 A1 0.05 - 0.2 ZfS A2 0.2 - 0.6 fS A3 0.6 - 0.8 fS B1 0.8 - 1.0 CfS	**(1b)** Skeletal soils (mainly Rudosols) - shallow stony loams derived from sediments	Hypernatric (CR), Brown (AB), **SODOSOL (SO)**	(10YR 4/4) ZfS: D, LO, abundant F-C roots @ 0.2 (10YR 5/4) @ 0.6 (10YR 6/3)	(10YR 7/3) CfS: D WE, SST, NP	1	W	1	1	F	-	-	S27 41.632	E150 59.210	*Observed vegetation: Pasture Grasslands* Canopy: 20m Understory: 10m Ground strata: short grasses and debris	- Observation made along State forest boundary - Adjacent to Moonie pipeline - Abundant ground surface debris
Gilbert Gully	OB50	Soil	Observation made within private property	A1 0.0 - 0.1 mC B1 0.1 - 1.0 mC	**(1b/2b)** Skeletal soils (mainly Rudosols) - shallow stony loams derived from sediments / Texture contrast soils (Chromosols / Sodosols / Kurosols) - Shallow mainly sandy surface (acidic or alkaline)	Crusty (BH), Brown (AB), **VERTOSOL (VE)**	(10YR 4/4) mC: D, VFI, SST, SPL, very few M coarse fragments, many VF roots	(10YR 3/4) mC: D, VFI, ST, PL, very few M coarse fragments @ 0.6 K @ 0.8 SLMO	1	P	1	1	F	-	-	S27 44.403	E151 04.620	*Observed vegetation: None* Canopy: none Understory: none Ground strata: short grasses	- Observation made within cleared grazing paddock - Soil type boundary located approximately 200m north of Observation
Gilbert Gully	OB51	Soil	Observation made adjacent to unsealed road within road reserve	A1 0.0 - 0.1 ZfS A2 0.1 - 0.5 CfS B1 0.5 - 0.7 fSC B2 0.7 - 1.0 CfS	**(4b/5b)** Brown/ grey non-cracking clays (Dermosols) - Derived from sediments and Brown/grey/dark cracking clays (Vertosols) - Derived from sediments (mainly clay plains)	Hypernatric (CR), Brown (AB), **SODOSOL (SO)**	(10YR 5/2) ZfS: D, LO, NS, NPL, many VF-F roots @ 0.1 (10YR 5/8) CfS: D, LO, NS, SPL, few F-C roots	(10YR 3/1) fSC: D, WE, SST, SPL @ 0.7 (10YR 5/4) CfS: D, WE, NPL, SST	1	I	1	1	F	-	-	S27 48.045	E150 55.069	*Observed vegetation: Ironbark - Cypress Pine Woodland* Canopy: 10-20m Understory: none Ground strata: sparse short grasses	- Cleared grazing land
Gilbert Gully	OB52	Soil	Observation made adjacent to unsealed road within State forest	O 0.0 - 0.01 A1 0.01 - 0.2 ZfS A2 0.2 - 0.5 fSC B1 0.5 - 0.7 fSCL B2 0.7 - 1.0 CLfS	**(2a)** Texture contrast soils (Chromosols / Sodosols / Kurosols) - Alluvial – predominantly mod deep to deep	Mottled-Hypernatric (FP), Brown (AB), **SODOSOL (SO)**	(10YR 6/3) ZfS: D, LO, NS, NPL, many VF roots @ 0.2 (10YR 5/8 w 10YR 6/2 mot) fSC: D, WE, SST, SPL, few F-M coarse fragments, very few F roots	(10YR 5/6 w 10YR 6/4 mot) fSCL: D, WE, SST, NPL, abundant F-M coarse fragments, very few F-C roots @ 0.7 (10YR 7/3) CLfS: D, WE, SST, NPL, few F-M coarse fragments	1	MW	1	1	F	-	-	S27 53.643	E150 56.724	*Observed vegetation: Poplar Box with Bulloak, Cypress Pine, Poplar Box, Blue Gum Regrowth* Canopy: 10-20m Understory: none Ground strata: sparse short grasses	- Natural - state forest - Abundant ground surface debris
Gilbert Gully	OB53	Water	Observation made on private property	N/A	N/A	N/A	N/A	N/A	2	W	2	2	D	-	-	S27 54.929	E150 52.779	*Observed vegetation: Ironbark - Cypress Pine Woodland* Canopy: 10-20m Understory: none Ground strata: short grasses	*Channel description* - Wide channel approximately 6-10m wide and 2m deep - Banks appear unstable with eroded steep sides - Bed substrate appears to be fine sand - Scattered surface boulders evident - Surrounding land is mostly cleared for grazing.
Gilbert Gully	OB54	Soil	Observation made within State forest	O 0.0 - 0.01 A1 0.01 - 0.15 ZfS A2 0.15 - 0.6 ZfS B1 0.6 - 0.8 mC B2 0.8 - 1.0 fSC	**(2b)** - Texture contrast soils (Chromosols / Sodosols / Kurosols) - Shallow mainly sandy surface (acidic or alkaline)	Mottled-Hypernatric (FP), Brown (AB), **SODOSOL (SO)**	(10YR 6/3) ZfS: D, LO, many VF roots @ 0.15 (10YR 7/2) ZfS: D, LO	(10YR 5/3 w 10YR 4/6, 10YR 4/1 mot) mC: D, WE, SST, VPL @ 0.8 (10YR 5/8 w 10YR 5/1 mot) fSC: D, WE, ST, SPL	1	MW	1	1	F	-	-	S27 50.748	E151 04.024	*Observed vegetation: Pasture Grasslands with Cypress Pine, Bullcak and Shrubs* Canopy: none Understory: none Ground strata: sparse short grasses	- Natural - State forest
Combabula	OB55	Soil	Observation made at soil cutting within local drainage line adjacent to unsealed road within road reserve	A1 0.0 - 0.1 ZfS B 0.1 - 1.0 ZCfS	**(2b/2c)** - Texture contrast soils (Chromosols / Sodosols / Kurosols) - Shallow mainly sandy surface (acidic or alkaline) and Shallow mainly loamy surface (acidic or alkaline)	Hypernatric (CR), Grey (AD), **SODOSOL (SO)**	(10YR 6/1) ZfS: D, LO, few F roots. Some oxidisation	(10YR 5/2) ZCfS: D, WE, few F roots.	3	W	1	1	F	-	-	S26 13.566	E149 34.730	*Observed vegetation: Blue Gum Regrowth* Canopy: none Understory: none Ground strata: sparse short grasses	- Description of cleaned back local drainage line steep bank where profile was already visible - Surrounding land use is cleared grazing land - Extremely eroded banks

Texture	
S	Sand
fS	Fine Sand
kS	Coarse Sand
L	Loam
C	Clay
Z	Silt
G	Gravel
IP	Fibric Peat

Structure	
WE	Weak
MO	Moderate
ST	Strong
WM	Weak to moderate
MS	Moderate to strong
GR	Granular
PL	Platy

Consistence	
LO	Loose
VFR	Very friable / very weak
FR	Friable / weak
FI	Firm
VFI	Very firm
STR	Strong
VSTR	Very strong
RI	Rigid
NST	Non-sticky
SST	Slightly sticky
ST	Sticky
VST	Very sticky
NPL	Non-plastic
SPL	Slightly plastic
PL	Plastic
VPL	Very plastic
D	Dry
SL MOi	Slight moist
MOi	Moist
G	Cracking
M	Self-mulching
H	Hard Setting
C	Surface Crust
K	Calcrete

Course Fragments	
N	None
V	Very few
F	Few
C	Common
M	Many
A	Abundant
D	Dominant
F	Fine gravel
M	Medium gravel
C	Course gravel
CB	Cobbles
S	Stones
B	Boulders
L	Large boulders

Drainage	
R	Rapidly drained
W	Well drained
MW	Moderately well drained
I	Imperfectly drained
P	Poorly drained
VP	Very poorly drained

Rooting	
N	None
V	Very few
F	Few
C	Common
M	Many
VF	Very fine
F	Fine
M	Medium
C	Course

Erosion	
1	Minor
2	Moderate
3	Severe

Terrain Class	
1	Low
2	Medium
3	High

Predominant Slope	
1	Flat
2	Low
3	Moderate
4	High

Slope Position	
C	Crest
U	Upper slope
M	Middle slope
Lo	Lower slope
D	Depression
Le	Level

Sample Location	Sample	Date	Mapped Soil Group	Field Soil Classification (ASC)	Emerson Class	Field pH	pH	EC	ECe (EC1:5 x conversion factor)	EC rating	Available Nutrients			Exchangeable Sodium Percent (ESP)*	Sodicity	CEC	Exchangeable Ions							Sulfate	SAR*
											TKN	% TKN by P weight					Ca	Mg	K	Na	Fe	Al			
Units			-	-	*Class number*	*pH units*	*pH units*	*µS/cm*	*µS/cm*	*NS, SS, MS, HS, ES*	*mg/kg*	*%*	*mg/kg*	*%*	*NS,S, SS*	*meq/100g*	*meq/100g*	*meq/100g*	*meq/100g*	*meq/100g*	*meq/100g*	*mg/kg*	*mg/kg*	*mg/kg*	*meq/100g*
Laboratory Detection Level			-	-	-	-	*0.1*	*10*	*10*	-	*100*	*1*	*1*	-	-	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*1*	*1*	*1*	*0.01*
OB03	0.0-0.1	25/08/2009	2c/5b	VE		8	5.8	580	5510	MS	300	0.03	3	9.1	S	17.5	8.8	6.2	0.9	1.6	<1	<1	144	0.59
OB03	0.9-1.0	25/08/2009	2c/5b	VE	1	8	5.5	1590	13674	HS				19.9	SS	22.1	10.8	6.8	<0.1	4.4	<1	<1	829	1.50
OB04	0.0-0.1	25/08/2009	3b	VE		6	7	110	1045	NS	651	0.07	5	ID	NS	23.1	9.5	13.4	0.2	<0.1	<1	<1	<1	<0.01
OB04	0.3-0.4	25/08/2009	3b	VE																				
OB05	0.0-0.1	24/08/2009	2d/5b	CH		5.5	7.4	20	460	NS	203	0.02	1	ID	NS	1.8	0.7	0.4	<0.1	<0.1	<1	61	13	<0.01
OB05	0.9-1.0	24/08/2009	2d/5b	CH	2	5	7.2	10	230	NS				ID	NS	1.9	0.3	0.5	<0.1	<0.1	<1	94	106	<0.01
OB07	0.0-0.1	25/08/2009	2d	VE		4.5	6.7	40	380	NS	580	0.06	6	ID	NS	12.5	4.7	5.9	0.8	<0.1	<1	101	<1	<0.01
OB07	0.9-1.0	25/08/2009	2d	VE	1	5	5.5	1080	8100	HS				29.6	SS	28.4	0.2	15	0.3	8.4	<1	400	<1	3.05
OB09	0.01-0.15	25/08/2009	2d/5b	RU		6.5	6.4	70	980	NS	356	0.04	4	ID	NS	6.8	4.8	1.7	0.3	<0.1	<1	<1	210	<0.01
OB11	0.0-0.1	25/08/2009	4b/5b	DE		8	6.0	360	3420	SS	470	0.05	4	1.7	NS	57.4	47.8	8.1	0.6	1	<1	<1	130	0.18
OB11	0.7-0.85	25/08/2009	4b/5b	DE	3	8	6.2	1090	9374	HS				12.3	S	60.2	42.2	10.2	0.3	7.4	<1	<1	524	1.45
OB12	0.0-0.1	25/08/2009	2b	VE		5.5	6.9	140	1330	NS	447	0.04	5	ID	NS	11.6	3.7	6.7	0.5	<0.1	<1	61	152	<0.01
OB12	0.9-1.0	25/08/2009	2b	VE	1	6	6.3	800	6880	MS				29.3	SS	19.1	1.4	11.7	0.3	5.6	<1	2	153	2.18
OB13	0.0-0.05	25/08/2009	2c/5b	KA		7.5	6.3	70	665	NS	877	0.09	10	ID	NS	30.4	21.5	7	1.9	<0.1	<1	<1	35	<0.01
OB13	0.6-0.7	25/08/2009	2c/5b	KA	2	7.5	6.8	60	570	NS				ID	NS	26.2	19.1	6.2	1	<0.1	<1	<1	154	<0.01
OB14	0.0-0.1	25/08/2009	2c/5b	SO		6	6.7	100	950	NS	545	0.05	10	7.1	S	18.4	11.1	5.1	0.9	1.3	<1	<1	565	0.44
OB14	0.7-0.85	25/08/2009	2c/5b	SO	3	8.5	7.3	520	4472	MS				16.4	SS	34.8	21.3	7.5	0.4	5.7	<1	<1	576	1.49
OB16	0.0-0.1	26/08/2009	2c/5b	RU		7	7.3	40	920	NS	287	0.03	4	ID	NS	26.2	17.5	7.8	0.9	<0.1	<1	<1	200	<0.01
OB17	0.0-0.1	26/08/2009	5b	VE		7	7.4	190	1805	NS	666	0.07	12	14.0	SS	17.2	11.2	2.4	1.2	2.4	14	<1	<1	0.91
OB17	0.6-0.7	26/08/2009	5b	VE	3	8.5	7.6	1060	9116	HS				23.5	SS	37.8	24	4.5	0.4	8.9	13	<1	164	2.35
OB23	0.0-0.1	27/08/2009	2b	VE		8	7.6	130	1118	NS	1140	0.11	37	1.6	NS	31.9	24.3	5.4	1.7	0.5	3	<1	97	0.13
OB23	0.9-1.0	27/08/2009	2b	VE	2	6	7.2	1220	7076	MS				28.5	SS	29.1	9	11.4	0.4	8.3	6	4	289	2.61
OB24	0.0-0.1	27/08/2009	5b / 5b[m]	VE		7	7.9	130	1235	NS	428	0.04	11	11.0	S	19.1	10.8	5.5	0.7	2.1	<1	<1	41	0.72
OB24	0.8-0.9	27/08/2009	5b / 5b[m]	VE	1	7.5	7.3	1380	8004	HS				35.6	SS	27.5	8.1	9.3	0.3	9.8	2	<1	234	3.33
OB25	0.0-0.1	27/08/2009	5b[m]	VE		7.5	7.9	100	950	NS	511	0.05	3	8.7	S	19.6	12.2	5.1	0.5	1.7	8	<1	77	0.58
OB26	0.0-0.1	27/08/2009	5b	VE		8.5	7.2	1090	8175	HS	483	0.05	5	21.1	SS	49.2	27.5	10.4	0.8	10.4	6	<1	144	2.39
OB26	0.9-1.0	27/08/2009	5b	VE	2	7.5	7.4	1280	9600	HS				26.5	SS	44.2	24.2	7.9	0.3	11.7	6	<1	160	2.92
OB27	0.0-0.1	27/08/2009	5b	VE			8.2	150	1425	NS	583	0.06	10	10.1	S	17.9	9.4	6.1	0.5	1.8	1	<1	20	0.63
OB27	0.4-0.5	27/08/2009	5b	VE	6		6.6	4120	30900	ES				4.1	NS	189.7	160	20.6	1.4	7.7	<1	<1	23647	0.81
OB29	0.0-0.1	27/08/2009	1b	KA		4.5	6.6	140	1330	NS	730	0.07	5	8.8	S	6.8	2	1.2	0.8	0.6	13	196	20	0.43
OB29	0.4-0.5	27/08/2009	1b	KA	5	5	6.4	50	475	NS				6.5	S	9.2	0.6	1.6	0.7	0.6	1	519	41	0.59
OB30	0.0-0.1	28/08/2009	1b	RU		6	6.3	200	2800	SS	667	0.07	2	18.3	SS	9.3	2.4	4.7	0.4	1.7	10	3	20	0.89
OB30	0.7-0.8	28/08/2009	1b	RU	3	7	6.6	170	2380	SS				15.8	SS	13.9	4.7	6.3	0.6	2.2	1	<1	15	0.96
OB31	0.0-0.1	28/08/2009	1b	RU		5.5	7.2	20	460	NS	253	0.03	2	20.0	SS	2	0.6	0.4	0.1	0.4	15	39	<1	0.56
OB32	0.01-0.1	28/08/2009	5b[m]	VE		6	6.2	580	4350	MS	539	0.05	10	15.9	SS	22.6	7.8	9.7	1.5	3.6	4	1	<1	1.22
OB34	0.01-0.1	28/08/2009	5b[m]	RU		4.5	6.8	40	920	NS	301	0.03	4	23.5	SS	3.4	0.3	1	<0.1	0.8	18	97	<1	0.95
OB35	0.1-0.2	28/08/2009	1a/2d	RU		6	6.8	70	665	NS	379	0.04	6	16.4	SS	7.3	2.6	2.9	0.4	1.2	11	7	<1	0.75
OB36	0.01-0.1	28/08/2009	2b	SO		5.5	6.6	90	2070	SS	210	0.02	1	47.6	SS	2.1	0.2	0.6	<0.1	1	12	17	20	1.54
OB36	0.9-1.0	28/08/2009	2b	SO	1	7	6.8	210	4830	MS				54.5	SS	10.1	<0.1	4.4	0.1	5.5	<1	<1	61	3.64
OB37	0.0-0.1	29/08/2009	2c	VE		6.5	6.8	250	1875	NS	497	0.05	2	25.2	SS	13.9	5.6	4.6	0.1	3.5	13	<1	56	1.54
OB37	0.9-1.0	29/08/2009	2c	VE	1	8	6.5	930	5394	MS				34.6	SS	30.1	8.5	11	0.1	10.4	4	<1	102	3.33
OB38	0.0-0.05	29/08/2009	5b	VE		5.5	7.5	50	375	NS	883	0.09	20	3.7	NS	18.9	8.8	7.5	1.4	0.7	9	33	<1	0.25
OB38	0.5-0.6	29/08/2009	5b	VE	1	6	6.6	530	3975	SS				26.0	SS	26.5	11.3	8	0.3	6.9	3	<1	<1	2.23
OB39	0.0-0.1	29/08/2009	5b[m]	SO		5.5	7.5	30	258	NS	455	0.05	2	10.1	S	7.9	3.3	3.4	0.1	0.8	9	15	28	0.46
OB39	0.9-1.0	29/08/2009	5b[m]	SO	1	8	6.7	330	2838	SS				43.7	SS	12.6	1.8	5.2	<0.1	5.5	<1	<1	21	2.92
OB40	0.0-0.1	29/08/2009	5b	VE		6	7.5	40	560	NS	223	0.02	15	13.2	S	5.3	2.5	1.8	0.1	0.7	6	2	21	0.48
OB40	0.6-0.7	29/08/2009	5b	VE	2	8.5	7.2	360	3096	SS				12.3	S	28.5	16.6	8.2	0.2	3.5	3	<1	<1	1.01
OB41	0.0-0.1	29/08/2009	2c	VE		6.5	7.5	120	1032	NS	358	0.04	4	23.0	SS	16.1	7.3	5	0.1	3.7	<1	<1	41	1.50
OB41	0.9-1.0	29/08/2009	2c	VE	1	7	6.8	350	2030	SS				41.5	SS	25.8	6.7	8.1	0.3	10.7	<1	<1	491	3.94
OB42	0.0-0.1	29/08/2009	2a	SO		6.5	6.6	230	2185	SS	238	0.02	<1	36.3	SS	8	0.8	4	0.3	2.9	<1	3	394	1.90
OB42	0.9-1.0	29/08/2009	2a	SO	1	6	7.3	150	1290	NS				47.3	SS	11.2	<0.1	5.4	0.2	5.3	4	15	429	3.23
OB43	0.01-0.15	29/08/2009	2b	RU			7.6	40	560	NS	211	0.02	2	24.1	SS	2.9	0.2	0.9	0.3	0.7	7	64	387	1.02
OB45	0.0-0.1	30/08/2009	2b/2c	SO		6	7	40	380	NS	616	0.06	8	5.0	NS	10.1	4.9	4.2	0.5	0.5	2	<1	396	0.23
OB45	0.9-1.0	30/08/2009	2b/2c	SO	1	8.5	7.2	190	1634	NS				39.9	SS	17.8	0.4	10	0.3	7.1	<1	1	475	3.11
OB46	0.0-0.1	30/08/2009	2b	SO		7	7.1	210	1806	NS	534	0.05	3	16.0	SS	16.2	6.9	5.7	0.9	2.6	<1	<1	479	1.03
OB46	0.9-1.0	30/08/2009	2b	SO	1	8.5	7.1	410	9430	HS				36.5	SS	15.9	4.1	5.8	0.1	5.8	<1	<1	145	2.60
OB47	0.0-0.1	30/08/2009	2a	SO		6.5	7.7	50	1150	NS	253	0.03	2	39.1	SS	11.5	2.2	4.5	0.2	4.5	1	<1	436	2.47
OB47	0.9-1.0	30/08/2009	2a	SO	1	7.5	6.6	280	6440	MS				40.0	SS	11.5	2.2	4.5	<0.1	4.6	<1	<1	132	2.50
OB49	0.01-0.1	30/08/2009	1b	SO		5.5	6.7	<10	<10	NS	253	0.03	3	21.1	SS	1.9	0.9	0.3	0.1	0.4	8	16	153	0.54
OB49	0.9-1.0	30/08/2009	1b	SO	2	7	7.1	60	1380	NS				44.1	SS	3.4	<0.1	1.3	0.5	1.5	8	1	83	1.82
OB50	0.0-0.1	31/08/2009	1b/2b	VE		6.5	6.6	160	1200	NS	450	0.04	6	22.6	SS	16.4	4.3	8	0.3	3.7	<1	<1	144	1.50
OB50	0.9-1.0	31/08/2009	1b/2b	VE	1	7	6.5	300	2250	SS				39.7	SS	23.2	3.9	9.8	0.3	9.2	<1	<1	91	3.53
OB51	0.0-0.1	31/08/2009	4b/5b	SO		6	7.3	20	460	NS	266	0.03	6	15.6	SS	3.2	1.1	0.8	0.6	0.5	<1	18	125	0.53
OB51	0.9-1.0	31/08/2009	4b/5b	SO	1	8.5	7.2	160	3680	SS				39.7	SS	13.1	4	3.6	0.3	5.2	<1	7	144	2.65
OB52	0.01-0.1	31/08/2009	2a	SO		6	7	20	460	NS	301	0.03	2	27.3	SS	3.3	1.1	0.7	0.2	0.9	4	32	83	0.94
OB52	0.9-1.0	31/08/2009	2a	SO	2	7.5	7	90	2070	SS				43.2	SS	3.7	0.1	1.8	<0.1	1.6	3	2	90	1.65
OB54	0.01-0.1	31/08/2009	2b	SO		5.5	7.9	20	280	NS	252	0.03	1	20.8	SS	2.4	1.1	0.5	0.2	0.5	2	13	103	0.53
OB54	0.9-1.0	31/08/2009	2b	SO	2	5.5	7.3	100	860	NS				34.8	SS	6.6	0.1	3	0.2	2.3	5	87	111	1.87
OB55	0.0-0.1	26/08/2009	2b/2c	SO		6.5	8	<10	<10	NS	<100	0.01	2	35.4	SS	6.5	0.1	2.9	0.2	2.3	5	87	56	1.87
OB55	0.9-1.0	26/08/2009	2b/2c	SO	3	8.5	7.4	160	3680	SS				44.7	SS	11.4	3.9	2.1	0.3	5.1	2	2	61	2.98

NOTES

*	Calculated Values	**	Soil sample could not be collected deep enough for comparison to mapped soil	NS	Non-saline	HS	Highly Saline	NS	Non Sodic	SAR	$(Na^{2+}) / \sqrt{[(Ca^{2+}) + (Mg^{2+}) / 2]}$
^	Indicates comparible soil with associated soil types.			SS	Slightly saline	ES	Extremely Saline	S	Sodic	ESP	$(Na^{2+})/CEC * 100$
nd	Not Detected	ID	Indeterminable	MS	Moderately Saline			SS	Strongly Sodic		

Appendix C Laboratory analysis plan

Sample location	Sample	Emerson Class	pH/EC	TKN /P	CEC	Exchangeable cations
OB03	0.0-0.1		x	x	x	x
OB03	0.9-1.0	x	x		x	x
OB04	0.0-0.1		x	x	x	x
OB04	0.3-0.4					
OB05	0.0-0.1		x	x	x	x
OB05	0.9-1.0	x	x		x	x
OB07	0.0-0.1		x	x	x	x
OB07	0.9-1.0	x	x		x	x
OB09	0.01-0.15		x	x	x	x
OB11	0.0-0.1		x	x	x	x
OB11	0.7-0.85	x	x		x	x
OB12	0.0-0.1		x	x	x	x
OB12	0.9-1.0	x	x		x	x
OB13	0.0-0.05		x	x	x	x
OB13	0.6-0.7	x	x		x	x
OB14	0.0-0.1		x	x	x	x
OB14	0.7-0.85	x	x		x	x
OB16	0.0-0.1		x	x	x	x
OB17	0.0-0.1		x	x	x	x
OB17	0.6-0.7	x	x		x	x
OB23	0.0-0.1		x	x	x	x
OB23	0.9-1.0	x	x		x	x
OB24	0.0-0.1		x	x	x	x
OB24	0.8-0.9	x	x		x	x
OB25	0.0-0.1		x	x	x	x
OB26	0.0-0.1		x	x	x	x
OB26	0.9-1.0	x	x		x	x
OB27	0.0-0.1		x	x	x	x
OB27	0.4-0.5	x	x		x	x

Sample location	Sample	Emerson Class	pH/EC	TKN /P	CEC	Exchangeable cations
OB29	0.0-0.1		x	x	x	x
OB29	0.4-0.5	x	x		x	x
OB30	0.0-0.1		x	x	x	x
OB30	0.7-0.8	x	x		x	x
OB31	0.0-0.1		x	x	x	x
OB32	0.01-0.1		x	x	x	x
OB34	0.01-0.1		x	x	x	x
OB35	0.1-0.2		x	x	x	x
OB36	0.01-0.1		x	x	x	x
OB36	0.9-1.0	x	x		x	x
OB37	0.0-0.1		x	x	x	x
OB37	0.9-1.0	x	x		x	x
OB38	0.0-0.05		x	x	x	x
OB38	0.5-0.6	x	x		x	x
OB39	0.0-0.1		x	x	x	x
OB39	0.9-1.0	x	x		x	x
OB40	0.0-0.1		x	x	x	x
OB40	0.6-0.7	x	x		x	x
OB41	0.0-0.1		x	x	x	x
OB41	0.9-1.0	x	x		x	x
OB42	0.0-0.1		x	x	x	x
OB42	0.9-1.0	x	x		x	x
OB43	0.01-0.15		x	x	x	x
OB45	0.0-0.1		x	x	x	x
OB45	0.9-1.0	x	x		x	x
OB46	0.0-0.1		x	x	x	x
OB46	0.9-1.0	x	x		x	x
OB47	0.0-0.1		x	x	x	x
OB47	0.9-1.0	x	x		x	x
OB49	0.01-0.1		x	x	x	x

Sample location	Sample	Emerson Class	pH/EC	TKN /P	CEC	Exchangeable cations
OB49	0.9-1.0	x	x		x	x
OB50	0.0-0.1		x	x	x	x
OB50	0.9-1.0	x	x		x	x
OB51	0.0-0.1		x	x	x	x
OB51	0.9-1.0	x	x		x	x
OB52	0.01-0.1		x	x	x	x
OB52	0.9-1.0	x	x		x	x
OB54	0.01-0.1		x	x	x	x
OB54	0.9-1.0	x	x		x	x
OB55	0.0-0.1		x	x	x	x

Appendix D Laboratory certificates

CERTIFICATE OF ANALYSIS

Analysis By: Bio-Track Pty Ltd
ABN 91 056 237 275
Mt. Glorious Road
Highvale, Brisbane, Australia, 4520
Ph. 07 3289 7179 Fx. 07 3289 7155

DATE OF REPORT 25 SEPTEMBER 2009 Page 1 of 3 Report Pages.
CLIENT NAME MR ALEX KOCHNIEFF c/o WORLEY PARSONS PTY LTD
CLIENT ADDRESS PO BOX 585 FORTITUDE VALLEY BRISBANE4006
PROJECT NAME APLNG UPSTREAM YOUR PROJECT/JOB REFERENCE 301001-00448 WBS 1BV4070
SAMPLING DATE 24-31/08/09 NUMBER OF SAMPLES 69 SAMPLE TYPE:SOIL SAMPLE
PACKAGING SAMPLES LABELLED - INTACT - BAGGED - CHILLED IN INSULATED PACKAGING ** SAMPLES DISPOSED ON 1/6/2010
DATE RECEIVED 03 SEPTEMBER 2009 LAB REF. LR03099.685

METHODOLOGY: EC pH as 1:5 air dried soil in water, 30 minute rolling shake Na K Mg Ca Fe Al S as 1:20 soil dried soil in 1 N NH4Cl, 60 minute rolling shake. Na Mg Ca Fe Al S measured by ICP OES, K by AAS. CEC (cation exchange capacity) as the sum of extracted cations, SAR (sodium adsorption ratio) as $Na/((Ca+Mg)/2)^{0.5}$, %Na as Na% of CEC. (meq/100 =milli-equivalents/100 g soil)

SAMPLE ID m depth	EC dS/m	pH	Na meq/100	K meq/100	Ca meq/100	Mg meq/100	Fe mg/kg	Al mg/kg	S mg/kg	CEC meq/100	SAR	% Na	Ca:Mg
OB03 0.0-0.1	0.58	5.8	1.6	0.9	8.8	6.2	<1	<1	144	17.5	0.59	9.3	1.4
OB03 0.9-1.0	1.59	5.5	4.4	<0.1	10.8	6.8	<1	<1	829	22.1	1.50	20.1	1.6
OB04 0.0-0.1	0.11	7.0	<0.1	0.2	9.5	13.4	<1	<1	<1	23.1	<0.01	<0.1	0.7
OB05 0.0-0.1	0.02	7.4	<0.1	<0.1	0.7	0.4	<1	61	13	1.8	<0.01	<0.1	2.0
OB05 0.9-1.0	0.01	7.2	<0.1	<0.1	0.3	0.5	<1	94	106	1.9	<0.01	<0.1	0.6
OB07 0.0-0.1	0.04	6.7	<0.1	0.8	4.7	5.9	<1	101	<1	12.5	<0.01	<0.1	0.8
OB07 0.9-1.0	1.08	5.5	8.4	0.3	0.2	15.0	<1	400	<1	28.4	3.05	29.6	<0.1
OB09 0.01-0.15	0.07	6.4	<0.1	0.3	4.8	1.7	<1	<1	210	6.8	<0.01	<0.1	2.9
OB11 0.0-0.1	0.36	6.0	1.0	0.6	47.8	8.1	<1	<1	130	57.4	0.18	1.7	5.9
OB11 0.7-0.85	1.09	6.2	7.4	0.3	42.2	10.2	<1	<1	524	60.2	1.45	12.4	4.1
OB12 0.0-0.1	0.14	6.9	<0.1	0.5	3.7	6.7	<1	61	152	11.6	<0.01	<0.1	0.6
OB12 0.9-1.0	0.80	6.3	5.6	0.3	1.4	11.7	<1	2	153	19.1	2.18	29.3	0.1
OB13 0.0-0.05	0.07	6.3	<0.1	1.9	21.5	7.0	<1	<1	35	30.4	<0.01	<0.1	3.1
OB13 0.6-0.7	0.06	6.8	<0.1	1.0	19.1	6.2	<1	<1	154	26.2	<0.01	<0.1	3.1
OB14 0.0-0.1	0.10	6.7	1.3	0.9	11.1	5.1	<1	<1	565	18.4	0.44	6.8	2.2
OB14 0.7-0.85	0.52	7.3	5.7	0.4	21.3	7.5	<1	<1	576	34.8	1.49	16.3	2.8
OB16 0.0-0.1	0.04	7.3	<0.1	0.9	17.5	7.8	<1	<1	200	26.2	<0.01	<0.1	2.2
OB17 0.0-0.1	0.19	7.4	2.4	1.2	11.2	2.4	14	<1	<1	17.2	0.91	13.8	4.6
OB17 0.6-0.7	1.06	7.6	8.9	0.4	24.0	4.5	13	<1	164	37.8	2.35	23.4	5.3
OB23 0.0-0.1	0.13	7.6	0.5	1.7	24.3	5.4	3	<1	97	31.9	0.13	1.6	4.5
OB23 0.9-1.0	1.22	7.2	8.3	0.4	9.0	11.4	6	4	289	29.1	2.61	28.5	0.8
OB24 0.0-0.1	0.13	7.9	2.1	0.7	10.8	5.5	<1	<1	41	19.1	0.72	10.8	2.0
OB24 0.8-0.9	1.38	7.3	9.8	0.3	8.1	9.3	2	<1	234	27.5	3.33	35.7	0.9
OB25 0.0-0.1	0.10	7.9	1.7	0.5	12.2	5.1	8	<1	77	19.6	0.58	8.7	2.4
OB26 0.0-0.1	1.09	7.2	10.4	0.8	27.5	10.4	6	<1	144	49.2	2.39	21.2	2.6
OB26 0.9-1.0	1.28	7.4	11.7	0.3	24.2	7.9	6	<1	160	44.2	2.92	26.5	3.1
OB27 0.0-0.1	0.15	8.2	1.8	0.5	9.4	6.1	1	<1	20	17.9	0.63	9.8	1.5
OB27 0.4-0.5	4.12	6.6	7.7	1.4	160.0	20.6	<1	<1	23647	189.7	0.81	4.1	7.8
OB29 0.0-0.1	0.14	6.6	0.6	0.8	2.0	1.2	13	196	20	6.8	0.43	8.2	1.7
OB29 0.4-0.5	0.05	6.4	0.6	0.7	0.6	1.6	1	519	41	9.2	0.59	6.6	0.4
OB30 0.0-0.1	0.20	6.3	1.7	0.4	2.4	4.7	10	3	20	9.3	0.89	18.1	0.5

Signatory P. Edwards For and behalf of Bio-Track Pty Ltd

CERTIFICATE OF ANALYSIS

Analysis By: Bio-Track Pty Ltd
ABN 91 056 237 275
Mt. Glorious Road
Highvale, Brisbane, Australia, 4520
Ph. 07 3289 7179 Fx. 07 3289 7155

DATE OF REPORT 25 SEPTEMBER 2009
CLIENT NAME MR ALEX KOCHNIEFF c/o WORLEY PARSONS PTY LTD
CLIENT ADDRESS PO BOX 585 FORTITUDE VALLEY BRISBANE4006
PROJECT NAME APLNG UPSTREAM YOUR PROJECT/JOB REFERENCE 301001-00448 WBS 1BV4070
SAMPLING DATE 24-31/08/09 NUMBER OF SAMPLES 69 SAMPLE TYPE:SOIL SAMPLE
PACKAGING SAMPLES LABELLED - INTACT - BAGGED - CHILLED IN INSULATED PACKAGING ** SAMPLES DISPOSED ON 1/6/2010
DATE RECEIVED 03 SEPTEMBER 2009 LAB REF. LR03099.685

METHODOLOGY: EC pH as 1:5 air dried soil in water, 30 minute rolling shake Na K Mg Ca Fe Al S as 1:20 soil dried soil in 1 N NH4Cl, 60 minute rolling shake, Na Mg Ca Fe Al S measured by ICP OES, K by AAS. CEC (cation exchange capacity) as the sum of extracted cations, SAR (sodium adsorption ratio) as $Na/((Ca+Mg)/2)^{0.5}$, %Na as Na% of CEC. (meq/100 =milli-equivalents/100 g soil)

SAMPLE ID m depth	EC dS/m	pH	Na meq/100	K meq/100	Ca meq/100	Mg meq/100	Fe mg/kg	Al mg/kg	S mg/kg	CEC meq/100	SAR	% Na	Ca:Mg
OB30 0.7-0.8	0.17	6.6	2.2	0.6	4.7	6.3	1	<1	15	13.9	0.96	16.1	0.7
OB31 0.0-0.1	0.02	7.2	0.4	0.1	0.6	0.4	15	39	<1	2.0	0.56	19.3	1.5
OB32 0.01-0.1	0.58	6.2	3.6	1.5	7.8	9.7	4	1	<1	22.6	1.22	16.0	0.8
OB34 0.01-0.1	0.04	6.8	0.8	<0.1	0.3	1.0	18	97	<1	3.4	0.95	23.0	0.3
OB35 0.1-0.2	0.07	6.8	1.2	0.4	2.6	2.9	11	7	<1	7.3	0.75	17.1	0.9
OB36 0.01-0.1	0.09	6.6	1.0	<0.1	0.2	0.6	12	17	20	2.1	1.54	47.0	0.3
OB36 0.9-1.0	0.21	6.8	5.5	0.1	<0.1	4.4	<1	<1	61	10.1	3.64	54.1	<0.1
OB37 0.0-0.1	0.25	6.8	3.5	0.1	5.6	4.6	13	<1	56	13.9	1.54	25.0	1.2
OB37 0.9-1.0	0.93	6.5	10.4	0.1	8.5	11.0	4	<1	102	30.1	3.33	34.6	0.8
OB38 0.0-0.05	0.05	7.5	0.7	1.4	8.8	7.5	9	33	<1	18.9	0.25	3.8	1.2
OB38 0.5-0.6	0.53	6.6	6.9	0.3	11.3	8.0	3	<1	<1	26.5	2.23	26.1	1.4
OB39 0.0-0.1	0.03	7.5	0.8	0.1	3.3	3.4	9	15	28	7.9	0.46	10.7	1.0
OB39 0.9-1.0	0.33	6.7	5.5	<0.1	1.8	5.2	<1	<1	21	12.6	2.92	43.6	0.4
OB40 0.0-0.1	0.04	7.5	0.7	0.1	2.5	1.8	6	2	21	5.3	0.48	13.6	1.4
OB40 0.6-0.7	0.36	7.2	3.5	0.2	16.6	8.2	3	<1	<1	28.5	1.01	12.4	2.0
OB41 0.0-0.1	0.12	7.5	3.7	0.1	7.3	5.0	<1	<1	41	16.1	1.50	23.0	1.5
OB41 0.9-1.0	0.35	6.8	10.7	0.3	6.7	8.1	<1	<1	491	25.8	3.94	41.6	0.8
OB42 0.0-0.1	0.23	6.6	2.9	0.3	0.8	4.0	<1	3	394	8.0	1.90	36.5	0.2
OB42 0.9-1.0	0.15	7.3	5.3	0.2	<0.1	5.4	4	15	429	11.2	3.23	47.7	<0.1
OB43 0.01-0.15	0.04	7.6	0.7	0.3	0.2	0.9	7	64	387	2.9	1.02	26.1	0.2
OB45 0.0-0.1	0.04	7.0	0.5	0.5	4.9	4.2	2	<1	396	10.1	0.23	4.9	1.2
OB45 0.9-1.0	0.19	7.2	7.1	0.3	0.4	10.0	<1	1	475	17.8	3.11	39.9	<0.1
OB46 0.0-0.1	0.21	7.1	2.6	0.9	6.9	5.7	<1	<1	479	16.2	1.03	16.1	1.2
OB46 0.9-1.0	0.41	7.1	5.8	0.1	4.1	5.8	<1	<1	145	15.9	2.60	36.5	0.7
OB47 0.0-0.1	0.05	7.7	4.5	0.2	2.2	4.5	1	<1	436	11.5	2.47	39.4	0.5
OB47 0.9-1.0	0.28	6.6	4.6	<0.1	2.2	4.5	<1	<1	132	11.5	2.50	40.1	0.5
OB49 0.01-0.1	<0.01	6.7	0.4	0.1	0.9	0.3	8	16	153	1.9	0.54	21.3	3.1
OB49 0.9-1.0	0.06	7.1	1.5	0.5	<0.1	1.3	8	1	83	3.4	1.82	43.9	<0.1
OB50 0.0-0.1	0.16	6.6	3.7	0.3	4.3	8.0	<1	<1	144	16.4	1.50	22.7	0.5
OB50 0.9-1.0	0.30	6.5	9.2	0.3	3.9	9.8	<1	<1	91	23.2	3.53	39.8	0.4
OB51 0.0-0.1	0.02	7.3	0.5	0.6	1.1	0.8	<1	18	125	3.2	0.53	16.2	1.4

Signatory

For and behalf of Bio-Track Pty Ltd

CERTIFICATE OF ANALYSIS

Analysis By: Bio-Track Pty Ltd
ABN 91 056 237 275
Mt. Glorious Road
Highvale, Brisbane, Australia, 4520
Ph. 07 3289 7179 Fx. 07 3289 7155

DATE OF REPORT 25 SEPTEMBER 2009
CLIENT NAME MR ALEX KOCHNIEFF c/o WORLEY PARSONS PTY LTD
CLIENT ADDRESS PO BOX 585 FORTITUDE VALLEY BRISBANE4006
PROJECT NAME APLNG UPSTREAM YOUR PROJECT/JOB REFERENCE 301001-00448 WBS 1BV4070
SAMPLING DATE 24-31/08/09 NUMBER OF SAMPLES 69 SAMPLE TYPE:SOIL SAMPLE
PACKAGING SAMPLES LABELLED - INTACT - BAGGED - CHILLED IN INSULATED PACKAGING ** SAMPLES DISPOSED ON 1/6/2010
DATE RECEIVED 03 SEPTEMBER 2009 LAB REF. LR03099.685

METHODOLOGY: EC pH as 1:5 air dried soil in water, 30 minute rolling shake Na K Mg Ca Fe Al S as 1:20 soil dried soil in 1 N NH4Cl, 60 minute rolling shake, Na Mg Ca Fe Al S measured by ICP OES, K by AAS. CEC (cation exchange capacity) as the sum of extracted cations, SAR (sodium adsorption ratio) as Na/((Ca+Mg)/2)^0.5, %Na as Na% of CEC. (meq/100 =milli-equivalents/100 g soil)

SAMPLE ID m depth	EC dS/m	pH	Na meq/100	K meq/100	Ca meq/100	Mg meq/100	Fe mg/kg	Al mg/kg	S mg/kg	CEC meq/100	SAR	% Na	Ca:Mg
OB51 0.9-1.0	0.16	7.2	5.2	0.3	4.0	3.6	<1	7	144	13.1	2.65	39.4	1.1
OB52 0.01-0.1	0.02	7.0	0.9	0.2	1.1	0.7	4	32	83	3.3	0.94	27.2	1.5
OB52 0.9-1.0	0.09	7.0	1.6	<0.1	0.1	1.8	3	2	90	3.7	1.65	44.1	<0.1
OB54 0.01-0.1	0.02	7.9	0.5	0.2	1.1	0.5	2	13	103	2.4	0.53	19.5	2.1
OB54 0.9-1.0	0.10	7.3	2.3	0.2	0.1	3.0	5	87	111	6.6	1.87	35.3	<0.1
OB55 0.0-0.1	<0.01	8.0	2.3	0.2	0.1	2.9	5	87	56	6.5	1.87	35.4	<0.1
OB55 0.9-1.0	0.16	7.4	5.1	0.3	3.9	2.1	2	2	61	11.4	2.98	45.1	1.9

Signatory

For and behalf of Bio-Track Pty Ltd

Determination of Soil Total Nitrogen

CERTIFICATE OF ANALYSIS

Analysis By: **Bio-Track Pty Ltd** ABN 91 056 237 275781 Mt. Glorious Road Highvale, Brisbane, Australia, 4520 Ph. 07 3289 7179 Fx. 07 3289 7155

DATE OF REPORT	01 OCTOBER 2009
CLIENT NAME	MR ALEX KOCHNIEFF c/o WORLEY PARSONS PTY LTD
CLIENT ADDRESS	PO BOX 585 PORTITUDE VALLEY BRISBANE4006
PROJECT NAME	APLNG UPSTREAM
SAMPLING DATE	24-31/08/09 NUMBER OF SAMPLES 39
PACKAGING	SAMPLES LABELLED - INTACT - BAGGED - CHILLED IN INSULATED PACKAGING
DISPOSAL	SAMPLES DISPOSED ON 1/6/2010
LOG-IN DATE	03 SEPTEMBER 2009 LAB REF. LR03099.691
METHOD	TECATOR AUTOANALYSER KJELDAL DIGESTION/TITRATION

SAMPLE ID	mg/kg %	Percentage KJELDAL NITROGEN (%)
OB03 0.0-0.1	300	0.03%
OB04 0.0-0.1	651	0.07%
OB05 0.0-0.1	203	0.02%
OB07 0.0-0.1	580	0.06%
OB09 0.01-0.15	356	0.04%
OB11 0.0-0.1	470	0.05%
OB12 0.0-0.1	447	0.04%
OB13 0.0-0.05	877	0.09%
OB14 0.0-0.1	545	0.05%
OB16 0.0-0.1	287	0.03%
OB17 0.0-0.1	666	0.07%
OB23 0.0-0.1	1140	0.11%
OB24 0.0-0.1	428	0.04%
OB25 0.0-0.1	511	0.05%
OB26 0.0-0.1	483	0.05%
OB27 0.0-0.1	583	0.06%
OB29 0.0-0.1	730	0.07%
OB30 0.0-0.1	667	0.07%
OB31 0.0-0.1	253	0.03%
OB32 0.01-0.1	539	0.05%
OB34 0.01-0.1	301	0.03%
OB35 0.1-0.2	379	0.04%
OB36 0.01-0.1	210	0.02%
OB37 0.0-0.1	497	0.05%
OB38 0.0-0.05	883	0.09%
OB39 0.0-0.1	455	0.05%
OB40 0.0-0.1	223	0.02%
OB41 0.0-0.1	358	0.04%
OB42 0.0-0.1	238	0.02%
OB43 0.01-0.15	211	0.02%
OB45 0.0-0.1	616	0.06%
OB46 0.0-0.1	534	0.05%
OB47 0.0-0.1	253	0.03%
OB49 0.0-0.1	253	0.03%
OB50 0.0-0.1	450	0.04%
OB51 0.0-0.1	266	0.03%
OB52 0.01-0.1	301	0.03%
OB54 0.01-0.1	252	0.03%
OB55 0.0-0.1	< 100	0.01%

Method: Boiling H2SO4 digest for 45 minutes, steam distillation and titration by Tecator autoanalyser.

Signatory _____ For and behalf of Bio-Track Pty Ltd

SOIL ANALYSIS REPORT

Analysis By: Bio-Track Pty Ltd
ABN 91 056 237 275
Mt. Glorious Road
Highvale, Brisbane, Australia, 4520
Ph. 07 3289 7179 Fx. 07 3289 7155

DATE OF REPORT 16 SEPTEMBER 2009
CLIENT NAME MR ALEX KOCHNIEFF
CLIENT FIRM WORLEY PARSONS PTY LTD
JOB REFERENCE 301001-00448 WBS 1BV4070
CLIENT ADDRESS PO BOX 585 FORTITUDE VALLEY BRISBANE4006
PROJECT NAME APLNG UPSTREAM SAMPLING DATE 24-31/08/09
NUMBER OF SAMPLES 39 SAMPLE TYPE SOIL SAMPLE
PACKAGING SAMPLES LABELLED - INTACT - BAGGED - CHILLED IN INSULATED PACKAGING **
SAMPLES DISPOSED ON 1/6/2010
LOG-IN DATE 03 SEPTEMBER 2009 LAB REF. LR03099.693

SAMPLE ID	P mg/kg
OB03 0.0-0.1	3
OB04 0.0-0.1	5
OB05 0.0-0.1	1
OB07 0.0-0.1	6
OB09 0.01-0.15	4
OB11 0.0-0.1	4
OB12 0.0-0.1	5
OB13 0.0-0.05	10
OB14 0.0-0.1	10
OB16 0.0-0.1	4
OB17 0.0-0.1	12
OB23 0.0-0.1	37
OB24 0.0-0.1	11
OB25 0.0-0.1	3
OB26 0.0-0.1	5
OB27 0.0-0.1	10
OB29 0.0-0.1	5
OB30 0.0-0.1	2
OB31 0.0-0.1	2
OB32 0.01-0.1	10
OB34 0.01-0.1	4
OB35 0.1-0.2	6
OB36 0.01-0.1	1
OB37 0.0-0.1	2
OB38 0.0-0.05	20
OB39 0.0-0.1	2
OB40 0.0-0.1	15
OB41 0.0-0.1	4
OB42 0.0-0.1	<1
OB43 0.01-0.15	2
OB45 0.0-0.1	8
OB46 0.0-0.1	3
OB47 0.0-0.1	2
OB49 0.0-0.1	3
OB50 0.0-0.1	6
OB51 0.0-0.1	6
OB52 0.01-0.1	2
OB54 0.01-0.1	1
OB55 0.0-0.1	2

ANALYTICAL METHOD
Phosphorus as 1:20 in 0.5 M NaHCO3, determination by ICP OES

Signatory

For and on behalf of Bio-Track Pty Ltd

SOIL ANALYSIS REPORT

Analysis By: Bio-Track Pty Ltd
ABN 91 056 237 275
Mt. Glorious Road
Highvale, Brisbane, Australia, 4520
Ph. 07 3289 7179 Fx. 07 3289 7155

DATE OF REPORT 21 SEPTEMBER 2009
CLIENT NAME MR ALEX KOCHNIEFF
CLIENT FIRM WORLEY PARSONS PTY LTD
JOB REFERENCE 301001-00448 WBS 1BV4070
CLIENT ADDRESS PO BOX 585 FORTITUDE VALLEY BRISBANE4006
PROJECT NAME APLNG UPSTREAM SAMPLING DATE 24-31/08/09
NUMBER OF SAMPLES 30 SAMPLE TYPE SOIL SAMPLE
PACKAGING SAMPLES LABELLED - INTACT - BAGGED - CHILLED IN INSULATED PACKAGING **
SAMPLES DISPOSED ON 1/6/2010
LOG-IN DATE 03 SEPTEMBER 2009 LAB REF. LR03099.697

SAMPLE ID	EMN CLAS
OB03 0.9-1.0	1
OB05 0.9-1.0	2
OB07 0.9-1.0	1
OB11 0.7-0.85	3
OB12 0.9-1.0	1
OB13 0.6-0.7	2
OB14 0.7-0.85	3
OB17 0.6-0.7	3
OB23 0.9-1.0	2
OB24 0.8-0.9	1
OB26 0.9-1.0	2
OB27 0.4-0.5	6
OB29 0.4-0.5	5
OB30 0.7-0.8	3
OB36 0.9-1.0	1
OB37 0.9-1.0	1
OB38 0.5-0.6	1
OB39 0.9-1.0	1
OB40 0.6-0.7	2
OB41 0.9-1.0	1
OB42 0.9-1.0	1
OB45 0.9-1.0	1
OB46 0.9-1.0	1
OB47 0.9-1.0	1
OB49 0.9-1.0	2
OB50 0.9-1.0	1
OB51 0.9-1.0	1
OB52 0.9-1.0	2
OB54 0.9-1.0	2
OB55 0.9-1.0	3

ANALYTICAL METHOD
EMN CLASS-Emmerson Aggregate Stability classification per AS1289.3.8.1 1997

Signatory  For and on behalf of Bio-Track Pty Ltd

Appendix E Photographs of soils



Photo 1: OB03 / 0.0 - 1.0 m



Photo 2: OB04 / 0.0 - 0.4m



Photo 3: OB05 / 0.0 – 1.0m



Photo 4: OB07 / 0.0 – 1.0m



Photo 5: OB09 / 0.0 – 0.2m



Photo 6: OB11 / 0.0 – 0.85m



Photo 7: OB12 / 0.0 – 1.0m



Photo 8: OB13 / 0.0 – 0.7m



Photo 9: OB14 / 0.0 – 0.85m



Photo 10: OB16 / 0.0 – 0.4m



Photo 11: OB17 / 0.0 – 0.7m



Photo 12: OB23 / 0.0 – 1.0m

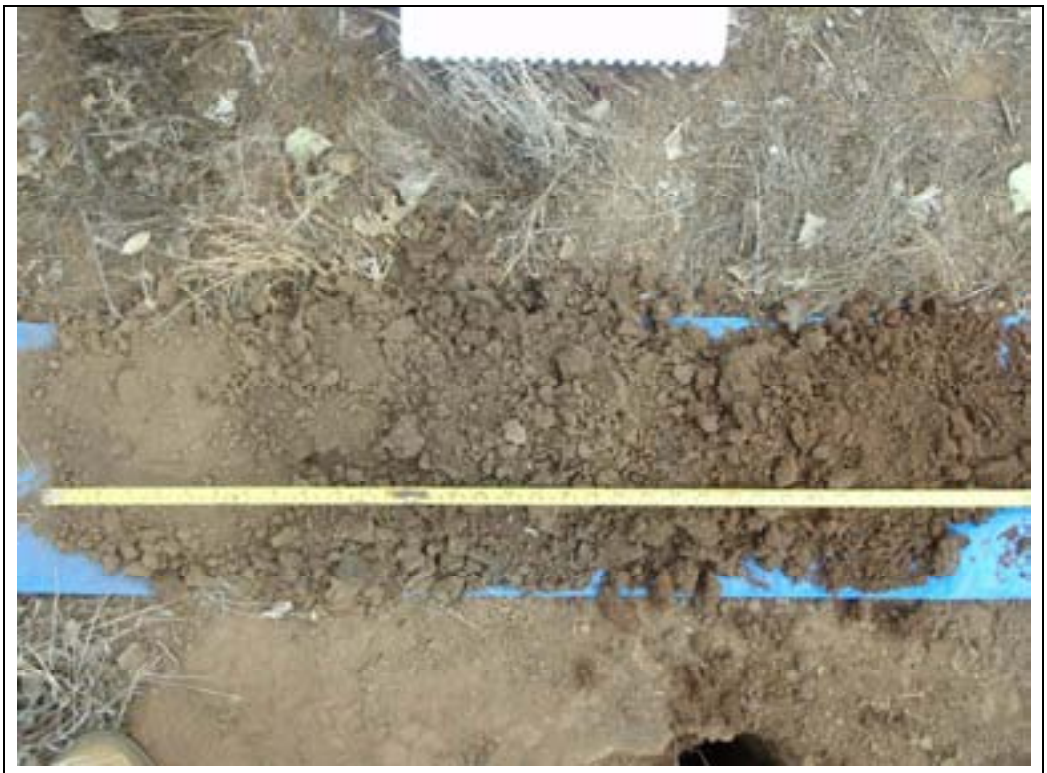


Photo 13: OB24 / 0.0 – 0.9m



Photo 14: OB25 / 0.0 – 0.4m



Photo 15: OB26 / 0.0 – 1.0m



Photo 16: OB27 / 0.0 – 0.5m



Photo 17: OB29 / 0.0 – 0.5m

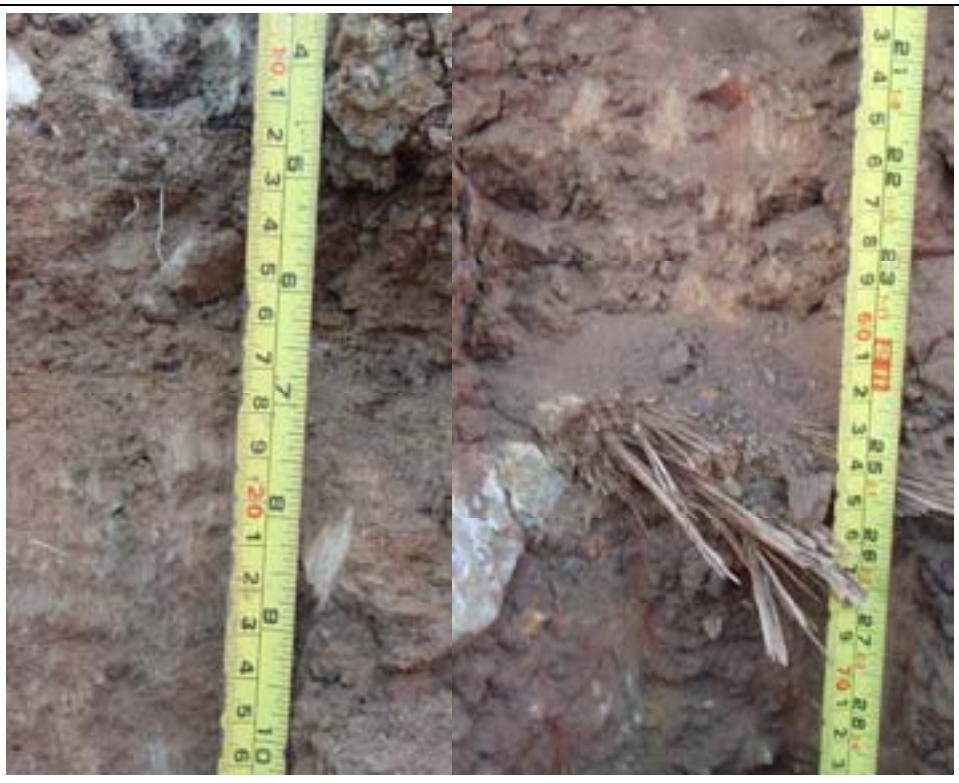


Photo 18: OB30 / 0.0 – 0.8m



Photo 19: OB31 / 0.0 – 0.3m



Photo 20: OB32 / 0.0 – 0.3m



Photo 21: OB34 / 0.0 – 0.4m

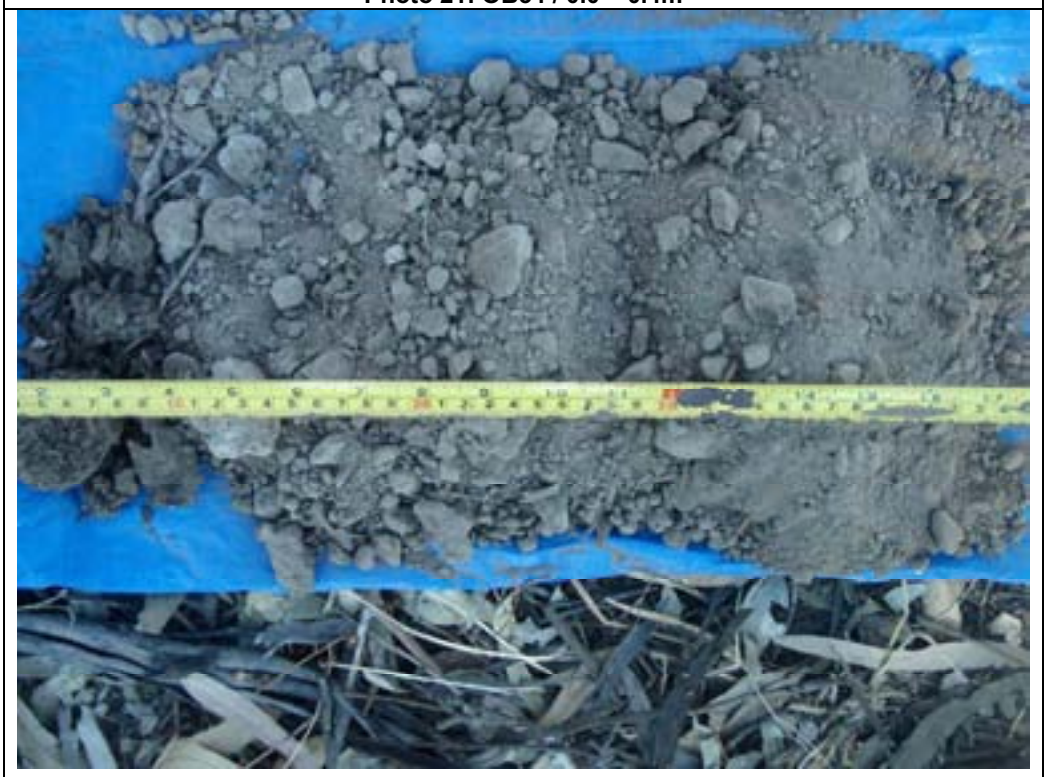


Photo 22: OB35 / 0.0 – 0.4m

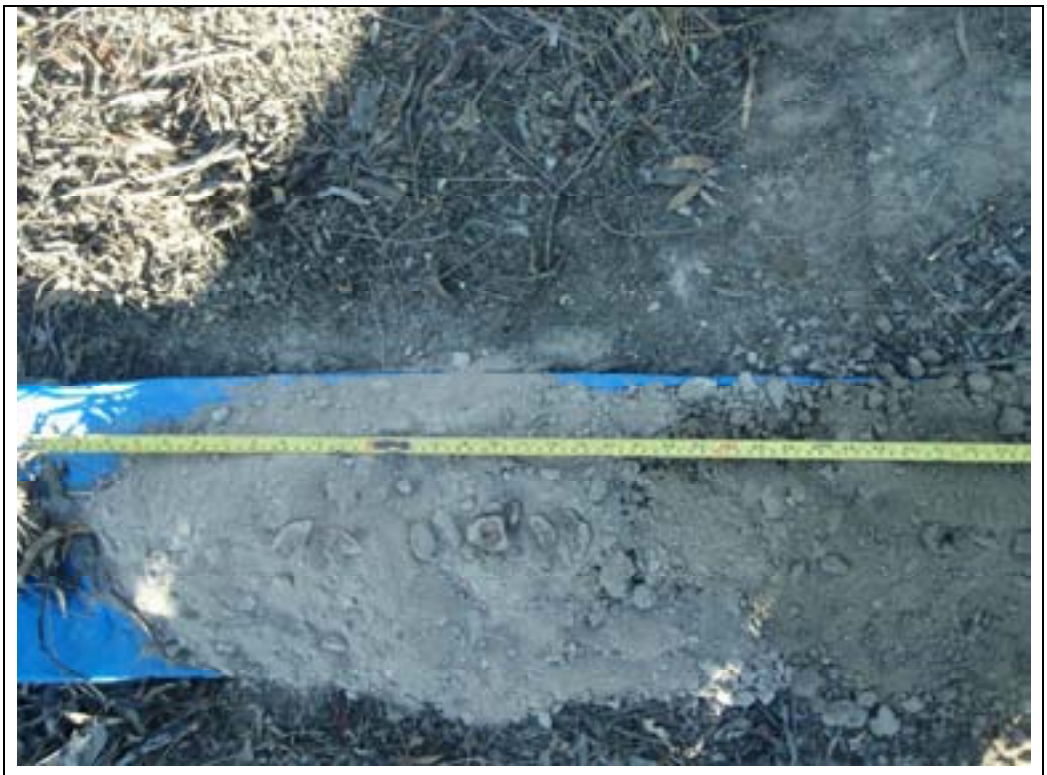


Photo 23: OB36 / 0.0 – 1.0m



Photo 24: OB37 / 0.0 – 1.0m



Photo 25: OB38 / 0.0 – 0.7m



Photo 26: OB39 / 0.0 – 1.0m



Photo 27: OB40 / 0.0 – 0.7m

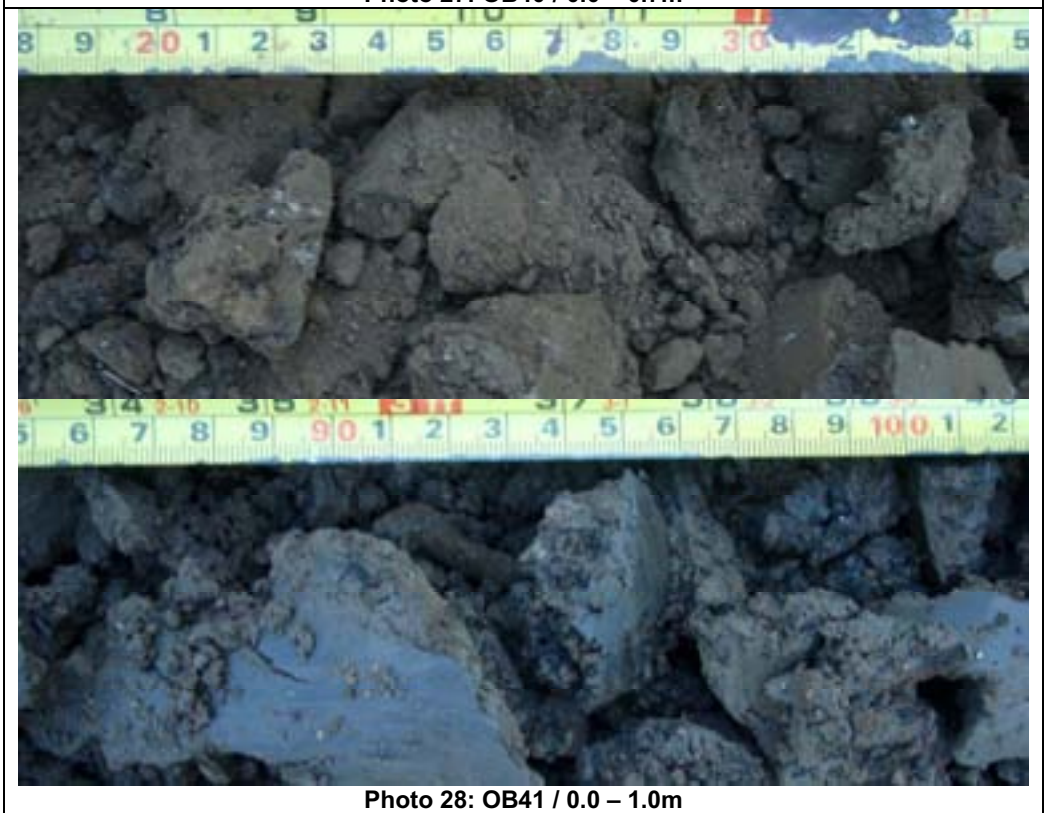


Photo 28: OB41 / 0.0 – 1.0m



Photo 29: OB42 / 0.0 – 1.0m



Photo 30: OB43 / 0.0 – 0.3m



Photo 31: OB45 / 0.0 – 1.0m



Photo 32: OB46 / 0.0 – 1.0m



Photo 33: OB47 / 0.0 – 1.0m



Photo 34: OB49 / 0.0 – 1.0m



Photo 35: OB50 / 0.0 – 1.0m



Photo 36: OB51 / 0.0 – 1.0m

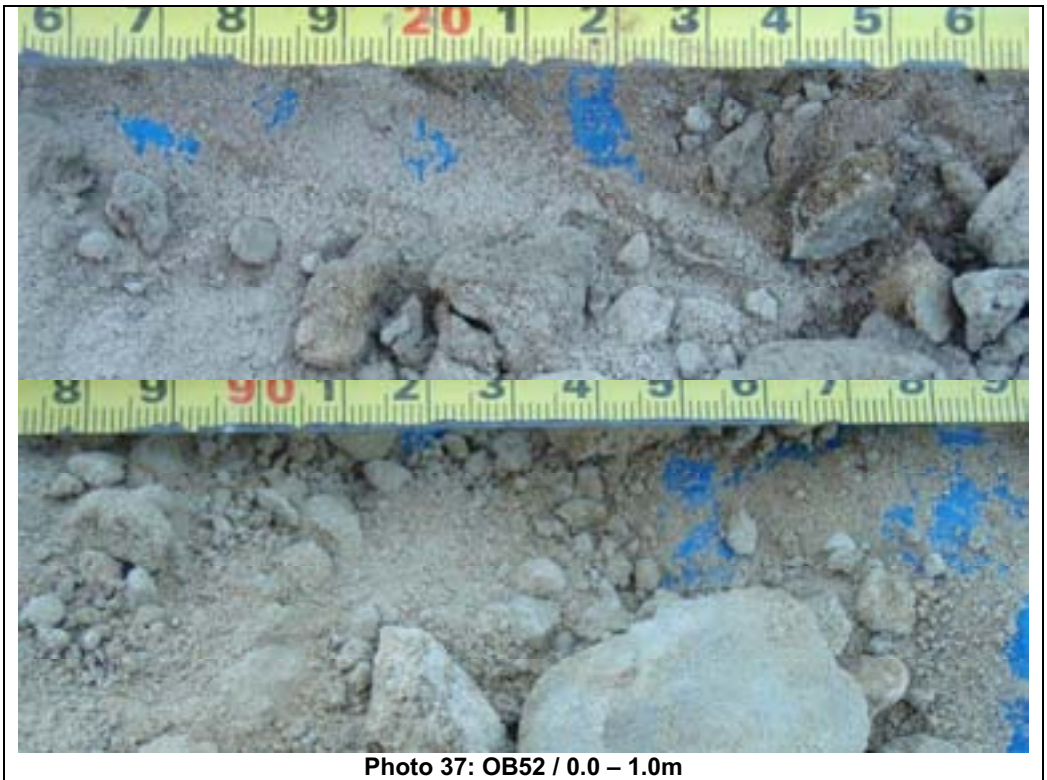


Photo 37: OB52 / 0.0 – 1.0m



Photo 38: OB54 / 0.0 – 1.0m



Photo 39: OB55 / 0.0 – 1.0m