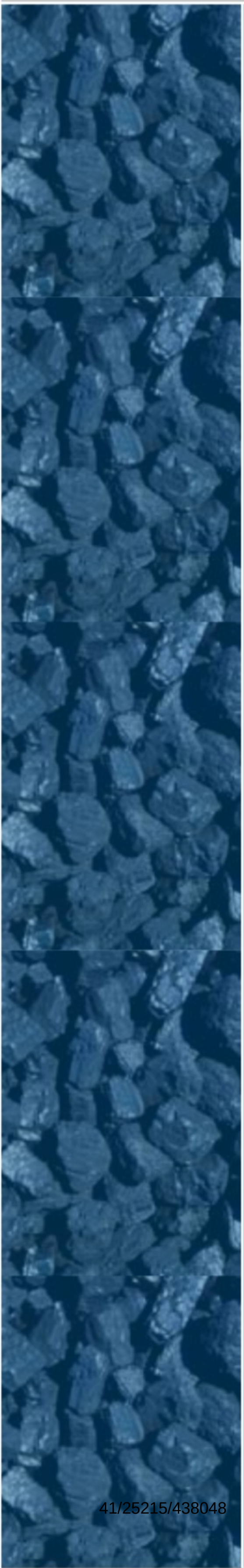
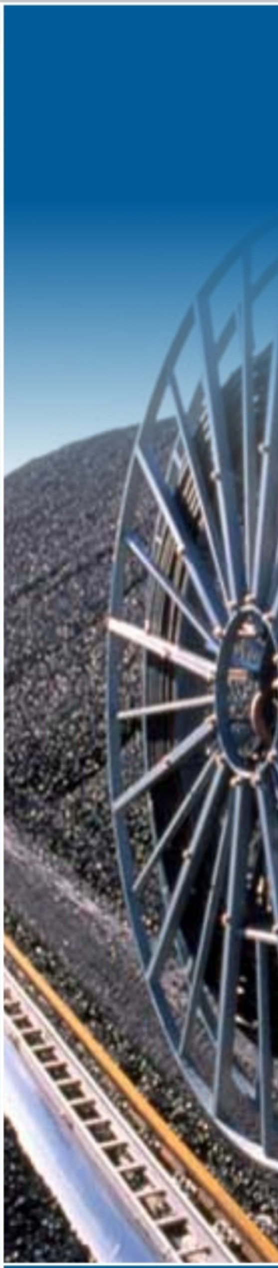
Adani Mining Pty Ltd





Adani Mining Pty Ltd

Report for Carmichael Coal Mine and Rail Project

Soils Assessment 25215-D-RP-0006

20 September 2012

Revision 2

This Carmichael Coal Mine and Rail Project: Rail Soils Assessment ("the Report") has been prepared by GHD Pty Ltd ("GHD") on behalf of and for Adani Mining Pty Ltd ("Adani") in accordance with an agreement between GHD and Adani.

The Report may only be used and relied on by Adani for the purpose of informing environmental assessments and planning approvals for the proposed Carmichael Coal Mine and Rail Project (Purpose)and may not be used by, or relied on by any person other than Adani.

The services undertaken by GHD in connection with preparing the Report were limited to those specifically detailed in Section 1 of the Report. The services undertaken by GHD in connection with preparing the Report excluded field investigation. Field investigation undertaken by other parties is reference in the Report where available.

The Report is based on conditions encountered and information reviewed, including assumptions made by GHD, at the time of preparing the Report. Assumptions made by GHD are listed within Section 1.5 of the Report and contained through the Report.

To the maximum extent permitted by law GHD expressly disclaims responsibility for or liability arising from:

- *any error in, or omission in connection with assumptions, or*
- *reliance on the Report by a third party, or use of this Report other than for the Purpose.*

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Appendices

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Glossary of Terms

Project Specific Terminology

Abbreviation	Term
The EIS	Carmichael Coal Mine and Rail Project Environmental Impact Statement
The Proponent	Adani Mining Pty Ltd
The Project	Carmichael Coal Mine and Rail Project
The Project (Mine)	Carmichael Coal Mine and Rail Project: Mine Component
The Project (Rail)	Carmichael Coal Mine and Rail Project: Rail Component

Generic Terminology

Abbreviation	Term
Adani	Adani Mining Pty Ltd
AHD	Australian Height Datum
ASC	Australian Soil Classification
Cardno UNG	Cardno Ullman and Nolan Geotechnic Pty Ltd
CEC	Cation exchange capacity
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DERM	Former Queensland Department of Environment and Resource Management
DHLGP	Department of Housing, Local Government and Planning
DNRM	Department of natural Resources and Mines
DPI	Department of Primary Industries
DUSLARA	Lorimer, MS 2005, The Desert Uplands: an overview of the Strategic Land Resource Assessment Project, Technical Report, Environmental Protection Agency, Queensland
EC	Electrical conductivity
EIS	Environmental Impact Statement

ESCP	Erosion and Sediment Control Plan
ESP	Exchangeable sodium percentage
Abbreviation	**Term**
GQAL	Good Quality Agricultural Land
IECA	International Erosion Control Association
KCM	Shields, P.G, Chamberlain H.J., and Booth N.J. 1993. Soils and Agricultural Use, in the Kilcummin Area, Central Queensland, Project Report Series: QO93011, Department of Natural Resources and Mines, Brisbane Queensland
LIDAR	Light Detection and Ranging
N	Nitrogen
P	Phosphorous
SPP 1/92	State Planning Policy 1/92 Development and the Conservation of Agricultural Land
SPP 1/12	Protection of Queensland's Strategic Cropping Land
ZCQ2	Gunn, R.H. Galloway, R.W. Pedley, L and Fitzpatrick, E.A, 1967. Lands of the Nogoa - Belyando Area, Queensland - Land Research Series No. 18, Commonwealth Scientific and Industrial Research Organisation, Australia, Melbourne, Victoria

Executive Summary

The Carmichael Coal Mine and Rail Project (the Project) comprises of two major components:

- The Project (Mine): a greenfield coal mine over EPC1690 and the eastern portion of EPC1080, which includes both open cut and underground mining, on mine infrastructure and associated mine processing facilities (the Mine) and the Mine (offsite) infrastructure.
- The Project (Rail): a greenfield rail line connecting the Mine to the existing Goonyella and Newlands rail systems to provide for the export of coal via the Port of Hay Point (Dudgeon Point expansion) and the Port of Abbot Point, respectively; including:
  - Rail (west): a 120 km dual gauge portion from the Mine site running west to east to Diamond Creek
  - Rail (east): a 69 km narrow gauge portion running east from Diamond Creek connecting to the Goonyella rail system south of Moranbah

An assessment of the Project (Rail) using available desktop information and preliminary geotechnical investigations relating to soils and land suitability has been undertaken. The Project (Rail) corridor is defined as approximately 189 kilometres (km) in length, by 95 metres (m) in width.

The Project (Rail) has an east-west orientation, starting in the west at the juncture with the Mine Site at approximately 240 m AHD. Moving eastward, the slope gently leads down onto a plain before rising to 220 m AHD near the Gregory Developmental Road, approximately 75 km east of the Mine Site. The Project (Rail) crosses another plain for approximately 50 km, before rising to a crest (360 m AHD), to the south of Moranbah. The Project (Rail) connects in the east with the existing Goonyella rail system at an elevation of approximately 280 m AHD.

The geology within the study area consists predominantly of Tertiary to Quaternary deposits (Quaternary Alluvium) comprising sands, silts, clays and alluvium.

Two publicly available land system reports and one soil survey report are relevant to the Study Area. These reports have been used to discuss the soil types along the alignment. Vertosols, Sodosols, Dermosols, Kandosols, Tenosols, Rudosols and Chromosols have been mapped within the Study Area.

As the Project (Rail) is located at approximately 200 m AHD, Acid Sulfate Soils are not deemed to be a risk in the Study Area. Acid generating geologies may be present within the corridor; however these were not identified during the desktop assessment.

The Project (Rail) has the potential to impact agricultural land mapped as being of good quality within the footprint of the alignment, and has the potential to fragment land parcels leading to a reduction and loss of access to agricultural land. Good Quality Agricultural Land mapping indicates that an area of approximately 1,334 hectares may be impacted by the Project (Rail) corridor.

Similarly, the Project (Rail) has the potential to impact on approximately 115 hectares of land mapped as strategic cropping land within the western cropping zone management area.

The following will be required to be undertaken prior to construction:

- Develop and agree to a soil survey methodology following the recognised guidelines
- Following the soil survey, it will be necessary to:
  - Determine the status of the Good Quality Agricultural Land impacted
  - Delineate the areas and locations of the major soil types
  - Verify the mapped strategic cropping land compared to that originally determined by remotely sensed methods
  - Highlight the presence of sodic, dispersive and aggressive soils
  - Determine topsoil stripping depths
- Develop an Erosion and Sediment Control Plan
- Record the current salinity status of risk areas

1. Introduction

1.1 Project Overview

Adani Mining Pty Ltd (Adani) is proposing to develop a 60 million tonne (product) per annum (Mtpa) thermal coal mine in the north Galilee Basin approximately 160 kilometres (km) north-west of the town of Clermont, Central Queensland. All coal will be railed via a privately owned rail line connecting to the existing QR National rail infrastructure, and shipped through coal terminal facilities at the Port of Abbot Point and the Port of Hay Point (Dudgeon Point expansion). The Carmichael Coal Mine and Rail Project (the Project) will have an operating life of approximately 90 years.

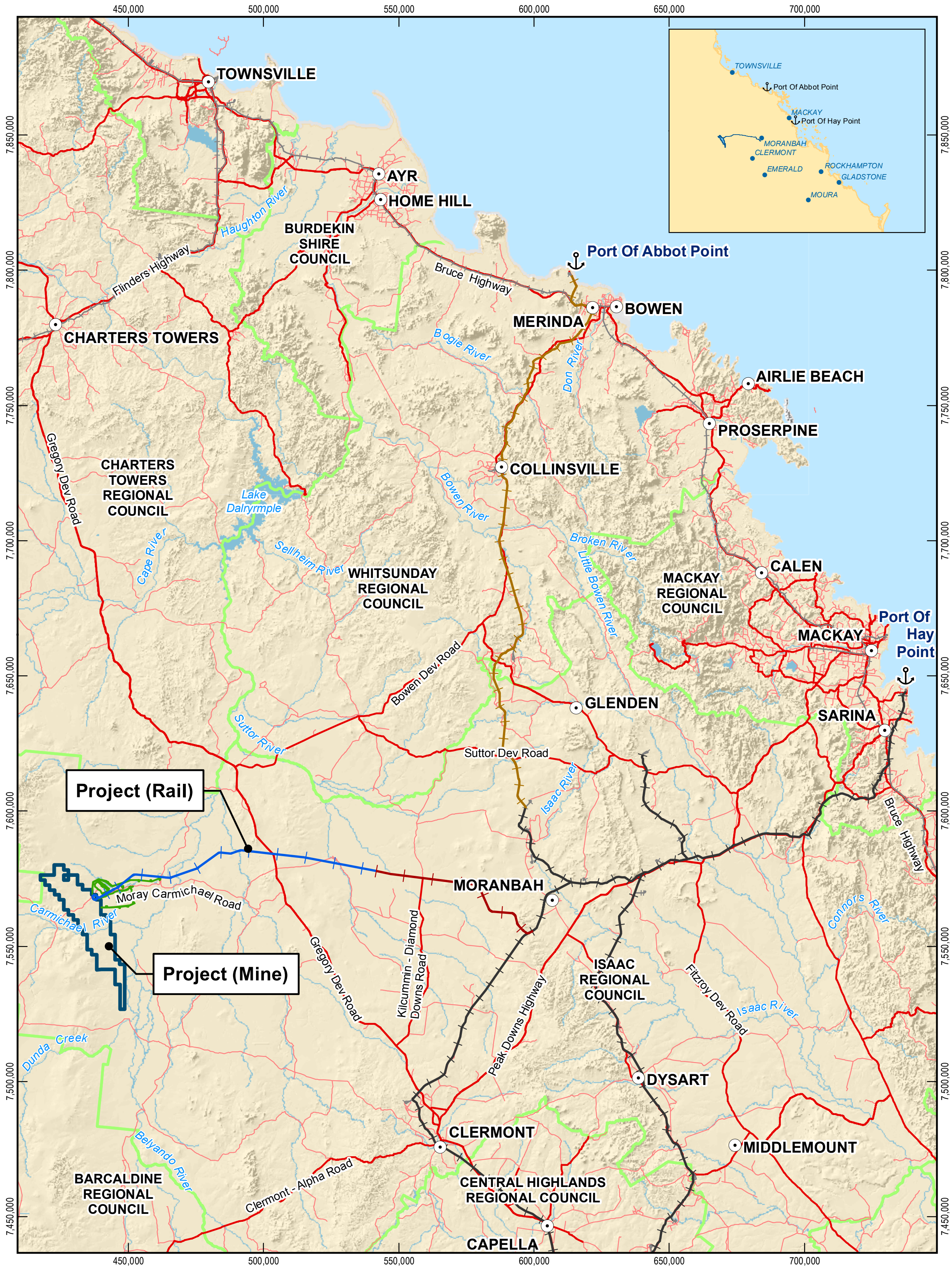
The Project comprises of two major components:

- The Project (Mine): a greenfield coal mine over EPC1690 and the eastern portion of EPC1080, which includes both open cut and underground mining, on mine infrastructure and associated mine processing facilities (the Mine) and the Mine (offsite) infrastructure including:
  - A workers accommodation village
  - An industrial development area and airport site
  - Water supply infrastructure
- The Project (Rail): a greenfield rail line connecting the Mine to the existing Goonyella and Newlands rail systems to provide for the export of coal via the Port of Hay Point (Dudgeon Point expansion) and the Port of Abbot Point, respectively; including:
  - Rail (west): a 120 km dual gauge portion from the Mine site running west to east to Diamond Creek
  - Rail (east): a 69 km narrow gauge portion running east from Diamond Creek connecting to the Goonyella rail system south of Moranbah

The Project has been declared a ‘significant project’ under the State Development and Public Works Organisation Act 1971 and as such, an Environmental Impact Statement (EIS) is required for the Project. The Project is also a ‘controlled action’ and requires assessment and approval under the Environment Protection and Biodiversity Conservation Act 1999.

The Project EIS has been developed with the objective of avoiding or mitigating all potential adverse impacts to environmental, social and economic values and enhancing positive impacts. Detailed descriptions of the Project are provided in Volume 2 Section 2 Project Description (Mine) and Volume 3 Section 2 Project Description (Rail).

Figure 1-1 shows the Project location.



LEGEND

- Town
- Major Port
- Other Rail Network
- Goonyella System
- Newlands System
- State Road
- Local Road
- Watercourse
- Local Government Area
- Project (Rail)
- Rail (West)
- Rail (East)
- Project (Mine)
- Mine (Offsite)

Based on or contains data provided by the State of QLD (DERM) [2010]. In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

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Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

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Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project

Job Number	41-25215
Revision	L
Date	28-08-2012

Project Location

Figure: 1-1

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Level 4, 201 Charlotte St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data Source: © Commonwealth of Australia (Geoscience Australia): Town, Railways, Watercourses (2007); DERM: LGA, (2011), Hillshade (2009); DMR: State Roads (2008); Gassman/Hyder: Mine (Offsite) (2012); DME: EPC1690 (2010), EPC1080 (2011); Adani: Alignment Opt9 Rev3 (2012). Created by: BW, JVC

1.2 Objective

The objective of this assessment is to detail the existing environmental values for soils and land within the area potentially impacted on by the Project (Rail), and to describe the potential for the construction and operation of the rail and associated infrastructure to change existing and potential land uses.

1.3 Scope of Reporting

The purpose of this report is to provide sufficient information for an informed decision to be made on the potential impacts of the Project (Rail) on existing soil resources and environmental values from the disturbance of soil and land within the Study Area. Proposed mitigation measures are also prescribed to manage and control the identified impacts.

Compliance with Section 3.2.2 of the Project terms of reference is detailed within Table 1-1.

Table 1-1 Terms of Reference Cross Reference

Terms of Reference Requirement/Section Number	Section of this Report
Section 3.2.2 Topography, Geology and Soils	
Provide maps locating the project in state regional and local contexts	Figure 1-1
Provide a description, map and series of cross-sections of the surficial and solid geology of the project area	Section 2.2 Figure 2-3
Describe geological properties that may influence ground stability, OH&S or quality of stormwater	Section 2.1.3
Review and discuss existing land system and land unit data of the Nogoa-Belyando area	Section 2.3.4
A soil survey should be conducted at 1:100,000 scale following standards in the Land Suitability Assessment Techniques in the *Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland*	Section 4
Describe soil profiles according to the *Australian Soil and Land Survey field Handbook* grouped according to parent material and position in the landscape	Section 2.3.4 Figure 2-5
Assess and document the depth and quality of useable topsoil and subsoil to be stripped and stockpiled for rehabilitation, and the physical and chemical properties of the soils	Section 4
Acid sulfate soil (ASS) investigations should be undertaken and ASS management plan prepared	Section 2.3.6

Terms of Reference Requirement/Section Number	Section of this Report
Section 3.2.2 Topography, Geology and Soils	
Mineral Resources	Volume 2 Section 2
Potential Impacts and Mitigation Measures	
Detail any potential impacts to the topography or geomorphology, including: Discussion of major topographic features and any measures taken to avoid or minimise impact Objectives used in re-contouring or consolidation, rehabilitation, landscaping and fencing	Section 3.2.1
Identify the possible soil erosion rate and describe techniques used to manage impact	Section 2.1.3, Section 3, Section 3.3.2 and Section 4
Identify all soil types and outline erosion potential	Section 2.3.4
Outline erosion-monitoring program and provide acceptable mitigation strategies	Section 3.2.1, Section 3.3.2 and Section 4
Assess likely erosion effects and summarise methods proposed to prevent or control erosion	Section 3.2.1, Section 3.3.2 and Section 4
Discuss potential for acid generation by disturbing potentially acid forming materials, and propose methods for managing and mitigating impacts If applicable, outline measure in an acid mine drainage management plan	Section 2.3.6
Discuss potential for acid, saline, neutral or alkaline drainage from waste dumps	Volume 4 Appendix V Acid Mine Drainage Report
Resource Utilisation	
Analyse effectiveness of mining proposal in achieving optimum utilisation	Volume 2 Section 6.
Demonstrate the proposal will 'best develop' the mineral resources, minimise resource wastage and avoid unnecessary sterilisation	Volume 3 Section 10 Volume 4 Appendix Z
Subsidence	Volume 2 Section 6
Land Disturbance	
Develop a strategy that will minimise the amount of land disturbed at any one time, describe the strategic approach, and the methods used for the proposal	Section 3.4.1 and Section 3.4.2

1.4 Methodology

1.4.1 Desktop

The desktop assessment of the landscape features along the rail corridor included a review of published information regarding soils, geology, topography and agricultural resources within the Study Area that may be impacted by the Project (Rail).

This information will indicate whether or not sites have previously been ground-truthed within the Study Area and what the local broad soil profile classes are in the district. This desktop assessment seeks to assist in the identification of soils that have adverse physical and chemical properties in the topsoil or subsoil profiles.

A review of the local geology assists in the identification of the soil parent material which is one of the primary drivers of soil type. Contour maps will identify the soil's position in the landscape and associated landform features. A review of existing soil mapping seeks to identify soil types at a district level and may be useful at a property scale.

1.4.2 Field Investigations

Golder Associates Pty Ltd was commissioned by Adani to undertake a preliminary geotechnical investigation within the Project (Rail) corridor[1]. The factual geotechnical report (Golders Associates Pty Ltd, 2011) has been used to inform the desktop assessment.

Field investigations comprised drilling of boreholes at four waterway crossings (Diamond, Mistake and Gowrie Creeks, and at the Belyando River) and excavation of test pits at 2 km intervals.

Following the preliminary investigations Adani commissioned Cardno Ullman and Nolan Geotechnic Pty Ltd (Cardno UNG) to carry out extensive geotechnical investigations on the rail project. These field investigations were carried out between May 2012 and September 2012. Reporting and analysis is currently underway. Field investigations have comprised the drilling of 27 boreholes, two at each bridge location and selective cuts as well as 194 test pits spaced at 500m to 1000m along the corridor. Selected disturbed and undisturbed samples recovered from the boreholes and test pits were submitted for laboratory tests.

The principal objectives of the investigation were to:

- Outline the engineering material properties along the proposed railway alignment from test pits and drilling operations
- Define design input for cuttings and embankments based on the material properties identified from the investigation
- Provide design input for bridge foundations based on the engineering geological conditions identified
- Provide geotechnical recommendations during planning of earthworks and bridge construction and for consideration during the development of earthworks and bridge specifications
- Pavement design for the rail and access roads

[1] Preliminary geotechnical investigation was confined to an earlier Project (Rail) corridor alignment and comprised of bore holes and test pits on five properties. Three potential quarry sites removed from the alignment were investigated.

- Development of appropriate earthworks design parameters based on the typical characteristics obtained from test pitting and drilling
- As well as input into design these investigations will confirm the location of major soil types, the presence of aggressive soils, and topsoil stripping depths

To facilitate the provision of resource material to the Project, a number of potential quarries and/or borrow areas are being investigated within the landscape as shown in Figure 1-2. Adani is currently undertaking investigations to prove the resources at each site and determine suitability for use. Resources targeted include ballast, capping material, sub-base material, and select fill (refer Volume 3, Section 2 Project Description). Investigations are governed by a Permit to Search approved in May 2012.

1.5 Assumptions and Limitations

Mapping datasets supplied by the former Department of Environment and Resource Management (DERM) have been used as part of the desktop assessment and are assumed to be accurate to the scale that they have been mapped to.

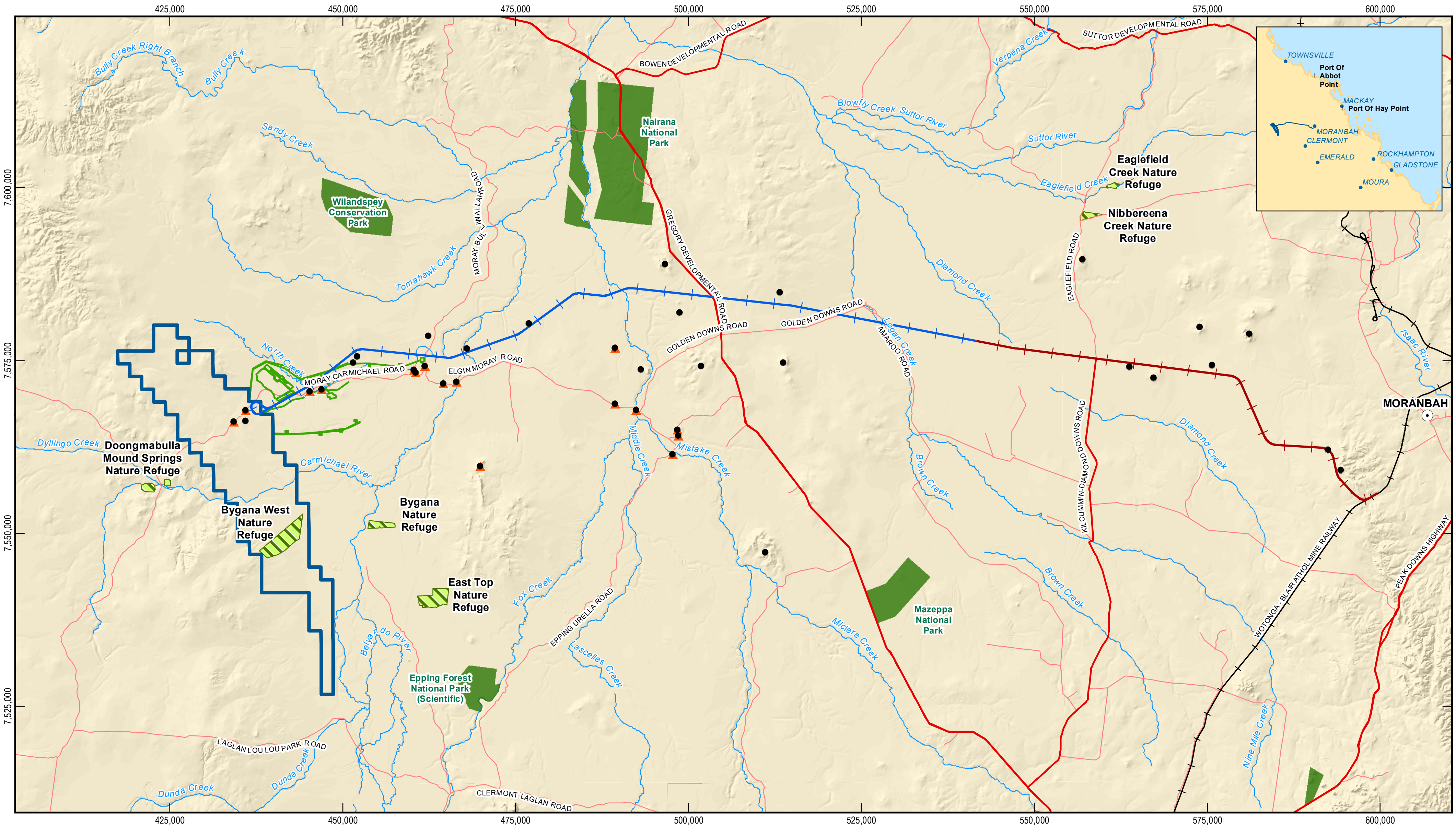
The description of soil types and geology presented here is based on a desktop study, supplemented by preliminary geotechnical investigations (Golder Associates Pty Ltd, 2011).

Soil surveys and geotechnical investigations undertaken by Cardno UNG are not included within this report and will be presented in a supplementary phase as required.

1.6 Study Area

The Study Area consists of the Project (Rail) corridor, including Rail (West) and Rail (East), and adjacent ancillary infrastructure, inclusive of potential quarry and borrow locations. The corridor is approximately 95 m wide.

A discussion on the soil and landscapes outside of this defined Study Area has not been included within this report.



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Kilometres

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Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- Investigation Areas
- Town
- Watercourse
- Existing Rail Network
- State Road
- Local Road
- Nature Refuge
- National Park
- Rail (West)
- Rail (East)
- Mine (Onsite)
- Mine (Offsite)

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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project

Job Number	41-25215
Revision	B
Date	14-09-2012

Potential Quarry and Borrow Locations

Figure 1-2

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Level 4, 201 Charlotte St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data source: DERM: DEM (2008), Nature Refuge (2011); DME: EPC1690 (2010), EPC1080 (2011): © Commonwealth of Australia (Geoscience Australia): Localities, Railways, Roads (2007); Adani: Alignment Opt9 Rev3, Investigation Areas (2012); Gassman/Hyder: Mine (Offsite) (2012). Created by: NR, CA

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2. Environmental Values

2.1 Topography

2.1.1 Overview

The Project (Rail) corridor predominantly lies in the alluvial floodplains of the Suttor River Drainage System (part of the Burdekin River Basin) and on low undulating country, with elevations ranging from 200 to 360 m Australian Height Datum (AHD). Figure 2-1 provides an overview of the topography traversed by the Project (Rail).

The landscape within the corridor is characterised by rolling dry savannah grassland topography under depleted second growth remnants of formerly extensive dry forests cleared from the 1950s to the 1980s for the cattle grazing that dominates the land use of the area.

At the Project (Rail)'s western extent, which is at the juncture with the Project (Mine), elevation is at approximately 240 m AHD. Moving eastward, the slope gently leads down onto a plain (200 m AHD) before rising to 220 m AHD near the Gregory Developmental Road, approximately 75 km east of the Mine Site. The Project (Rail) traverses another plain for approximately 50 km, before rising to a crest (360 m AHD), to the south of Moranbah. The rail corridor at its eastern extent connects with the existing Goonyella rail system (280 m AHD).

The Project (Rail) is predominantly within the Belyando River / Suttor River sub catchment (crossing the main stems of the Belyando River, Mistake Creek and Logan Creek.

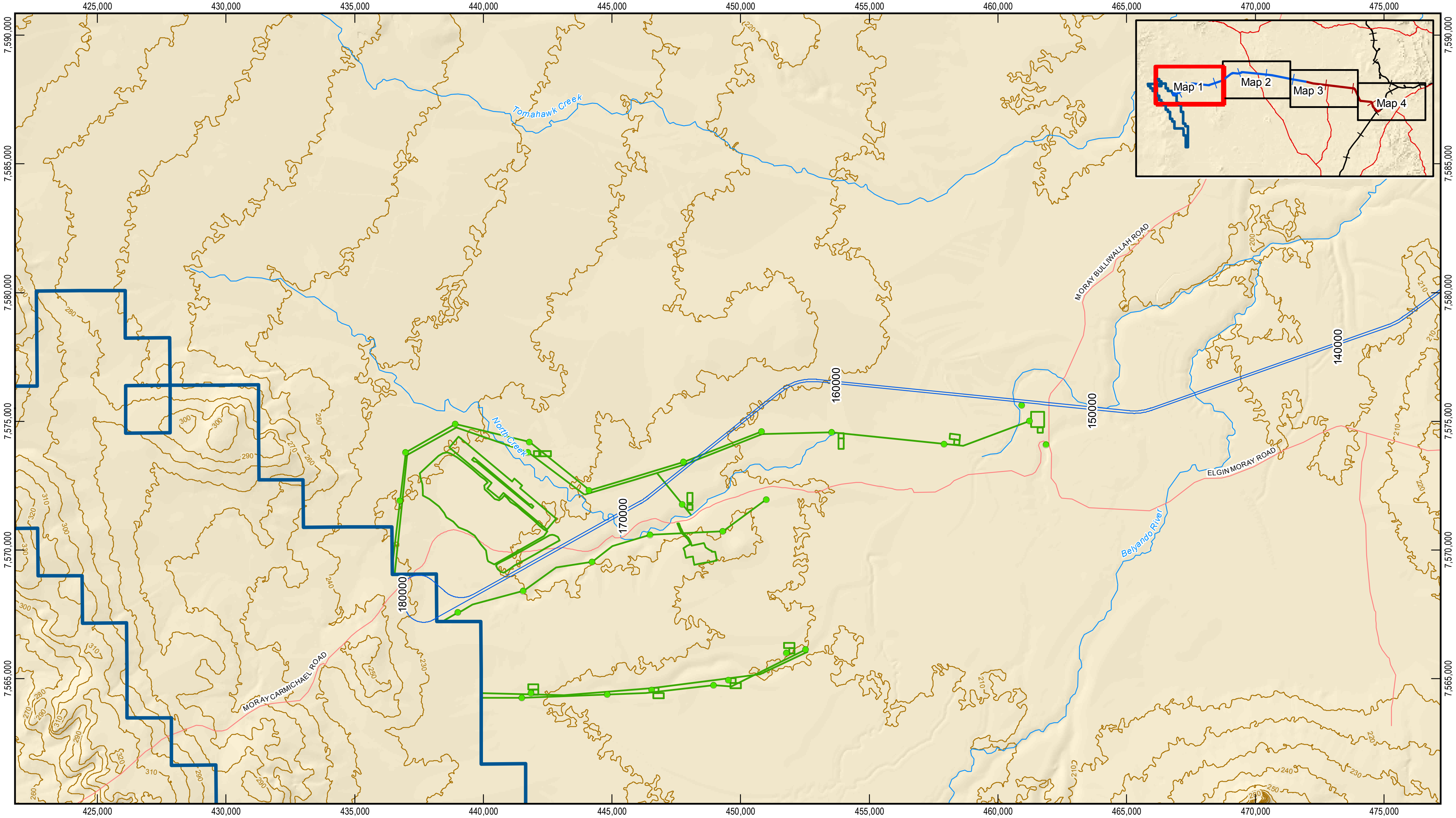
The Belyando River and Suttor River comprise the southern headwaters of the Burdekin River (and 60 per cent of its 130,000 km^2 catchment area). Along with the Cape and Upper Burdekin River, these catchments are the main contributors to the Burdekin Falls Dam, which lies 60 km downstream of the Project (Rail). The Burdekin Falls Dam has no backwater influence on the hydrology of the Belyando or Suttor Rivers in the vicinity of the Project (Rail).

The last 27 km of the rail corridor (in the east) enters the Isaac River catchment via Grosvenor Creek. Grosvenor Creek is part of the 142,665 km^2 Fitzroy River Basin. A number of ephemeral tributaries of these main waterways along with farm dams (created within the tributaries) are also traversed.

The rail corridor intersects several non-perennial watercourses, including (from east to west) Grosvenor Creek (minor), Logan Creek (major), Gowrie Creek (minor), Mistake Creek (major), Belyando River (major), and North Creek (major). A number of other minor and un-named, non-perennial gullies and watercourses were also identified as being intersected by the rail corridor.

The Belyando River and Logan Creek are within Wetland Management Areas. However, these are not classed as having High Ecological Significance. Four Wetland Protection Areas were identified to the north of the Project (Rail) in the vicinity of the Belyando River. None of these protection areas are traversed by the Project (Rail) (refer Volume 4 Appendix AC Rail Hydrology Report).

All the watercourses flow in a general northward direction towards the Suttor River. Stream flows reflect rainfall variability and seasonality, with summer flooding and an absence of flow between May and November being not uncommon (refer Volume 4 Appendix AC Rail Hydrology Report).



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Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- Town
- State Road
- Local Road
- Existing Railway
- Watercourse
- Contour - 10m
- Rail (West)
- Rail (East)
- Mine (Onsite)
- Mine (Offsite)
- Mine (Offsite)

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Carmichael Coal Mine and Rail Project

Topography

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Date	03-09-2012

Figure: 2-1
Sheet 1 of 4

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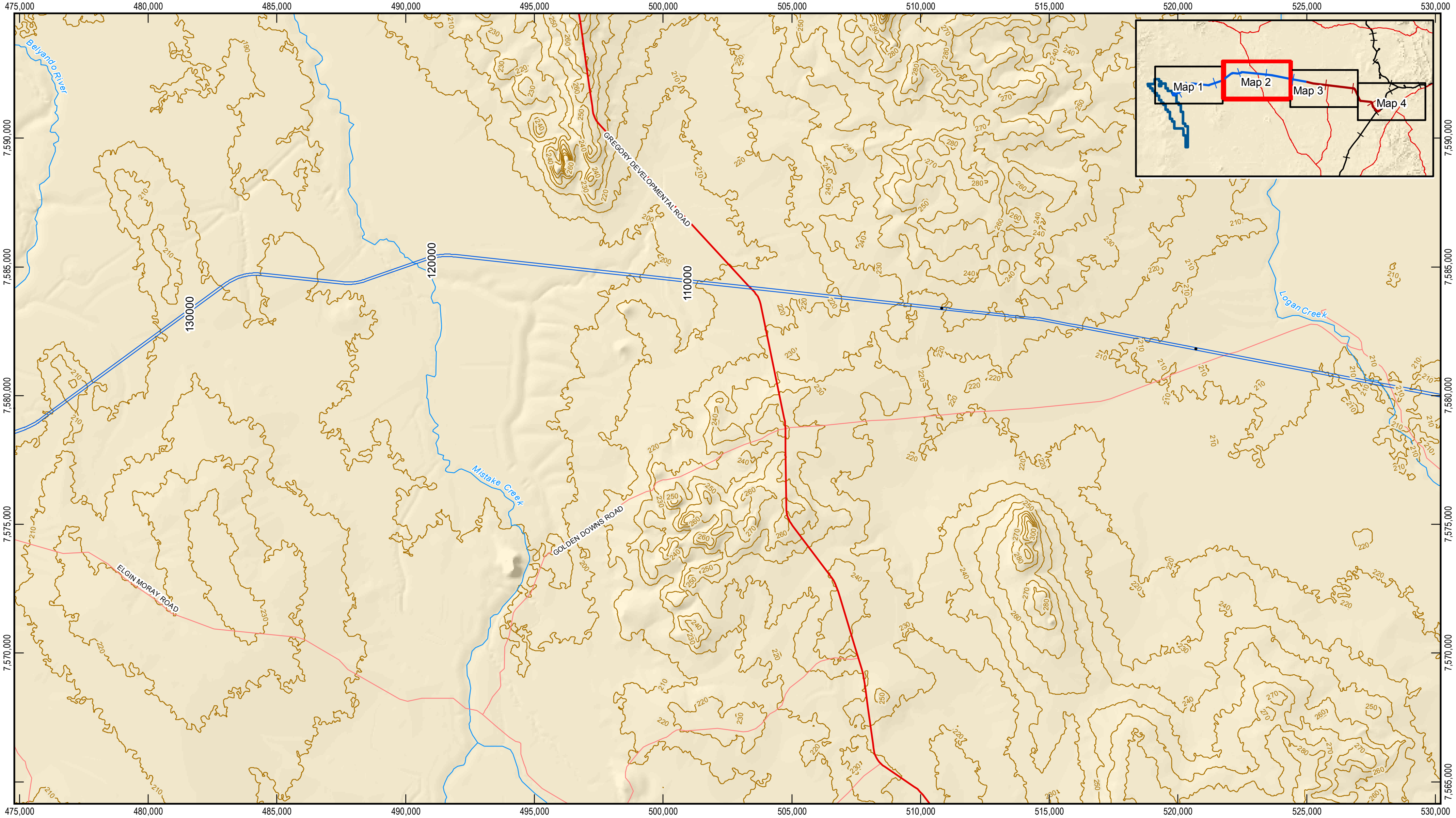
Data source: DME: EPC1690 (2010), EPC1080 (2011), © Commonwealth of Australia (Geoscience Australia): Localities, Railways, Roads (2007);
DERM: 10m Contours (2011); Adani: Alignment Opt9 Rev3 (2012); Gassman/Hyder: Mine (Offsite) (2012). Created by: BW, CA



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Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- Town
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- Local Road
- Existing Railway
- Watercourse
- Contour - 10m
- Rail (West)
- Rail (East)
- Mine (Onsite)
- Mine (Offsite)
- Mine (Offsite)

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project

Topography

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Date	03-09-2012

Figure: 2-1

Sheet 2 of 4

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Data source: DME: EPC1690 (2010), EPC1080 (2011), © Commonwealth of Australia (Geoscience Australia): Localities, Railways, Roads (2007);
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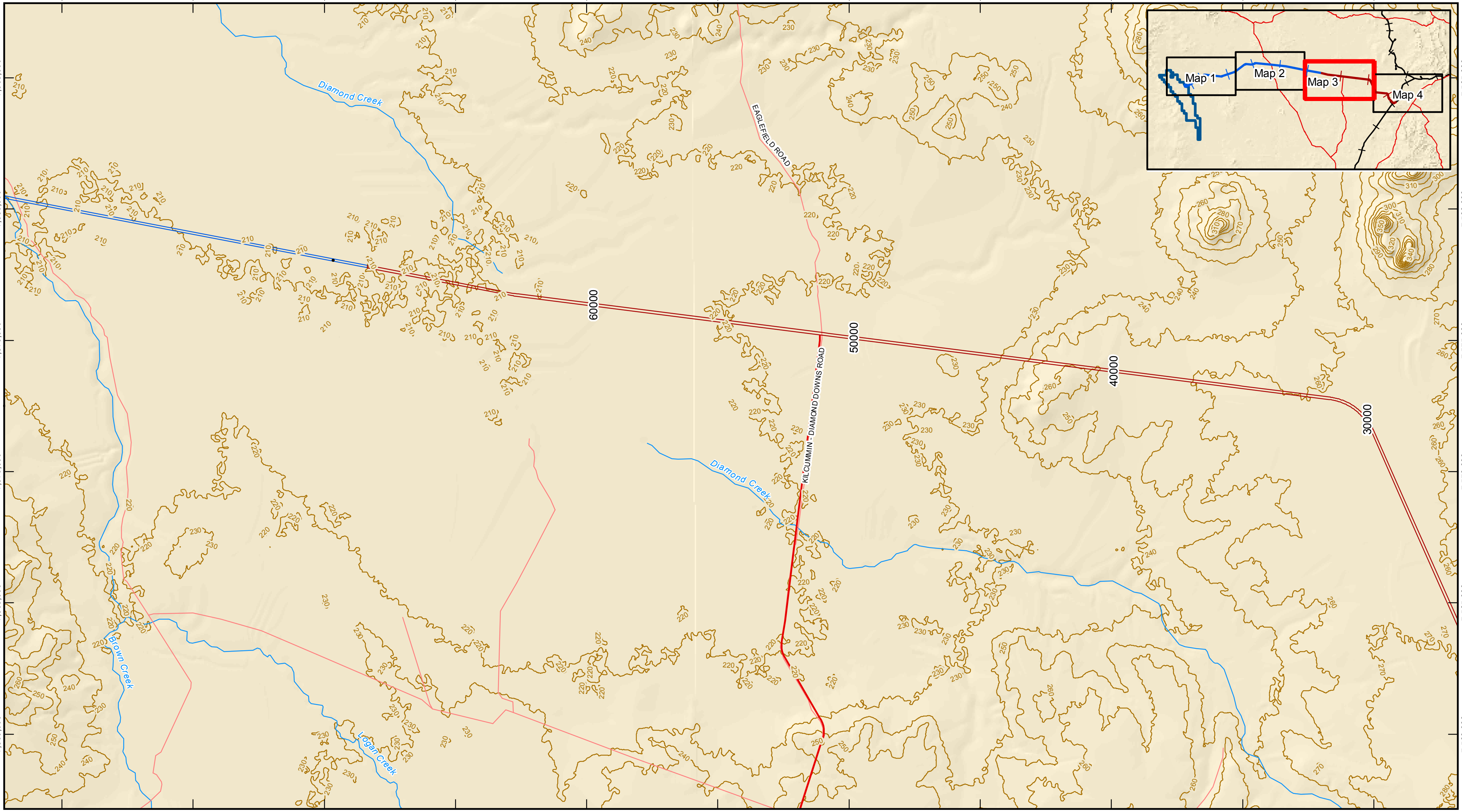

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Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- Town
- State Road
- Local Road
- Existing Railway
- Watercourse
- Contour - 10m
- Rail (West)
- Rail (East)
- Mine (Onsite)
- Mine (Offsite)
- Mine (Offsite)

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Carmichael Coal Mine and Rail Project

Topography

Job Number	41-25215
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Figure: 2-1
Sheet 3 of 4

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Data source: DME: EPC1690 (2010), EPC1080 (2011), © Commonwealth of Australia (Geoscience Australia): Localities, Railways, Roads (2007);
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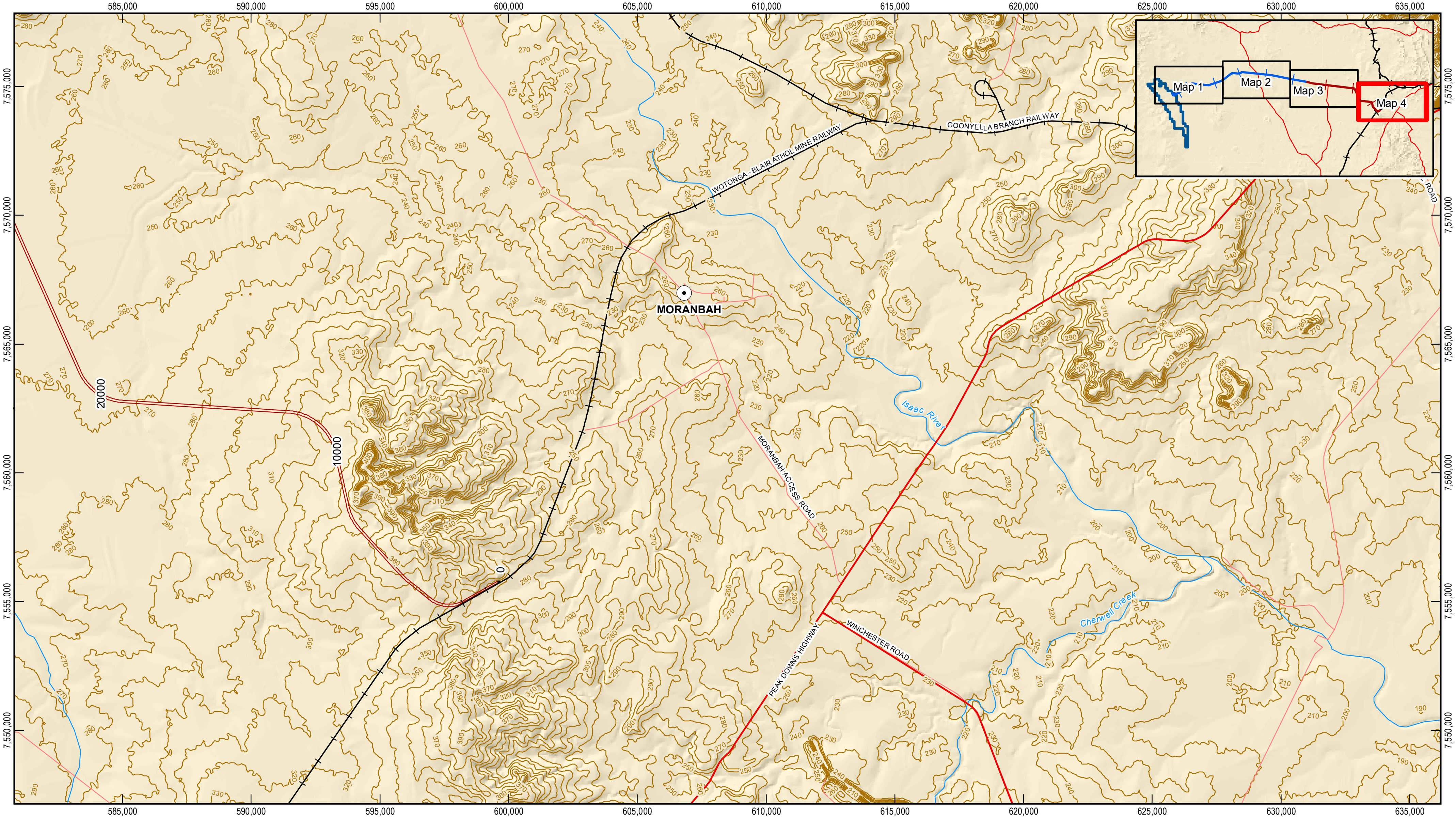

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Horizontal Datum: Geocentric Datum of Australia (GDA)
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LEGEND

- Town
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- Rail (East)
- Mine (Onsite)
- Mine (Offsite)
- Mine (Offsite)

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Carmichael Coal Mine and Rail Project

Topography

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Figure: 2-1
Sheet 4 of 4

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DERM: 10m Contours (2011); Adani: Alignment Opt9 Rev3 (2012); Gassman/Hyder: Mine (Offsite) (2012). Created by: BW, CA

2.1.2 Landform

Table 2-1 details the broad landforms likely to be intersected by the rail corridor and has been extracted from the Atlas of Australian Soils Database. In summary the Project (Rail) area is predominantly flat with areas of relief found between the Gregory Developmental Road, the Elgin Moray Road and the Twin Hills Road. Gilgais (shallow depressions which during the wet season are filled with water) are characteristic of the alignment (Golder Associates Pty Ltd, 2011).

Table 2-1 Project (Rail) Landforms

Project (Rail) Location		Landform Description
From (km)	To (km)	
Rail (west)		
190	186	Level or very gently undulating outwash plains dissected by numerous small shallow prior stream channels, some of which are sand-filled
186	184	Level plains with moderate to strong gilgai microrelief (0.6 to 1.2 m)
184	181	Broadly undulating or level plains: dominant soils are deep brown clays
181	178	Level plains with moderate to strong gilgai microrelief (0.6 to 1.2 m)
178	176	Broadly undulating or level plains: dominant soils are deep brown clays
176	174	Level plains with moderate to strong gilgai microrelief (0.6 to 1.2 m)
174	168	Level or very gently undulating outwash plains dissected by numerous small shallow prior stream channels, some of which are sand-filled
168	159	Broadly undulating or level plains
159	154	Level plains with moderate to strong gilgai microrelief (1 m)
154	152	Gently undulating plains
152	151	Undulating low rises that are old levees of major streams
151	146	Alluvial plains associated with major streams; numerous braided channels may occur and many areas are subject to irregular flooding
146	142	Level plains with moderate to strong gilgai microrelief (1 m)
142	141	Alluvial plains associated with major streams; numerous braided channels may occur and many areas are subject to irregular flooding
141	137	Level plains with moderate to strong gilgai microrelief (1 m)
137	135	Gently undulating plains
135	132	Broadly undulating or level plains
132	130	Gently undulating plains
130	122	Level plains with moderate to strong gilgai microrelief (1 m)

Project (Rail) Location		Landform Description
From (km)	To (km)	
122	118	Alluvial plains associated with major streams; numerous braided channels may occur and many areas are subject to irregular flooding
118	106	Level plains with moderate to strong gilgai microrelief (1 m)
106	103	Gently undulating plains
103	99	Undulating lands, often with high gravelly ridges
99	96	Gently to moderately undulating lands with some high ridges
96	95	Undulating lands, often with high gravelly ridges
95	87	Level plains with moderate to strong gilgai microrelief (1 m)
87	84	Alluvial plains associated with major streams; numerous braided channels may occur and many areas are subject to irregular flooding
84	81	Extensive level old alluvial plains that have a very slight (few inches) gilgai microrelief
81	79	Broadly undulating or level plains
79	70	Extensive level old alluvial plains that have a very slight (few inches) gilgai microrelief
Rail (east)		
70	65	Broadly undulating or level plains
65	62	Extensive level old alluvial plains that have a very slight (few inches) gilgai microrelief
62	43	Level or very gently undulating clay plains with slight to moderate (0.5 m) gilgai microrelief, occasionally stronger (1 m). Where the unit is adjacent to major streams many small braided channels occur and the area is subject to flooding.
43	31	Broadly undulating or level plains
31	19	Level or very gently undulating clay plains with slight to moderate (0.5 m) gilgai microrelief, occasionally stronger (1 m). Where the unit is adjacent to major streams many small braided channels occur and the area is subject to flooding.
19	16	Gently or broadly undulating plains
16	5	Gently undulating lands with broad ridge crests and low rises
5	Goonyella system connection	Hilly deeply dissected plateaux consisting of level stony plateau surfaces, high bluffs and cliffs bordering narrow valleys, and some undulating colluvial slopes and alluvial flats; massive sandstone outcrop is common

Source: Atlas of Australian Soils Database

2.1.3 Slope Hazard

A slope hazard analysis has been undertaken along the proposed rail corridor using a combination of Light Detection and Ranging (LIDAR) data and contour (10 m) data. The Project (Rail) is predominantly located within very gently inclined areas, with the exception of those areas around major drainage lines. Figure 2-2 depicts the slope variation within the Study Area[2]. Golder Associates Pty Ltd (2011) reports no evidence of existing or former landslides within the Rail (West) and Rail (East) areas (based on aerial photography and satellite imagery).

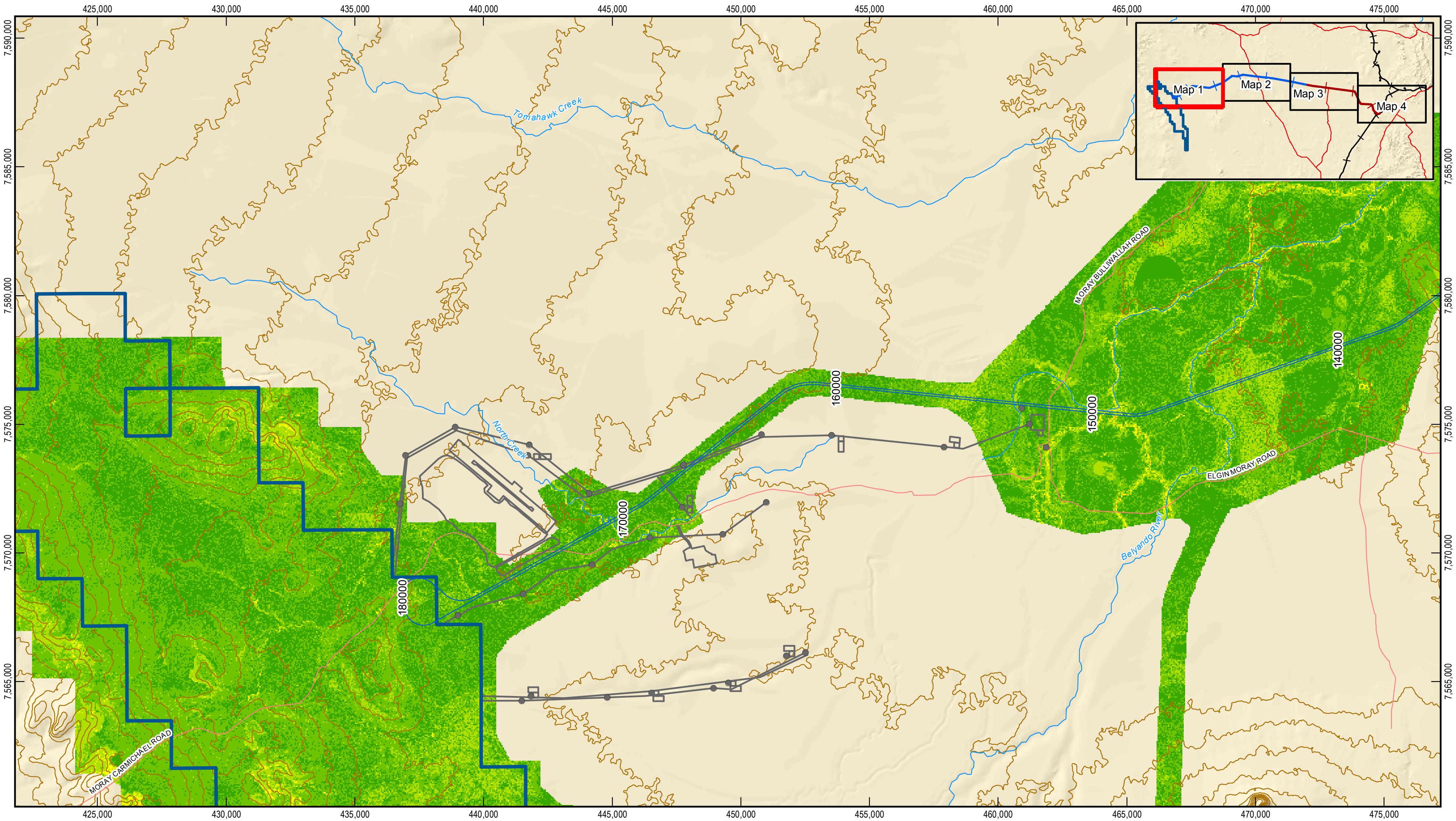
Areas of steep and long slopes are at risk of erosion and landslides under wet weather conditions. Erosion in regards to topography is a factor of both the slope gradient and slope length. The Queensland Department of Main Roads' (2002), Road Drainage Design Manual, details the erosion risk ratings for slope gradient and length. These are provided in Table 2-2.

Table 2-2 Erosion Rating for Modal Slope Classes

Class	Per cent (%)	Erosion Rating
Level	<1	Very Low (1)
Very Gently Inclined	1 to 3	Low (2)
Gently Inclined	3 to 10	Moderate (3)
Moderately Inclined	10 to 32	High (4)
Steep	32 - 56	Very High (5)
Very Steep	56 – 100	Very High (5)
Precipitous	>100	Very High (5)

The majority of the Project (Rail) alignment is in areas ranging from level to gently inclined, as shown in Figure 2-2, which results in a very low to moderate erosion rating based on modal slope. The Project (Rail) does not travel through broad areas regarded as moderately inclined to steep and only minor occurrences of very steep to cliffed. These high to very high erosion risk areas (very steep to cliffed) are mostly confined to within the major drainage lines of the Belyando River, and its tributaries, Mistake Creek and Logan Creek. As the Project (Rail) alignment progresses towards Moranbah, it fringes an area with topographical features that have a high to very high erosion risk, approximately 8 km from the rail connection.

[2] A slope hazard analysis is not currently possible at or about chainage 65 km to 100 km as a result of realignment to outside of the area previously covered by LIDAR survey.



1:200,000 (at A4)

0 1 2 3 4 5

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

Town	Existing Railway	Mine (Onsite)	Slope Classification
State Road	Contour - 10m	Mine (Offsite)	<=1%
Local Road	Rail (West)	Mine (Offsite)	>1% - <=3%
Watercourse	Rail (East)		>3% - <=10%
			>10% - <=32%
			>32% - <=56%
			>56% - <=100%
			>100%

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Slope Hazard

Figure: 2-2
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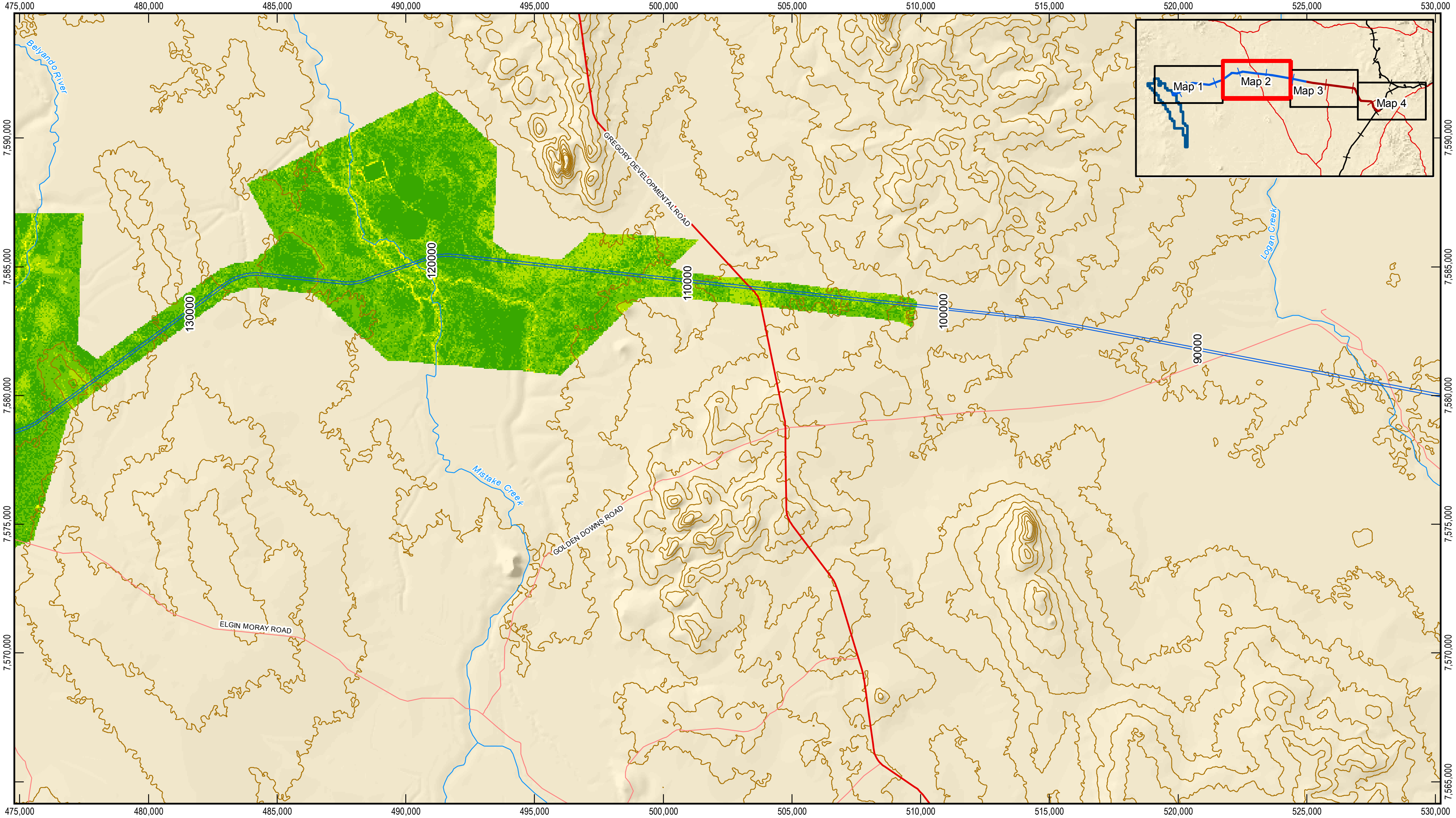
Data source: DME: EPC1690 (2010), EPC1080 (2011); © Commonwealth of Australia (Geoscience Australia): Localities, Railways, Roads (2007);
GHD: Slope Hazard (2011); Adani: Alignment Opt9 Rev3 (2012); Gassman/Hyder: Mine (Offsite) (2012). Created by: BW, CA



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0 1 2 3 4 5

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- Town
- State Road
- Local Road
- Watercourse
- Existing Railway
- Contour - 10m
- Rail (West)
- Rail (East)
- Mine (Onsite)
- Mine (Offsite)
- Mine (Offsite)

Slope Classification

- <=1%
- >1% - <=3%
- >3% - <=10%
- >10% - <=32%
- >32% - <=56%
- >56% - <=100%
- >100%

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Figure: 2-2
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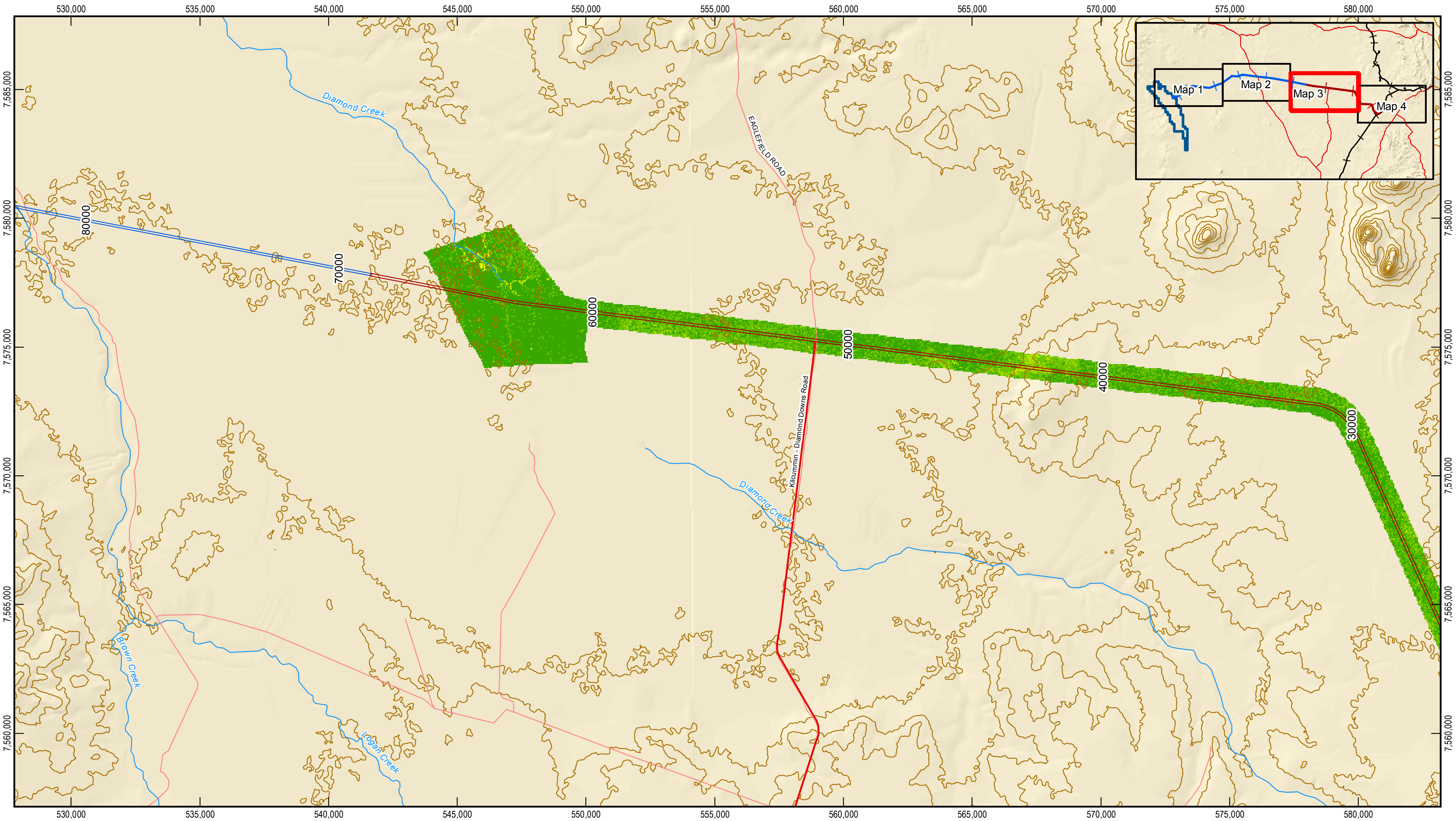

1:200,000 (at A4)

0 1 2 3 4 5

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
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LEGEND

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- State Road
- Local Road
- Watercourse
- Existing Railway
- Contour - 10m
- Rail (West)
- Rail (East)
- Mine (Onsite)
- Mine (Offsite)
- Mine (Offsite)

Slope Classification

- <=1%
- >1% - <=3%
- >3% - <=10%
- >10% - <=32%
- >32% - <=56%
- >56% - <=100%
- >100%

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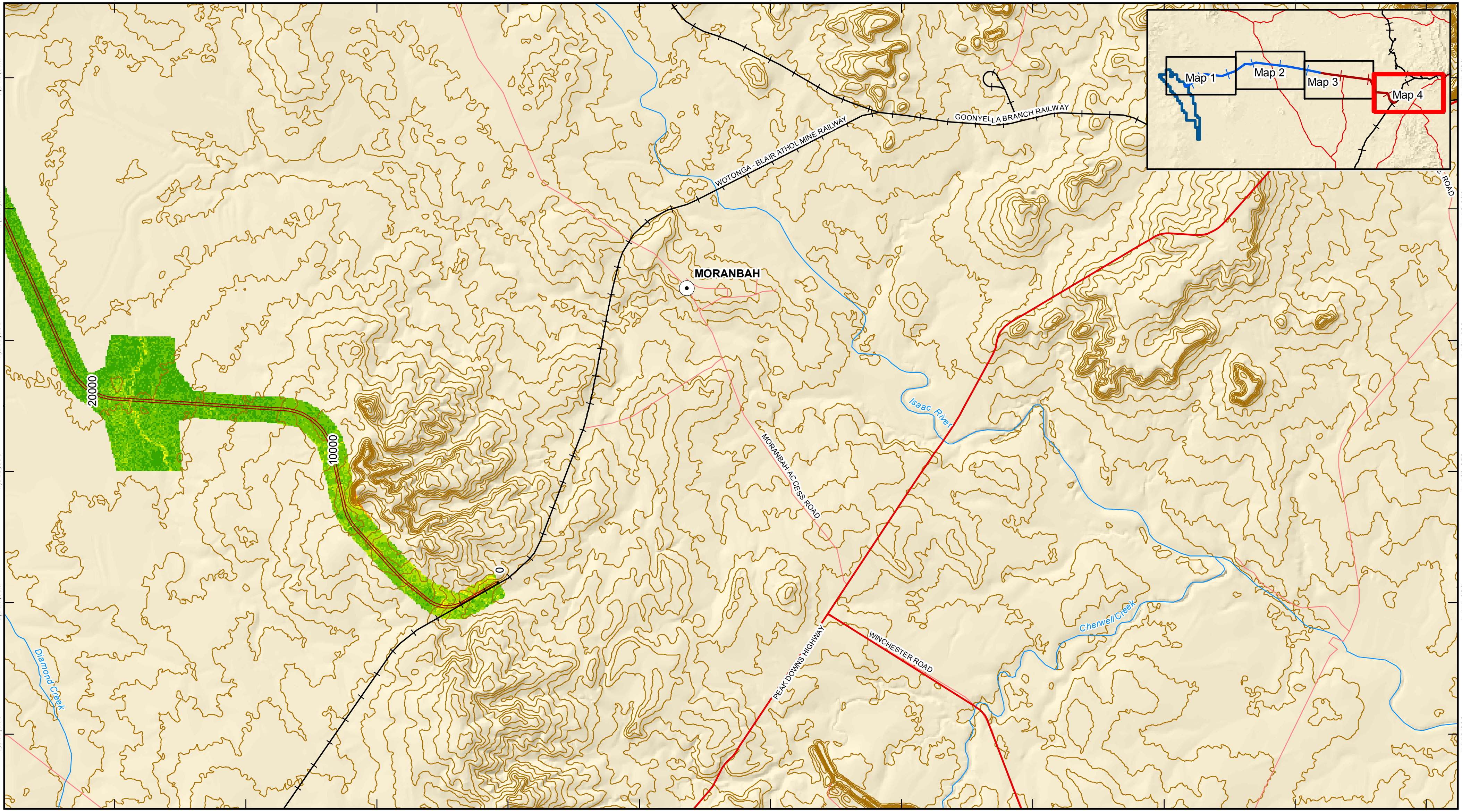

1:200,000 (at A4)

0 1 2 3 4 5

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
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N

LEGEND

- Town
- State Road
- Local Road
- Watercourse
- Existing Railway
- Contour - 10m
- Rail (West)
- Rail (East)
- Mine (Onsite)
- Mine (Offsite)
- Mine (Offsite)

Slope Classification

- <=1%
- >1% - <=3%
- >3% - <=10%
- >10% - <=32%
- >32% - <=56%
- >56% - <=100%
- >100%

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Figure: 2-2
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The above assessment of risk in Table 2-2 is based on modal slope, being the most common slope gradient across a landform. Slope length is the other factor when discussing erosion risk from a topographical perspective. Slope length determines the capacity of the runoff to concentrate and detach soil particles. Sustained slope length creates a higher risk of soil displacement. Erosion risk ratings based on slope length are provided in Table 2-3.

Table 2-3 Erosion Rating for Slope Length

Slope Length	Risk Rating
<5 m	Very Low (1)
5 to 25 m	Low (2)
25 to 50 m	Moderate (3)
50 to 100 m	High (4)
>100 m	Very High (5)

The average of the ratings from both Table 2-2 and Table 2-3 are used to provide an overall risk associated with slope. In summary the Project (Rail) alignment traverses areas of sustained slope length (>100 m) regarded as a very high erosion risk, but with very low to moderate modal slope rating. An overall risk rating for the Project based on both aspects of slope is considered to be moderate. However specific management practices will be required to be prescribed in an Erosion and Sediment Control Plan (ESCP) for those short distances of steep to precipitous slope as they are generally associated with the water crossings and drainage lines.

The slope analysis will assist in determining the level of management required across the Project (Rail) with regards to managing erosion, sediment control and water movement across the site.

2.2 Geology

2.2.1 Overview

A review was undertaken of available information relevant to the Project (Rail) area. The resources assessed included:

- Buchanan Geological Sheet, 1:250,000 Geological Series (Department of National Development, 1970) and the accompanying explanatory notes
- Clermont Geological Sheet, 1:250,000 Geological Series (Department of National Development, 1969) and the accompanying explanatory notes
- Mount Coolon Geological Map, 1: 250,000 Geological Series (Department of Mines and Energy, 1998) and the accompanying explanatory notes

The Project (Rail) corridor lies across two main tectonic elements, which from west to east are the Drummond Basin and Anakie Province:

- The Anakie Province contains the oldest rocks of the two tectonic elements and was probably deposited in the Nepoproterozoic or Early Cambrian. The Province comprises a zone of moderately deformed rocks which outcrop in the western portion of the Province. This terrain is comprised of the Early Palaeozoic Anakie Metamorphic Group, overlain by down-faulted blocks of the Early Devonian Ukalunda beds and multiple deformed fine grained sedimentary rocks (Hutton *et al*, 1998).
- The Drummond Basin is a large intracratonic basin which developed in Central Queensland between the Late Devonian and the Early Carboniferous. It contains a thick sequence of continental sediments and volcanics with a few marine interbeds near the base (Hutton *et al*, 1998).

2.2.2 Geology Overview – 1:250,000 Mapping

An overview of the geology types, interpreted from the 1:250,000 geological maps and accompanying explanatory notes is provided herein.

The west of the rail corridor traverses an area of fluvial and colluvial deposits, which were laid down over the area during the Tertiary. These quaternary deposits are a mixture of silt, sand and gravel, with some alluvium in the fluvial deposition environments between approximately 176.5 km to 165 km. These fluvial quaternary deposits are approximately 15 m thick. There are some areas of soil, sand and gravel deposited from in-situ weathering and Aeolian processes until approximately 158 km. The rail corridor returns to an area of alluvium up until 138 km. A small area between the Belyando River and Mistake Creek, at approximately 135 km, incorporates some poorly sorted argillaceous sandstone, deposited from fluvial or piedmont deposits near hills and ranges, before returning to the superficial soil, sand and gravels, alternating with some alluvium areas.

The Project (Rail) then traverses the Star of Hope Formation at approximately 106 km which is an area of the Drummond Basin sequence. It consists of medium grained volcanolithic sandstone, conglomerate, and tuffaceous sandstone, with some possible tuff, rhyolite and sinter. The rail corridor returns to an area of mud, sand and gravel and some colluvium deposits.

The Mount Hall Formation, again within the Drummond Basin sequence, is traversed at approximately 102 km and is characterised by medium grained quartzose to feldspathic sandstone, pebbly sandstone, conglomerate and siltstone. Any outcrop of the Mount Hall Formation is generally very poor with the only commonly outcropping rocks being a band of medium-grained quartzose sandstone grading downward into a pebbly sandstone and finally an oligomict pebble conglomerate comprising mainly rounded pebbles of white milky quartz (and rarely, other lithic clasts) in a medium-grained quartzose sandstone matrix. This rock type commonly occurs as ridges (Hutton, *et al* 1998).

Following the Mount Hall Formation, the Anakie Metamorphic Group is traversed. It is Neoproterozoic or early Cambium, and consists of multiply deformed, fine to very fine-grained sandstone and siltstone, phylite and schist. Tertiary deposits of mottled, leached and weathered rocks overlie the Anakie Metamorphic Group in this area. The alignment returns to an area of Quaternary deposits of mud, sand and gravel, before progressing into a sustained area of the Quaternary alluvial deposits, from Logan Creek until before progressing back into the older alluvium from approximately 45 km from the eastern end of the rail corridor. Tertiary aged high level alluvium and colluvium is traversed following the older alluvium, until approximately 25 km from the eastern end of the rail corridor.

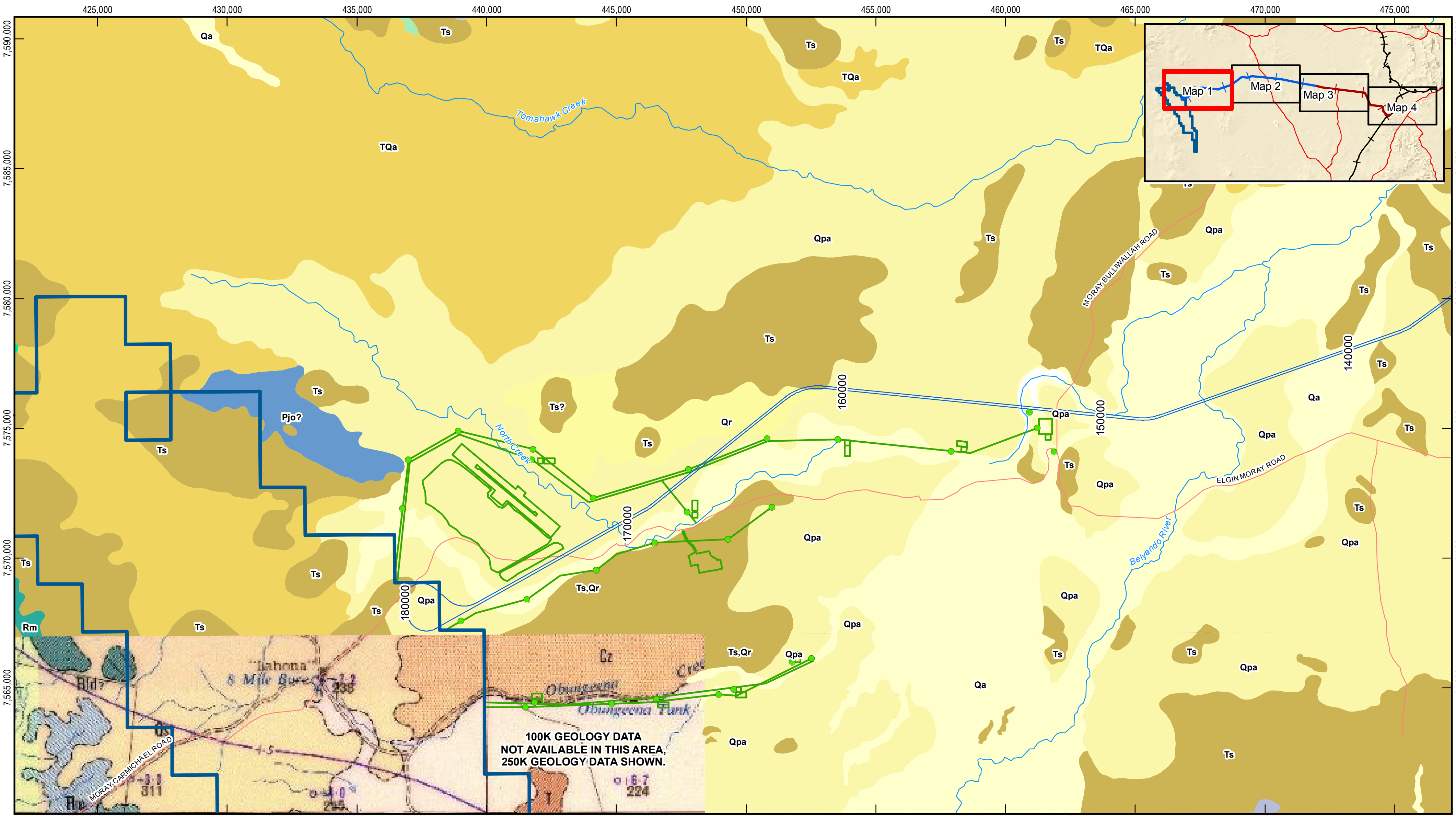
As the Project (Rail) approaches the rail connection near Moranbah it traverses an area of undifferentiated heavy-textured dark soil, which is reported as forming in situ over basalt. The Project (Rail) then progresses through an area of sandier soils and superficial deposits overlying the Blackwater Group. The Project (Rail) does fringe the upper Permian, Clarkei Bed, a shallow shelf near the western boundary of the Bowen Basin, consisting of quartz, sandstone, siltstone, carbonaceous shale and some minor coal. Within this geological feature lies Mount Dillinger, located approximately 1.6 km north-east of the Project (Rail).

2.2.3 Geology Overview – 1:100,000 Mapping

The following 1:100,000 scale geology maps have been used to describe the geology with relation to Project (Rail) distances:

- Bulliwallah Geological Map 8254, 1: 100,000 Geological Series (2008)
- Gunjulla Geological Map 8354, 1: 100,000 Geological Series (2008)
- Kilcummin Geological Map 8453, 1: 100,000 Geological Series (2008)
- Mount Tutah Geological Map 8154, 1: 100,000 Geological Series (2008)
- Wyena Geological Map 8454, 1: 100,000 Geological Series (2008)

There are 14 geological units underlying the Project (Rail), displayed in Figure 2-3. The properties of these units are summarised in Appendix B. No fault lines, or fossils, were identified on the available geological maps as being present under the Project (Rail).



1:200,000 (at A4)

0 1 2 3 4 5

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- Town
- State Road
- Local Road
- Other Rail Network
- Watercourse
- Rail (West)
- Rail (East)
- Mine (Onsite)
- Mine (Offsite)
- Mine (Offsite)

NOTE: Detailed Geological Unit Information is included on Sheet 5

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1:100,000 Mapped Geology

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Figure: 2-3

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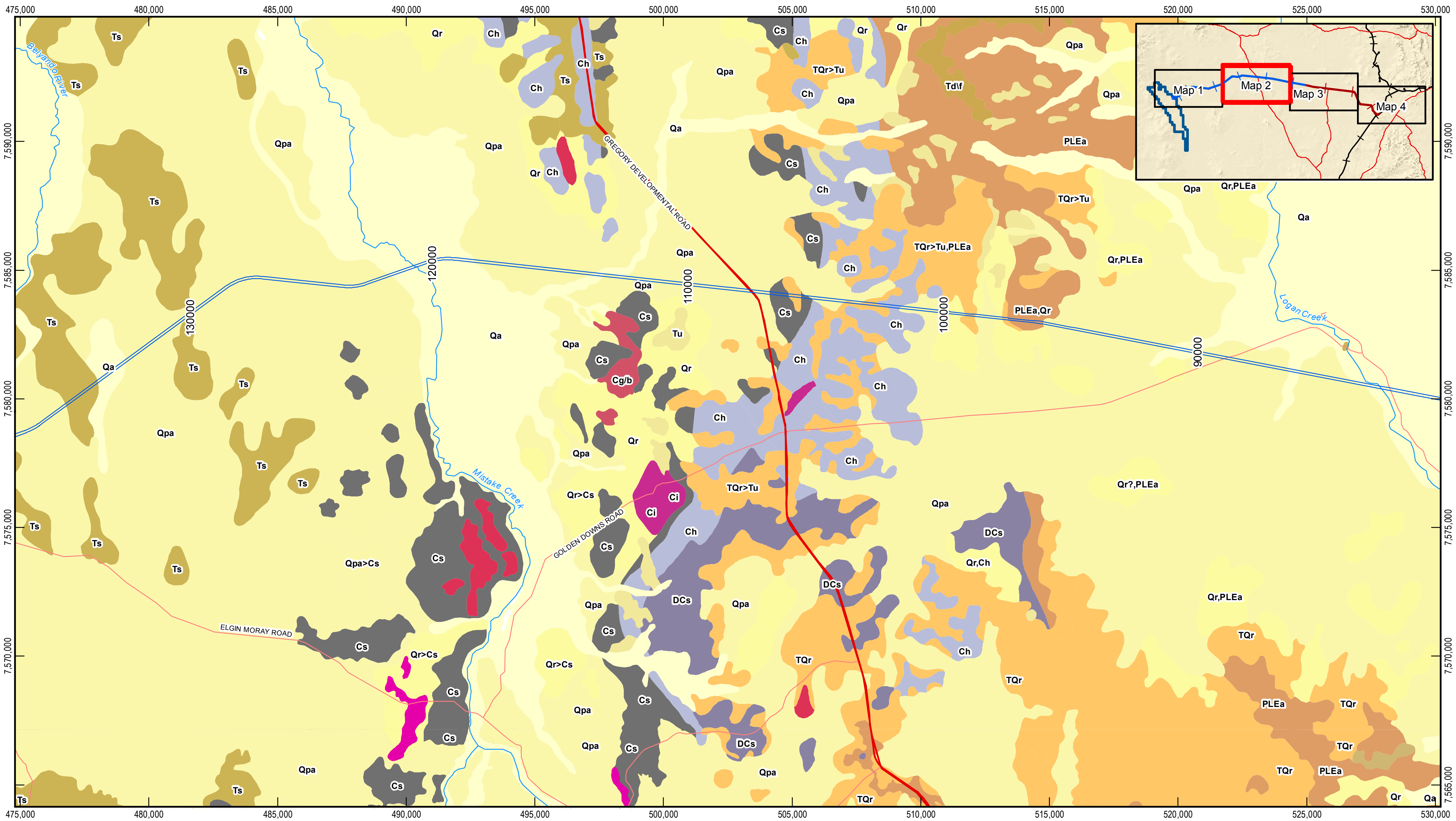
Data source: DME: EPC1690 (2010), EPC1080 (2011), 100k Geology (2011), 250k Geology Raster (2009); © Commonwealth of Australia (Geoscience Australia): Localities, Railways, Roads (2007); Adani: Alignment Opt9 Rev3 (2012); Gassman/Hyder: Mine (Offsite) (2012). Created by: BW, CA



1:200,000 (at A4)

0 1 2 3 4 5

Kilometres

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Figure: 2-3
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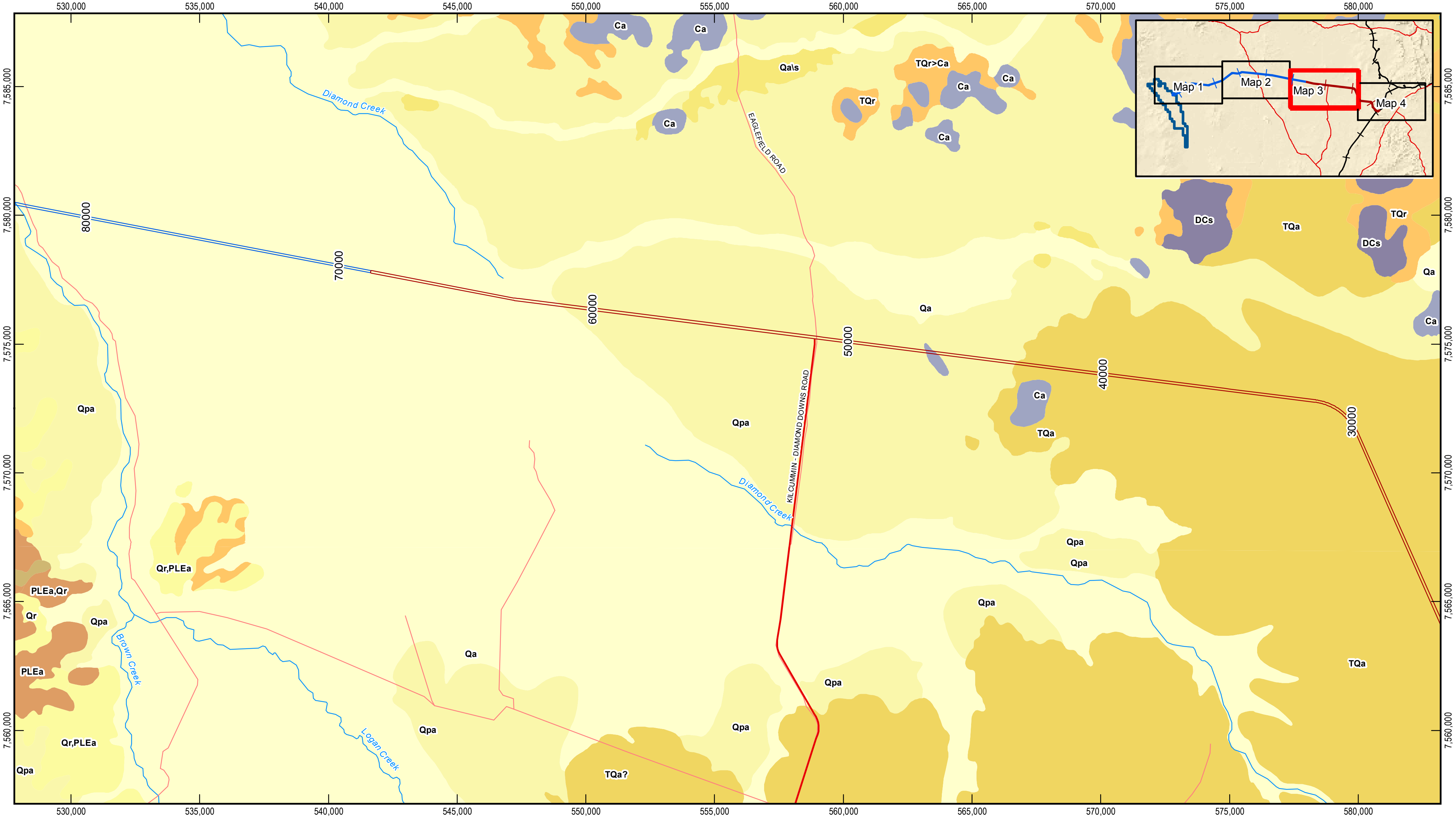

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0 1 2 3 4 5

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
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LEGEND

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- Mine (Offsite)

NOTE: Detailed Geological Unit Information is included on Sheet 5

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Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project

1:100,000 Mapped Geology

Job Number	41-25215
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Figure: 2-3
Sheet 3 of 5

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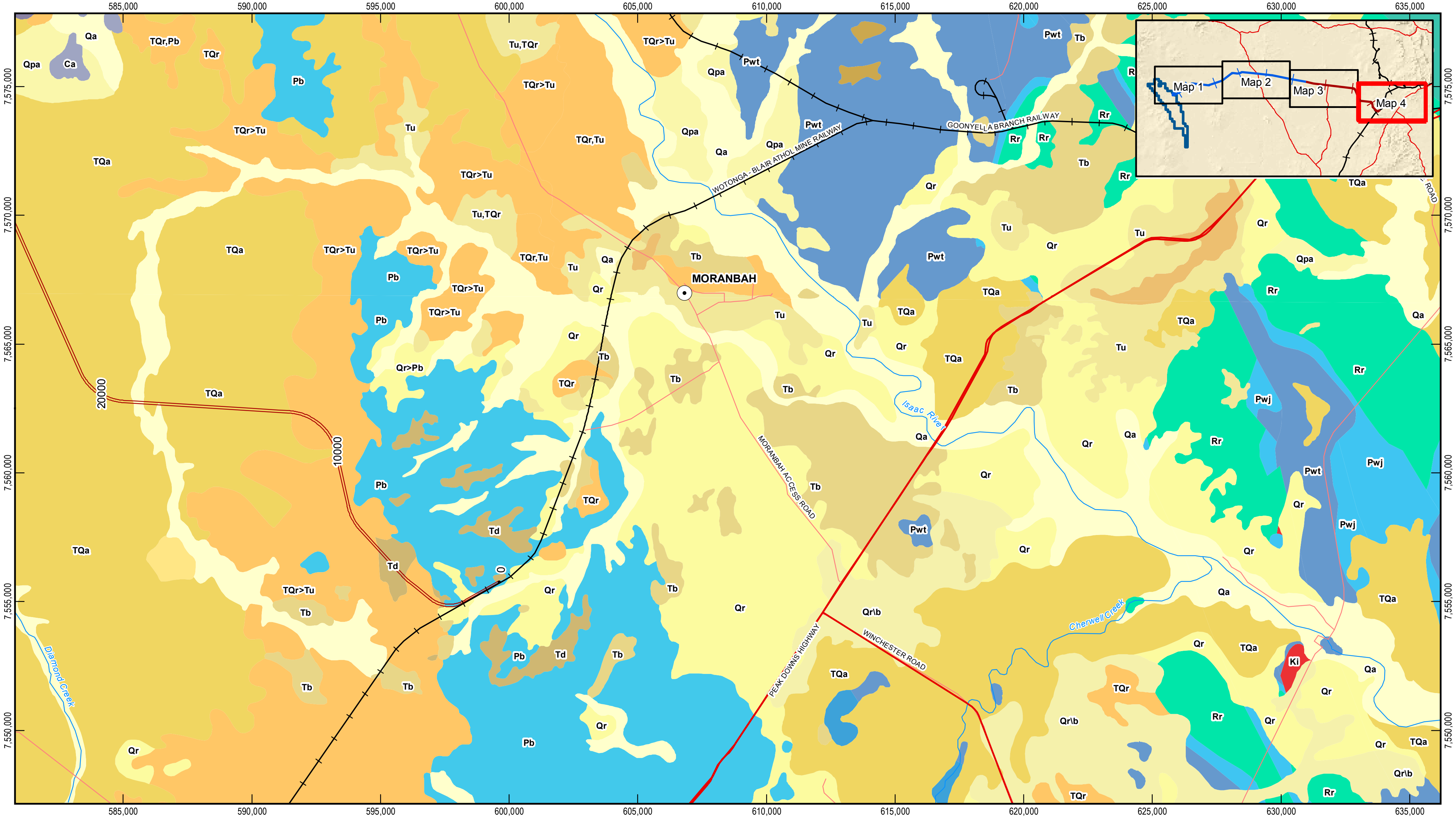

1:200,000 (at A4)

0 1 2 3 4 5

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GHD adani

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Carmichael Coal Mine and Rail Project

1:100,000 Mapped Geology

Job Number	41-25215
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Figure: 2-3
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Geology Unit	Age	Lithology Summary
Ca	LATE DEVONIAN? - EARLY CARBONIFEROUS	White and grey siltstone and fine sandstone, minor medium to very coarse-grained sandstone, chert, granule to pebble conglomerate, rare tuff, ignimbrite and dacite/andesite
Cg/b	CARBONIFEROUS	Grey, fine to medium-grained pyroxene gabbro and dolerite; locally uralitised
Ch	EARLY CARBONIFEROUS	Quartzose to feldspathic sublabile sandstone, quartz-pebble conglomerate, mudstone and red and green siltstone
Ci	CARBONIFEROUS	Undivided high level intrusives; dacite, andesite, altered dolerite?
Cid	CARBONIFEROUS	Intrusive dacite, generally porphyritic
CPg	CARBONIFEROUS - EARLY PERMIAN	Biotite granite to granodiorite and other unassigned granitoids
CPg,TQr	PERMIAN	Granite, granodiorite, quartz-feldspar porphyry, quartz-tourmaline breccia
CPjj?	LATE CARBONIFEROUS - EARLY PERMIAN	Mudstone, siltstone, sandstone
Cs	EARLY CARBONIFEROUS	Lithic conglomerate, feldspatholithic sandstone, rhyolitic to dacitic ignimbrite and flows, tuffaceous siltstone and rare sinter
Cs?	EARLY CARBONIFEROUS	Lithic conglomerate, feldspatholithic sandstone, rhyolitic to dacitic ignimbrite and flows, tuffaceous siltstone and rare sinter
Cvbl/b	CARBONIFEROUS	Moderately crystal rich to crystal rich rhyolitic ignimbrite, well developed eutaxitic texture
DCs	LATE DEVONIAN - EARLY CARBONIFEROUS	Rhyolite, dacite, rhyolitic ignimbrite, volcaniclastic sediments, sinter, minor sandstone and siltstone
Ki	CRETACEOUS	Trachyte, volcaniclastics, quartz porphyry, rhyolite aplite, granodiorite, diorite, gabbro
Pb	EARLY PERMIAN - LATE PERMIAN	Quartzose to lithic sandstone, siltstone, carbonaceous shale, minor coal and sandy coquinite
Pb?	EARLY PERMIAN - LATE PERMIAN	Sandstone, siltstone, carbonaceous shale, minor coal and sandy coquinite
Pjo?	EARLY PERMIAN	Sandstone, siltstone, mudstone, conglomerate, tuff
PLEa	NEOPROTEROZOIC - CAMBRIAN?	Siltstone, fine sandstone, phyllite, schist, commonly cleaved and multiply deformed
PLEa,Qr	NEOPROTEROZOIC - CAMBRIAN?	Siltstone, fine sandstone, phyllite, schist, commonly cleaved and multiply deformed
PLEa?	NEOPROTEROZOIC? - EARLY CAMBRIAN?	Undivided mica schist, quartzite and phyllite
Pwb	LATE PERMIAN	Labile sandstone, siltstone, mudstone, coal, conglomerate in the east
Pwj	LATE PERMIAN	Calcareous sandstone, calcareous shale, mudstone, coal, concretionary limestone
Pwt	LATE PERMIAN	Lithic sandstone, conglomerate, mudstone, carbonaceous shale, coal, tuff, tuffaceous (cherty) mudstone
Qa	QUATERNARY	Clay, silt, sand, gravel; flood plain alluvium
Qas	QUATERNARY	Sandy alluvial tracts
Qf	QUATERNARY	Alluvial fan deposits, bajadas
Qpa	PLEISTOCENE	Clay, silt, sand, gravel; flood plain alluvium on high terraces
Qpa>Cs	PLEISTOCENE	Clay, silt, sand, gravel; flood plain alluvium on high terraces
Qr	QUATERNARY	Clay, silt, sand, gravel and soil; colluvial and residual deposits
Qr,Ch	QUATERNARY	Clay, silt, sand, gravel and soil; colluvial and residual deposits

1:200,000 (at A4)
0 1 2 3 4 5
Kilometres
Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

NOTE
Geological unit descriptions are limited to those shown in the map extent.
Additional geological units not described here may be present in surrounding areas.

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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project

1:100,000 Mapped Geology

Job Number 41-25215
Revision B
Date 30-08-2012

Figure: 2-3
Sheet 5 of 5

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Data source: DME: 100k Geology (2011). Created by: BW, CA

2.3 Soils

2.3.1 Overview

The soil and land suitability assessment has been undertaken at a desktop level to date using the following guidelines and publications, as applicable:

- *Planning Guidelines: The Identification of Good Quality Agricultural Land* (Department of Primary Industries (DPI), 1993)
- *Protecting Queensland's strategic cropping land: Guidelines for Applying the Proposed Strategic Cropping Land Criteria* (DERM, 2011)
- *Australian Soil and Land Survey Field Handbook* (National Committee on Soil and Terrain, 2009)
- *Best Practice Erosion and Sediment Control – International Association of Erosion Control* (IECA, 2008)
- *Guideline: EPA Best Practice Urban Stormwater Management: Erosion and Sediment Control* (Environmental Protection Agency, 2008)
- *'Site Assessment', Road Drainage Design Manual* (Queensland Department of Transport and Main Roads, 2002)

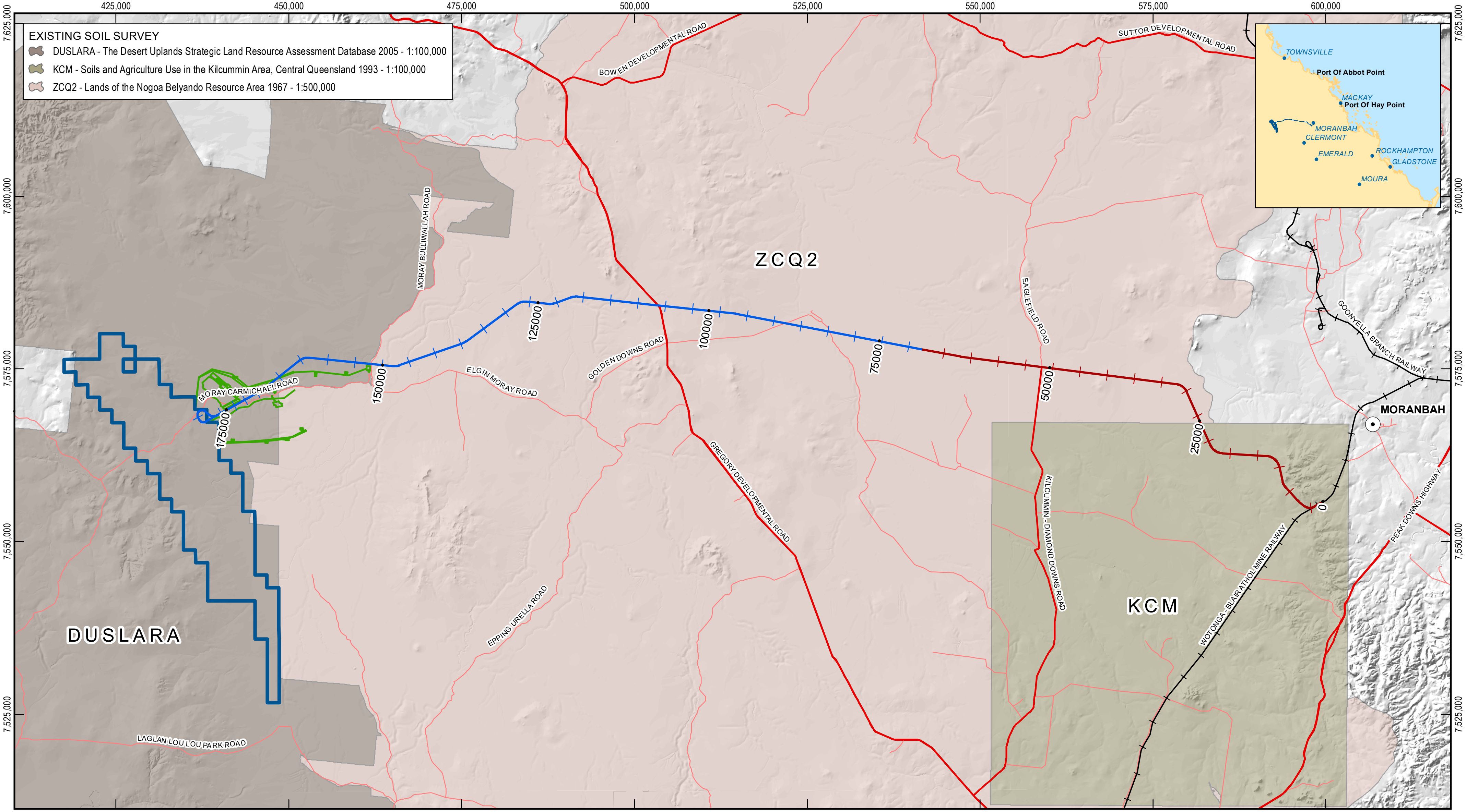
2.3.2 Existing Soil and Land System Information

Existing soil and land system mapping and information has been used to assess the proposed Study Area. Two publicly available land system reports and one soil survey report were reviewed to distinguish varying landscapes and soil types along the proposed rail corridor. An assessment of the dominant soils and landforms that are expected to occur within the study area has been undertaken with reference to the aforementioned reports.

The Australian Natural Resource Atlas Website (http://www.anra.gov.au/topics/soils/overview/qld.html) defines the two different mapping forms as:

- Land systems are repeating patterns of soils, vegetation, geology and geomorphology. Scales are usually broad (1:250,000 to 1:500,000) and the polygons large. Associated attributes include broad statements of dominant soils or vegetation types, land condition and potential land capability.
- Soils mapping is generally at a smaller scale, and focuses on soil type or soil association as the dominant mapped entity. Associated attributes include soil types and proportions, land qualities and land suitability (a five class system which rates the suitability of the polygon for a range of defined land uses).

The existing land system and soils reports together with their associated scales and the relevance to the rail corridor are shown in in Figure 2-4 and included in Table 2-4.



1:750,000 (at A4)

0 5 10 15 20 25

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- Town
- State Road
- Local Road
- Existing Railway
- Rail (West)
- Rail (East)
- Mine (Onsite)
- Mine (Offsite)

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Carmichael Coal Mine and Rail Project

Soil and Land System Reports and Relevance to Study Area

Job Number	41-25215
Revision	D
Date	03-09-2012

Figure 2-4

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Level 4, 201 Charlotte St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data source: DERM: Combined Soils, Land System Reports (2010); DME: EPC1690 (2010), EPC1080 (2011); © Commonwealth of Australia (Geoscience Australia): Localities, Railways, Roads (2007); Adani: Alignment Opt9 Rev3 (2012); Gassman/Hyder: Mine (Offsite) (2012); GHD: Northern Missing Link (2011). Created by: BW, CA

Table 2-4 Land System and Soil Survey Reports

Existing Published Report	Report Type / Scale	Relevance to Study Area (km)	Project (Rail) Reference
Lorimer, MS 2005, *The Desert Uplands: an overview of the Strategic Land Resource Assessment Project*, Technical Report, Environmental Protection Agency, Queensland. (DUSLARA)	Land System / 1:100,000	Mine Site to 152 km	Section DUSLARA
Gunn, R.H. Galloway, R.W. Pedley, L and Fitzpatrick, E.A, 1967. *Lands of the Nogoa - Belyando Area, Queensland - Land Research Series No. 18*, Commonwealth Scientific and Industrial Research Organisation, Australia, Melbourne, Victoria (ZCQ2)	Land System / 1: 500,000	152 km to 20 km	Section ZCQ2
Shields, P.G, Chamberlain H.J., and Booth N.J. 1993. *Soils and Agricultural Use, in the Kilcummin Area, Central Queensland*, *Project Report Series: QO93011*, Department of Natural Resources and Mines, Brisbane Queensland (KCM)	Soil Mapping / 1:100,000	20 km to 0 km (Goonyella system rail connection)	Section KCM

DERM was approached to determine if additional information was able to be made available, particularly information contained within the Soil and Land Information database. This information is unfortunately not available to the public in a user friendly format.

Instead the publically available DERM Combined Soils Database was used. It was found that the polygons of the Combined Soils Database typically coincided with the polygons of the published mapping and also contained the same land descriptor coding to allow identification and cross referencing.

At a preliminary desktop assessment level the soil types (Australian Soil Classification (ASC) (Isbell, 2002)) have been mapped for the Study Area using the Combined Soils Database (refer 2.3.4). This soils mapping is suitable for the purposes of the EIS and providing an overview of expected soil types within the Project (Rail) area. More detailed surveys are currently underway to distinguish changes in landscape and soil types, particularly in areas mapped at 1:500,000.

Land resource information available was more detailed but was split between three reports with inconsistent nomenclature. Therefore, the soils classification is considered in three zones, with the ASC providing a consistent soil nomenclature across the three zones. From west to east, the relevant information describes the western 37 km within the DUSLARA report (1:100,000) (Section DUSLARA), the central 132 km in the ZCQ2 document (1:500,000) (Section ZCQ2) and the eastern 20 km of the rail corridor was reported in the KCM data (1:100,000) (Section KCM).

The Australian Soil Resource Information System was also used in discussing potential ASS risk for the Study Area.

2.3.3 Land Suitability Criteria

Land suitability rankings have been applied to data from the ZCQ2 and KCM reports. The DUSLARA dataset does not allow for a land suitability ranking to be applied.

The two methods of land evaluation traditionally used in Queensland are '*land capability*' and '*land suitability*':

- Land capability assessment, as described by Rosser *et al.* (1974), concerns the allocation of land units to one of eight classes on the basis of the extent of limitations for general agricultural use. It is usually applied to broad scale land resource assessment.
- Land suitability rankings are more refined and apply to the capacity of land resources to sustain particular forms of land use such as arable farming, irrigated agriculture and forestry. Such rankings can be applied to smaller land units and are thus more useful in determining post-development land use options.

2.3.3.1 Land Capability

The ZCQ2 dataset uses the land capability class system, which is a United States Department of Agricultural standard that was adopted in Queensland when the ZCQ2 study was undertaken (1967). This is detailed in Table 2-5.

Table 2-5 Land Capability Classes (Gunn *et al*, 1967)

Class	Land Capability	Description
1	Cultivation with slight limitations	This is land with few or no limitations. With good management it is suitable for long-continued cropping, without special practices. It is nearly level, has deep easily worked soil, and erosion hazard is low. The soils are well drained but not droughty and are either well supplied with nutrients or highly responsive to fertilizer applications. The climate is favourable to a wide range of cultivated crops, pastures, or forest.
2	Cultivation with moderate limitations	This is land with slight limitations. It is arable land and limitations are few and the practices easy to apply. It may require moderate conservation practices which will depend on the limitations but will include such practices as strip cropping, stubble mulching, etc. where erosion is the major hazard.
3	Limited cultivation and/ or pasture improvement	This is land with moderate limitations. It is arable land but limitations may restrict the choice of plants grown, or require special conservation practices, or both. A combination of intensive measures is necessary for permanent use of the land. Such measures as adequate mechanical protection will be necessary if erosion is the limiting factor and the land is cultivated.
4	Intensive grazing	This is land which is subject to severe limitations and is suitable for occasional but not regular cultivation. It is primarily grazing land. The choice of plants may be very limited or more intensive conservation practices may be necessary.

Class	Land Capability	Description
5	Moderate grazing	This is nearly level land that has little or no erosion hazard even if cultivated, but has other limitations which it is not practical to remove and which prevent the normal production of cultivated crops. This land may be used for pasture or forestry with few or no limitations. Special crops may be grown on it but only with the use of special practices.
6	Limited grazing	This is land which has such severe limitations that it is unsuitable for cultivation, but it is suitable for grazing or forestry subject only to moderate limitation in use. Limitations of soils or slopes are such that pasture improvement practices requiring the use of tractors and machinery are practicable.
7	Limited grazing	This is land with very severe limitations which make it unsuitable for cultivation and restrict its use even for grazing or forestry. Limitations are such that pasture improvement practices requiring the use of tractors and machinery are impractical.
8	Unsuitable for cultivation or grazing	This is land with such severe limitations that it is not suitable for cultivation, grazing, or commercial forestry. Its main value is for watershed protection and wildlife and recreation reserves.

2.3.3.2 Land Suitability

Land suitability is classified into five classes with suitability decreasing progressively from Class 1 to Class 5 as described in Table 2-6. Land is classified on the basis of a particular land use that allows optimum production with minimal degradation to the land resource in the long-term.

Table 2-6 Land Suitability Classes

Class	Land Suitability	Description
1	Very high	Suitable land with negligible limitations. This is highly productive land requiring only simple management practices to maintain economic production
2	High	Suitable land with minor limitations which either reduce production or require more than the simple management practices of Class 1 land to maintain economic production
3	Fair	Suitable land with moderate limitations which either further lower production or require more than those management practices of Class 2 land to maintain economic production
4	Low	Marginal land, which is presently considered unsuitable due to severe limitations. The long term significance of these limitations on the proposed land use is unknown. The use of this land is dependent upon undertaking additional studies to determine whether the effect of the limitation(s) can be reduced to achieve sustained economic production
5	Very low	Unsuitable land with extreme limitations that generally preclude its use for agricultural activities

Land is considered less suitable as the severity of limitations for a land use increase, reflecting either:

- Reduced potential for production; and / or
- Increased inputs to achieve an acceptable level of production; and / or
- Increased inputs required to prevent land degradation

2.3.4 Land Systems, Land Units and Soil Types

2.3.4.1 Project (Rail) Section DUSLARA

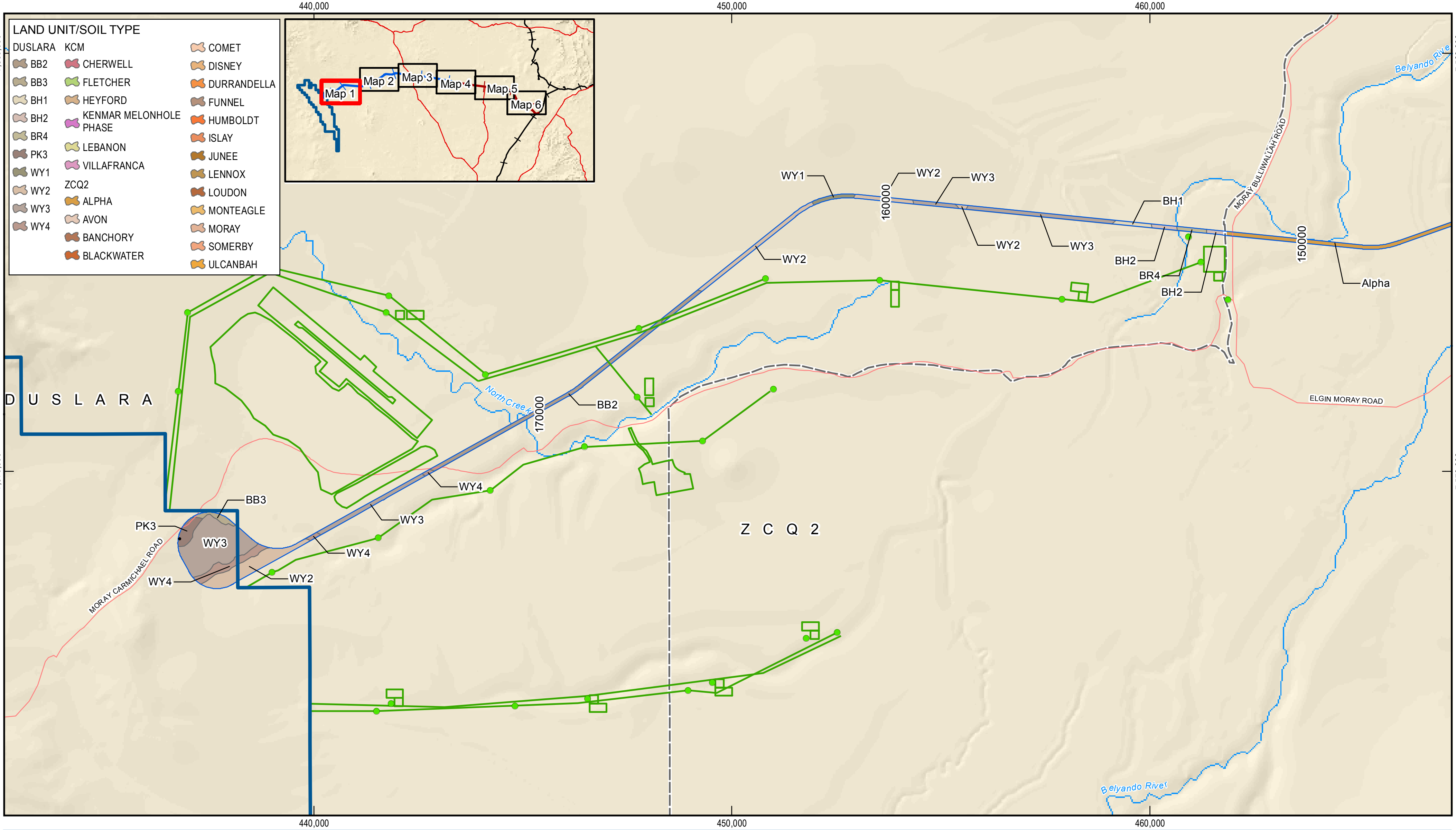
The DUSLARA land resource study (Lorimer, 2005) is based on the land system concept and involved the use of remote sensing techniques initially to identify broad geomorphic features, followed by an intensive period of field work to collect site, soil and vegetation information. The land system method in which soil-vegetation associations conform to a predictable and recurring pattern within areas of similar geology, physiography and climate, provides a consistent, logical identification of different land types across the whole bioregion. The DUSLARA land resource study has been mapped at a scale of 1:100,000 (Lorimer, 2005).

The Project (Rail) traverses the DUSLARA land resource study area for approximately 37 km commencing from the Mine Site heading east (refer Figure 2-4). Within this section of the proposed Project (Rail) five land systems, divided further into nine land units are traversed by the alignment. Details of the five land systems and subsequent land units traversed by the Project (Rail) are discussed in Table 2-7 and shown in Figure 2-5.

Table 2-7 Soil Types Mapped within Project (Rail) Section DUSLARA

Start km)	Finish (km)	Land System	Land form	Land Unit
187.5	189.5	Beenboona	Alluvium - Alluvial fan	BB2
87.2	187.5	Willandspey	Lacustrine plain	WY4
184.4	187.2	Willandspey	Lacustrine plain	WY3
184.1	184.4	Willandspey	Lacustrine plain	WY4
181.2	184.1	Willandspey	Lacustrine plain	WY2
181	181.2	Willandspey	Lacustrine plain	WY4
180.2	181	Willandspey	Lacustrine plain	WY3
179.3	180.2	Plain Creek	Rises and low hills on folded sediments	PK3
178.3	179.3	Beenboona	Alluvium - Alluvial fan	BB3
187.2	187.5	Willandspey	Lacustrine plain	WY4
177.6	178.20	Willandspey	Lacustrine plain	WY3
177.30	177.60	Willandspey	Lacustrine plain	WY4

Start km)	Finish (km)	Land System	Land form	Land Unit
176.30	177.30	Willandspey	Lacustrine plain	WY2
176.00	176.30	Willandspey	Lacustrine plain	WY4
173.10	176.00	Willandspey	Lacustrine plain	WY3
172.90	172.90	Beenboona	Alluvium - Alluvial fan	BB2
172.90	173.10	Willandspey	Lacustrine plain	WY4
166.30	170.90	Willandspey	Lacustrine plain	WY3
166.20	166.30	Willandspey	Lacustrine plain	WY3
165.20	166.20	Willandspey	Lacustrine plain	WY2
161.70	165.20	Willandspey	Lacustrine plain	WY2
160.70	161.70	Willandspey	Lacustrine plain	WY2
159.30	160.70	Willandspey	Lacustrine plain	WY3
158.20	159.30	Willandspey	Lacustrine plain	WY3
158.00	158.20	Willandspey	Lacustrine plain	WY3
154.50	158.00	Willandspey	Lacustrine plain	WY3
153.60	154.50	Bulliwallah	Lateritised surface - Plain	BH2
153.00	153.60	Belyando River	Alluvium - River flood plain	BR4
152.30	153.00	Belyando River	Alluvium - River flood plain	BR4
151.80	152.30	Bulliwallah	Lateritised surface - Plain	BH2



1:125,000 (at A4)

0 1 2 3 4 5

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- Town
- State Road
- Local Road
- Watercourse
- Existing Railway
- Rail (West)
- Rail (East)
- Land System Report Boundary
- Mine (Onsite)
- Mine (Offsite)
- Mine (Offsite)

Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project

Land System, Land Unit and Soil Type

Job Number	41-23244
Revision	C
Date	03-09-2012

Figure 2-5
Sheet 1 of 6

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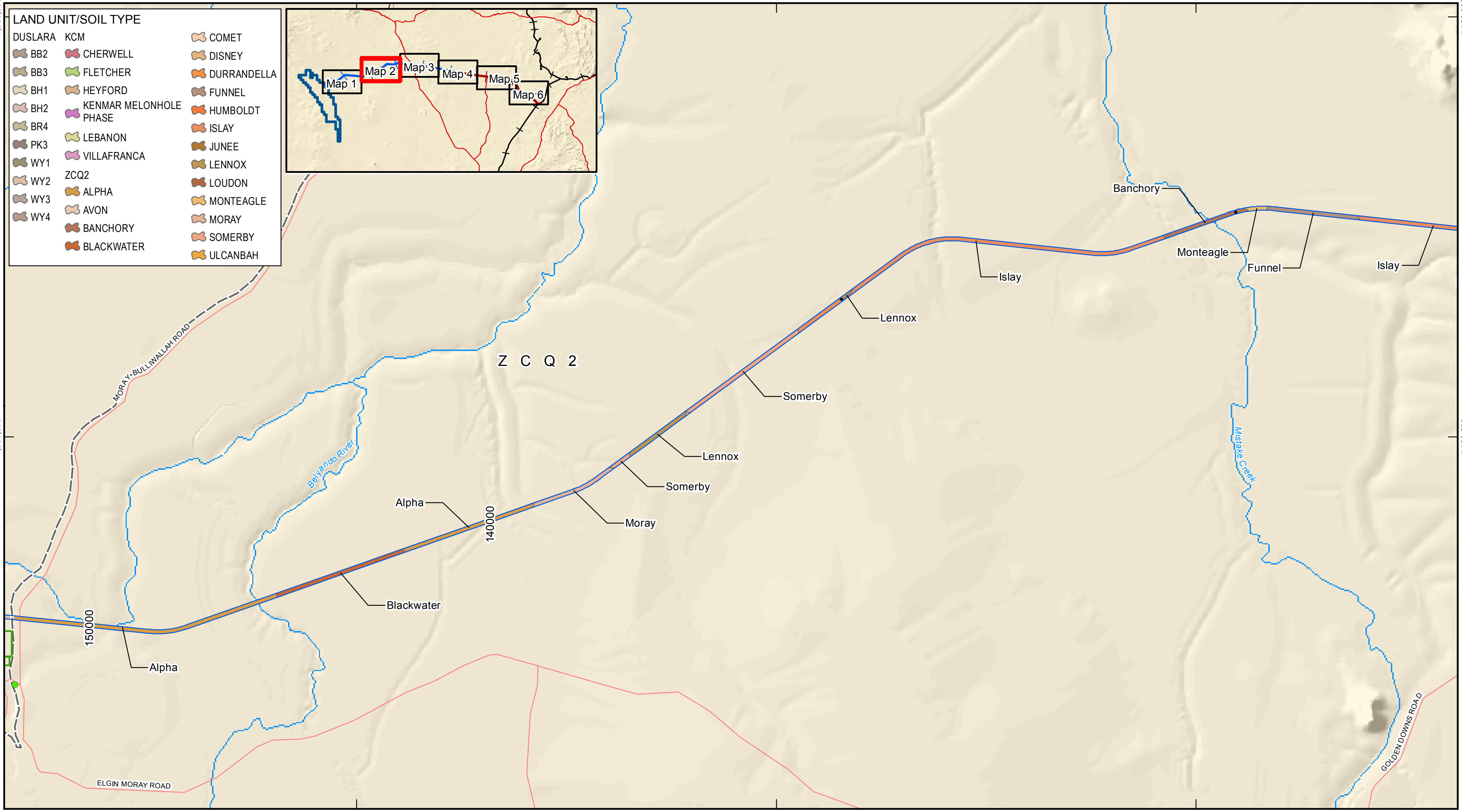
Level 4, 201 Charlotte St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data source: DERM: Combined Soils 2m & 100k (2010); DME: EPC1690 (2010), EPC1080 (2011); © Commonwealth of Australia (Geoscience Australia): Localities, Railways, Roads (2007); Adani: Alignment Opt9 Rev3 (2012); Gassman/Hyder: Mine (Offsite) (2012). Created by: BW, CA



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Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

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- Mine (Offsite)

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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project

Land System, Land Unit and Soil Type

Job Number	41-23244
Revision	C
Date	03-09-2012

Figure 2-5
Sheet 2 of 6

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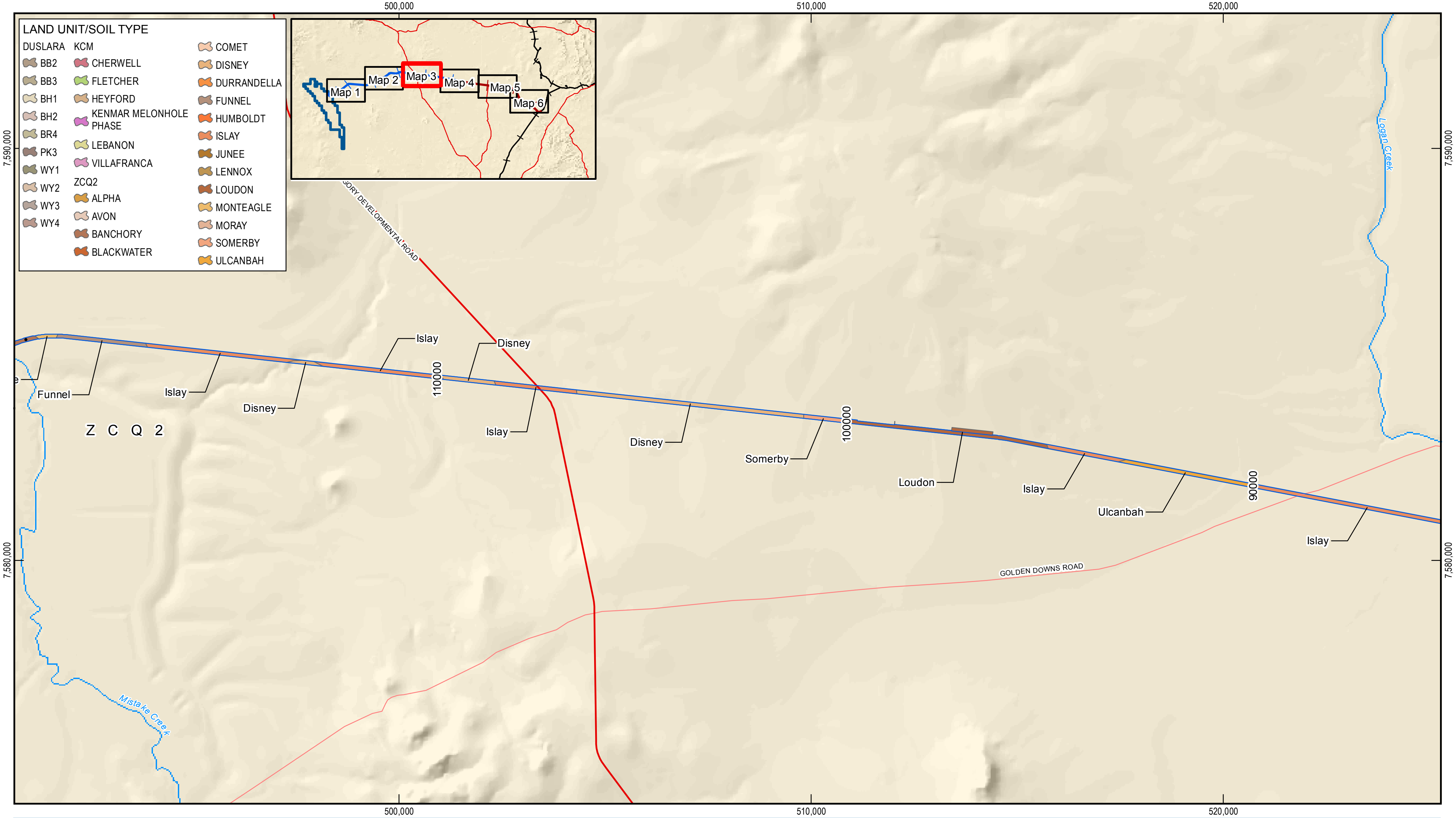

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Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
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- Mine (Offsite)

Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project

Land System, Land Unit and Soil Type

Job Number	41-23244
Revision	C
Date	03-09-2012

Figure 2-5
Sheet 3 of 6

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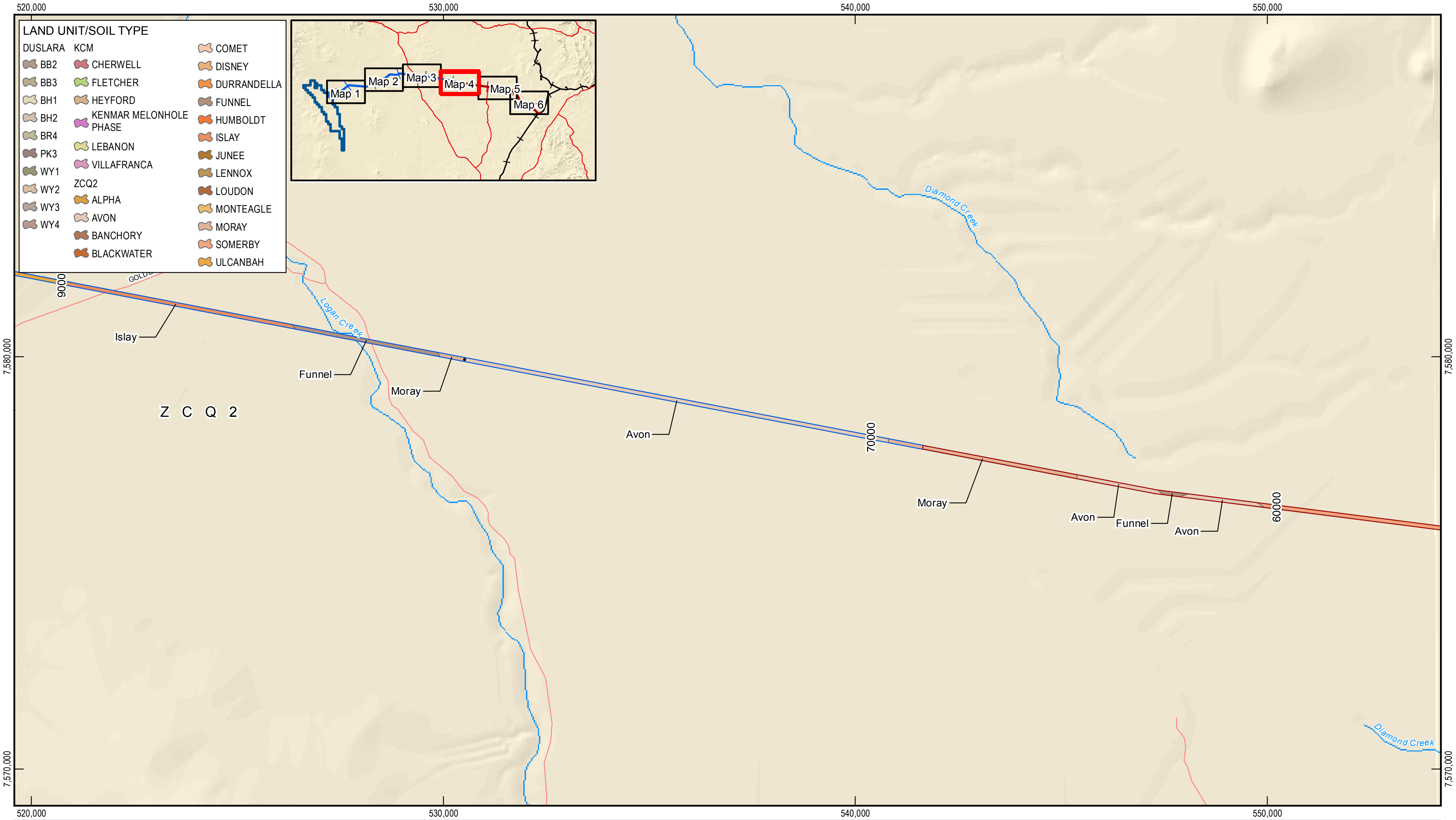
Data source: DERM: Combined Soils 2m & 100k (2010); DME: EPC1690 (2010), EPC1080 (2011); © Commonwealth of Australia (Geoscience Australia): Localities, Railways, Roads (2007); Adani: Alignment Opt9 Rev3 (2012); Gassman/Hyder: Mine (Offsite) (2012). Created by: BW, CA



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Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
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GHD adani

Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project

Land System, Land Unit and Soil Type

Job Number	41-23244
Revision	C
Date	03-09-2012

Figure 2-5
Sheet 4 of 6

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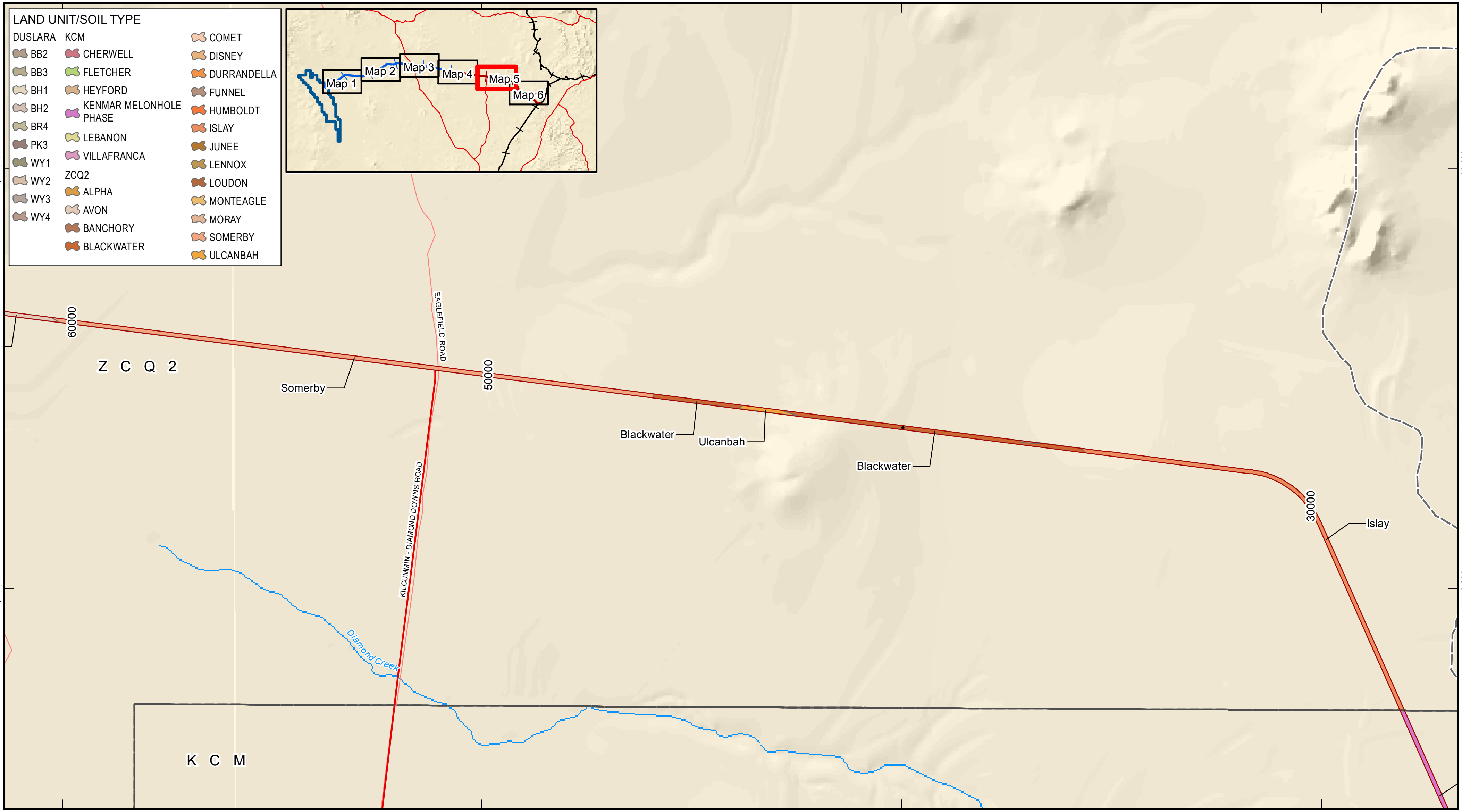

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Kilometres

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Horizontal Datum: Geocentric Datum of Australia (GDA)
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Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project

Land System, Land Unit and Soil Type

Job Number	41-23244
Revision	C
Date	03-09-2012

Figure 2-5
Sheet 5 of 6

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Level 4, 201 Charlotte St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

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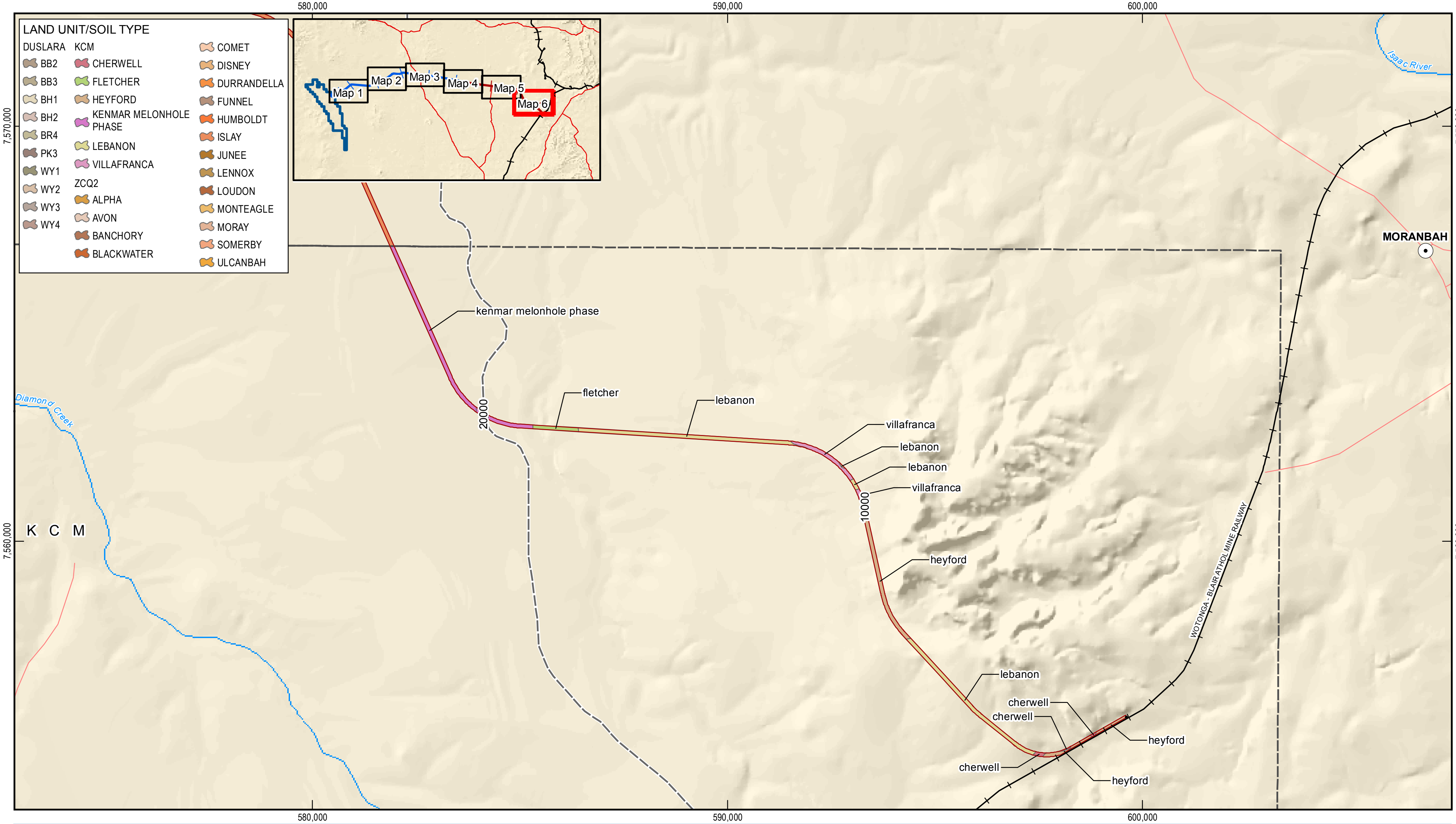

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Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
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GHD adani

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Carmichael Coal Mine and Rail Project

Land System, Land Unit and Soil Type

Job Number	41-23244
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Date	03-09-2012

Figure 2-5
Sheet 6 of 6

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Level 4, 201 Charlotte St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data source: DERM: Combined Soils 2m & 100k (2010); DME: EPC1690 (2010), EPC1080 (2011); © Commonwealth of Australia (Geoscience Australia): Localities, Railways, Roads (2007); Adani: Alignment Opt9 Rev3 (2012); Gassman/Hyder: Mine (Offsite) (2012). Created by: BW, CA

Below are extracts from the DUSLARA land resource study for each of the land systems and land units described in Table 2-7.

Bulliwallah Land System

This land system represents an outlier of the Desert Uplands plateau. Ironstone exposures occur along the margins of the elevated plain. BH1 is the dominant land unit with red gradational soils and yellowish-brown texture-contrast soils supporting open woodlands of silver-leaved ironbark and pastures of black speargrass and wiregrass. Small-localised areas (BH2) occur with mixtures of Reid River box and/or gidgee and/or brigalow on uniform clay soils.

- BH1 land unit

This is the predominant land unit within the Bulliwallah land system. Soil types present include yellow Chromosols (texture-contrast profiles), which are considered dominant, and some minor occurrences of deep sandy Tenosols (uniform-textured profiles). On the gentle crests and fringing the plateau, shallow, gravelly, red Kandosols (gradational-textured profiles) may be encountered.

A representative soil profile of the dominant Chromosols soil is provided below in Table 2-8. It is considered to be a texture-contrast soil profile with thick sandy loam topsoil over yellowish-brown clay, which is slightly mottled, sodic and contains hard carbonate nodules below 1 m depth.

Table 2-8 Land Unit BH1 Representative Soil Profile Morphology (Chromosols)

Horizon	Depth (m)	Description
A11	0.0 -0.10	Brown sandy loam; no mottles; no coarse fragments; massive; no segregations; dry weak; abrupt to A12.
A12	0.10 – 0.45	Brown sandy loam; no mottles; no coarse fragments; massive; no segregations; dry weak.
B21t	0.45 – 0.85	Light yellowish brown light clay; very few (<2 per cent) fine (<5 mm) distinct orange mottles; very few small pebbles subrounded Ironstone coarse fragments; massive; no segregations; dry firm.
B22c	0.85 – 1.40	Brownish yellow light clay; few (2-10 per cent) medium (5-15 mm) prominent red mottles; few (2-10 per cent) medium (5-15 mm) prominent grey mottles; very few small pebbles subrounded Ironstone coarse fragments; massive; few (2 - 10 %) medium (2 -6 mm) Ferromanganiferous nodules.
B23k	1.40 – 2.00+	Light reddish brown light clay; very few (<2 per cent) fine (<5 mm) prominent orange mottles; very few (<2 per cent) fine (<5 mm) prominent grey mottles; no coarse fragments; few (2-10 %) medium (2-6 mm) Calcareous concretions; few (2- 10 per cent) medium (2-6 mm) Ferromanganiferous nodules.

The BH1 land unit is reported as being phosphorus deficient throughout, with low potassium levels and other nutrient deficiencies, and has easily erodible topsoil. Due to the low nutrient status, the long term productivity of this land unit under introduced pasture faces major limitations. Limited areas of BH1 land unit are mapped as present within the Project (Rail) area, within the vicinity of the Belyando River floodplain.

- BH2 land unit

The dominant landform element to which this land unit applies is the depressions and lower slopes in the landscape. There are two different soil types applicable to this land unit, which are the very deep, brown Vertosols (uniform cracking-clay soils) which are associated with the woodland mixture of *Acacia cambagei* (gidgee) and *A. harpophylla* (brigalow). The other soil, yellow Sodosol, texture-contrast profiles with sodic subsoils, correlates with the *Eucalyptus brownii* (Reid River box), and is generally found around the fringe of the Vertosol-Acacia associations.

There are no representative profiles provided within the DUSLARA report. Salt accumulation within the topsoil may result from clearing. The cracking clay soils will create some limitations with trafficking during wet periods due to the soil water storage. Limited areas of the BH2 land unit are mapped as present within the Project (Rail) area, within the vicinity of the Belyando River floodplain.

Belyando River Land System

This land system represents the Belyando River floodplain between "Forrester" and "Bulliwallah" - a distance of approximately 140 km. Within the broad riparian zone, four land units are apparent, one of these land units is traversed by the proposed rail corridor being the actual streambeds and channels (BR4), easily recognised by the presence of river red gum, although coolabah and/or brigalow may be present also.

- BR4 Land Unit

The dominant landform elements to which this land unit applies are the streambed and levee of the Belyando River flood plain. Due to the ever-changing quantities of sediment that are eroded and deposited during flood events, the soil types are highly variable. Deep Tenosols (uniform sandy profiles with minimal profile development) are considered to be the most common soil type within the land unit. Where the streambed has cut down and exposed the clays underlying a large portion of the river valley, brigalow becomes dominant.

There are no representative profiles provided within the DUSLARA report.

Beenboona Land System

The soils and vegetation are extremely variable within this land system because of the different proportions of sand and clay in the alluvium, the different ages of sediments and the variable depth of soil. This land system is situated within the lower slope of the landscape resulting in a complex arrangement of soil types.

- BB2 Land Unit

This land unit comprises the gently undulating plains within the land system. The soils are reported as being sandy alluvium of variable depth. The deep sandy deposits have formed red Kandosols (gradational profiles) whereas the very shallow or non-existent deposits reflect the characteristic properties of the underlying cracking-clay soils. The two different soil types support tall woodlands of *Eucalyptus melanophloia* (silver-leaved ironbark), with some *E. crebra* (narrow-leaved ironbark) and *E. brownii* (Red River box) on the sandy soils, and dense woodlands of brigalow with the occasional *E. cambageana* (blackbutt) on the clayey soils.

A representative soil profile of the dominant Kandosol soil is provided below in Table 2-9. It is described as reddish yellow, sandy clay loam gradually increasing in clay content to a yellow, light clay.

Table 2-9 Land Unit BB2 Representative Soil Profile Morphology (Kandosol)

Horizon	Depth (m)	Description
A	0.0 -0.52	Reddish yellow fine sandy clay loam; no mottles; no coarse fragments; massive; no segregations; dry very weak; gradual to B21t.
B21t	0.52 – 1.25	Brownish yellow light clay; no mottles; no coarse fragments; massive; few (2-10 per cent) medium (2-6 mm) Ferruginous concretions; dry very weak; Clear to B22.
B22	1.25 – 1.55	Yellow light clay; no mottles; no coarse fragments; massive; few (2-10 per cent) medium (2-6 mm) Ferruginous concretions; dry very weak.
Dc	1.55 – 2.00+	Moderately cemented continuous nodular thin iron pan

The gradational soils within the BB2 land unit have very low nutrient levels, and are phosphorus deficient. The uniform clay soils retain moisture for an extended period, and are therefore more conducive to sustaining pasture growth.

Willandspey Land System

This land system is characterised by an extensive plain of deep, grey and red brown clay soils. The high positions, or crests, in the landscape have shallow gradational soils over a hardpan, and support mid-high woodlands of ironbark, box and bloodwood (WY1). The vegetation is predominantly brigalow, but mid-high forests of gidgee occur on the gentle rises with red-brown cracking-clay soils (WY2) and tall closed woodlands of brigalow predominate on the poorly drained plains with gilgaied, grey cracking-clay soils (WY3). River red gum, in association with brigalow and false sandalwood, is confined to the drainage depressions where sandy alluvium of variable depths overlies the grey, cracking-clay soils (WY4). Lorimer (2005) reported that a majority of the land system has been cleared and sown to introduce pasture species, as the soils are deep and relatively fertile.

- WY1 Land Unit

The two dominant soil types within this land unit include the shallow sandy Kandosols (gradational-textured profiles) which alternate with clayey Dermosols (uniform-textured profiles with structured subsoils) and both overlie a hardpan of either ironstone or calcrete, respectively.

A representative soil profile of the Dermosol soil is provided below in Table 2-10. It is described as being a thin dark brown, clay loam topsoil grading into dark reddish brown light clay with a calcareous hardpan at 0.3 m depth.

Table 2-10 Land Unit WY1 Representative Soil Profile Morphology (Dermosols)

Horizon	Depth (m)	Description
A	0.0 -0.04	Dark brown clay loam; no mottles; no coarse fragments; moderate (5-10 mm) subangular blocky structure; no segregations; dry weak; abrupt to B21.
B21	0.04 – 0.21	Dark reddish brown light clay; no mottles; no coarse fragments; moderate (10-20 mm) subangular blocky structure; no segregations; dry weak.
B22	0.21 – 0.30	Dark reddish brown light clay; no mottles; few strong (2-5 mm) subangular blocky structure; no segregations; dry firm.
Dc	0.30 – 2.00+	Moderately cemented continuous nodular calcrete pan.

Due to the dominant soil types within this land unit being shallow and limited in area, and the presence of a hardpan, productivity and land use options are restricted. The topsoils are reported as being moderately dispersible and are considered prone to surface sealing. The other soil type, a Kandosol, has a thin sandy surface which is highly susceptible to sheet erosion. The soils are reported as having a high nutrient status, although phosphorus is deficient.

- WY2 Land Unit

Soil types are reported as being moderately well drained clay soils and are believed to be remnants of an old lakebed. The soils are characterised by deep, red-brown Vertosols (uniform, cracking-clay soils) with self-mulching topsoils.

A representative soil profile of the Vertosol soil is provided below in Table 2-11.

Table 2-11 Land Unit WY2 Representative Soil Profile Morphology (Vertosols)

Horizon	Depth (m)	Description
A11	0.0 -0.04	Reddish brown medium clay; no mottles; no coarse fragments; moderate (2-5 mm) platy structure; no segregations; dry very weak; abrupt to B21.
B21	0.04 – 0.70	Reddish brown medium heavy clay; no mottles; no coarse fragments; moderate (50-100 mm) subangular blocky structure; no segregations; dry firm.
B22c	0.70 – 1.00	Brown medium heavy clay; no mottles; no coarse fragments; very few (0-2 per cent) medium (2-6 mm) Calcareous concretions dry strong; very few (0-2 per cent) fine (0-2 mm) Gypseous crystals dry strong; very few (0–2 per cent) fine (0-2 mm) Manganiferous concretions dry strong.
B23c	1.00 – 1.35	Brown medium heavy clay; No mottles; no coarse fragments; few (2 - 10 %) fine (0 - 2 mm) Manganiferous Concretions
B24	1.35 – 1.90+	Greyish brown medium clay; common (10-20 per cent) fine (<5 mm) prominent red mottles; no coarse fragments; no segregations; dry strong.

With the exception of phosphorus deficiencies the soils have a high nutrient status. The soils are reported as being sodic, which normally retards the movement of water down through the soil; however, the increasing amount of lime with depth maintains good structure which improves aeration and drainage. A high salt content occurs in the subsoil below 0.7 m. The high salt content in the deep subsoil is not a threat to pasture production unless the vegetative ground cover is removed and evaporation from the soil surface is allowed to occur, thereby concentrating salts in the topsoil. Vegetation plays an important role in preventing salinity.

- WY3 Land Unit

A very-gently undulating clay plain that was once an extensive lakebed is characteristic of this land unit. Deep, grey Vertosols (uniform cracking-clay soils) predominate. They are poorly drained, have self-mulching topsoil, and a high salt content. Gilgai micro relief is not always evident if the soil profile is located in a depression and kept in a moist condition.

A representative soil profile of the Vertosol soil is provided below in Table 2-12. It is described as being a uniform grey, cracking-clay, with a self-mulching topsoil and an acidic, saline subsoil.

Table 2-12 Land Unit WY3 Representative Soil Profile Morphology (Vertosols)

Horizon	Depth (m)	Description
A11	0.0 -0.02	Light clay; no mottles; no coarse fragments; moderate (<2 mm) subangular blocky structure; no segregations; clear to B21.
B21	0.02 – 0.70	Grey heavy clay; no mottles; no coarse fragments; moderate no segregations; dry very firm; gradual to B22.
B22	0.70 – 2.00+	Grey heavy clay; few (2-10 per cent) medium 5-15 mm prominent red mottles; no coarse fragments; moderate no segregations; dry very firm.

Like WY2, WY3 typically has a high salt content below 0.7 m. The general nutrient status is high, albeit with a phosphorus deficiency. Inundation and ponding can restrict stock and vehicle movement during wet periods. The heavy clay soils have a high shrink-swell capacity, which results in a gilgai micro-relief and serious ramifications for buildings, roads, pipelines and underground cables. The depth and salinity of a ground water table should be known and monitored. This land unit has a very high susceptibility to salinity; however vegetative cover plays an important role in preventing evaporation from occurring which would increase salinity levels in the soil surface.

- WY4 Land Unit

This land unit represents the drainage depressions and creek lines draining the clay plain and the adjacent land systems at a higher elevation. Sandy topsoils overlie yellow, silty clays in stream channels and levees.

These are loose sandy soils of very low fertility, subject to erosion and redistribution by fast flowing water. There are no representative profiles provided within the DUSLARA report for the WY4 land unit.

Plain Creek Land System

This land system represents the steep hill landform on folded bedrock normally found in the Brigalow Belt bioregion. The lower slopes (PK3) have texture-contrast soils with brown sodic clay subsoils and mid-high woodlands of narrow-leaved ironbark, silver-leaved ironbark and ghost gum.

- PK3 Land Unit

This land unit represents the gentle slopes of the Plains Creek land system. Brown Sodosols (texture-contrast profiles with sodic subsoils) and Dermosols (profiles with structured subsoils but lacking a texture-contrast profile) are predominant, with the colour of the subsoil changing to yellowish-grey in areas with poorer drainage.

A representative soil profile of the Sodosol soil is provided below in Table 2-13. The soil is described as being a texture-contrast soil with a thick dark brown sandy clay loam topsoil and bleached A2 horizon overlying brown light medium clay.

Table 2-13 Land Unit PK3 Representative Soil Profile Morphology (Sodosols)

Horizon	Depths	Description
A11	0.0 -0.09	Dark brown (10YR3/3-Moist); sandy clay loam; massive grade of structure; earthy fabric; dry; very firm consistence; field pH 7 (Raupach, 0.05); clear change to A12.
A12	0.09 – 0.22	Brown (10YR4/3-Moist); sandy clay loam; heavy; massive grade of structure; earthy fabric; dry; strong consistence; 2-10 per cent medium gravelly (6-20 mm), subrounded, coarse fragments; field pH 6.5 (Raupach, 0.15); gradual change to A2.
A2	0.22 – 0.45	Yellowish brown (10YR5/4-Moist); sandy clay loam heavy; massive grade of structure; earthy fabric; dry; strong consistence; 10-20 per cent coarse gravelly (20-60 mm) subrounded, coarse fragments; few (2-10 per cent) Ferromanganiferous nodules; medium (2-6 mm) segregations; field pH 6.5 (Raupach, 0.35); gradual change to B21.
B21	0.45 – 0.65	Brown (10YR4/3-Moist); light medium clay; smooth-ped fabric; dry; common (10-20 per cent) Ferromanganiferous nodules, coarse (6-20 mm) segregations; field pH 7.5.
B22	0.65 -1.20+	Dark yellowish brown (10YR4/4-Moist); light medium clay; smooth-ped fabric; dry; common (10-20 per cent) Ferromanganiferous nodules; medium (2-6 mm) segregations; field pH 9 (Raupach, 1.1).

2.3.4.2 Project (Rail) Section ZCQ2

As described by Gunn *et al* (1967), the ZCQ2 reporting covers a survey area of 90,000 km^2 in Central Queensland. The land system mapping is based on the identification of distinctive patterns from aerial photographs. These patterns are mapped initially by stereoscopic examination and then studied systematically in the field. Variations in tone, texture and relief in the patterns reflect mainly differences in land form and vegetation as governed by geomorphic history, lithology, soil and climate. The final interpretation of these areas and mapping was done after completion of the detailed site survey (Gunn *et al*, 1967). For this assessment the land systems only are discussed. Within each land system there are a number of possible land units, however from a desktop assessment, the relevant land units cannot be interpreted.

Table 2-14 details the location of each land system within the ZCQ2 reporting area that is traversed by the Project (Rail), and provides its corresponding land capability class (refer Section 2.3.3). GQAL is specifically discussed further in Section 2.4. The associated ASC has been inferred from the details contained within the soils report.

Table 2-14 Project (Rail) Section ZCQ2 Mapped Soil Types

Start (km)	Finish (km)	Land System	Australian Soil Classification	Land Capability
145.4	151.8	Alpha	Kandosol	3
142.1	145.4	Blackwater	Vertosol	3
138.9	142.1	Alpha	Kandosol	3
136.8	138.9	Moray	Vertosol	3
136.3	136.8	Somerby	Vertosol	4
134.6	136.3	Lennox	Kandosol	6
134.5	134.6	Moray	Vertosol	3
131.3	134.5	Somerby	Vertosol	4
129.9	131.3	Islay	Vertosol	3
129.8	129.9	Lennox	Kandosol	6
121.8	129.8	Islay	Vertosol	3
119.7	121.8	Banchory	Vertosol	5
119.2	119.7	Monteagle	Sodosol	4
117	119.2	Funnel	Vertosol	5
113.5	117	Islay	Vertosol	3
112.8	113.5	Disney	Kandosol	4
109.8	112.8	Islay	Vertosol	3
108.5	109.8	Disney	Kandosol	4
106.6	108.5	Islay	Vertosol	3
101	106.6	Disney	Kandosol	4
100	101	Somerby	Vertosol	4
95	100	Loudon	Rudosol	7-8
93.2	95	Islay	Vertosol	3
90.1	93.2	Ulcanbah	Sodosol	3
84.2	90.1	Islay	Vertosol	3
80.6	84.2	Funnel	Vertosol	5
80	80.6	Moray	Vertosol	3
69.5	80	Avon	Vertosol	3
64.9	69.5	Moray	Vertosol	3
62.8	64.9	Avon	Vertosol	3
62.2	62.8	Funnel	Vertosol	5
60.3	62.2	Avon	Vertosol	3
46	60.3	Somerby	Vertosol	4
43.9	46	Blackwater	Vertosol	3
42.7	43.9	Ulcanbah	Sodosol	3

Start (km)	Finish (km)	Land System	Australian Soil Classification	Land Capability
35.7	42.7	Blackwater	Vertosol	3
19.9	35.7	Islay	Vertosol	3

Islay Land System (Vertosol)

The Islay land system is associated with gidgee plains with gilgaied clay soils on acid clay exposed within the tertiary weathered zone. The Islay land system is mostly found within the Belyando catchment, where the tertiary land surface and weathered zone have been partially removed. Due to the salinity and / or alkalinity, moderate erosion and low and unreliable rainfall, the Islay land system has a land class of three. Within the Islay land system there are five land units.

Based on the Queensland Combined Soils Database, possible soil profile characteristics, for the Islay land system are detailed in Table 2-15.

Table 2-15 Islay Land System Soil Characteristics

Depth (m)	Texture Grade	CEC (cmol/kg)	EC (dS/m)	ESP (%)	pH	Total N (cmol/kg)	Total P (cmol/kg)
0-0.07	Silty Clay	43.33	0.14	1.84	8.1	0.11	0.03
0.07-0.66	Silty Clay	40.45	0.34	1.78	8	0.06	0.03
0.66-1.09	Silty Clay	48.33	0.59	23.5	8.7	0.02	0.02

CEC cation exchange capacity; EC electrical conductivity; ESP exchangeable sodium percentage; N – nitrogen; P - phosphorous

Blackwater Land System (Vertosol)

The Blackwater land system is associated with brigalow plains with cracking clay soils on acid clay exposed within the tertiary weathered zone, which is similar to that of the Islay land system. The Blackwater land system comprises five land units.

The Blackwater land system is mostly found within the Belyando catchment, where the tertiary land surface and weathered zone have been partially removed. Due to the salinity and / or alkalinity, moderate erosion and low and unreliable rainfall, the Blackwater land system has a land class of three. Within the Blackwater land system there are five different land units, with varying differences.

Based on the Queensland Combined Soils Database, the soil profile characteristics are detailed in Table 2-16 for the Blackwater land system.

Table 2-16 Blackwater Land System Soil Characteristics

Depth (m)	Texture Grade	CEC (cmol/kg)	EC (dS/m)	ESP (%)	pH	Total N (cmol/kg)	Total P (cmol/kg)
0-0.7	Clayey Loam	43.33	0.13	12.15	6.9	0.07	0.06
0.7-0.82	Silty Clay	40.45	0.17	15.85	8.5	0.02	0.03
0.82-1.18	Silty Clay	48.33	1.97	17.7	8.1	0.02	0.04

Ulcanbah Land System (Sodosol)

Like both Islay and Blackwater land systems, the Ulcanbah land system comprises clay plains with Gidgee and cracking clay soils on shales and acid clay exposed within the tertiary weathered zone. The Ulcanbah land system is broken down into four land units.

The Ulcanbah land system is mostly found within the Belyando catchment, where the tertiary land surface and weathered zone have been partially removed. Due to the salinity and / or alkalinity, moderate erosion and low and unreliable rainfall, the Ulcanbah land system has a land class of three.

Based on the Queensland Combined Soils Database, the soil profile characteristics are detailed in Table 2-17 for the Ulcanbah land system.

Table 2-17 Ulcanbah Land System Soil Characteristics

Depth (m)	Texture Grade	CEC (cmol/kg)	EC (dS/m)	ESP (%)	pH	Total N (cmol/kg)	Total P (cmol/kg)
0-0.1	Silty Clay	43.33	0.14	3.55	8.4	0.11	0.03
0.1-0.77	Silty Clay	40.45	0.34	1.39	8.8	0.03	0.03
0.77-1.16	Silty Clay	48.33	0.59	14.0	8.7	0.01	0.02

Somerby Land System (Vertosol)

The Somerby land system is associated with brigalow and cracking clay soils on acid clay exposed within the tertiary weathered zone, similar to that of above land systems. There are six land units within this land system.

The Somerby land system is mostly found within the Belyando catchment, where the tertiary land surface and weathered zone have been partially removed. Due to the moderate erosion, shallow soils, salinity and / or alkalinity, and microrelief, the Somerby land system has a land class of four, meaning it has limited suitability for cultivation and / or pasture improvement.

Based on the Queensland Combined Soils Database, the soil profile characteristics are detailed in Table 2-18 for the Somerby land system.

Table 2-18 Somerby Land System Soil Characteristics

Depth (m)	Texture Grade	CEC (cmol/kg)	EC (dS/m)	ESP (%)	pH	Total N (cmol/kg)	Total P (cmol/kg)
0-0.11	Clayey Loam	43.33	0.14	1.84	7	0.11	0.03
0.11-0.16	Clayey Loam	5	0.04	1.8	7.2	0.08	0.04
0.16-0.81	Silty Clay	40.45	0.34	1.3	8.3	0.05	0.03
0.81-1.22	Silty Clay	48.33	0.59	13.87	8.7	0.02	0.02

Avon Land System (Sodosol)

The Avon land system is associated with gently undulating grassland with cracking clay soils on alkaline clays deposited within the Tertiary weathered zone. The Avon land system is broken down into four land units. The Avon land system is a depositional land system within the tertiary weathered zone.

Due to the salinity and / or alkalinity, moderate erosion and low and unreliable rainfall, the Avon land system has a land class of three, meaning it has potential use for cultivation with some moderate limitations.

Based on the Queensland Combined Soils Database, the soil profile characteristics are detailed in Table 2-19 for the Avon land system.

Table 2-19 Avon Land System Soil Characteristics

Depth (m)	Texture Grade	CEC (cmol/kg)	EC (dS/m)	ESP (%)	pH	Total N (cmol/kg)	Total P (cmol/kg)
0-0.03	Silty Clay	33.02	0.01	1.84	8	0.08	0.05
0.03-0.44	Silty Clay	48.08	1.11	6.89	7.6	0.05	0.02
0.44-0.97	Silty Clay	54.08	1.37	13.0	5.5	0.02	0.04

Funnel Land System (Vertosol)

The Funnel land system is a post tertiary land system associated with flooded alluvial plains with coolibah and cracking clay soils. The Funnel land system is broken down into five land units.

The Funnel land system has a land class rating of five, meaning it has a potential use for intensive grazing only, the major limitation is due to the very frequent overflowing that is likely to occur as it is within the lower alluvial plains.

Based on the Queensland Combined Soils Database, the soil profile characteristics are detailed in Table 2-20 for the Funnel land system.

Table 2-20 Funnel Land System Soil Characteristics

Depth (m)	Texture Grade	CEC (cmol/kg)	EC (dS/m)	ESP (%)	pH	Total N (cmol/kg)	Total P (cmol/kg)
0-0.23	Clayey Loam	51.25	0.11	1.84	6.3	0.13	0.1
0.23-0.95	Silty Clay	31.5	0.33	3.55	8.5	0.12	0.09
0.95-1.17	Silty Clay	25.38	0.72	7.81	7.2	0.02	0.03

Moray Land System (Vertosol)

The Moray land system is described as comprising plains and lowlands with gidgee and cracking clay soils on alkaline clay deposited within the Tertiary weathered zone. There are four land units within this land system. The Moray land system is a depositional land system within the Tertiary weathered zone. The land system is likely to be undulating to level grasslands and gidgee scrub on stone free gypseous clays.

Due to the salinity and / or alkalinity, moderate erosion and low and unreliable rainfall, the Moray land system has a land class of three meaning it has potential use for cultivation, with some moderate limitations.

Based on the Queensland Combined Soils Database, the soil profile characteristics are detailed in Table 2-21 for the Moray land system.

Table 2-21 Moray Land System Soil Characteristics

Depth (m)	Texture Grade	CEC (cmol/kg)	EC (dS/m)	ESP (%)	pH	Total N (cmol/kg)	Total P (cmol/kg)
0-0.03	Silty Clay	46.67	0.23	1.84	8	0.1	0.02
0.03-0.4	Silty Clay	46.73	0.7	6.9	7.5	0.04	0.01
0.4-0.96	Silty Clay	49.9	2.08	14.4	5.5	0.02	0.01

Louden Land System (Rudosol)

The Loudon land system is described as low hills with lancewood and some ironbark on weathered volcanics and Drummond basin sediments plus intervening lowlands with box, brigalow and blackwood. The soil types are generally shallow rocky soils. The land system has been broken down into six land units. The Loudon land system is further described as an erosional land system within the Tertiary weathered zone.

The Loudon land system has a potential use for only limited grazing, with major limitations being very steep slopes, rocks, shallow or sandy soils (land class of between seven and eight).

Based on the Queensland Combined Soils Database, the soil profile characteristics are detailed in Table 2-22 for the Louden land system.

Table 2-22 Louden Land System Soil Characteristics

Depth (m)	Texture Grade	CEC (cmol/kg)	EC (dS/m)	ESP (%)	pH	Total N (cmol/kg)	Total P (cmol/kg)
0-0.34	Sandy Loam	17	0.07	43.1	5.5	0.07	0.03
0.34-0.78	Silty Clay	9	0.08	1	4.7	0.04	0.01

Disney Land System (Kandosol)

The Disney land system is characterised by small lateritic mesas with ironbark and red or yellow earths on Tertiary sandstone; surrounding lowlands with box and brigalow and texture contrast soils on weathered Drummond Basin sediments.

The Disney land system has a potential use for limited cultivation and / or pasture improvement, and is susceptible to moderate erosion. The land system has a land class of four, due to shallow soils, salinity and / or alkalinity, with gilgai micro relief in parts.

Based on the Queensland Combined Soils Database, the soil profile characteristics are detailed in Table 2-23 for the Disney land system.

Table 2-23 Disney Land System Soil Characteristics

Depth (m)	Texture Grade	CEC (cmol/kg)	EC (dS/m)	ESP (%)	pH	Total N (cmol/kg)	Total P (cmol/kg)
0-0.27	Sandy Loam	7	0.14	2.3	6.7	0.08	0.01
0.27-0.9	Sandy Clayey Loam	15	0.8	44	9.3	0.05	0.01
0.9-1.19	Sandy Clayey Loam	18	0.97	40	6.5	0.01	0.01

Monteagle Land System (Sodosol)

The Monteagle land system is described as lowlands with box and texture contrast soils on slightly stripped Tertiary land surface.

The Monteagle land system has a potential use for limited cultivation and / or pasture improvement, and has a moderate erosion risk. The land system has a land class of four, due to shallow soils, salinity and / or alkalinity, with (gilgai) micro relief in parts

Based on the Queensland Combined Soils Database, the soil profile characteristics are detailed in Table 2-24 for the Monteagle land system.

Table 2-24 Monteagle Land System Soil Characteristics

Depth (m)	Texture Grade	CEC (cmol/kg)	EC (dS/m)	ESP (%)	pH	Total N (cmol/kg)	Total P (cmol/kg)
0-0.29	Loamy Sand	43.3	0.14	3.55	8.4	0.11	0.03
0.29-0.37	Loamy Sand	2	0.01	3.2	5.4	0.02	0.01
0.37-1.03	Loamy Clay	40.45	0.34	33	8.8	0.03	0.03

Banchory Land System (Vertosol)

The Banchory land system is described as alluvial plains with gidgee and cracking clay soils. The land system is within a post tertiary alluvial system, within the lower alluvial plains. This land system has a land class rating of five, meaning it has a potential land use of intensive grazing. The limitation within this land system is the very frequent overflow from streams/drainage lines.

Based on the Queensland Combined Soils Database, the soil profile characteristics are detailed in Table 2-25 for the Banchory land system.

Table 2-25 Banchory Land System Soil Characteristics

Depth (m)	Texture Grade	CEC (cmol/kg)	EC (dS/m)	ESP (%)	pH	Total N (cmol/kg)	Total P (cmol/kg)
0-0.07	Silty Clay	33.02	0.1	1.8	6.4	0.07	0.03
0.07-0.75	Silty Clay	31	0.15	1.8	8.5	0.05	0.02
0.75-1.05	Silty Clay	31.5	0.121	9.1	6.1	0.02	0.03

Lennox Land System (Kandosol)

The Lennox land system is associated with the plains and lowlands with silver leaved ironbark and yellow and red earths on intact tertiary surfaces. This land system is encountered on stable or moderately stripped tertiary land surfaces and has relief ranging from undulating to level.

The land system has a land use class of six, with the potential use limited to moderate grazing. The major limitations are low rainfall, soil fertility, and water holding capacity; stones and severe erosion.

Based on the Queensland Combined Soils Database, the possible soil profile characteristics are detailed in Table 2-26 for the Lennox land system.

Table 2-26 Lennox Land System Soil Characteristics

Depth (m)	Texture Grade	CEC (cmol/kg)	EC (dS/m)	ESP (%)	pH	Total N (cmol/kg)	Total P (cmol/kg)
0-0.33	Sandy Loam	3.7	0.02	3.26	6.7	0.03	0.01
0.33-1	Sandy Clayey Loam	7.6	0.02	4.6	5.6	0.02	0.01
1-1.2	Sandy Clayey Loam	8.67	0.02	3.13	6.5	0.02	0.01

Alpha Land System (Kandosol)

The Alpha land system is associated with alluvial plains with box vegetation and texture contrast soils in non-basaltic alluvium. The land system is within a post tertiary landscape, within the higher alluvial plains.

Due to the salinity and / or alkalinity, moderate erosion and low and unreliable rainfall, the Alpha land system has a land class of three meaning it has potential use for cultivation, with some moderate limitations.

Based on the Queensland Combined Soils Database, the soil profile characteristics are detailed in Table 2-27 for the Lennox land system.

Table 2-27 Alpha Land System Soil Characteristics

Depth (m)	Texture Grade	CEC (cmol/kg)	EC (dS/m)	ESP (%)	pH	Total N (cmol/kg)	Total P (cmol/kg)
0-0.39	Loamy Sand	15	0.05	3.26	6.7	0.01	0.04
0.39-0.72	Loamy Sand	5.57	0.04	2.66	6.5	0.02	0.02
0.72-1.22	Loamy Clay	19	0.06	5.5	7.7	0.02	0.04

2.3.4.3 Project (Rail) Section KCM

The KCM dataset covers the eastern 25 km portion of the Project (Rail).

The Kilcummin 1:100,000 map sheet is located on the north-western edge of Queensland's Central Highlands. Its centre is approximately 50 km north of Clermont and 190 km south-west of the coastal city of Mackay. The area comprises approximately 285,000 ha. Rainfed, broadacre cropping and grazing beef cattle are the predominant land uses of the surrounding region.

The KCM Project (Rail) section descends westwards from a ridge at 360 m to approximately 260 m. The soils in this section of the Project (Rail) are reported as being Vertosols, Sodosols, Rudosols and Kandosols.

Table 2-28 (together with the corresponding land class (refer Section 2.3.3), and GQAL status (refer Section 2.4) are described below according to their unique identifiers, using information within Shields *et al* (1993) and also from information extracted from the Queensland Combined Soils Database. The associated ASC has been inferred from the details contained within the soils report.

Table 2-28 Rail (West) and Rail (East) KCM Mapped Soil Types

Start (km)	Finish (km)	Soil Type	Australian Soil Classification	Land Suitability	GQAL Status
20.20	24.60	Kenmar melonhole phase	Vertosol	4	3
18.70	20.20	Kenmar melonhole phase	Sodosol	4	3
17.60	18.70	Fletcher	Sodosol	4	4
12.40	17.60	Lebanon	Kandosol	5	4
10.70	12.40	Villafranca	Kandosol	5	4
10.50	10.70	Lebanon	Kandosol	5	4
10.10	10.50	Villafranca	Kandosol	5	4
6.60	10.10	Heyford	Kandosol	5	4
2.50	6.60	Lebanon	Kandosol	5	4
2.20	2.50	Cherwell	Dermasol	5	5
0.95	2.20	Heyford	Dermasol	5	4
0.90	0.95	Cherwell	Dermasol	5	5
0.00	0.90	Heyford	Dermasol	5	4

Heyford Soil Type

A hard setting duplex soil with sandstone gravel and dark to red-brown, loamy sand to sandy clay loam surface and bleached subsurface over an alkaline, mottled grey-yellow and red-brown clay subsoil overlying sandstone. The soils on these areas have a drainage rating of three and a permeability rating of one. The soil profile for this soil type, as extracted from the Queensland Combined Soils Database, is summarised in Table 2-29 below.

Table 2-29 A Typical Profile for the Heyford Soil Type

Depth (m)	Texture Grade	CEC (cmol/kg)	EC (dS/m)	ESP (%)	pH	Total N (cmol/kg)	Total P (cmol/kg)
0-0.18	Loamy Sand	10.2	0.06	3.95	6.3	0.09	0.02
0.18-0.43	Loamy Sand	15.2	0.08	5.66	6.7	0.04	0.04
0.43-0.61	Silty Clay	17.7	0.16	21.0	7.5	0.04	0.02
0.61-1.07	Silty Clay	19.9	0.39	21.9	8.4	0.03	0.01
1.07-1.5	Loamy Silty Clay	20.4	0.51	33.1	8.2	0.02	0.03

These soils tend to be located on gently undulating plains and rises and formed from Permian sedimentary rocks. The predominant vegetation associated with this group is poplar box woodland.

Shields *et al's* (1993) assessment of land suitability for broadacre cropping for this soil group showed that the limiting factors were available water, soil physical factors, soil workability and water erosion. Therefore, this land is considered unsuitable for cropping due to extreme limitations.

The suitability of the land for grazing was limited by the available water, nutrient deficiency, soil physical factors, rockiness and vegetation (Shields *et al*, 1993). Therefore, this land is considered suitable for native pastures of low productivity over sown with shrubby stylos. After clearing, the regrowth of woody weeds was considered a hazard for this land type.

Cherwell Soil Type

A very rocky and gravelly, red-brown to dark, sand to sandy clay loam with acid to neutral reaction trend overlying sandstone by 600 mm depth. The soil in these areas has a drainage rating of five, and a permeability rating of three. The soil profile for this soil type is summarised in Table 2-30.

Table 2-30 A Typical Profile for the Cherwell Soil Type

Depth (m)	Texture Grade	CEC (cmol/kg)	EC (dS/m)	ESP (%)	pH	Total N (cmol/kg)	Total P (cmol/kg)
0-0.18	Loamy Sand	7.6	0.11	3.88	5.6	0.08	0.02
0.18-0.36	Sand	7.2	0.07	6.04	5.5	0.07	0.03
0.36-0.46	Sand	8.1	0.44	6.26	5.6	0.06	0.02

These soils are found on rolling low hills, undulating rises and plateau remains, overlying Permian sedimentary rocks. The predominant natural vegetation is lancewood scrub.

An assessment of land suitability for broadacre cropping (Shields *et al*, 1993) for this group showed that the limiting factors were available water, nutrient deficiency, soil workability, rockiness, water erosion and topography. Therefore, this land was considered unsuitable for cropping due to extreme limitations.

The suitability of the land for grazing was limited by the available water, nutrient deficiency, soil physical factors, rockiness and water erosion. Therefore, this land is considered suitable only for native pastures of low productivity. Clearing of vegetation was not recommended due to a high erosion risk (Shields *et al*, 1993).

Lebanon Soil Type

A hard setting duplex soil with ferruginised gravel and dark to brown, loamy sand to sandy clay loam surface, usually with a bleached subsurface, over a generally mottled grey-brown, yellow-brown and red clay subsoil with neutral to alkaline reaction trend overlying ferricrete. The soils on these areas have a drainage rating of three and a permeability rating of one. The soil profile for this soil type is summarised in Table 2-31.

Table 2-31 A Typical Profile for the Lebanon Soil Type

Depth (m)	Texture Grade	CEC (cmol/kg)	EC (dS/m)	ESP (%)	pH	Total N (cmol/kg)	Total P (cmol/kg)
0-0.21	Loamy Sand	10.5	0.06	3.71	6.6	0.09	0.03
0.21-0.51	Sand	12	0.05	10.09	6.7	0.07	0.03
0.51-0.76	Clayey Loam	17.1	0.13	19.04	7.4	0.05	0.02
0.76-1.23	Loamy Silty Clay	18.2	0.34	40.55	8.4	0.03	0.02

The associated landscapes are level to gently undulating plains and have formed from Cainozoic ferricrete and weathered sediments. They tend to be associated with poplar box open woodlands.

An assessment of land suitability for broad acre cropping for this group showed that the limiting factors were available water, nutrient deficiency, soil physical factors, soil workability and water erosion (Shields *et al*, 1993). Therefore, this land was considered unsuitable for cropping due to extreme limitations.

The suitability of the land for grazing was limited by the available water, nutrient deficiency, soil physical factors, water erosion and vegetation (Shields *et al*, 1993). Therefore, this land is considered suitable for native pastures of low productivity over sown with shrubby stylos. After clearing, the regrowth of woody weeds was considered a hazard for this land type.

Fletcher Soil Type

A firm to hard setting, red to grey-brown, non-cracking clay with neutral to alkaline reaction trend overlying unconsolidated sediments. The soil on these areas has a drainage rating of four and a permeability rating of two. The soil profile for this soil type is summarised in Table 2-33. These soils tend to be located on alluvial plains, overlying Quaternary alluvium. They are often associated with poplar box or coolabah woodlands.

Table 2-32 A Typical Profile for the Fletcher Soil Type

Depth (m)	Texture Grade	CEC (cmol/kg)	EC (dS/m)	ESP (%)	pH	Total N (cmol/kg)	Total P (cmol/kg)
0-0.13	Loamy Clay	28.4	0.16	6.59	7.4	0.14	0.06
0.13-0.85	Silty Clay	31	0.29	12.2	7.7	0.11	0.04
0.85-1.2	Loamy Silty Clay	30.5	0.79	11.67	6.2	0.02	0.04

An assessment of land suitability for broad acre cropping for this group showed that the limiting factors were available water, nutrient deficiency, soil physical factors, soil workability, wetness, flooding and topography (Shields *et al*, 1993). Therefore, this land was considered unsuitable for cropping due to severe to extreme limitations.

The suitability of the land for grazing was limited by the available water, soil physical factors, flooding and vegetation. Therefore, this land is considered suitable for highly productive native pastures but is only marginal land for sown pastures (Shields *et al*, 1993). The long term productivity of sown pastures was doubtful.

Kenmar melonhole Soil Type

A normal linear and lattice gilgai complex overlying buried layers. The mounds are self-mulching to firm, grey to grey brown clay with acid to alkaline reaction trend. The depressions are very fine self-mulching, dark to grey-brown, cracking clay with acid to alkaline trend. The soils on these areas have a drainage rating of three and a permeability rating of one. The soil profile for this soil type is summarised in Table 2-33.

These soils tend to be located on elevated, levels plains to undulating rises. They tend to form on overlying Cainozoic clay sediments and are often associated with gidgee or brigalow scrub.

Table 2-33 A Typical Profile for the Kenmar Soil Type

Depth (m)	Texture Grade	CEC (cmol/kg)	EC (dS/m)	ESP (%)	pH	Total N (cmol/kg)	Total P (cmol/kg)
0-0.1	Silty Clay	32.6	0.15	4.93	8.3	0.12	0.04
0.1-0.47	Silty Heavy Clay	34.8	0.34	12.63	8.3	0.07	0.03
0.47-1.35	Silty Heavy Clay	32.9	0.88	19.1	7.2	0.03	0.02

An assessment of land suitability for broad acre cropping for this group showed that the limiting factors were available water, soil physical factors, soil workability, micro relief and wetness (Shields *et al*, 1993). Therefore, this land was considered unsuitable for cropping due to severe limitations.

The suitability of the land for grazing was limited by the available water, nutrient deficiency, soil physical factors, water erosion and vegetation (Shields *et al*, 1993). Therefore, this land is considered suitable for native pastures or a range of sown pastures. After clearing, the regrowth of woody weeds was considered a hazard for this land type.

Villafranca Soil Type

Villafranca soil is a hard setting, red, massive, gradational soil with acid to neutral reaction trend overlying ferricrete. Table 2-34 summarises the soil profile for this soil type.

Table 2-34 A Typical Profile for the Villafranca Soil Type

Depth (m)	Texture Grade	CEC (cmol/kg)	EC (dS/m)	ESP (%)	pH	Total N (cmol/kg)	Total P (cmol/kg)
0-0.13	Loamy Sand	10.42	0.06	2.81	6.4	0.10	0.043
0.13-0.43	Loamy Sand	6.94	0.03	6.86	6.4	0.13	0.036
0.43-0.76	Sandy Clay	11.12	0.04	6.60	6.8	0.06	0.036

An assessment of land suitability for broad acre cropping (Shields *et al*, 1993) for this group showed that the soil is unsuitable for cropping due to a combination of water availability, nutrient deficiency, soil physical factors restricting plant growth, soil workability and water erosion limitations. The soils contain native pastures of low productivity but are suitable for over sowing with shrubby stylos.

2.3.5 Overview of Dominant Soil Orders

A review of available broad scale soil types and available literature has identified the following soil types mapped as present within the vicinity of the Project (Rail). These are described below using the ASC (Isbell, 2002):

- Vertosols - 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. Vertosols are mapped as dominating the landscape in the Project (Rail) area.
- Kandosols – the Kandosols soil order accommodates soils with weak or massive sub-soil structure, a clay content of greater than 15 per cent in the B horizon, no strong texture contrast and no carbonate throughout the profile.
- Dermosols – distinguished by their moderate to strong structured B2 (sub – soil) horizon and the lack of a strong texture contrast between the A and B horizons. These soils are not high in free iron (<5 per cent), nor are they calcareous throughout the profile. Dermosols are a diverse order, bringing together a wide range of soils with some common important properties.
- Tenosols – Tenosols may be considered as intermediate between Rudosols (characterised by having only a minimal development of soil features such as horizons) and Kandosols in which B horizon development is clearly expressed with more than 15 per cent clay. Tenosols thus encompass a fairly wide range of soils which apart from some A horizons, do not have a strong degree of horizon development.
- Chromosols – the essential feature of Chromosols is the strong texture contrast between the A and B horizons. They are distinguished from other texture contrast soils by not being strongly acidic (Kurosols) or sodic (Sodosols) in their upper B horizon. In their natural condition, these soils may have favourable physical and chemical properties but many now have hard setting surface layers with structural degradation caused by long term cultivation.
- Rudosols – soils with negligible (rudimentary) pedological organisation apart from the minimal development of an A horizon or the presence of less than 10% of B horizon. The soils are apedal or only weakly structured in A horizon. There is little texture or colour change with depth and cemented pans may be present as a substrate material.

- Sodosols – Sodosols are soils with a strong texture contrast between A horizons and sodic B horizons and which are not strongly acid.

Project (Rail) soil types are mapped in Figure 2-6.

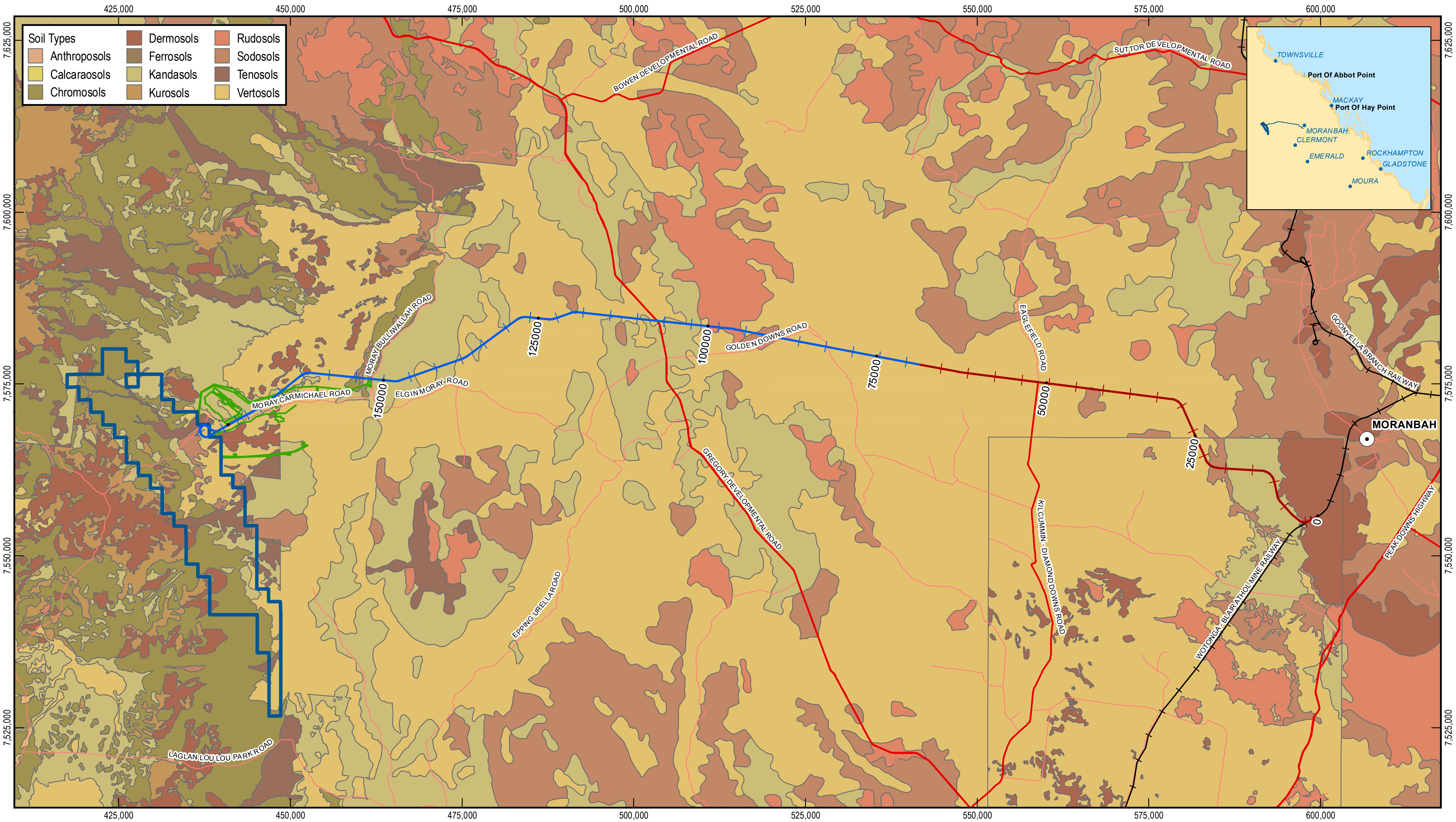
2.3.6 Acid Sulfate Soils

The State Planning Policy 2/02: Planning and Management of Development Involving Acid Sulfate Soils states that ASS occurs along coastal areas, generally where land elevation is less than 5 m AHD. However, ASS is known to also occur in some inland areas within river and lake beds, irrigation channels and in saline seepage areas. The Australian Soil Resource Information System (www.asris.csiro.au) for ASS was reviewed. Based on information in the ASS Atlas, there is an extremely low probability of encountering ASS within the Project (Rail) area.

2.3.1 Erodible Soils

Soil erodibility is determined by the rate of infiltration at the surface, permeability of the soil profile, coherence of the soil particles, lack of vegetative cover, loss of soil organic matter and surface sealing (Department of Main Roads, 2002). Soil types most susceptible to erosion are the texture contrast soils (duplex soils), particularly soils that are highly sodic as the higher sodium content results in soil particles being easily separated and hence, more easily mobilised by wind and water.

Table 2-35 details the erodibility ratings of the various soil types likely to be encountered along the Project (Rail) area. Included also are the relevant ASCs for the soil types.



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0 5 10 15 20 25

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- Town
- State Road
- Local Road
- Existing Railway
- Rail (West)
- Rail (East)
- Mine (Onsite)
- Mine (Offsite)

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Australian Soil Classification

Job Number	41-25215
Revision	D
Date	03-09-2012

Figure 2-6

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Data source: DERM: Combined Soils (2010); DME: EPC1690 (2010), EPC1080 (2011); © Commonwealth of Australia (Geoscience Australia): Localities, Railways, Roads (2007); Adani: Alignment Opt9 Rev3 (2012); Gassman/Hyder: Mine (Offsite) (2012); GHD: Northern Missing Link (2011). Created by: BW, CA

Table 2-35 Erodibility of soil types encountered along the Project (Rail)

Soil Types (ASC)	Description of Erodibility Characteristics	Erodibility Rating
Uniform sands and sandy loams (Rudosols and Tenosols)	Incoherent sand, loamy sand, clayey sand and coherent sandy loam with single grained massive structure. Coarse textured surface layers are generally either loose or incoherent or firm and weakly coherent. Raindrop splash can easily detach the soil particles. Subsoils are also susceptible to detachment.	Moderate (3)
Uniform loams and clay loams Massive (Kandasols) Structured (Rudosols, Tenosols and Dermosols)	Coherent loams, sandy clay loams and clay loams with massive to strong structure. The medium texture results in these soils being moderately permeable regardless of structure. Significant energy is required to detach such soils.	Very Low (1)
Uniform non-cracking clays (Dermosols)	Light to heavy clays with strong structure: ◗ Fine aggregates – the high clay content is offset by the strong structure and moderate permeability due to the fine aggregates ◗ Coarse aggregates – similar erodible characteristics to the uniform cracking clays	Very Low (1) Low (2)
Uniform cracking clays (Vertosols)	Light medium to heavy clays that shrink and crack open when dry and swell when wet, gilgai micro relief common. Moderate to strong structure but generally coarse aggregate below the surface resulting in slow to very slow permeability. Soils are erodible under considerable energy.	Low (2)
Sandy gradational Soils (Kandosols)	Texture gradually increases from a sandy surface to sandy clay loam or sandy light clay with depth; single grain to massive structure. Similar erodible characteristics to the uniform sands and sandy loams.	Moderate (3)
Loamy gradational soils (Dermosols and Kandosols)	Texture gradually increases from a loamy surface to sandy clay loam or clay with depth; massive to strong structure. These soils have a coherent medium textured surface that grades into clay subsoil. The soils are moderately permeable regardless of subsoil structure and require considerable energy to detach. The high proportion of clay sized particles makes them susceptible to erosion by running water.	Low (2)
Texture contrast soils (non-dispersive) (Chromosols)	Sandy or loamy surface abruptly overlaying non dispersive and generally friable clay subsoil. The erodibility of the surface and subsurface varies from moderate- for the sandy layers to low- for the loamy layers. The structure of the clay subsoil varies and profile permeability varies from slow to moderate. The clay particles in the subsoil are not prone to dispersion but their light weight renders them very susceptible to erosion by running water.	Moderate (3)

Soil Types (ASC)	Description of Erodibility Characteristics	Erodibility Rating
Texture Contrast Soils (dispersive) (Chromosols and Sodosols)	◗ Sandy or loamy surface abruptly overlying a hard, dispersive clay subsoil ◗ If soil is sodic (ESP 6-14 per cent) and/or Ca:Mg <0.5 ◗ If soil is strongly sodic (ESP >15 per cent) and/or Ca:MG <0.1	High (4) Very High (5)

Source: Department of Transport and Main Roads, 2010.

2.4 Good Quality Agricultural Soils

The Queensland Government recognises the importance of land that is capable of sustaining long-term agricultural practices for present and future agricultural commodities. Therefore, it is required that the location and extent of GQAL be identified and included in strategic plans, where present.

GQAL is land that is capable of sustainable use for agriculture with a reasonable level of inputs and without causing degradation of land or other natural resources. There are four Agricultural Land Classes (A to D) defined for Queensland as detailed in Table 2-36. GQAL is defined as Class A agricultural land, and in some cases includes Class B agricultural land, under the Agricultural Land Class ranking.

Table 2-36 Agricultural Land Classes

Class	Description
Class A	**Crop land** – land that is suitable for current and potential crops with limitations to production which range from none to moderate levels.
Class 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.
Class C	**Pasture land** – land that is suitable only for improved or native pastures due to limitations which preclude continuous cultivation for crop production; but some areas may tolerate a short period of ground disturbance for pasture establishment.
C1	Land suitable for sown pastures with moderate limitations
C2	Land suitable for sown pastures with severe limitations
C3	Land suitable for light grazing of native pastures in inaccessible areas
Class 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.

Source: DPI and Department of Housing, Local Government and Planning (DHLGP), 1993

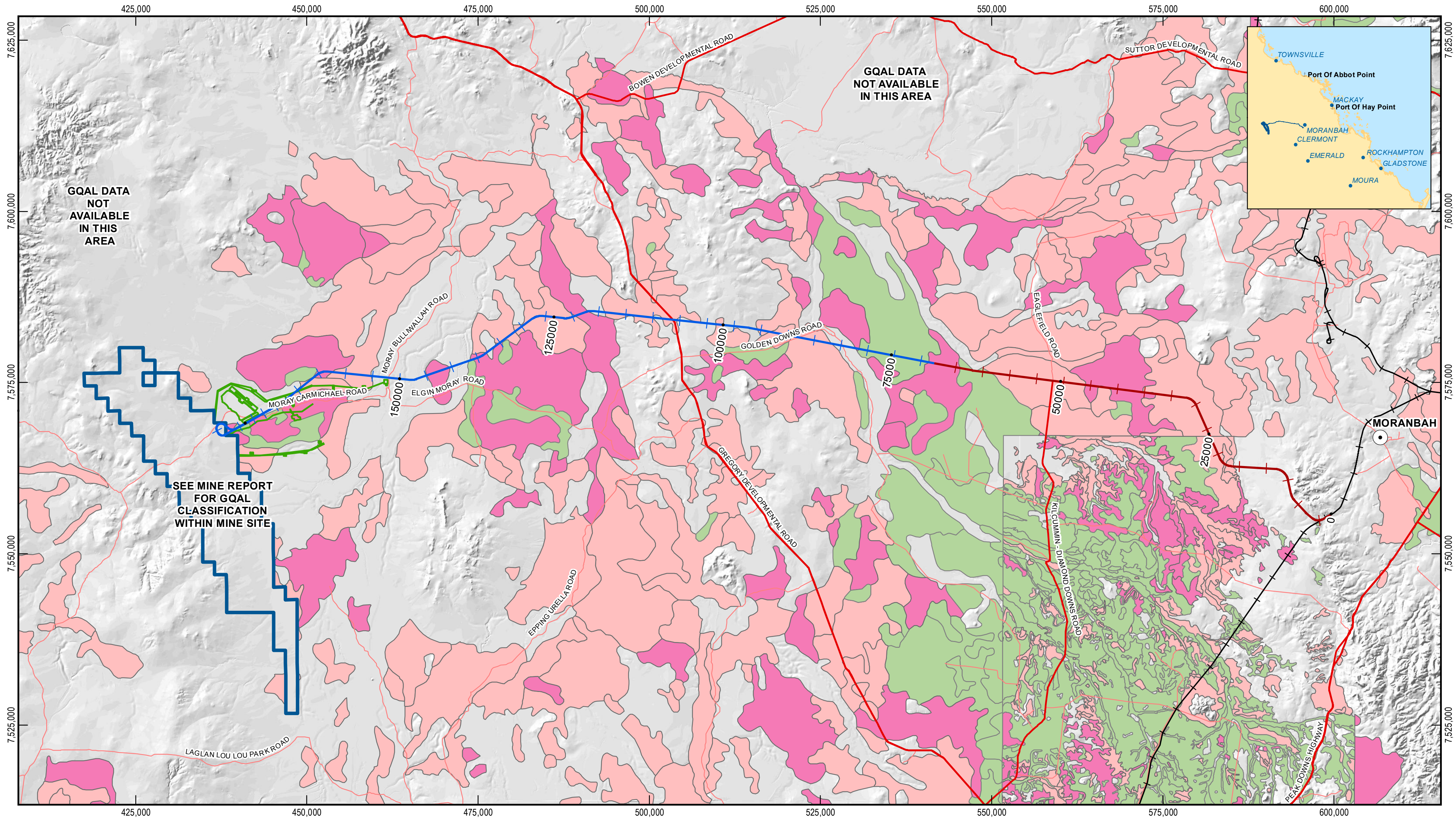
Australia has a limited supply of good quality agricultural land, with only 1-2 per cent of land supporting highly productive agriculture. Environmental impacts from farming in these lands are easier to manage than in other areas, as the soil, topographic and climatic conditions are more favourable. Like any limited and non-renewable resource, it is important to conserve this land and State Planning Policy 1/92 Development and the Conservation of Agricultural Land (SPP 1/92) sets up the policy basis for protecting land that is suitable for agricultural production.

The relevant reports and mapping data used to assess GQAL for the area potentially impacted on by the Project (Rail) included:

- Lands of the Nogoa – Belyando Area, Queensland, Land Research Series No. 18, Commonwealth Scientific and Industrial Research Organisation (CSIRO)
- Soils and Agricultural Use, in the Kilcummin Area, Central Queensland, Project Report Series: QO93011
- Belyando Shire Council Planning Scheme Land Characteristics Map, Good quality agricultural land 1:100,000 (2008). Integrated Planning Act 1997, Planning Scheme for Belyando Shire
- Planning Guidelines for the Identification of Good Quality Agricultural Land, 1993

The above studies and their associated data sets allowed for a desktop assessment of GQAL within the Project (Rail) area. Belyando Shire GQAL map (2008) was identified as the most recent GQAL mapping completed by the state government for the Project (Rail). Belyando Shire Planning Scheme recognizes GQAL classes A, B and C1 as GQAL land and only these classes are shown in Figure 2-7.

Land mapped as suitable for cropping (Class A) is limited within the Project (Rail) area. Land considered marginal for cropping (Class B) is more widespread along the Project (Rail) albeit still limited in extent. Class C1 agricultural land, land considered suitable only for sown pastures with moderate limitations, dominates the landscape in the vicinity of the Project (Rail). The Project (Rail) also traverses through pockets of non-agricultural land along the rail corridor, particularly at the intersections of roads, creeks and at the Goonyella rail system connection.



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0 5 10 15 20 25

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- Town
- State Road
- Local Road
- Existing Railway
- Rail (West)
- Rail (East)
- Mine (Onsite)
- Mine (Offsite)

Good Quality Agricultrual Land

- A
- B
- C1

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Carmichael Coal Mine and Rail Project

Good Quality Agricultural Land

Job Number	41-25215
Revision	D
Date	03-09-2012

Figure 2-7

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Data source: Belyando Shire Council Planning Scheme: GQAL (2009); (DME: EPC1690 (2010), EPC1080 (2011); © Commonwealth of Australia (Geoscience Australia): Localities, Railways, Roads (2007); Adani: Alignment Opt9 Rev3 (2012); Gassman/Hyder: Mine (Offsite) (2012). Created by: BW, CA

2.5 Strategic Cropping Land

The Queensland Government considers that the best cropping land, defined as strategic cropping land, is a finite resource that must be conserved and managed for the longer term. As a general aim, planning and approval powers should be used to protect such land from those developments that would lead to its permanent alienation or diminished productivity. Two areas of strategic cropping land are identified, namely Protection Areas and Management Areas.

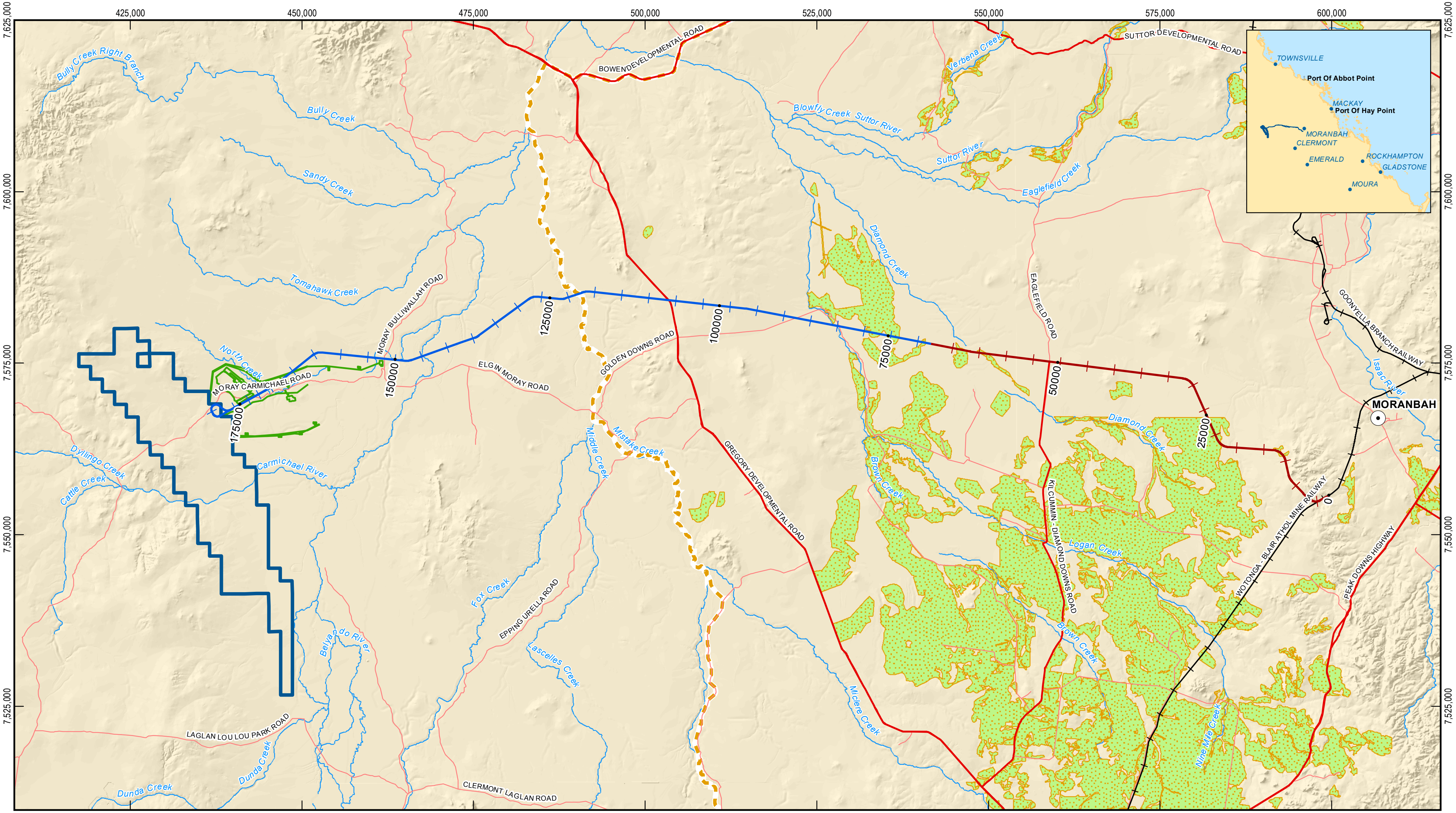
On 6 December 2011, the *Strategic Cropping Land Act 2011* was given assent by the Governor in Council and commenced on 30 January 2012. The *Strategic Cropping Land Act 2011* is supported by the Strategic Cropping Land Regulation 2011 and State Planning Policy 1/12: Protection of Queensland’s Strategic Cropping Land (SPP 1/12). SPP1/12 is designed to ensure that planning and development assessment includes appropriate consideration of strategic cropping land.

SPP 1/12 will operate in tandem with SPP 1/92, which applies to a broader range of agricultural lands.

Trigger maps published by DERM (2010) were reviewed and approximately 120 km of the Project (Rail) corridor traverses the western extent of the strategic cropping land Management Area in the western cropping zone. There are no strategic cropping land Protection Areas within the Project (Rail) vicinity.

Strategic cropping land is limited in extent within the Project (Rail) area and occurs in fragmented parcels. The Project (Rail) corridor does traverse areas mapped as strategic cropping land within the western cropping zone. Figure 2-8 shows the extent of mapped strategic cropping land within the vicinity of the Project (Rail) (refer Section 3.4.2 for discussion on potential impacts).

As this is a desktop assessment, the mapped strategic cropping land is yet to be confirmed against the eight criteria prescribed in the legislation. If necessary, the land may be assessed for a history of cropping.



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0 5 10 15 20 25

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- Town
- State Road
- Local Road
- Watercourse
- Existing Railway
- Rail (West)
- Rail (East)
- Mine (Onsite)
- Mine (Offsite)
- Strategic Cropping Land
- Western Cropping Boundary

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Carmichael Coal Mine and Rail Project

Strategic Cropping Land Overview
Western Cropping Only

Job Number	41-25215
Revision	D
Date	03-09-2012

Figure 2-8

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Data source: DERM: Strategic Cropping Land, Western Cropping Boundary (2011); DME: EPC1690 (2010), EPC1080 (2011); © Commonwealth of Australia (Geoscience Australia): Localities, Railways, Roads (2007); Adani: Alignment Opt9 Rev3 (2012); Gassman/Hyder: Mine (Offsite) (2012); GHD: Northern Missing Link (2011). Created by: BW, CA

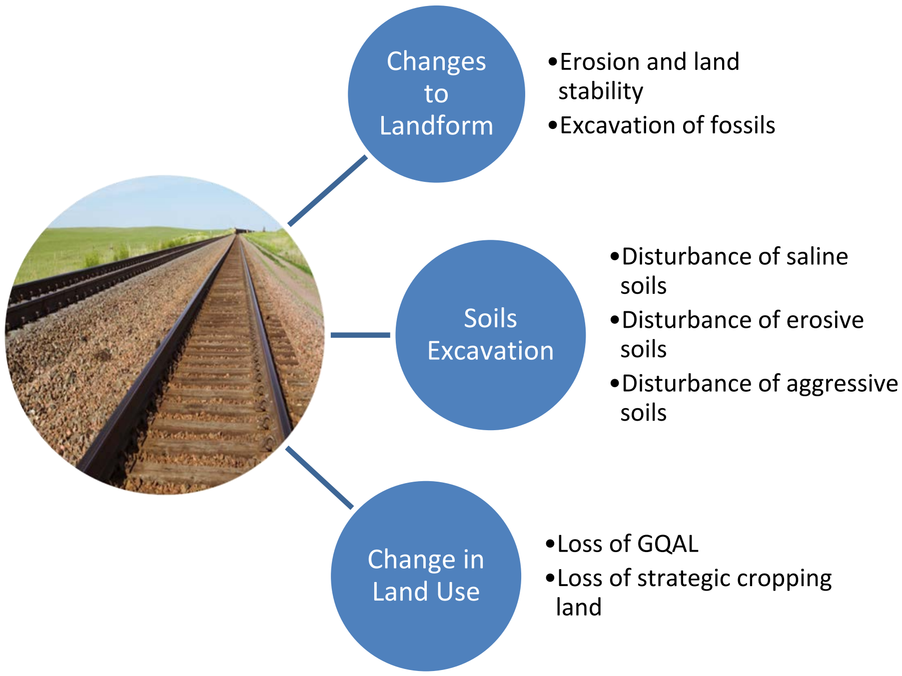
3. Potential Impacts and Management Measures

3.1 Overview

Potential impacts associated with the development of the Project (Rail) relevant to soils principally relate to the construction phase works and permanent alteration of land form.

Figure 3-1 provides a conceptual overview of the potential impacts which are discussed in the following sections herein.

Figure 3-1 Conceptual Diagram of Potential Impacts



To date assessment is based on desktop data and mapping. While this is considered appropriate for the EIS to identify broad scale potential impacts and advise on appropriate management and control measures, it is recognised that further soil survey will be required to better define specifics and establish further controls during the construction and operation phases of the Project (Rail) as discussed below and in Section 1.4.2.

A soil survey will facilitate the following:

- Ground truthing and verification (or refuting) of mapped soil types within the Project (Rail)
- Identification and mapping of salinity discharge areas
- Validation of GQAL mapping and allocation of a GQAL class to each soil type encountered
- Validation of strategic cropping land mapping and confirmation of strategic cropping land status

3.2 Changes to Landform

3.2.1 Erosion and Land Stability

Potential Impact

The potential impacts of the Project (Rail) include erosion risk and land slip based on slope. The construction of the Project (Rail) may impact topography particularly in areas associated with the Belyando River crossing, cuttings in the vicinity of the Goonyella system connection and the balloon loop near the Mine Site.

A localised change to landform (where the Project (Rail) is situated) will be an unavoidable result of the Project (Rail). In order to construct the Project (Rail) there will be requirements to fill and cut within the current landscape. While the Project (Project) will be confined to a 95 m wide corridor, the nature of the Project (Rail) will result in the final contours after construction differing from the original landform.

Topographically the land traversed by the Project (Rail) is considered to be relatively flat (elevations range between 200 m and 360 m AHD) and no significant landforms have been identified as present within the Project (Rail) area.

Landform, hydrology and hydrogeological conditions are closely connected (refer Volume 4 Appendix AB Rail Hydrology Report and Volume 4 Appendix AC Rail Hydrogeology Report, respectively). It is likely that drainage, including groundwater infiltration, sheet flow and creeks / streams will be altered to varying degrees as a result of this Project (Rail). This may result in impacts on downstream ecosystems due to increases or decreases in runoff and redirection of drainage lines.

Management Measures

In general, works within topographical features that pose a risk to the environment from erosion due to slope length and gradient (e.g. the Belyando River crossing), are to be avoided, where possible, and carefully managed during wet weather periods and erosive rainfall events. As water is the main cause of detachment of exposed soils, the other being wind, works are required to be managed to avoid increasing the risk of erosion due to climatic conditions in areas where the topographical features are considered to be most susceptible to erosion.

Managing the landforms in a way that will not alter the overall catchment behaviour is an important part in reducing the impacts on the change to landform. The following matters will be addressed to facilitate that this aspect is managed appropriately:

- Maintain drainage flows and pathways into the various catchments that will be affected by the Project (Rail) (refer to Volume 4 Appendix AB Rail Hydrology Report for discussion on afflux and surface water flows)
- Maintain the integrity of topsoil resources (associated with construction and temporary disturbances outside of the rail corridor) as close to pre-disturbance conditions as possible, which may require the addition of ameliorants
- Maintain the overall catchment gradients as close to that of pre-disturbance condition
- Carefully manage (through appropriate erosion and sediment controls, amongst others) areas of steep slopes and areas that will require significant landform change

3.2.2 Excavation of Fossils

Potential Impact

There is limited potential for fossils to be encountered during the Project (Rail) construction. Rail construction is anticipated to include generally shallow earthworks with lower potential to intersect weathered rocks with intact fossils. Available 1:250,000 geology mapping of the Project (Rail) area does not indicate the presence of recorded fossils.

Management Measures

Not applicable.

3.3 Soils Excavations

3.3.1 Soil Salinity

Potential Impact

Removal of vegetation from some environments results in a rise of the water table which in turn can lead to the accumulation of soluble salts on the soil surface. This process is known as secondary salinisation. Salt accumulation in soils can have a profound effect on development and catchment health. It can lead to die back in non-salt-tolerant vegetation and result in increased erosion hazard due to loss of groundcover and soil structural decline causing increased levels of runoff. Secondary salinisation can also affect infrastructure causing damage to building foundations, the breaking up of road pavements, and the corrosion of pipes and underground services.

There has been no field assessment undertaken at this stage to identify the location of discharge zones or potentially high risk salinity areas.

Information on observed depths to groundwater in bores within the vicinity of the Project (Rail) (refer Volume 4 Appendix AC Rail Hydrogeology) suggests that groundwater is typically encountered between around 15 and 75 m below ground level. Interaction between surface water and groundwater resources in the Project (Rail) area is likely to be limited to major watercourses including the Belyando River and Mistake Creek. Flows in these river systems are relatively persistent and permanent to semi-permanent waterholes are maintained year-round suggesting a degree of groundwater support. As such in the unlikely event that high risk saline areas are identified, they will be localised.

Management Measures

Appropriate management measures will reduce the potential to increase salinity of soils and groundwater within the Project (Rail) area:

- Further geotechnical investigations undertaken during detailed design will refine data with regard to soil salinity level, substrate lithology and other geological features
- Dewatering of shallow groundwater, if required for bridge pile and/or culvert construction, will be of a short duration and no long-term impacts are expected. However, if extended dewatering is identified during detailed design and major drawdown of the alluvial aquifer is expected, a groundwater management plan may be required. The management plan will include objectives and targets to be met and detail monitoring requirements (refer Volume 4 Appendix AC Rail Hydrogeology Report).

- Clearing will be confined to the Project (Rail) corridor and infrastructure areas and minimised wherever possible, particularly in areas where temporary infrastructure is to be established. Existing trees and shrubs, particularly in discharge and just above the discharge areas, will be retained as far as is practicable. This will assist in management of the water table and prevent salinisation. This retention of vegetation assists in maintaining groundwater levels at sufficient depths below ground level. This prevents salt accumulation from occurring in the topsoil by preventing capillary rise from occurring.
- Temporarily disturbed areas will be stabilised as soon as practical by reinstating topsoil and subsoil and compacting replaced soils
- Any bare ground associated with temporary infrastructure (eg construction camps) after the completion of the Project will be re-vegetated in line with pre clearing conditions, such as suitable pasture and native vegetation

3.3.2 Soil Erosion

Potential Impact

The construction and operation of the Project (Rail) will result in a range of changes to the landscape that will increase the risk of erosion, these include:

- Clearing of vegetative cover
- Changes in topography, drainage patterns and localised concentration of storm water flows due to construction of both access tracks and the rail corridor
- Excavation and stockpiling of material
- Construction during high rainfall events, particularly erosive rainfall events
- Constructing through areas with high soil erodibility risks
- Constructing in areas of high risk slope gradient and length

Topographical features, soil types and construction methods will be the primary drivers for erosion risk during the construction of the rail and associated infrastructure. The soil types likely to be traversed during the construction each have varying erosion risks.

Sediments that are entrained in water runoff have the potential to collect in the surface waters. The coarser soil particles such as sands and silts will deposit as the velocity of water slows down, whilst the suspended clays will remain in suspension until the water becomes still or mixes with saline waters.

Deposition of elevated levels of coarse and fine sediments can cause adverse effects on aquatic and estuarine ecosystems. Benthic communities can be smothered reducing light transmission through water, resulting in lowered ability for aquatic plants to function and generating negative impacts for organisms that rely on these plants for food and shelter.

Loss of topsoil and to a lesser extent subsoil from the construction area is important in terms of rehabilitation success. Topsoil is the most valuable resource in relation to rehabilitation and needs to be retained onsite and in a good re-usable condition.

Management Measures

Progressive rehabilitation will be undertaken to stabilise temporarily disturbed areas as quickly as practical and to limit erosion. Erosion and sediment control measures will be employed, which are consistent with the practices described in the IECA, Best Practice Erosion and Sediment Control Guideline, 2008.

Prior to construction commencing, an ESCP will be developed in accordance with IECA, 2008, and will be used during the duration of the construction (refer Volume 3 Section 13 Environmental Management Plan). The ESCP will focus on all aspects of construction and provide the required performance criteria for all controls to be implemented across the Project. The ESCP will be referred to when developing all onsite detailed ESCP's.

3.3.3 Sodic, Dispersive and Aggressive Soils

Potential Impact

A soil is considered sodic when sodium reaches a concentration where it starts to affect soil structure, which in Australian soils is commonly at an ESP of > 6 per cent (Isbell, *et al* 1983). When sodic soils are wetted the sodium weakens the bonds between soil particles resulting in clay swelling causing slaking or dispersion (Rengasamy and Walters, 1994). Such dispersion may occur in sodic soils without any disturbance at all. The dispersed clay particles can be easily moved by water or wind and can migrate through the soil clogging soil pores and reducing infiltration and drainage which causes higher run-off volumes. Dispersed clay particles may also be entrained in water and can contribute to water pollution. This may lead to a range of problems for construction sites including high water run-off and erosion rates, water pollution, tunnel formation, reduced workability, difficulty with vegetation establishment, and reduced vegetation growth due to low water holding capacity and root penetration (Raine and Loch, 2003).

It is important to note that not all sodic soils are dispersive and not all dispersive soils are sodic. Other factors such as salinity, texture, clay mineralogy and organic matter can all influence soil dispersion. Dispersive soils can be problematic for construction and maintenance activities if not managed well and therefore will be investigated so that their constraints can be addressed in design and project planning.

Aggressive soils are those that have chemical or physical properties that are restrictive to plant growth. Such properties include elevated sodicity, salinities, or acidities (and less commonly high alkalinities). Inversion of these soils during excavation and reinstatement may result in ongoing maintenance issues and costs due to the formation of soil surfaces that are restrictive to vegetation establishment and plant growth.

Areas of Sodosols have been identified along the Project (Rail) route. Sodosols are characterised as being texture contrast soils (i.e. the topsoil is of a lighter texture than the subsoil) in which the subsoil is sodic and not strongly acidic.

Of the sodic soils, topsoils tend to be *marginally sodic* to *sodic* with ESP's mostly ranging between 5 per cent to 15 per cent with a few occurrences of *strongly sodic* soil (ESP's 15 per cent to 25 per cent). In the subsoils sodicity is much greater tending towards strong sodicity with areas of soils with ESPs that exceed 25 per cent.

Bringing sodic subsoils to the surface may result in highly erodable surfaces with surface crusting and hard setting issues effecting vegetation establishment and growth.

Management Measures

For Project (Rail) areas associated with temporary activities (e.g. construction camps) the reinstatement of acidic or saline soils may be problematic due to reduced capacity to re-establish vegetation and stabilise surfaces. Whilst sodic soils and acidic soils may be easily ameliorated (gypsum for sodic soils, and lime for acidic soils) this is costly and resource intensive. Saline soils are more difficult to ameliorate, and need to generally be capped with non-aggressive soil if vegetation establishment is desired.

A soil management plan will be developed detailing any treatment and management requirements for sodic, dispersive and aggressive soil within the Project (Rail) area.

3.3.4 Acid Sulfate Soils

Potential Impact

Mapping indicates the ASS is unlikely to be present within the Project (Rail) Study Area.

Management Measures

Not applicable.

3.4 Change in Land Use

3.4.1 Good Quality Agricultural Land

Potential Impact

The Project (Rail) has the potential to impact areas mapped as GQAL, based on the former Belyando Shire Council's Planning Scheme 2009 GQAL mapping.

The Project (Rail) has the potential to fragment land parcels leading to a reduction and loss of access to agricultural land. GQAL mapping indicates that in the order of 1334 ha of GQAL (Class A, B and C1) will potentially be impacted as a result of Rail (west) and Rail (east), as detailed in Table 3-1 (Belyando Shire Council Planning Scheme, 2008). Class C1 land, or pasture land classed as being suitable only for improved or native pastures due to limitations which preclude continuous cultivation for crop production, comprises 54 per cent of the potentially impacted area.

Table 3-1 Good Quality Agricultural Land within Project (Rail)

GQAL Class	Area of GQAL within Rail (West) and Rail (East)*	
	ha	Per cent
A	158	12
B	454	34
C1	722	54
Total	1334	100

*Total area calculation based on 95 m Rail (East) and Rail (West) corridor.

Management Measures

The objective is to minimise the impact on GQAL. Potential impacts on GQAL have been avoided and minimised through route selection whereby GQAL constraints (amongst others) were considered.

The Project (Rail) alignment largely avoids land mapped as being Class A GQAL and attempts to traverse the outer extremes of Class B mapped areas to avoid and minimise fragmentation (refer Figure 2-7).

Mitigation and management measures to further avoid or minimize potential impacts on agricultural productivity of soils will include:

- Continued consultation with directly affected landowners in relation to the limiting effects of fragmentation, for example by providing stock crossings and other crossings as necessary and the provision of compensation.
- Maintain surface drainage patterns through design of culverts and cut/fill areas. Where changes in flows cannot be avoided, soil stabilization to prevent salinisation or other forms of soil degradation will be considered.
- Limiting overall areas of disturbance during construction
- Limiting vehicle movements to designated access tracks during construction
- Setting aside all stripped topsoil for use in reinstatement. Topsoil stockpiles will be managed to maintain soil fertility and other soil properties
- Develop and implement an ESCP (refer Volume 3 Section 13 Environmental Management Plan). Erosion control structures will remain in place until reinstatement is complete
- Reinstating all temporarily disturbed areas progressively during and after construction. Reinstatement will be as close as possible to pre-construction conditions. If soils have been damaged, reinstatement will include appropriate amelioration measures such as fertilizer to restore soils to pre-construction productivity.
- Ripping soils in areas where compaction may have occurred
- Develop and agree to a soil survey methodology with the Department of Natural Resources and Mines (DNRM) for the Project (Rail) to better define the presence and nature of GQAL within the Project (Rail) and developing additional management measures as appropriate.

3.4.2 Strategic Cropping Land

Potential Impact

In accordance with the *Strategic Cropping Land Act 2011*, a permanent impact (in relation to the Project (Rail) is defined as development that impedes the land from being cropped for at least 50 years and results in the land being unable to be restored to its pre-development condition.

Six individual polygons of strategic cropping land mapped within the western cropping zone will be traversed by the Project (Rail). As detailed in Table 3-2, strategic cropping land mapping indicates that in the order of 115 ha will potentially be impacted by the Project (Rail).

Table 3-2 Strategic Cropping Land (management) within the Project (Rail)

Chainage Start	Chainage Finish	Total Strategic Cropping Land Polygon Area	Area of Strategic Cropping Land within Project (Rail)*
km	km	ha	ha
10.7	12.4	124	15.2
20.2	24.6	37431	42.4
60.3	61.3	280	9.1
63.6	64.9	476	12.3
69.5	70.1	1281	5.1
73.5	75.2	9395	16.1
76.3	77.8	9395	14.9

*Total area calculation based on 95 m Project (Rail) corridor.

Assessment of impacts on strategic cropping land is based on desktop data and mapping. Areas currently mapped as strategic cropping land within the Project (Rail) have not been assessed against the eight criteria to confirm that the mapped strategic cropping land is strategic cropping land. Further, potentially impacted areas have not been assessed for a history of cropping as a result of land access constraints. However, it is understood that only a single area adjacent to the Project (Rail) is irrigated for the production of pasture crops.

Management Measures

Potential impacts on strategic cropping land have been avoided and minimised through route selection. Where mapped strategic cropping land is unable to be avoided, the route selection process has considered (amongst other environmental, social, cultural, economic and technical constraints) the placement of the Project (Rail) such that it traverses around or as close as possible to, the edges of polygons to minimise fragmentation.

The SCL Act provides for a number of alternatives in dealing with strategic cropping land. It may be agreed that a financial contribution commensurate with the area of impact on all mapped potential strategic cropping land is the most sensible and conservative outcome in order to manage the potential impacts. Alternatively, measures to further avoid or minimise potential impacts would include:

- Develop and agree a soil survey methodology with DNRM for the Project (Rail) to determine the actual presence of strategic cropping land prior to construction. This survey methodology will consider evaluation of soils within the western cropping zone and in particular those mapped as strategic cropping land against eight criteria set by prescribed in the legislation
- Ongoing consultation with landowners and consideration of compensatory measures where there are unavoidable impacts to SCL (management) areas
- If areas are confirmed as strategic cropping land, a cropping history assessment will be undertaken
- Limiting overall areas of disturbance during construction
- Reinstating all temporarily disturbed areas progressively during and after construction. Reinstatement will be as close as possible to pre-construction conditions. Where soils may have been damaged, reinstatement will include appropriate amelioration measures to restore soils to pre-construction productivity and ripping soils in areas where compaction may have occurred

- If areas are confirmed as strategic cropping land mitigation will be required for infrastructure and activities considered permanent (ie rail and service road infrastructure). A Deed of Agreement will be established between Adani and the Department of Agriculture, Fisheries and Forestry (DAFF) to facilitate mitigation.

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4. Conclusion

The Project (Rail) has an east-west orientation, starting in the west at the juncture with the Mine Site at approximately 240 m AHD. Moving eastward, the slope gently leads down onto a plain before rising to 220 m AHD near the Gregory Developmental Road, approximately 75 km east of the Mine Site. The Project (Rail) crosses another plain for approximately 50 km, before rising to a crest (360 m AHD) to the south of Moranbah.

A number of soil types have been mapped within the Study Area. Vertosols are mapped as dominating, with Chromosols and Sodosols occupying large expanses. Other soil types mapped as present are Kurosols, Kandosols, Rudosols and Tenosols. A field survey will be undertaken to delineate further the soil types within the Study Area and the presence (or not) of GQAL and strategic cropping land. Problematic soils such as saline, sodic, acidic and dispersive soils will be present along the Project (Rail) area. The Project (Rail) is predicted to fragment and sterilise mapped GQAL and strategic cropping land areas.

The main impacts associated with the Project (Rail) will be impacts to agricultural land and increased risk of erosion in areas of construction and operation. The presence of problematic soils will also pose risks for successful rehabilitation.

The following will be undertaken prior to construction:

- Develop and agree to a soil survey methodology with DNRM for the Project (Rail) recognising the guidelines as follows:
  - Australian Soil and Land Survey: Guidelines for Survey Soil and Land Resources (McKenzie *et al*, 2008)
  - Land Suitability Assessment Techniques. (DME, 1995)
  - ASC (Isbell, 2002)
  - Australian Soil survey and Land Survey Field Handbook. (National Committee on Soil and Terrain, (NCTS) 2009)
  - Protecting Queensland's Strategic Cropping Land – Guidelines for Applying the Proposed Strategic Cropping Land Criteria (DERM, 2011)
  - Planning Guidelines: the Identification of Good Quality Agricultural Land (DPI/DHLGP) 1993)
- The soil survey methodology will determine methods to confirm the GQAL status of land impacted, the location of major soil types, the strategic cropping land status of mapped strategic cropping land areas, the presence of aggressive soils and topsoil stripping depths.
- Development of an ESCP in accordance with the Best Practice Erosion and Sediment Control (IECA, 2008) guidelines
- Field works to record the current salinity status of risk areas

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Appendix A

Terms of Reference Cross-reference

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Terms of Reference Requirement/Section Number	Section of this Report
Section 3.2.2 Topography, Geology and Soils	
Provide maps locating the project in state, regional and local contexts	Figure 1-1
Provide a description, map and series of cross-sections of the surficial and solid geology of the project area	Section 2.2 Figure 2-3
Describe geological properties that may influence ground stability, OH&S or quality of stormwater	Sections 2.1.2 and 2.1.3
Review and discuss existing land system and land unit data of the Nogoa-Belyando area	Section 2.3.2 and 2.3.4
A soil survey should be conducted at 1:100,000 scale following standards in the Land Suitability Assessment Techniques in the *Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland*	Sections 1.4 and 4
Describe soil profiles according to the *Australian Soil and Land Survey field Handbook* grouped according to parent material and position in the landscape	Section 2.3.4 Figure 2-5
Assess and document the depth and quality of useable topsoil and subsoil to be stripped and stockpiled for rehabilitation, and the physical and chemical properties of the soils	Sections 1.4 and 4
Acid sulfate soil (ASS) investigations should be undertaken and ASS management plan prepared	Section 2.3.6
Mineral Resources	
Summarise the results of studies and surveys undertaken	Volume 2 Section 2
Describe in detail the location, tonnage and quality of the mineral, extractive and petroleum and gas resources	Volume 2 Section 2
Provide maps showing the general location of the project area, in particular: Location and aerial extent of the mineral resources to be developed or mined Location and boundaries of mining tenure (granted or proposed) which to project area is / will be subjected Location of proposed mine excavation(s) Location and boundaries of project sites Location and boundaries of any other features (waste / spoil dumps, water storage, etc) Location of any proposed buffers surrounding the working areas Any part of the resource not intended to be mined and/or may be sterilised by operations	Volume 2 Section 2

Terms of Reference Requirement/Section Number	Section of this Report
Section 3.2.2 Topography, Geology and Soils	
Potential Impacts and Mitigation Measures	
Detail any potential impacts to the topography or geomorphology, including: Discussion of major topographic features and any measures taken to avoid or minimise impact Objectives used in re-contouring or consolidation, rehabilitation, landscaping and fencing	Section 3.2.1
Identify the possible soil erosion rate and describe techniques used to manage impact	Section 2.1.3, Section 3, Section 3.3.2 and Section 4
Identify all soil types and outline erosion potential	Section 2.3.4
Outline erosion-monitoring program and provide acceptable mitigation strategies	Section 3.2.1, Section 3.3.2 and Section 4
Assess likely erosion effects and summarise methods proposed to prevent or control erosion	Section 3.2.1, Section 3.3.2 and Section 4
Discuss potential for acid generation by disturbing potentially acid forming materials, and propose methods for managing and mitigating impacts If applicable, outline measure in an acid mine drainage management plan	Section 2.3.6
Discuss potential for acid, saline, neutral or alkaline drainage from waste dumps	Volume 4 Appendix V Acid Mine Drainage Report
Resource Utilisation	
Analyse effectiveness of mining proposal in achieving optimum utilisation	Volume 2 Section 6.
Demonstrate the proposal will 'best develop' the mineral resources, minimise resource wastage and avoid unnecessary sterilisation	Volume 3 Section 10 Volume 4 Appendix Z
Subsidence	
Provide comprehensive surface subsidence predictions, taking into account topographic variations, geological complexities, etc	Volume 2 Section 6.
Provide a detailed description of subsidence effects on surface and groundwater hydrology as well as on terrestrial ecosystems	Volume 2 Section 6.
Propose mitigation measures to deal with any significant impacts resulting from subsidence. Detail a subsidence management plan.	Volume 2 Section 6.
Land Disturbance	
Develop a strategy that will minimise the amount of land disturbed at any one time, describe the strategic approach, and the methods used for the proposal	Section 3.4.1 and Section 3.4.2

Terms of Reference Requirement/Section Number	Section of this Report
Section 3.2.2 Topography, Geology and Soils	
If applicable, describe impact of diverted waterways on land use both upstream and downstream, and detail any long-term monitoring plans	Volume 3 Section 6
Describe: Rehabilitating diverted creeks during operations and reinstating creeks after operations cease Remove dams or transferring responsibility for dams to landholder and ongoing dam management Final drainage and seepage control systems Rehabilitation objectives, indicators and completion criteria	Volume 3 Section 6
Describe the transfer of responsibility to the landholder and ongoing maintenance and monitoring required for features of mining activity (ie: dams, levees, waterway diversions)	Volume 3 Section 6
Demonstrate where final voids and uncompacted overburden and workings at the end of mining would lie in relation to flood levels (up to & including the 'maximum flood level')	Volume 3 Section 6
Include (but not limited to): Predicted storage capacity of void water during annual exceedance probability 1 in 25, 1 in 50, 1 in 100, 1 in 200 and 1 in 1,000 year rainfall events and potential for discharge Predicted quality of void water during release events Predicted impact on the environment caused by release events Modelling and assessment of practicable management measures to mitigate contaminant increases in storage dams Develop a monitoring program to be undertaken both during and after mining Ability of the final void water to meet rehabilitation criteria	Volume 3 Section 6
Review and discuss alternatives to leaving a final void and derive a preferred option	Volume 3 Section 6

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Appendix B

Project (Rail) Geological Units Summary

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Project (Rail) Location		Rock Name	Age	Lithology Summary
Start (km)	Finish (km)			
189.50	184.80	Qpa	Pleistocene	Clay, silt, sand, gravel; flood-plain alluvium on high terraces
184.80	183.90	Qa	Quaternary	Clay, silt, sand, gravel; flood-plain alluvium
183.90	179.90	Qpa	Pleistocene	Clay, silt, sand, gravel; flood-plain alluvium on high terraces
179.90	179.20	Ts	Tertiary	Clayey sublabile to quartzose sandstone, sandy claystone, laminated siltstone, and minor conglomerate
179.20	176.40	Qpa	PLEISTOCENE	Clay, silt, sand, gravel; flood-plain alluvium on high terraces
176.3	175.4	Qa	Quaternary	Clay, silt, sand, gravel; floodplain alluvium
175.0	164.4	Qpa	Pleistocene	Clay, silt, sand, gravel; flood plain alluvium on high terraces
164.4	161.3	Qr	Quaternary	Clay, silt, sand, gravel and soil; colluvial and residual deposits
161.3	160.5	Ts	Tertiary	Clayey sublabile to quartzose sandstone, sandy claystone, laminated siltstone, and minor conglomerate
160.5	160.5	Qr	Quaternary	Clay, silt, sand, gravel and soil; colluvial and residual deposits
160.5	153.0	Qpa	Pleistocene	Clay, silt, sand, gravel; flood plain alluvium on high terraces
153.0	152.8	Water body (unspecified)	Water body	Water body, unspecified
152.8	152.3	Qa	Quaternary	Clay, silt, sand, gravel; floodplain alluvium
152.3	152.3	Water body (unspecified)	Water body	Water body, unspecified
152.3	152.1	Qa	Quaternary	Clay, silt, sand, gravel; floodplain alluvium
152.1	150.8	Qpa	Pleistocene	Clay, silt, sand, gravel; flood plain alluvium on high terraces

Project (Rail) Location		Rock Name	Age	Lithology Summary
Start (km)	Finish (km)			
150.8	145.5	Qa	Quaternary	Clay, silt, sand, gravel; floodplain alluvium
145.5	141.4	Qpa	Pleistocene	Clay, silt, sand, gravel; flood plain alluvium on high terraces
141.4	138.5	Qa	Quaternary	Clay, silt, sand, gravel; floodplain alluvium
138.5	135.8	Qpa	Pleistocene	Clay, silt, sand, gravel; flood plain alluvium on high terraces
135.8	134.3	Ts	Tertiary	Clayey sublabile to quartzose sandstone, sandy claystone, laminated siltstone, and minor conglomerate
134.3	132.9	Qa	Quaternary	Clay, silt, sand, gravel; floodplain alluvium
132.9	121.6	Qpa	Pleistocene	Clay, silt, sand, gravel; flood plain alluvium on high terraces
121.6	118.2	Qa	Quaternary	Clay, silt, sand, gravel; floodplain alluvium
118.2	113.5	Qpa	Pleistocene	Clay, silt, sand, gravel; flood plain alluvium on high terraces
113.5	113.2	Qa	Quaternary	Clay, silt, sand, gravel; floodplain alluvium
113.2	106.6	Qpa	Pleistocene	Clay, silt, sand, gravel; flood-plain alluvium on high terraces
106.6	105.9	Star of Hope Formation	Early Carboniferous	Lithic conglomerate, feldspatholithic sandstone, rhyolitic to dacitic ignimbrite and flows, tuffaceous siltstone and rare sinter
105.9	105.4	TQr>Ts	Late Tertiary - Quaternary	Clay, silt, sand, gravel and soil; colluvial and residual deposits (generally on older land surfaces)
105.4	105.0	Star of Hope Formation	Early Carboniferous	Lithic conglomerate, feldspatholithic sandstone, rhyolitic to dacitic ignimbrite and flows, tuffaceous siltstone and rare sinter
105.0	103.7	Qpa	Pleistocene	Clay, silt, sand, gravel; flood-plain alluvium on high terraces

Project (Rail) Location		Rock Name	Age	Lithology Summary
Start (km)	Finish (km)			
103.7	103.3	TQr	Late Tertiary - Quaternary	Clay, silt, sand, gravel and soil; colluvial and residual deposits (generally on older land surfaces)
103.3	103.1	Qpa	Pleistocene	Clay, silt, sand, gravel; flood-plain alluvium on high terraces
103.1	102.3	TQr	Late Tertiary - Quaternary	Clay, silt, sand, gravel and soil; colluvial and residual deposits (generally on older land surfaces)
102.3	101.5	Mount Hall Formation	Early Carboniferous	Quartzose to feldspathic sublabile sandstone, quartz-pebble conglomerate, mudstone and red and green siltstone
101.5	99.8	Qpa	Pleistocene	Clay, silt, sand, gravel; flood-plain alluvium on high terraces
99.8	99.0	Qr, Anakie Metamorphic Group	Quaternary	Clay, silt, sand, gravel and soil; colluvial and residual deposits
99.0	98.6	TQr >Suttor Formation, Anakie Metamorphic Group	Tertiary - Quaternary	Older residual soils, colluvium
98.6	97.7	Qpa	Pleistocene	Clay, silt, sand, gravel; flood-plain alluvium on high terraces
97.7	97.6	Qr, Anakie Metamorphic Group	Quaternary	Clay, silt, sand, gravel and soil; colluvial and residual deposits
97.6	97.3	TQr	Late Tertiary - Quaternary	Clay, silt, sand, gravel and soil; colluvial and residual deposits (generally on older land surfaces)
97.3	95.9	Qr, Anakie Metamorphic Group	Neoproterozoiz - Cambrian	Siltstone, fine sandstone, phyllite, schist, commonly cleaved and multiply deformed
95.9	90.9	Qpa	Pleistocene	Clay, silt, sand, gravel; flood-plain alluvium on high terraces
90.9	89.8	Qa	Quaternary	Clay, silt, sand, gravel; flood-plain alluvium
89.8	86.2	Qpa	Pleistocene	Clay, silt, sand, gravel; flood-plain alluvium on high terraces
86.2	85.8	Qa	Quaternary	Clay, silt, sand, gravel; flood-plain alluvium

Project (Rail) Location		Rock Name	Age	Lithology Summary
Start (km)	Finish (km)			
85.8	83.6	Qpa	Pleistocene	Clay, silt, sand, gravel; flood-plain alluvium on high terraces
83.6	61.1	Qa	Quaternary	Clay, silt, sand, gravel; flood-plain alluvium
61.1	46.8	Qpa	Pleistocene	Clay, silt, sand, gravel; flood plain alluvium on high terraces
46.8	46.3	Mount Rankin Formation	Late Devonian - Early Carboniferous	White and grey siltstone and fine sandstone, minor medium to very coarse-grained sandstone, chert, granule to pebble conglomerate, rare tuff, ignimbrite and dacite/andesite
46.3	43.3	Qpa	Pleistocene	Clay, silt, sand, gravel; flood plain alluvium on high terraces
43.3	18.6	TQa	Late Tertiary - Quaternary	Locally red-brown mottled, poorly consolidated sand, silt, clay, minor gravel; high-level alluvial deposits, generally dissected, and related to present stream valleys
18.6	18.2	Qa	Quaternary	Clay, silt, sand, gravel; floodplain alluvium
18.2	17.7	TQa	Late Tertiary - Quaternary	Locally red-brown mottled, poorly consolidated sand, silt, clay, minor gravel; high-level alluvial deposits, generally dissected, and related to present stream valleys
17.7	17.6	Qa	Quaternary	Clay, silt, sand, gravel; floodplain alluvium
17.6	12.5	TQa	Late Tertiary - Quaternary	Locally red-brown mottled, poorly consolidated sand, silt, clay, minor gravel; high-level alluvial deposits, generally dissected, and related to present stream valleys
12.5	5.8	TQr>Ts	Late Tertiary - Quaternary	Clay, silt, sand, gravel and soil; colluvial and residual deposits (generally on older land surfaces)
5.8	4.2	Td	Tertiary	Duricrusted palaeosols at the top of deep weathering profiles, including ferricrete and silcrete; duricrusted old land surfaces

Project (Rail) Location		Rock Name	Age	Lithology Summary
Start (km)	Finish (km)			
4.2	2.5	TQr>Ts	Late Tertiary - Quaternary	Clay, silt, sand, gravel and soil; colluvial and residual deposits (generally on older land surfaces)
2.5	2.4	Td	Tertiary	Duricrusted palaeosols at the top of deep weathering profiles, including ferricrete and silcrete; duricrusted old land surfaces
2.4	1.7	Back Creek Group	Early Permian – Late Permian	Quartzose to lithic sandstone, siltstone, carbonaceous shale, minor coal and sandy coquinite
1.7	1.2	Qr	Quaternary	Clay, silt, sand, gravel and soil; colluvial and residual deposits
1.2	0.9	Qa	Quaternary	Clay, silt, sand, gravel; floodplain alluvium
0.9	Goonyella system connection	Back Creek Group	Early Permian – Late Permian	Quartzose to lithic sandstone, siltstone, carbonaceous shale, minor coal and sandy coquinite

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