Chapter 13

Geology, Topography and Soils

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13. GEOLOGY, TOPOGRAPHY AND SOILS

13.1 Introduction

This chapter describes the existing environmental values of the geology, topography and soils that may be affected by the construction and operation of the Byerwen Coal Project (the project), the impacts on those environmental values and the mitigation strategies for those impacts.

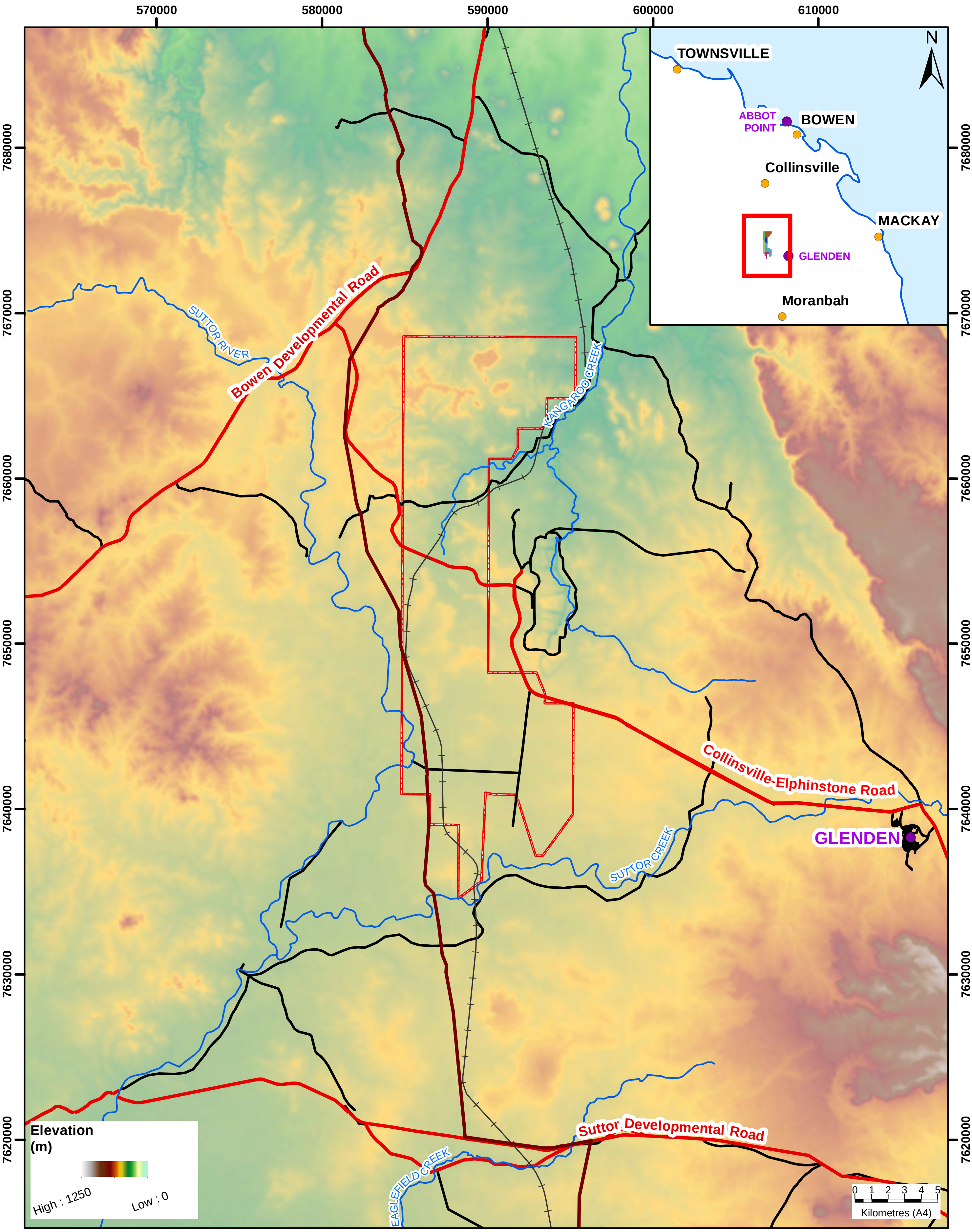
Topics addressed in this chapter include topography and geology of the region, soil characteristics and classifications, mineral reserves and erosion and stability. Information in this chapter is based on the Byerwen Coal Project Land Technical Report provided in **Appendix 14**, as well as geological information collected by the proponent.

Underground mining is not being considered as part of the project (detail regarding the removal of underground mining as part of the project is provided in **Chapter 1 Section 1.12**). Accordingly the potential issue of subsidence associated with underground mining is no longer relevant to the project. However a qualitative engineering review was undertaken by the proponent to ascertain if any other project aspects pose potential subsidence risks, including, open cut mining, water infrastructure, MIA, CHPP and linear infrastructure. No subsidence related impacts are expected to arise as a result of the project and therefore subsidence is not considered further in this chapter.

13.2 Topography

The topography of the project and surrounding area is shown on **Figure 13-1** and can be summarised as follows:

- Elevation on the project site ranges between approximately 250 m Australian Height Datum (AHD) (where Kangaroo Creek leaves the site) to approximately 390 m AHD (on the mesas in the north).
- The majority of the southern third of the site is level-to-very-gently inclined (slope <1 – 3 %).
- The central and northern sections are more undulating and include level to very gently inclined areas interspersed with moderately inclined to steep areas, with the steeper areas typically bounding small mesas or the sandstone highlands in the north-west.



Legend

- Project Area
- Burdekin to Moranbah Pipeline
- Watercourses
- GAP Rail line
- Main Towns
- Highway
- Main Road
- Formed and Unformed Local Roads

Local Area Topography		QCOAL GROUP
Figure 13-1	**Byerwen Coal Project**	environmental and licensing professionals pty ltd
Date: *30/01/2013*	**Author:** samuel.ferguson **Map Scale:** 1:300,000	
Revision: R1	**Coordinate System:** GDA 1994 MGA Zone 55	
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13.3 Geology

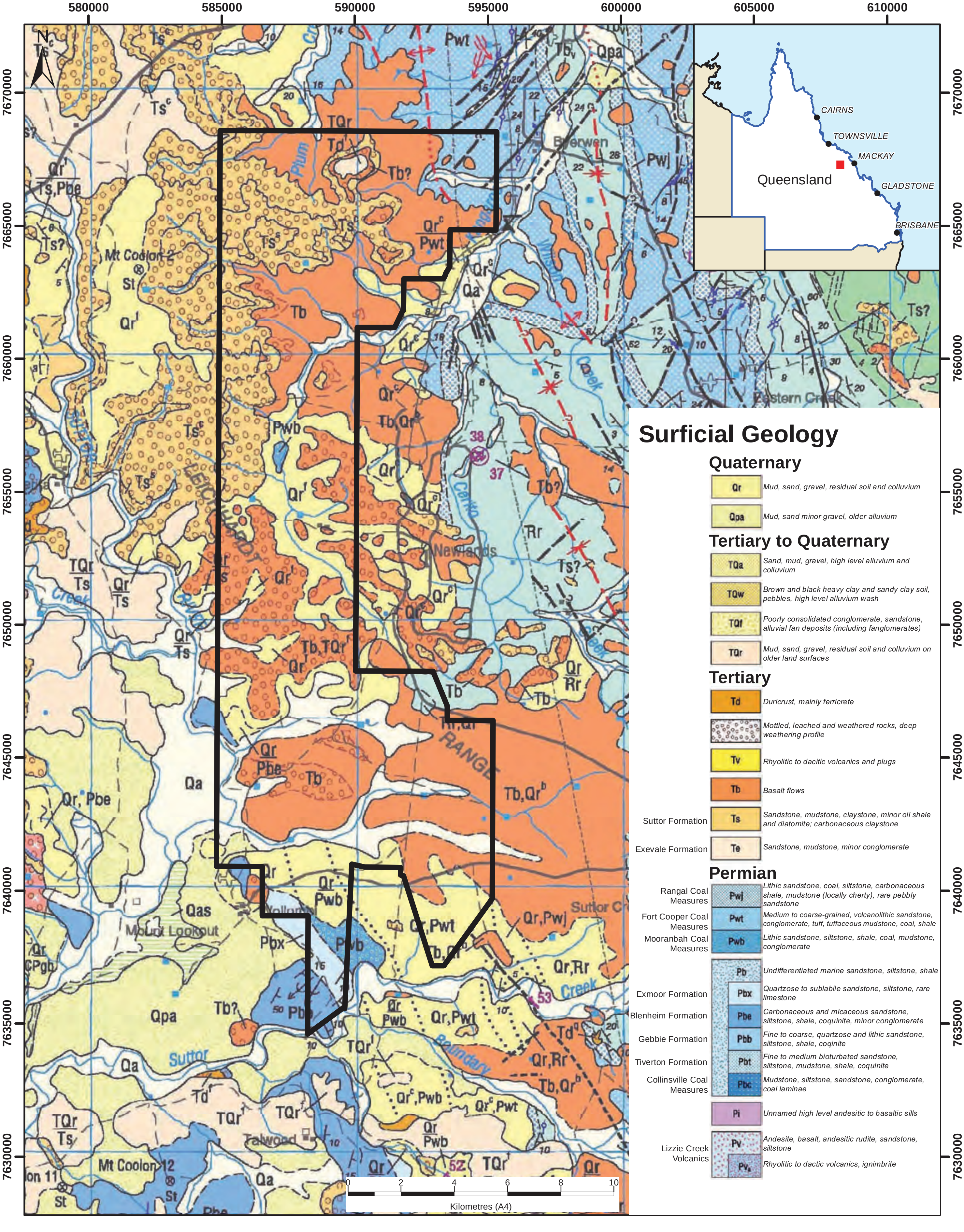
13.3.1 Geology of the Project Area

The project is located within the Northern Bowen Basin which is characterised by typical basin fill fluvial (and some marine) sediments, comprising mudstones, siltstones, sandstones and coal seams. The regional geology is described in the 1:250,000 Mount Coolon Geology map sheet, published by the Queensland Department of Mines and Energy, 1997. **Figure 13-2** illustrates the regional geology from the 1:250,000 geological mapping.

The Bowen Basin contains Early Permian rocks of the marginal marine Back Creek Group, Late Permian coal-bearing (non-marine) strata of the Blackwater Group, fluviatile sedimentary rocks of Triassic Rewan Group, and overlying Tertiary basalt and sediments of the Suttor Formation and Quaternary alluvium deposits. A summary of the stratigraphy in the project area is provided in **Table 13-1**.

Table 13-1 Stratigraphy of the Byerwen Area

Age	Group	Formation	Description	Thickness
Quaternary		Alluvium	Mud, sand, minor gravel (alluvium), residual soil and colluvium	5m - 10m
Tertiary		Suttor Formation	Quartz sandstone, clayey sandstone, mudstone and conglomerate; fluvial and lacustrine sediments and minor interbedded basalt	100m - 150m
Triassic	Rewan Group	Arcadia Formation	Green lithic sandstone, green and red sandstone and mudstone	230m
		Sagittarius Sandstone	Feldspathic and lithic sandstone with mudstone interbeds	280m
Late Permian	Blackwater Group	Rangal Coal Measures (RCM)	Sandstone, siltstone, mudstone, coal, tuff and conglomerate	60m
		Fort Cooper Coal Measures (FCCM)	Medium to coarse-grained, volcano-lithic sandstone, conglomerate, tuff, tuffaceous mudstone, coal and shale	400m
		Moranbah Coal Measures (MCM)	Lithic sandstone, siltstone, shale, coal, mudstone and conglomerate	290m
Early Permian	Back Creek Group	Exmoor Formation	Quartzose to sub-labile sandstone, siltstone and rare limestone	85m
		Gebbie Formation	Quartzose to lithic sandstone, sandy siltstone, siltstone, carbonaceous shale and calcareous sandstone	
		Tiverton Formation	Lithic sandstone, coquinite, calcareous sandstone and siltstone, conglomerate	
		Blenheim Formation	Carbonaceous and micaceous sandstone, siltstone, shale, coquinite and minor conglomerate	



Legend

Project Area

Regional Geology

Figure 13-2

Byerwen Coal Project

QCOAL GROUP

elp environmental and licensing professionals pty ltd

Date: 30/01/2013

Author: samuel.ferguson

Map Scale: 1:185,000

Revision: R1

Coordinate System: GDA 1994 MGA Zone 55

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13.3.2 Stratigraphy

The major geological units in the project area include Quaternary deposits, Tertiary material, Triassic material and coal measures.

13.3.2.1 Quaternary Deposits

Laterally restricted sheets of Quaternary age (i.e. 10,000 years – 1.8 million years) alluvium are present in the project area overlying Tertiary material. Basalt flows that followed pre-Tertiary valleys, and the differential erosion of Cainozoic sediments, have resulted in a highly variable thickness of cover and depth of weathering.

13.3.2.2 Tertiary Material

A layer of Tertiary age (i.e. 1.8 – 66 million years) basalts and sediments of the Suttor Formation are present overlying the Triassic - Permian sequence up to 150 m thick.

13.3.2.3 Triassic Material

Triassic material (i.e. 200-250 million years) comprising sandstones and mudstone of the Rewan Group is present overlying Permian Coal Measures up to 280 m thick. The upper boundary of the Rangal Coal Measures with the overlying Rewan Group is commonly transitional.

13.3.2.4 Coal Measures

The Blackwater Group contains Permian age (i.e. 248-290 million years) coal measures. The Rangal Coal Measures represent the uppermost unit of the Blackwater Group, and although attaining a maximum thickness in the order of 220 m, are generally less than 100 m thick in the project area. Coal from the Rangal Coal Measures may be mined during the latter half of the mine life. The main seam of interest in the Rangal Coal Measures is the Leichhardt seam, a correlation of the Upper Newlands seam which is between 4.5 and 6.5 m thick in the surrounding vicinity.

The Fort Cooper Coal Measures, the central unit of the Blackwater Group, do not contain target coal seams in the project area (based on resource drilling undertaken). However, current coal extraction from the FCCM may be undertaken should suitable seams be identified during operations.

The Moranbah Coal Measures (MCM) are the lowermost formation of the Blackwater Group and represent the main stratigraphic unit of interest in the project area. This unit is approximately 290 m thick in the project area and contains up to seven persistent coal seams. The principal seams of economic interest are the Goonyella Lower (6 to 8 m thick) and Goonyella Middle (6 to 10 m thick). This unit conformably overlies the marginal marine Exmoor Formation.

The coal seams to be mined are shown on geological cross-sections in **Figure 13-3**, **Figure 13-4** and **Figure 13-5**.

13.3.3 Geological Structure

The project area is located southwest of the Burton Range Fault Zone, a major northwest trending reverse fault. Thrust faults with a similar trend are indicated to be present in the broader area surrounding the project, and include the Suttor Creek Fault which passes through the project area. The main strike direction of the thrust faults is north-west. Evidence of smaller-scale faulting within the project area has also been identified during exploration works, in the form of seam repetitions and in-seam shear zones. The Permian formations in the project area strike north-north west, dipping to the east at between 4^{o} and 12^{o}.

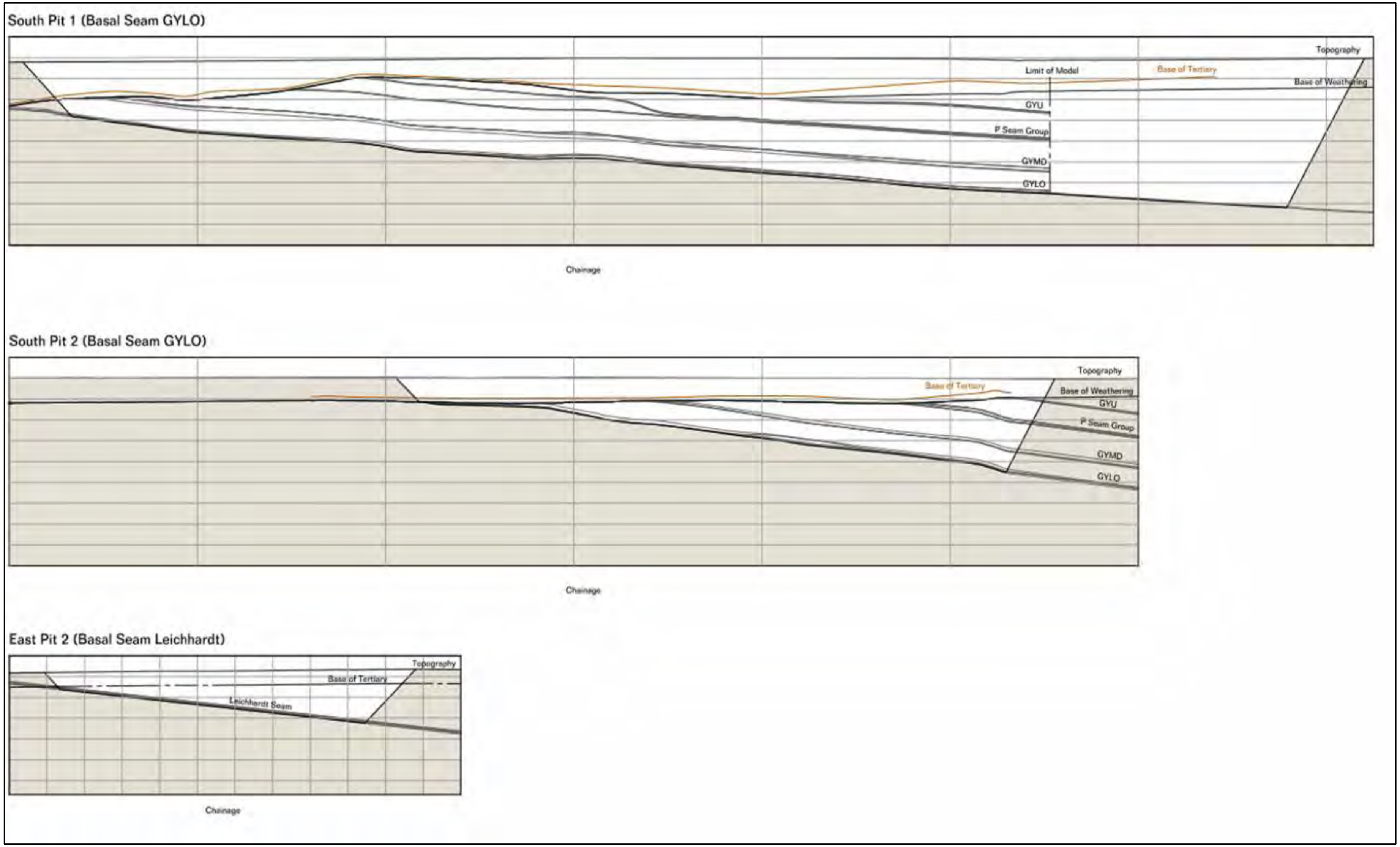


Figure 13-3 Geological Cross Sections – South and East Pits

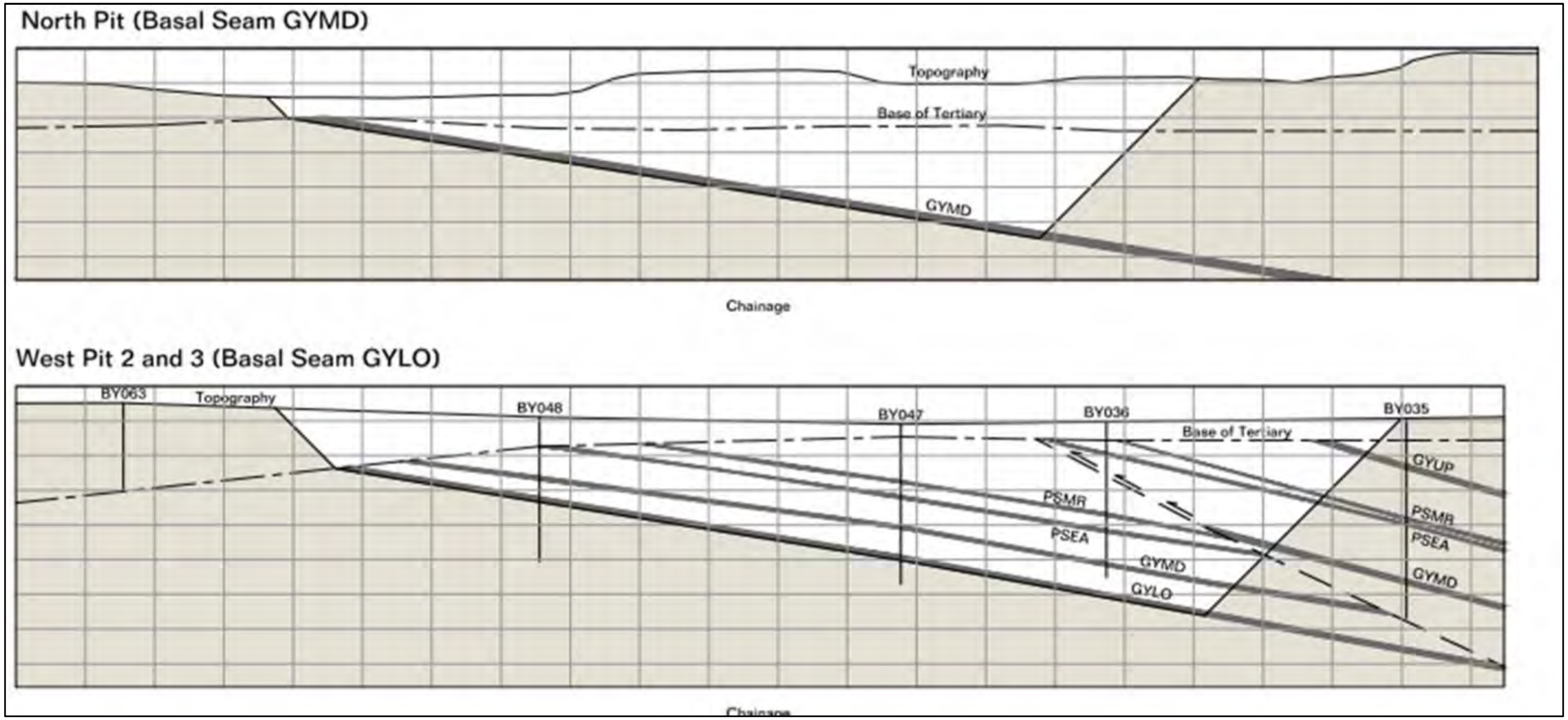


Figure 13-4 Geological Cross Sections – North and West Pits 2 and 3

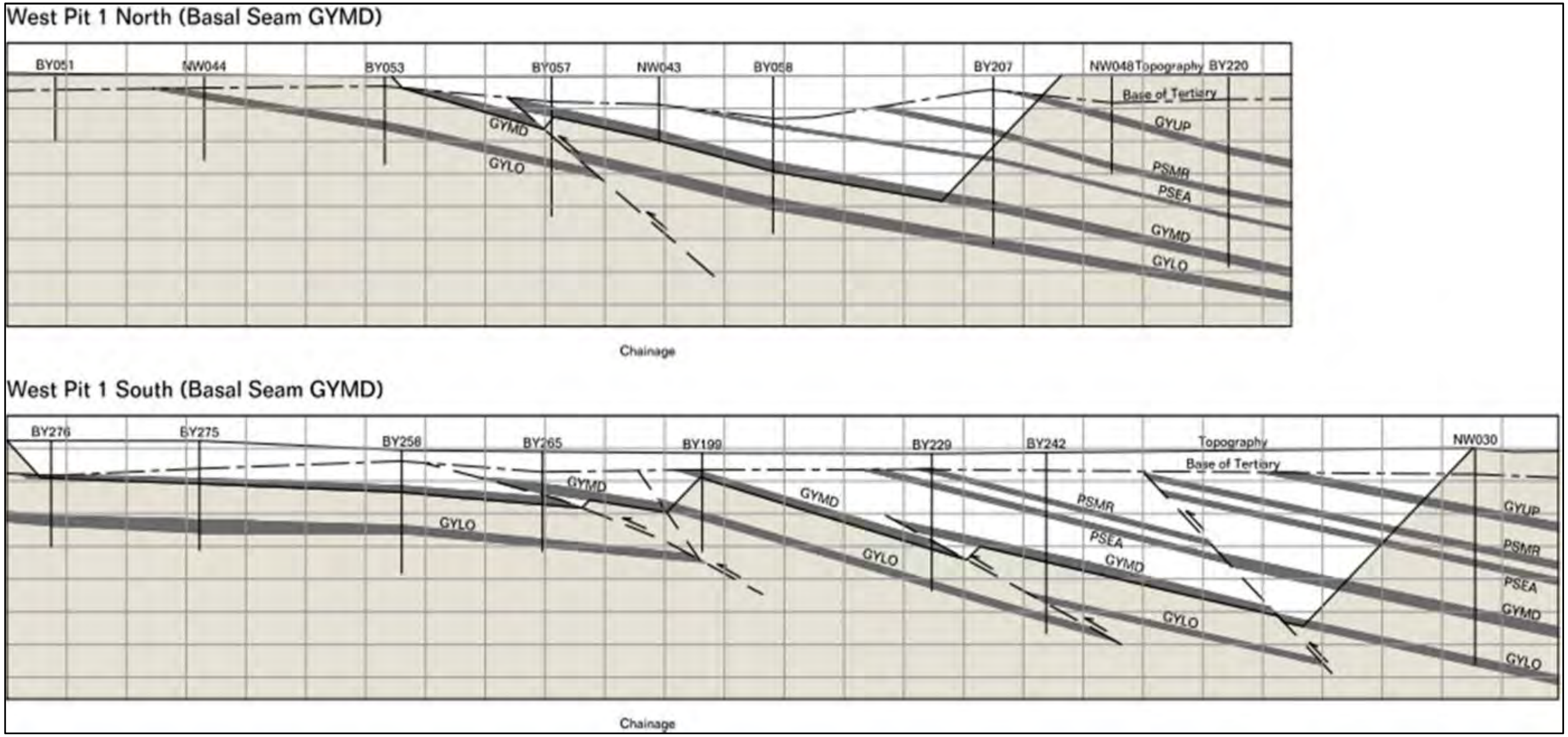


Figure 13-5 Geological Cross Sections –West Pit 1

13.3.4 Presence of Fossils

The likelihood of uncovering significant fossils at the site is expected to be low, based on information from Xstrata's adjacent Newlands Coal Expansion Project, which identified that significant fossils had not been encountered during the ongoing operations at the existing mine. Additionally, no fossil localities are identified to be present in the project area on published geology maps (Mount Coolon 1:250,000 geology map). Pieces of fossilised trees were identified during the NRA 2011 land survey in the far north-eastern corner of the ML 10355 (outside the project footprint) in the areas of the Fort Cooper Coal Measures. The Fort Cooper Coal Measures also outcrop at Homevale Station (approximately 60 km east of the project site) where they reportedly contain an important *Glossopteris* plant fossil site (Australian Heritage Council, 2012).

In the event that a suspected significant fossil is encountered, mine operations will be managed to preserve the find. The find will be assessed by a mine geologist and reported to the regulator (or appropriate government agency).

13.4 Mineral Resources

13.4.1 Resource Classification

Coal exploration within the project area dates back to the early 1970s and several companies have investigated the economic potential of the coal measures in the Bowen Basin. The exploration activity undertaken to date in the project area includes the collection of data relating to coal thickness, raw coal quality and washed coal quality. Overall, in excess of 450 exploration holes have been drilled within the area covered by the project mining lease application (MLA) areas.

Exploration undertaken in the northern Bowen Basin in recent years by QCoal Pty Ltd (QCoal), the parent company of the proponent, has resulted in the delineation of a significant coal resource of 690 Mt in the project area. Geological modelling of the project deposits was undertaken by the proponent using the following data:

- Topography model generated from digital contour data
- Visual base of weathering
- Drill hole data
- Down hole geophysical data.

13.4.2 Resource Estimation

The project has a coal resource of approximately 690 Mt. Extraction of the coal resource will be at a rate of approximately 15 Mtpa Run of Mine (ROM) coal. The mine will produce approximately 10 Mtpa of product coal for the export market over the 50 year project life (two years for construction, 46 years of mining operation and 2 years for decommissioning and rehabilitation).

Four mining zones have been identified for the project (north, south, east and west), comprising eight open pits. Total projected coal resources for the project are summarised in **Table 13-2.** The resources' areas are shown in figures in **Chapter 5** and **7**.

Table 13-2 Projected Coal Resource Summary Byerwen Coal Project

Pit	ROM Coal (Mt)
South Pit 1	344
South Pit 2	44
East Pit 1	15
East Pit 2	14
West Pit 1	74
West Pit 2	61
West Pit 3	122
North Pit 1	26
Total	**690**

Whilst the quality of the primary seams does vary throughout the project area, production from the project will primarily be high quality coking coal with some thermal coal.

13.4.3 Resource Utilisation

The data relating to coal thickness, raw coal quality and washed coal quality has been interpreted by the proponent to generate in situ resource estimates that take into account the best practice selective mining of the coal seams, to maximise coal recovery and to minimise waste dilution.

Mining is proposed down to the base economic coal seam within the Moranbah Coal Measures, so as to leave no economic coal resources at depth below the open cut. It is considered that the mining method chosen, and mine plan is the optimum for maximizing the utilisation of the currently known resource.

The mine plan was developed to optimise production based on the geological conditions and overall strike length of the potential mine. The mining schedule is based on taking advantage of the area of shallowest depth from surface to top of coal and orienting the mining such that it advances progressively deeper along the coal seam wherever possible. The open cuts will become deeper as mining progresses to the east. The maximum depth below surface level of the open cuts will vary between 140 m in East Pit 2 and 350 m in South Pit 1.

The geological analysis has clearly delineated the area of coal deposits within the project area. This has been incorporated into the mine design and selection of sites for mine infrastructure, overburden dumps, haul roads and other activities/facilities to minimise potential sterilisation of coal resources. The alignment of the Goonyella to Abbot Point (GAP) rail line has sterilised some coal resource from potential extraction.

Coal seams extend at depth southeast beyond the presently proposed area of mining activities.

No economic coal seam gas resource has been identified by the proponent within Exploration Permit for Coal (EPC) 614 and 739. Part of the MLA areas are overlapped by the current petroleum exploration permit ATP688P held by BNG (Surat) Pty Ltd.

13.4.4 Byerwen Coal Project Area

Details of the project area, tenures and proposed operational layout, including the boundary of the proposed open cut excavation, relevant infrastructure and the mine layout over time are provided in **Chapter 5** and **Chapter 7**.

13.5 Soils

A soil survey of the areas that will be impacted by mining activities and infrastructure associated with the project was conducted by NRA in 2011, the results of which are described below. The technical report prepared by NRA is provided in **Appendix 14**.

13.5.1 Survey Methodology

The survey comprised the observation of land use, landform, erosion and a detailed description of dominant soils. The survey was undertaken in accordance with the following standards:

- *The Australian Soil and Land Survey Field Handbook* (NCST 2009)
- *Guidelines for Surveying Soil and Land Resources* (McKenzie et al. 2008)
- *The Australian Soil Classification* (Isbell, 1996).

Soils identified during the survey were mapped using field observations informed by existing soil and geology maps and remote sensing imagery. Field observations and existing soil mapping were sufficient to map the soils in the majority of the project area at a scale of 1:50,000.

Assessment of soil stripping depths (for the collection of 'useable soil') was made on the basis of observed soil attributes supplemented by laboratory analytical data.

13.5.2 Soil Types

Ten soil groups were identified within the project area during the field survey. An area on the south-western boundary was not accessible at the time of the survey. Previous soil mapping by Isbell and Murtha (1970) describes a soil in this area that is similar to the sodosols. This area has been tentatively mapped and assessed as containing sodosols.

A summary of each soil type is presented below. Their distribution is provided in **Figure 13-6**. Full descriptions of the soils sampled are provided in **Appendix 14**. Waste rock characterisation, including sodicity, metals and acidity is further described in **Chapter 9**.

13.5.2.1.1 Rudosols

Rudosols were found in the centre of the project site. They appear to have a distribution limited to the upper tributaries of Kangaroo Creek. These soils have fertility issues and become sodic below 0.3 m. Examples of moderate gully erosion were observed in these soils.

13.5.2.1.2 Sodosols

Sodosols were found either side of Kangaroo Creek and down-slope of the sandstone bluffs throughout the central and northern regions of the project site. These soils have fertility issues below 0.3 m, and are sodic below 0.6 m. Magnesium enhanced sodicity may also be an issue below a depth of 0.3 m. Moderate to severe gully erosion was observed where these soils had been disturbed.

13.5.2.1.3 Northern Kandosols

These soils are typical on the elevated areas of sandstone in the north of the project site. The surface material is acidic and the soil has fertility issues below 0.6 m. None of the analysed samples reported significant exchangeable sodium percentage (ESP) or magnesium enhanced sodicity.

13.5.2.1.4 Central Kandosols

The central kandosols occur in two forms – brown and red. These soils are similar and inter-related and are treated as one unit. The red kandosols are dominant on the elevated, better-drained areas and the brown kandosols are more common on areas of lower elevation. These soils may have fertility issues below 0.6 m, and magnesium enhanced sodicity may be an issue below 0.9 m.

13.5.2.1.5 Central Dermosols

Central dermosols have a limited distribution in the centre of the project site in association with the central kandosols, central vertosols, rudosols, and chromosols. These soils have fertility issues and become sodic below 0.3 m.

13.5.2.1.6 Southern Dermosols

The southern dermosols occur in association with the southern dark vertosols and central kandosols in the southern part of the project site. The soils have fertility issues and are sodic (including magnesium enhanced sodicity) below 0.3 m.

13.5.2.1.7 Brown Vertosols

Brown vertosols occur in areas of melonhole gilgai and are typically associated with the central kandosols. These soils are strongly sodic (including magnesium enhanced sodicity) and saline below 0.3 m.

13.5.2.1.8 Northern Dark Vertosols

The northern dark vertosols occur mainly in the north-eastern part of the project site. These soils are sodic (with magnesium enhanced sodicity) below 0.3 m and have fertility issues throughout the profile.

13.5.2.1.9 Central Dark Vertosols

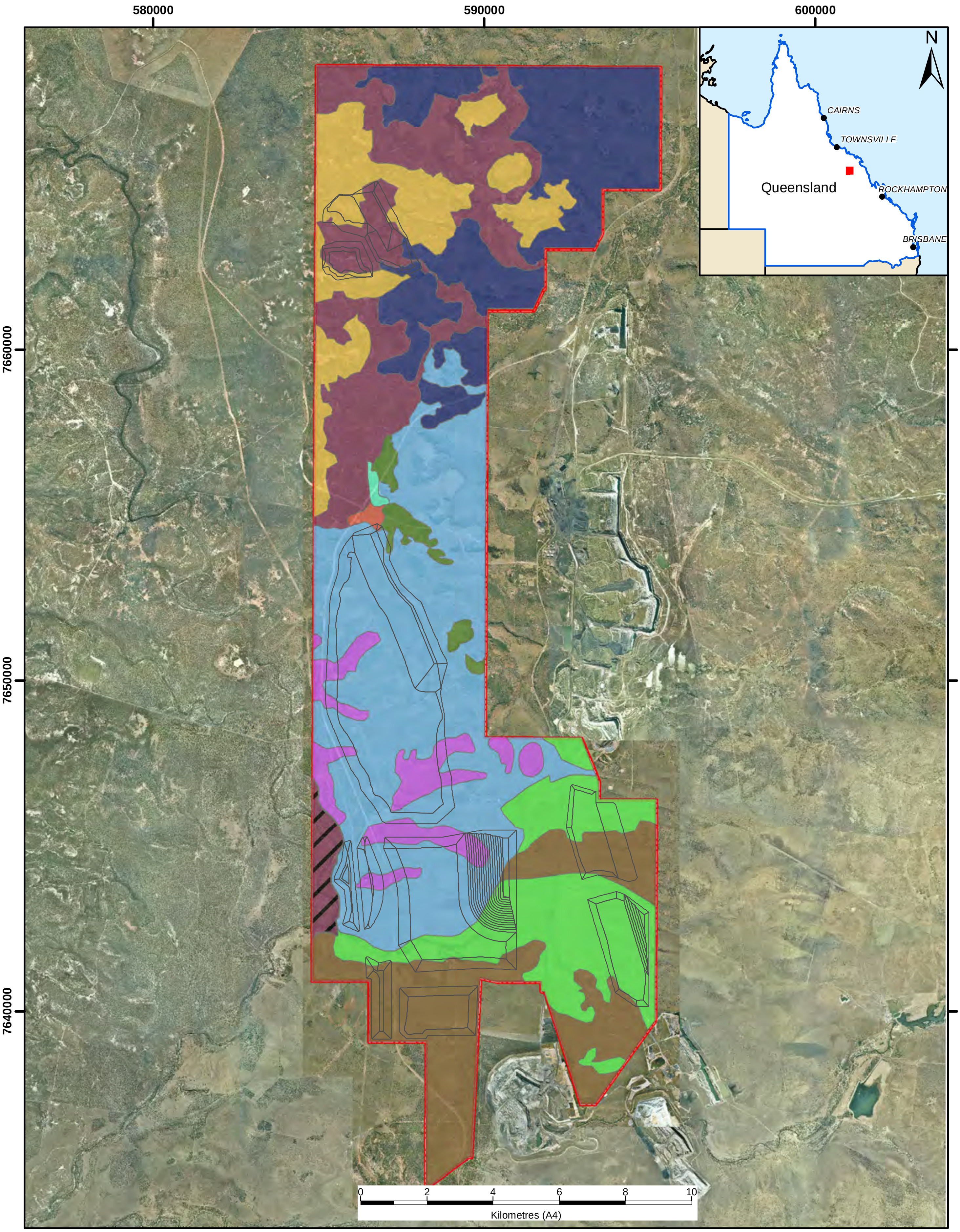
The central dark vertosols are shallow cracking clays that occur in association with the rudosols, sodosols, central dermosols, and central kandosols. These soils appear to be stable and have minor fertility issues below 0.3 m.

13.5.2.1.10 Southern Dark Vertosols

The southern dark vertosols occur in association with the southern dermosols and the central kandosols. Typically they are deep clays that form a cracking surface. Magnesium enhanced sodicity may be an issue in these soils.

13.5.3 Summary of Soil Properties and Management Issues

Table 13-3 summarises the main properties for the identified soil types within the project area. The following sections detail the management issues on site in regard to these soil properties.



Legend

- Project Area
- Waste Rock Dumps and Pits

Soil Unit

- Rudosols
- Sodosols
- Unconfirmed Sodosols
- Northern Kandosols
- Central Kandosols (Red/Brown)
- Central Dermosols
- Southern Dermosols
- Brown Vertosols
- Northern Dark Vertosols
- Central Dark Vertosols
- Southern Dark Vertosols

Soils of the Project Area

Figure 13-6

Byerwen Coal Project

Date: *30/01/2013*

Author: samuel.ferguson

Map Scale: 1:150,000

Revision: R1

Coordinate System: GDA 1994 MGA Zone 55

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Table 13-3 Summary of Soil Properties and Management Issues

Soil type	Description	Erosion Potential	Soil Acidity	Salinity Class	Sodicity	Dispersibility	Inherent Fertility
Rudosols	Poorly developed soils (alluvium)	Moderate gully erosion observed	Non acidic	Very low to low	Sodic below 0.3m	Near complete to complete dispersion at all depths	Fertility issues below 0.6 m
Sodosols	Texture contrast soils	Moderate sheet to moderate severe gully erosion	Non acidic	Medium salinity below 0.9m	Magnesium enhanced sodicity below 0.3 m, sodic below 0.6 m	Slight to moderate dispersion below 0.7m	Fertility issues below 0.3 m
Northern Kandosols	Deep unstructured soils	No significant accelerated erosion observed	Surface material is acidic	Very low	Non-sodic	No dispersion	Fertility issues below 0.6 m
Central Kandosols	Deep unstructured clayey soils	No significant accelerated erosion observed	Non acidic	Very low	Magnesium enhanced sodicity may be an issue below 0.9 m	Slight dispersion in surface soils	Fertility issues below 0.6 m
Central Dermosols	Red form	No significant accelerated erosion observed	Non acidic	Very low to low	Sodic below 0.3 m	Near complete to complete dispersion below 0.4m	Fertility issues below 0.3 m
Southern Dermosols	Brown form	No significant accelerated erosion observed	Non acidic	Medium to high salinity below 0.3m	The soils are sodic (including Mg enhanced sodicity) below 0.3 m	Moderate to near complete dispersion	Fertility issues below 0.3 m
Brown Vertosols	Deep structure brown soils	No significant accelerated erosion observed	Non acidic	Medium to extreme salinity below 0.3m	Strongly sodic with magnesium enhanced sodicity below 0.3m	Moderate dispersion in surface soils	Fertility issues below 0.9 m

Soil type	Description	Erosion Potential	Soil Acidity	Salinity Class	Sodicity	Dispersibility	Inherent Fertility
Northern Dark Vertosols	Deep structured brown soils	Active minor gully erosion observed	Non acidic	Medium salinity below 0.6m	These soils are sodic (with magnesium enhanced sodicity) below 0.3 m	Unknown	Fertility issues throughout the profile
Central Dark Vertosols	Deep cracking soils in areas of gilgai	No significant accelerated erosion observed	Non acidic	Very low to low	Non sodic	No dispersion	Fertility issues below 0.3 m
Southern Dark Vertosols	Deep cracking soils	No significant accelerated erosion observed	Non acidic	Very low to low	magnesium enhanced sodicity may be an issue in this soil	No dispersion	Fertility issues below 0.9 m

13.5.4 Soil Stability and Suitability for Construction of Project Facilities

Quarry materials will be sourced from onsite deposits, where possible, for use as road base, select fill, rail ballast, rock protection, sealing aggregates and other construction materials. Further geotechnical investigations are required to confirm the quality/suitability of the deposits for construction purposes; although it is likely that only low to medium quality material will be available. It is expected that waste rock from open pit excavations will provide the majority of construction materials.

It is also expected that all or the majority of quarry materials can be sourced from onsite deposits. These deposits consist of basaltic materials that overlay waste rock from open pits. No additional disturbance to areas outside of the pit footprint will be required to obtain quarry materials. If these deposits are not suitable for a particular purpose, material will be sourced from nearby quarries.

In addition geotechnical studies will be conducted on the stability and suitability of soils for construction purposes, including for pipelines to inform the detailed design stage.

13.6 Potential Impacts and Mitigation Measures

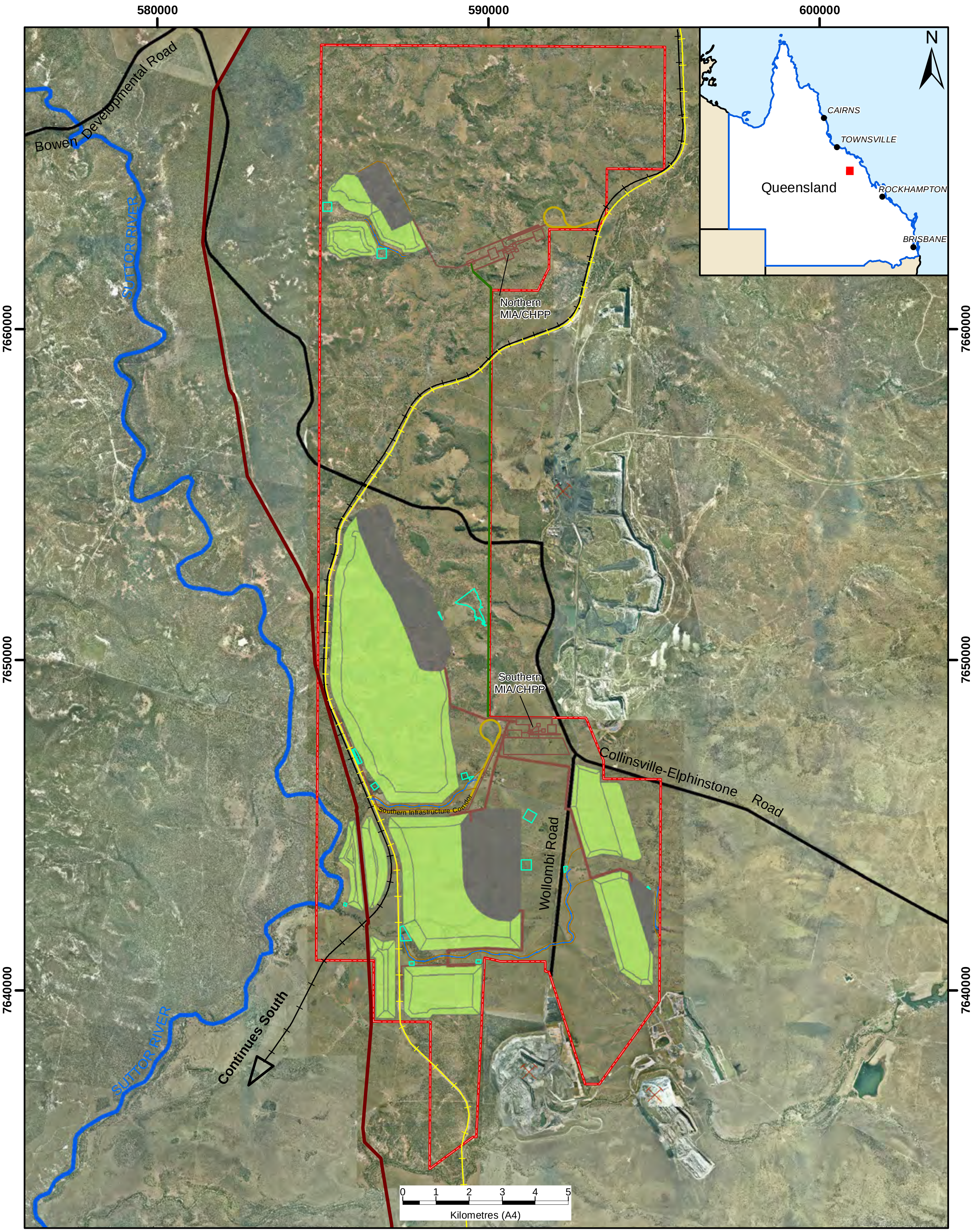
The potential impacts of the project on topography and soils and proposed mitigation measures are outlined in the following sections.

13.6.1 Land Disturbance

The footprint of the project is shown in **Figure 13-7** and the disturbance area of each mine component is provided in **Table 13-4**, which shows the area of completed rehabilitation of waste rock dumps at each major stage of development.

Table 13-4 Estimated Project Footprint at Each Major Stage of Development

Area	Footprint (ha)					
	Year 1	Year 3	Year 5	Year 10	Year 25	Final Landform (Year 46)
West Pit 1	59	175	580	603	163	0
West Pit 2	0	0	0	0	217	81
West Pit 3	0	0	0	0	92	467
South Pit 1	0	216	256	347	592	543
South Pit 2	0	0	0	113	185	0
East Pit 1	0	0	0	0	153	0
East Pit 2	0	0	0	0	0	88
North Pit 1	0	0	0	0	353	163
Infrastructure	347	523	522	526	915	907
Completed Rehabilitation	0	0	105	598	2,093	4,749
Total Footprint	**406**	**914**	**1,464**	**2,186**	**4,764**	**6,997**



Legend

- Project Area
- Completed Rehab
- Final Void
- Existing Mine Site
- Burdekin to Moranbah Pipeline
- GAP Rail line
- Alpha Coal Project Rail Line
- Mine Infrastructure
- Train Loading Facilities
- Central Infrastructure Corridor
- Suttor River
- Drainage Bund
- Drainage Diversion
- Formed Road
- Dam footprint

Project Disturbance Areas		QCOAL GROUP
Figure 13-7	Byerwen Coal Project	elp environmental and licensing professionals pty ltd
Date: 28/02/2013	Author: samuel.ferguson Map Scale: 1:150,000	
Revision: R1	Coordinate System: GDA 1994 MGA Zone 55	

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13.6.2 Topography

13.6.2.1 Impacts

Final voids, waste rock dumps and decommissioned co-disposal dams will permanently alter the topography of the project site.

13.6.2.2 Mitigation

Details of rehabilitation and decommissioning, including final landform design for areas where topography is altered is provided in **Chapter 10**. Following rehabilitation and decommissioning, impacts to topography are expected to be moderate.

Watercourse and drainage line diversions will remain following mine closure to permanently divert water around areas of altered topography, these will be completed to be stable, self sustaining and require no ongoing management or monitoring.

13.6.3 Soil Quality

13.6.3.1 Impacts

Approximately 6,100 ha (87%) of the total project footprint of 7,000 ha will comprise waste rock dumps and open pit excavations / final voids. As described in **Chapter 7**, these areas will be disturbed sequentially over the mine life and not simultaneously. Soil is a valuable resource for successful rehabilitation.

Unless salvaged prior to disturbance, soils can be physically degraded (by compaction, deformation and loss of structure) in-situ without alterations to landform, particularly where heavy machinery is used such as haul roads. This degradation can severely limit revegetation potential and can also decrease water infiltration, increase run-off and cause accelerated erosion even on low slopes.

Once soil is salvaged for rehabilitation the soil quality can be affected by mixing of poor and good quality soils, poor topsoil stripping and handling, length of time stockpiled, location of stockpile and by contamination from mining activities. All of these have the potential to affect soil productivity and rehabilitation success. Poor quality soils (e.g. highly erodible, low fertility soils) may not be salvaged due to their potential detrimental impacts on rehabilitation success.

The movement of soil also has the potential to transfer weeds and pathogens into areas previously unaffected.

The approximate coverage of each soil type, considerations for rehabilitation, relative erosion risk, volume of soil potentially available for re-use and potential stripping depths for areas to be disturbed by mining activities are provided in **Table 13-5**.

Table 13-5 Soil Stripping Depths and Approximate Salvage Volumes

Soil	Disturbance (ha)	Potential stripping depth	Considerations/Erosion Risk*	Volume of soil potentially available for salvage (m^3)
Rudosols	0	Collect surface material only (surface to 0.3 m)	• Sodic below this depth • Moderate gully erosion observed • Erosion risk: high	0 (no expected disturbance)
Sodosols	408	Collect surface material only (surface to 0.3 m)	• Fertility issues and magnesium enhanced sodicity below 0.3 m, sodic below 0.6 m • Moderate to severe gully erosion observed • Erosion risk: low for surface material (to 0.3 m), high below 0.3 m.	1,224,000 of surface material
Northern Kandosols	163	Collect and stockpile surface material (surface to 0.3 m) and sub-surface material (0.3 to 1.0 m depth) separately	• Surface material is acidic (fertility) • Material below 0.6 m has fertility issues • Erosion risk: low	489,000 of surface material 1,141,000 of subsurface material
Central Kandosols	3,373	Collect and stockpile surface material (surface to 0.3 m) and sub-surface material (0.3 to 0.9 m depth) separately	• Fertility issues below 0.6 m • Magnesium enhanced sodicity may be an issue below 0.9 m • Erosion risk: low to 0.9 m, medium below 0.9 m.	10,119,000 of surface material 20,238,000 of subsurface material
Central Dermosols	4	Collect surface material only (surface to 0.3 m)	• Fertility issues and sodic below 0.3 m • Erosion risk: low for surface material (to 0.3 m), high below 0.3 m.	12,000 of surface material
Southern Dermosols	910	Collect surface material only (surface to 0.3 m)	• The soils have fertility issues and are sodic (including magnesium enhanced sodicity) below 0.3 m • Erosion risk: low for surface material, high below 0.3 m	2,730,000 of surface material

Soil	Disturbance (ha)	Potential stripping depth	Considerations/Erosion Risk*	Volume of soil potentially available for salvage (m^3)
Brown Vertosols	700	Not suitable for rehabilitation.	• Strongly sodic and magnesium enhanced sodicity • Erosion risk: high	Do not salvage. Dispose of within spoil piles at depth or in co-disposal dams
Northern Dark Vertosols	204	Collect surface material only (surface to 0.3 m)	• These soils are sodic (with magnesium enhanced sodicity) below 0.3 m and have fertility issues throughout the profile • Gully erosion observed • Erosion risk: low for surface material (to 0.3 m), high below 0.3 m	612,000 of surface material
Central Dark Vertosols	8	Collect and stockpile surface material (surface to 0.3 m) and sub-surface material (0.3 to 0.7 m) separately	• Material below 0.3 m has fertility issues. • Erosion risk: low	24,000 of surface material 32,000 of subsurface material
Southern Dark Vertosols	1,166	Collect and stockpile surface material (surface to 0.3 m) and sub-surface material (0.3 to 0.9 m) separately	• Magnesium enhanced sodicity may be an issue in this soil (though dispersion was not observed during testing) • These have fertility issues below 0.9 m • Erosion risk: medium.	3,498,000 of surface material 6,996,000 of subsurface material
Total	**6,934#**	-	-	**18,708,000 of surface material** **28,407,000 of subsurface material**

* The erosion risk assigned is relative to the other soils in the project area. It is based on field observations of erosion and results for sodicity and dispersiveness.

This is comparable to the total footprint area described in **Table 13-4** (6,997 ha) with the discrepancy an artefact of GIS mapping.

Sodic soils will require management to minimise erosion or amelioration if used in rehabilitation. They are especially prone to gully and tunnel erosion, even in low sloping situations, where concentrated runoff may occur in minor drainage channels.

Moderate salinity may restrict the growth of moderately sensitive crops and grasses. If these soils were to be respread on the surface, they may affect the growth of some pasture species. It is common that salinity levels increase with depth. Careful separation of topsoil and subsoil will avoid exposure of these sodic/saline layers from occurring following reinstatement of the final rehabilitated landform. However, some soils have elevated salinity levels at or very near the surface which may affect topsoil stripping and subsequent rehabilitation measures.

Varying levels of dispersion were evident in surface and subsoils with the exception of central kandosols, northern kandasols, central dark vertosols and southern dark vertosols. This has implications for subsoil management and associated erosion and turbidity levels in stormwater detention structures and downstream water quality as discussed in **Chapter 15**.

13.6.3.2 Mitigation

A Soil Management Plan will be developed prior to commencement of mining activities to identify the soils best suited to rehabilitation at the recommended depth of cover (300 mm) from the potentially available surface and subsurface materials as outlined in **Table 13-5**. A depth of 300 mm of soil has been found to produce a high revegetation performance.

There are approximately 47 million m^3 of suitable surface and subsurface material, which provides sufficient volume to select the optimal soils for rehabilitation to a depth of cover of 300 mm. These soils will be stripped and stockpiled or used directly in rehabilitation.

Ideally, areas where soils have saline and/or sodic properties should be avoided altogether (i.e. areas of sodosols, southern dermosols and brown vertosols). Where it is impracticable to avoid these areas then the management approach will need to consider the following:

- Surface material is invariably of greater agronomic value than overburden and therefore as a general rule should be salvaged (to a nominal depth of 300 mm) for use in rehabilitation activities.
- Where the disturbance activity is temporary such as roads, tracks, infrastructure areas, the decision to salvage must be made in the context of the inherent limitation of subsurface soils. Exposure of problematic subsurface soils may present a greater environmental risk than not collecting surface material ahead of disturbance.
- For all other soils, in the circumstance where suitable soil material extends to depth and the mining activity represents a permanent loss of such soil material (i.e. waste rock dumps, co-disposal dams and/or open pits), soil material recovery to the depth specified in the Soil Management Plan should occur. Surface soil material (nominally 300 mm) should be salvaged and stored separately. Any suitable soil below this (using recommended stripping depths in **Table 13-5**) may also be harvested and stockpiled.
- Wherever practicable, salvaged soil material will be directly placed on areas to be rehabilitated. Typically, it is not possible to operate a salvage and direct placement approach from the outset. Soils will be used directly in rehabilitation once waste rock dumps are stabilised and have achieved their final landform. It is also preferable that minimal quantities of soil be stockpiled, to the extent that salvageable soils available for direct placement are used preferentially to previously stockpiled soils.

The selection of locations for soil stockpiles will be incorporated into mine planning and drainage design. The locations, creation date, source of soil and volumes of all soil stockpiles will be recorded in the Soil Management Plan and this plan updated if stockpiles are relocated or if resources are used in rehabilitation.

In order to maximise the value of topsoil resources on-site, be they from areas of Good Quality Agricultural Land (GQAL) or otherwise, on-site, the Soil Management Plan will include consideration of the following precautions:

- Mining activities to be planned to minimise soil disturbance.
- The sodosols, northern dark vertosols and southern dark vertosols are prone to gully formation. Where these soils will be disturbed and left exposed (i.e. after stripping), or stockpiled, appropriate drainage will be constructed to avoid high water velocities or concentration of drainage.
- An erosion and sediment control plan (ESCP) will be prepared for the site prior to commencement of mining activities.
- Where possible, soil disturbance will occur during the dry season.
- Surface and sub-soils will be stripped, handled and stockpiled separately.
- Soil quality declines in storage particularly after the first year. Where stripped soils cannot be directly placed, they will be stockpiled. Stockpiles will not exceed a maximum height of 2 m and will be located in a suitable area e.g. free of future disturbance and away from drainage lines.
- Where possible, soils should not be stripped, handled or re-spread when they are wet and prone to damage through smearing and compaction or when they are dry and powdery. Ideally soils should be friable and moist and not smear when worked in the hand. Soil that is stripped when it is wet will be damaged and may become anaerobic in storage thereby killing beneficial microorganisms and viable seed. This diminishes its value and potentially compromises rehabilitation outcomes.
- Soil will not be pushed to the edges of the disturbance area. It will be transported to specific locations where it can be effectively protected and managed.
- Earth scrapers (or box scrapers) are likely to be used for stripping. Equipment movements on the unstripped topsoil will be minimised. If excavators are used, equipment will preferentially work on the exposed subsoil or overburden so as to minimise the compaction of the topsoil being stripped. All haulage routes will be located on the subsoil or overburden, not the unstripped topsoil.
- Topsoil stockpiles will be located away from watercourses and areas that may be subject to flooding or water logging or where they could be impacted by vehicular traffic and contamination from mine wastes.
- Stockpiles will be preferentially located on the footprint of future open pit mining areas so as not to create any additional disturbance.
- Soil stockpiles will be allowed to self-seed with existing species and/or stockpiles will be seeded with plant species selected for rehabilitation.
- Diversion banks or drains will be installed upslope of stockpiles to minimise run-on and stockpile erosion. An ESCP will be implemented to ensure sediment export is minimised.

With the implementation of the above mitigation measures, impacts to soil quality are expected to be minor.

13.6.4 Erosion and Stability

13.6.4.1 Impacts

The removal of vegetation and/or topsoil and the creation of new landforms can impact on soils resistance to erosion. The impacts of soil erosion and sediment transport are located at the site of erosion, in the transporting waters and at the site of sediment deposition. At the site of erosion the most serious impact is generally the loss of valuable soil, particularly topsoil. This soil loss, and associated poor surface stability, reduces the potential for agriculture, site rehabilitation and natural regeneration. Additional impacts may include damage to infrastructure such as roads and building foundations, exposure of bedrock, which hinders construction activities, and creation of deep rills or gullies that can cause access problems. Soil erosion may also occur off-site due to increased water run-off. The transport of soil into waterways can affect hydrology and geomorphology as well as water quality.

Soil erosion may result in the following.

- potential loss of agricultural productivity
- decrease in rehabilitation potential or increase in management effort required for successful rehabilitation particularly where infertile subsoils are exposed
- decreased capacity for soils to intercept and store rainfall resulting in decreased soil water storage and increased run-off potentially affecting downstream hydrology
- decrease in ecosystem services
- decrease in visual amenity.

13.6.4.2 Erosion Rates

An indication of erosion rates from permanent and temporary landforms on a nearby coal project (approximately 50 km to the south-east of the Byerwen project) is provided in **Appendix 14**. This work examined erosion rates of plots on re-profiled landforms (waste rock dumps) with varying vegetation coverage. Plot slopes were between 8° and 10°. The greatest erosion rates were observed on plots with the least vegetation cover and vice versa. The relationship between ground cover and soil loss is represented graphically in **Figure 13-8**. Similar erosion rates could be expected on Byerwen project landforms. From this it can be seen that one of the most important aspects of erosion control is the reinstatement of ground cover. Erosion loss decreases exponentially with percentage ground cover and is greatly reduced when cover exceeds 50%. For long-term stabilisation in tropical climates, IECA (2008) recommends a minimum ground cover of 80% which will considered as the target for this project.

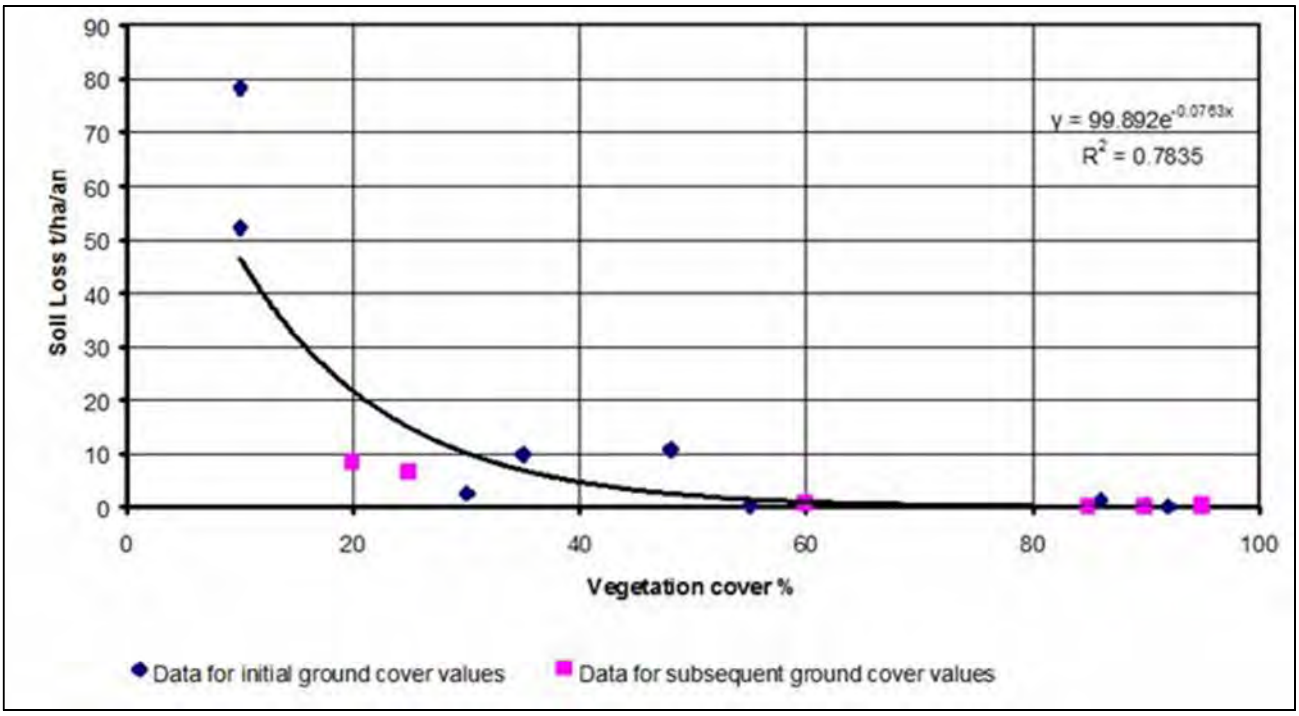

Figure 13-8 Erosion Rates on Waste Rock Dumps at a Nearby Coal Mine

13.6.4.3 Mitigation

The water management strategy is presented in **Chapter 8**. This strategy involves activities that are a mitigation measure for impacts to soils, namely:

- the use of sediment dams to capture sediment affected waters from waste rock dumps
- separation of clean water from water from areas of disturbance.

An ESCP will be developed for the project. Erosion and sediment control will be in accordance with the *Soil Erosion and Sediment Control-Engineering Guidelines for Queensland Construction Sites* (Engineers Australia, 1996) and the *EPA Best Practice Urban Stormwater Management-Erosion and Sediment Control* guideline (EPA, 2008). Additional guidance will be obtained from IECA (2008) *Best Practice Erosion and Sediment Control*. The ESCP will be approved by a suitably qualified person (such as a Certified Professional in Erosion and Sediment Control). The ESCP will be amended as the mine develops to account for changes in final landform design and infrastructure locations. The most critical aspects of the ESCP are set out below.

- Development of the ESCP will be integrated into the mine planning process.
- Sensitive areas (soils with high or very high erosion potential) that may require specific measures will be identified. Such soils will include the sodosols, rudosols, brown vertosols, northern dark vertosols and the southern dark vertosols. Other sensitive areas may be delineated from flora and fauna or cultural studies.
- The period of maximum disturbance will be planned to occur in the dry season (nominally May to October) where possible.
- The extent and duration of disturbance (topsoil and subsoil exposure) will be minimised.
- Boundaries of areas to be cleared will be delineated on project drawings and/or in the field to define the extent of authorised clearing. Clearing will be authorised by use of a 'permit to clear'

system. Boundary constraints may also be imposed based on the outcomes associated with flora and fauna or cultural studies.

- If vegetation clearing must be carried out well ahead of earthworks, clearing will be limited to woody vegetation. Grubbing out and removal of ground cover should be carried out as close to the time of earthworks as possible.
- Erosion potential and volume of run-on water will be controlled to minimise the amount of sediment affected water released by diverting upslope clean water around the disturbed areas in a controlled manner (or passing it through the site in a manner that separates it from dirty site water).
- All drainage structures and sediment controls will have design specifications appropriate to the rainfall regime and design life.
- Erosion controls (such as surface protection or vegetation) will be used to prevent on-site damage and minimise sediment generation and mobilisation.
- Sediment controls (such as silt fencing and sediment dams) will be used to treat run-off from disturbed areas prior to leaving the site.
- Sediment controls will be located as close to the source as possible.
- Erosion and sediment control structures will be installed as required, prior to disturbance in that area of site.
- Grading of soil will be away from watercourses (except where watercourses are realigned or crossed) and any stockpiled material will be located at least 10 m from any watercourse
- Disturbed areas will be stabilised as soon as possible (progressively).
- Control structures will be inspected regularly, particularly after rain, to identify and rectify failures or maintenance requirement (e.g. repair, removal of sediment).

Soil with a risk of erosion has been identified on site. These materials require specific erosion and sedimentation control measures, such as:

- drainage controls on roads/disturbance areas on slopes (whoa boys and turnout drains spaced to reflect slope)
- minimising slope lengths on disturbed areas/engineered landforms
- drains to channel water over high erosion risk materials (e.g. over waste rock dumps that contain high erosion risk materials).

Details of the rehabilitation of the site, including final landform design is provided in **Chapter 10.** Rehabilitated mine landforms will be designed to minimise slope angle and length. Low erosion risk soil will be preferentially used on areas with longer and/or steeper slopes. **Table 13-5** provides a relative erosion risk for soils expected to be disturbed by the project.

One of the most important aspects of erosion control is the reinstatement of ground cover. Erosion loss decreases exponentially with percentage ground cover and is greatly reduced when cover exceeds 50%.

Temporary surface protection may be provided by trash blanketing or other measures such as hydromulching, bonded fibre matrix (BFM) or erosion control matting, but vegetation establishment will be required for long-term soil stabilisation. Fast establishing grasses and ground covers can provide good early surface protection against sheet and rill erosion. Ideally they should be non-invasive (preferably native) and have a horizontal growth habit. Deeper rooted plants (generally trees and shrubs) provide the best protection from mass movement. On cut and fill batter protection is required in the long-term.

All revegetated areas will be monitored to ensure the desired ground cover is achieved and further seeding or planting is conducted in areas that do not meet the desired target.

With the implementation of the above mitigation measures, impacts from erosion are expected to be minor.

13.6.4.4 Monitoring

Monitoring of the performance of erosion and sediment control structures will be carried out both pre- and post-wet season and following any significant events. Monitoring may be done using visual methods (such as those for recording erosion features) and/or more quantitative methods such as those using erosion monitoring pins, or measuring sediment loads from monitored catchments.

13.6.5 Local Waterways

13.6.5.1 Impacts

The movement of eroded soil into waterways results in degradation of water quality with respect to suspended solids/turbidity, nutrients associated with soil material, as well as metals and metalloids associated with mineralised soils, potentially leading to the following:

- impacts on aquatic organisms and waterway productivity through light interception, proliferation of nuisance organisms or direct toxicity
- changes in species composition as a result of changes in water quality
- reduction in potential potability of water for humans and livestock
- reduction in quality of water for crop irrigation
- decline in aesthetic and recreational values that may be of cultural significance.

The deposition of eroded soil and sediment, sometimes at considerable distance from the site of soil loss can result in the following:

- smothering and degradation of natural in-stream and near-stream habitats
- increase in stream bank erosion and channel width resulting in damage to riparian habitat and property loss
- reduced navigability
- increase in over bank flooding due to stream bed aggradation and potential impacts on surrounding land uses or environmental values
- damage to in-stream infrastructure (dams, culverts).

13.6.5.2 Mitigation

The water management strategy, including management of sediment-affected water is presented in **Chapter 8**.

Erosion mitigation measures are outlined in **Section 13.6.3**. Additional measures specifically relevant to waterways include the following:

- Where earthworks are carried out in proximity to a watercourse, disturbance will be repaired and stabilised on completion of works.
- Felled timber will be removed from the area and stockpiled away from the watercourse.

- Temporary earth banks will be installed along any cleared slope on approaches to watercourses to divert dirty water away from the watercourse and into a vegetated area or sediment control structure.
- Clean rock (with minimum fines) and culverts will be used for temporary watercourse crossings. These structures are to be removed with care to minimise sedimentation of the watercourse.
- Where buried infrastructure crosses a drainage line, work will be preferentially scheduled for the dry season (no flow conditions) with sufficient lead time to allow any backfilling and stabilisation to take place prior to wet season flows.
- The discharge of diverted water (piped or pumped) will not cause stream bed or bank erosion downstream of the works.
- Water discharged to a waterway will meet project water quality objectives.

With the implementation of the above mitigation measures, impacts on local waterways are expected to be minor.

13.7 Conclusion

The coal resource will be effectively utilised. It is considered that the mining method chosen, and mine plan is the optimum for maximizing utilisation of the currently known resource.

Final voids, waste rock dumps and decommissioned co-disposal dams will permanently alter the topography of the project site. Watercourse and drainage line diversions will remain following mine closure to permanently divert water around areas of altered topography.

The project will impact soils through physical disturbance within the 7,000 ha footprint of project activities. There are a variety of surface and subsurface soils in the project area, with varying degrees of suitability for use in rehabilitation. The soils best suited to rehabilitation at the recommended depth (300 mm) from the potentially available surface and subsurface materials, will be salvaged from areas of disturbance.

The removal of vegetation and/or topsoil and the creation of new landforms will impact on soils resistance to erosion and potentially result in the movement of eroded soils to waterways. Soil with a risk of erosion has also been identified on site.

A Soil Management Plan will be developed prior to commencement of mining activities to manage the disturbance of soils, identify soils best suited to rehabilitation and manage the stockpiling of soils for use in rehabilitation. Following the initial years of soil stripping and stockpiling, soils will be used directly in rehabilitation in preference to stockpiling.

An ESCP will be developed prior to commencement of mining activities and implemented to manage erosion and stability issues and impacts to waterways. This will be complemented by water management measures described in the water management plan to limit release of sediment affected water.

Rehabilitation and decommissioning of the site will be managed as described in **Chapter 10** with areas where topography is altered to be rehabilitated to their final landform design.

With the implementation of the proposed mitigation measures, impacts on topography are expected to be moderate; and impacts on soil quality, erosion potential and local waterways are expected to be minor.