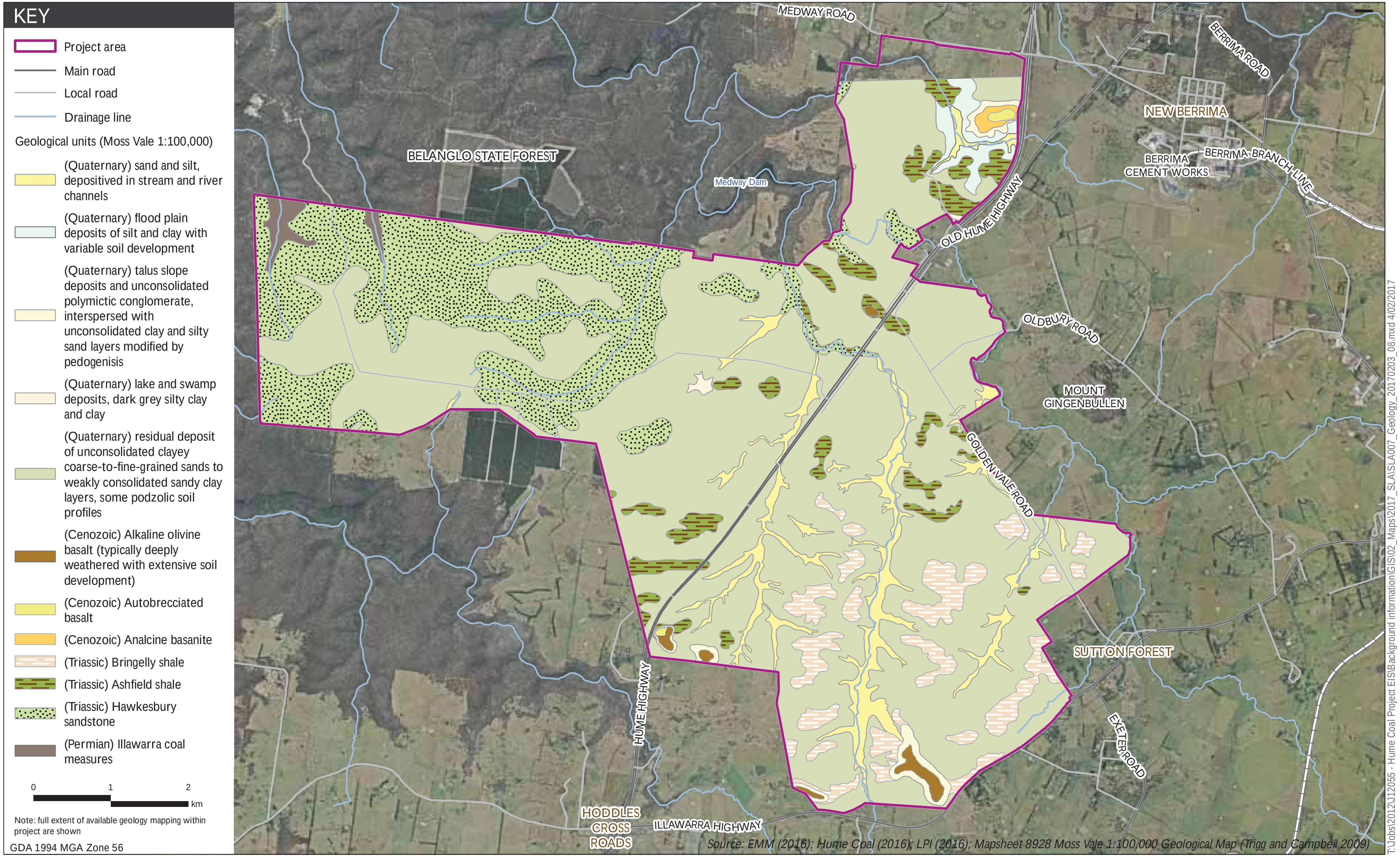

Surface geology of project area

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Figure 3.4

3.4.2 Hydrogeology

The Hawkesbury Sandstone is the main groundwater bearing unit in the region, though groundwater is also present in other units. The Wianamatta Group Shale unit has low permeability and acts as a regional aquitard to downward vertical flow. Groundwater quality is similar within the Hawkesbury Sandstone and the Wongawilli Seam, and is typically fresh, and bores within the sandstone range in yield from low to high. Salinity is higher in some areas due to infiltration of more saline water from the overlying Wianamatta Group shales, which are of marine origin. High iron and manganese concentrations have been observed at some locations, particularly monitoring bores located to the north of the project area. Groundwater within the shales is generally brackish to saline, and bores within the shale are generally very low yielding.

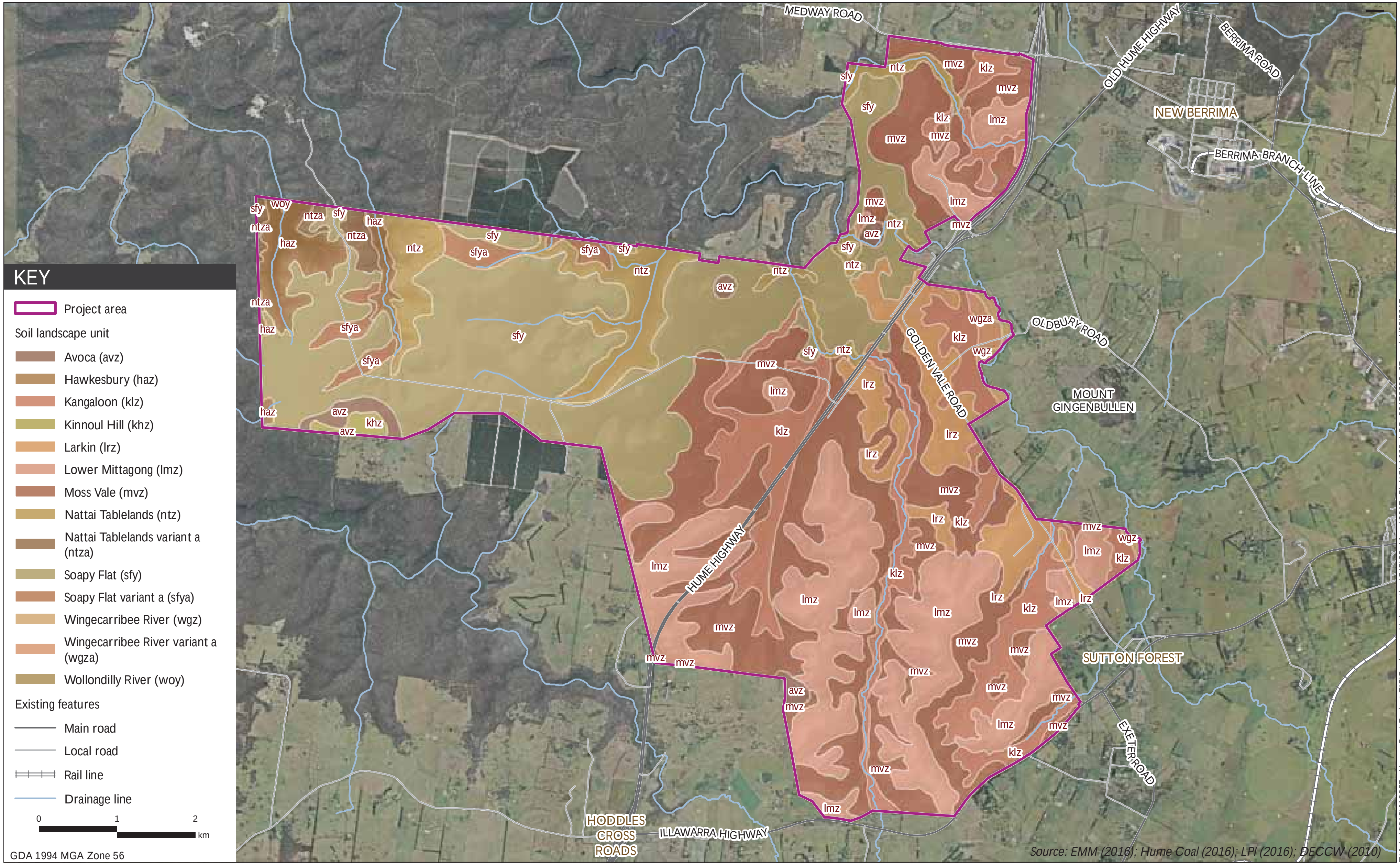
3.5 Regional soil mapping

3.5.1 Soil and land resources mapping

The *Soil and Land resources of the Hawkesbury-Nepean Catchment Map* (1:100,000) identifies 14 soil landscapes within the project area (DECC 2008) (Figure 3.5). The most extensive landscapes in the project area are the Soapy Flat landscape (26% of area), rises and low hills on Hawkesbury Sandstone; and the Moss Vale landscape (24% of area), rises on Wianemetta Group Shale (see Table 3.2). The other significant soil landscapes include Lower Mittagong, Kangaloon, and Nattai Tablelands. The soil landscapes are described in Table 3.2. The soil landscapes are not grouped by soil type, instead they are mostly grouped based on geological origin and similarity in local relief and slopes. Therefore each landscape may include a range of soil types within each landscape. Similarly, each soil type described in Section 4 occurs across more than one soil landscape. The most extensive landscapes in the project area are the Soapy Flat landscape and the Moss Vale landscape, together comprising 50% of the area.

Table 3.2 Soil landscapes and extent in the project area

Geological Origin	Soil landscape	Approx. area (ha)	Percentage of total (%)
Hawkesbury Sandstone	Hawkesbury	140.3	2.8
	Soapy Flat	1317	26.1
	Soapy Flat variant a	87.6	1.7
	Nattai Tablelands	318.4	6.3
	Nattai Tablelands variant a	41.6	0.8
Laterite and Ordovician Metasediments	Larkin	302.4	6.0
Quaternary Alluvium	Wingecarribee River	21.9	0.43
	Wingecarribee River variant a	17.3	0.34
	Wollondilly River	1.2	0.02
Tertiary Basalt	Kinnoul Hill	18	0.36
	Avoca	52.5	1.05
Wianametta Group Shale	Kangaloon	591.6	11.7
	Lower Mittagong	919.6	18.2
	Moss Vale	1221.6	24.2
TOTAL		**5051**	



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Soil landscapes of the project area (OEH mapping)

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Figure 3.5

Table 3.3 Description of the soil landscapes in the project area

Description	General landscape (project area and beyond)	Land use	Soils and vegetation	Erosion
Avoca	Rises and low hills on Tertiary Basalt (basalt). Local relief 10-90 m; altitude 519-1041 m; slopes 3-20%; rock outcrop <2%.	Beef production on improved pastures occurs along with some olive and grape enterprises.	Gravelly Brown and Red Ferrosols and occasional Red Ferrosol. Most of this landscape has been extensively cleared and improved pasture varieties have been sown. Small areas of woodland still remain.	Sheet erosion is common in cultivated paddocks. Localised steeper slopes are prone to mass movement.
Hawkesbury	Scarps and benches within hills on Hawkesbury Sandstone. Local relief 40-200m; altitude 1-1016m; slopes 20-70%; rock outcrop >50%.	Belanglo State Forest	Leptic and Orthic Tenosols and Rudeosols, Yellow Kandosols, and Kurosols.	Severe sheet erosion during storms and after bushfires.
Kangaloon	Foot slopes within plain on Wiamatta Group Shale. Local relief 0-9m; altitudue 531-745m; slopes 1-3%; rock outcrop nil.	Grazing	Brown Kurosols and Hydrosols. Extensively cleared open grassland.	Waterlogging as a result of tree clearing.
Kinnoul Hill	Hills on Tertiary Basalt (basalt). Local relief 30-100 m; altitude 489-1123 m; slopes 20-50%; rock outcrop nil.	Improved pastures used for grazing.	Rudosols and Red Ferrosols. Most of this landscape has been cleared for cattle grazing.	Clearing of many steep slopes has resulted in a large amount of soil loss. Localised landslips occur.
Lower Mittagong	Rises and low hills on Wianamatta Group Shale (shale). Local relief 5-90 m; altitude 534-820 m; slopes 0-25%; rock outcrop nil.	Beef cattle grazing, rural residential development, olive and vineyard development, plus urban development around Mittagong and Moss Vale.	Brown Kurosols, Red Kurosols, Brown Dermosols and Red and Brown Kandosols, with Yellow Natric Kurosols in drainage lines. Generally Mittagong Sandstone Woodland community.	Minor to moderate gully erosion occurs in cleared drainage plains. Minor sheet erosion is common.
Larkin	Plain and rises on laterite, shale and sandstone-quartz. Local relief 0-10 m; altitude 576-1012 m; slopes 2-6%; rock outcrop nil.	Cattle grazing plus some minor areas of sheep grazing.	Red Ferrosols and Red Kurosols on shales with Red Kandosols and Ferrosols on sandstones. Due to the moderate fertility of these soils most areas of the original open forest have been cleared for grazing.	Moderate sheet erosion in overgrazed paddocks.
Moss Vale	Rises on Wianamatta Group Shale (shale). Local relief 5-30 m; altitude 544-740 m; slopes 0-5%; rock outcrop nil.	Beef cattle grazing and rural residential development.	Yellow Kurosol, Red Kurosols, Brown Kurosols and Yellow Kandosols. Mostly cleared pasture with isolated paddock trees.	Minor to moderate gully erosion occurs in cleared drainage plains.

Table 3.3 Description of the soil landscapes in the project area

Description	General landscape (project area and beyond)	Land use	Soils and vegetation	Erosion
Nattai Tablelands	Rises and low hills on Hawkesbury Sandstone. Local relief 10-90m; altitude 87-793m; slopes 2-25%; rock outcrop 10-20%.	Predominantly uncleared native vegetation due to steep slopes and remote location.	Yellow Kandosols, Orthic Tenosols, Rudosols, Yellow Kurosols and Chromosols on shales. Soils are discontinuous, with sandstone benches and small scarps outcropping.	Minor to moderate sheet erosion is common where shrub/understorey has been cleared.
Nattai Tablelands variant A	Plateau on Hawkesbury Sandstone. Local relief 10-90m; altitude 412-782m; slopes 2-25%; rock outcrop >50%.	Predominantly native bushland and scrub.	Discontinuous Leptic Tenosols (Earthy Sands) interspersed with significant rock outcrop. Uncleared woodland to open-forest communities.	Minor to moderate sheet erosion is common where shrub/understorey has been cleared.
Soapy Flat	Rises and low hills on Hawkesbury Sandstone. Local relief 10-30 m; altitude 477-796 m; slopes 2-10%; rock outcrop <2%.	Crown reserve, including Soapy Flat reserve.	Brown Dermosols, Yellow Kurosols and Chromosols, Orthic Tenosols on ridges and Hydrosols (Acid Peats) in swamps.	Minor sheet erosion occurs where ground cover is cleared.
Soapy Flat variant A	Footslopes within rises on Hawkesbury Sandstone. Local relief 10-30 m; altitude 490-716 m; slopes 2-10%; rock outcrop <2%.	Crown reserve, including Soapy Flat reserve as well as pine forestry operations in Belanglo State Forest.	Orthic Tenosols (Deep Earthy Sands). Extensively cleared woodland.	Minor sheet erosion occurs where ground cover is cleared.
Wingecarribee River	Plains and stream channels within flood plain on Quaternary Alluvium. Local relief 0-5 m; altitude 629-688 m; slopes 0-1%; rock outcrop nil.	Extensively cleared open woodland, grassland and water communities. Area predominantly used for grazing.	Dermosols (Chocolate Soils and Wiesenbodens).	Localised erosion of stream banks and faecal contamination of waters due to stock.
Wingecarribee River variant A	Plains and levees within terrace and flood plain on Quaternary Alluvium. Local relief 0-5 m; altitude 630-667 m; slopes 0-1%; rock outcrop nil.	Extensively cleared open woodland, grassland and water communities. Area predominantly used for grazing.	Hydrosols (Gleyed Podzolic Soils).	Occasional erosion of banks and unformed roads and tracks.
Wollondilly River	Alluvial plain and terrace on Quaternary Alluvium. Local relief 0-15m; altitude 110-720m; slopes 1-6%; rock outcrop nil.	Belanglo State Forest.	Rudosols, Brown Dermosols, Yellow Kandosols, Brown Chromosols. Riparian woodland.	Minor sheet and streambank erosion. Common gullying along drainage lines.

Notes: 1. Source: Soil and Land Resources of the Hawkesbury-Nepean Catchment.

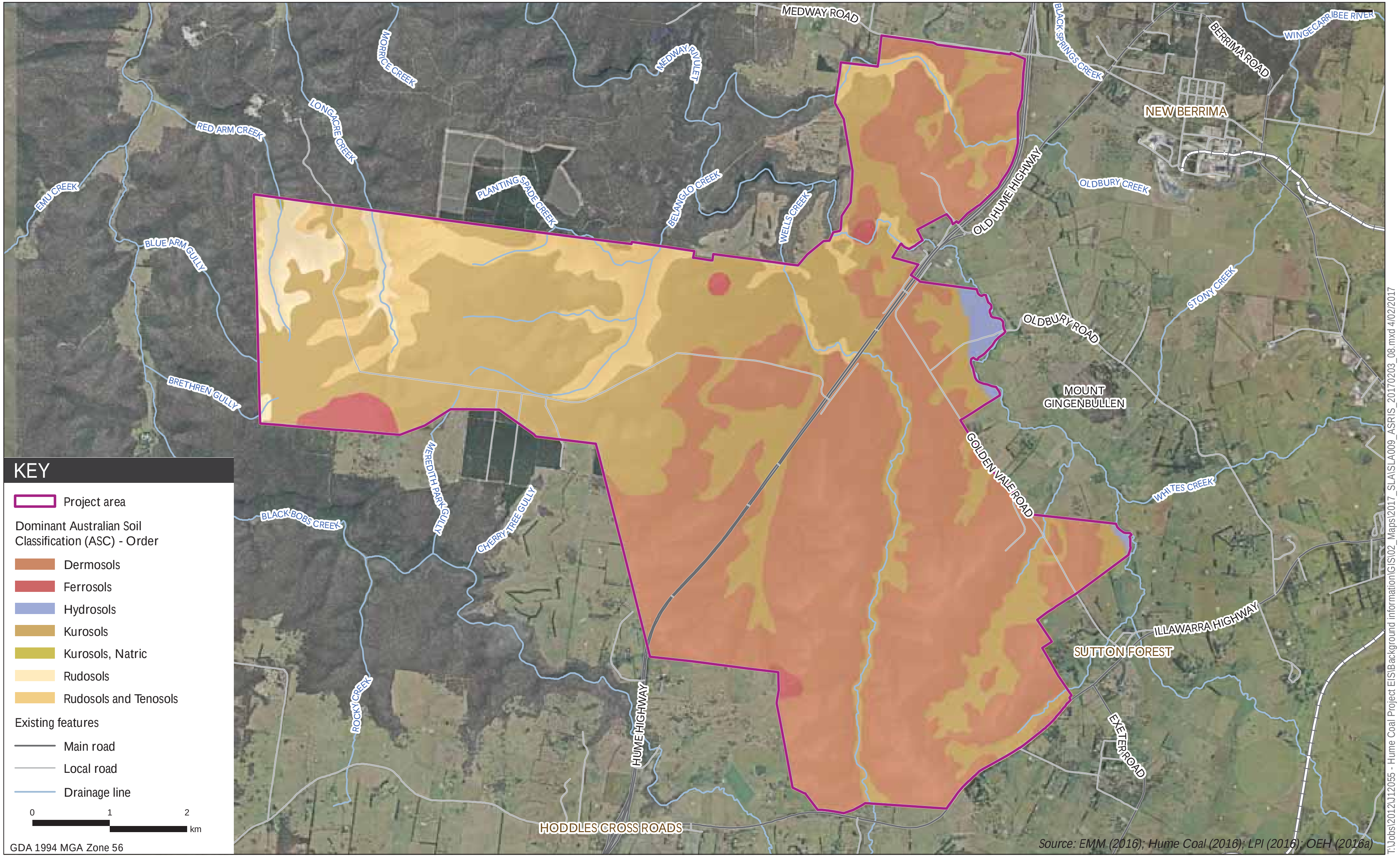
3.5.2 Australian soil classification

The Australian Soil Classification (ASC) scheme (Isbell 1996) is a multi-category scheme with soil classes defined on the basis of diagnostic horizons and their arrangement in vertical sequence as seen in an exposed soil profile. Table 3.4 provides descriptions of the ASC orders which are currently mapped on a regional scale within the project area (OEH 2016a) and some indicative information of agricultural values. Figure 3.6 shows the soil distribution across the project area. This mapping is based on a small number of historic soil survey observations and is superseded by more detailed mapping undertaken for the project by EMM (Section 4). The table also shows the percentage of each soil order within the project area.

Table 3.4 Regional soil mapping - ASC soil orders distribution in the project area

Order	Description	Agricultural potential[1]	Soil Landscapes	Approximate location	% of project
Kurosol	Soils with strong texture contrast between A horizons and strongly acid B horizons.	Very low with high acidity (pH<5.5), low chemical fertility, low water-holding capacity and often sodic.	Soapy Flat; Wollondilly River	Widespread in the lower sloped areas of the western part of the project, including most of the Belanglo forest area.	26.12%
Rudosols and Tenosols	Weakly structured throughout the profile with the exception of the A horizon. Often shallow ie. bedrock is located near surface.	Very low with low chemical fertility, poor structure and low water-holding capacity.	Soapy Flat variant a, Nattai Tablelands (incl. variant a); Hawkesbury	Steeper slopes of the western part of the project, including most of the Belanglo forest area.	11.6%
Ferrosols	Soils lacking a strong texture contrast and with a B horizon containing elevated free iron oxide. A gradual increase in clay content with depth. The subsoil maybe acidic.	Generally high because of their good structure and moderate to high chemical fertility and water holding capacity.	Avoca, Kinnoul Hill	Predominately located in the north-east and south-east.	1.4%
Dermosols	Lack a strong texture contrast and have a well structured B horizon. It has a gradual increase in clay content with depth. It has a more defined structure then Kandosols.	High with good structure and moderate to high chemical fertility and water-holding capacity with few problems.	Kangaloon Lower Mittagong, Moss Vale, Larkin	Widespread over the north-east and most of the southern and central area	60.1%
Hydrosol	Soils that are saturated in the major part of the solum for at least 2-3 months in most years.	Very low due to seasonal or permanent saturation.	Wingecarribee R Wingecarribee R variant a	Associated with water ways on the north-eastern boundary.	0.78%

Notes: 1.Based on Gray and Murphy (2002).



Regional soil mapping - Australian Soil Classification (OEH mapping)

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Figure 3.6

3.5.3 Great soil groups

Great soil groups (GSG) is a soil classification system developed by Stace et al (1968) based on the description of soil properties such as colour, texture, structure, drainage, lime, iron, organic matter and salt accumulation, as well as on theories of soil formation. Historic soil mapping identified from NSW government mapping (OEH 2016b) for the project area comprise Podzolic soils, Earths, Kraznozems and Clay soils. The general characteristics of each of these Great Soil Groups are described in Table 3.5.

Table 3.5 Regional soil mapping - Great Soil Groups distribution (%) in the project area

	Great Soil Group (GSG)	ASC Equivalent[1]	Soil Landscape	%
Podzolics and solodics	Yellow Podzolic Soils (volcanics and granodiorites)	Dermosols	Lower Mittagong, Moss Vale	42.4
	Yellow Podzolic Soils - less fertile (granites and metasediment)	Dermosols	Kangaloon	11.7
	Brown Podzolic Soils	Kurosols	Soapy Flat	26.1
	Soloths	Kurosols	Wollondilly River	0.02
	Gleyed Podzolic Soils	Hydrosols	Wingecarribee R variant a	0.34
Earths	Red Earths - more fertile (volcanics and granodiorites)	Dermosols	Larkin	6
Clays	Weisenboden	Hydrosols	Wingecarribee R	0.43
Chemozem and prairie soils	Chocolate Soils	Ferrosols	Avoca	1.05
Euchrozems and kraznozems	Kraznozems	Ferrosols	Kinnoul Hill	0.36
Sands	Earthy Sands	Rudosols and Tenosols	Nattai Tablelands and variant a, Soapy Flat variant a	8.8
	Siliceous Sands	Rudosols and Tenosols	Hawkesbury	2.8

Notes: 1. Australian Soil Classification equivalent.

3.5.4 Hydrologic soil group

The hydrologic soil groups (OEH 2016c) present in the project area comprise predominately group C – Slow infiltration, with small areas of group B, D and A. These are defined as follows (Table 3.6):

- **A:** soils having high infiltration rates, even when thoroughly wetted and consisting chiefly of deep, well to excessively-drained sands or gravels. These soils have a high rate of water transmission.
- **B:** soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.
- **C:** soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.
- **D:** soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

Table 3.6 Hydrologic Soil Groups in project area

Hydrologic Soil Group[1]	Landscape Units	% in project area
High Infiltration (A)	Earthy Sands, Siliceous Sands (ASC Rudosols and Tenosols); Kraznozems	11.9
Moderate Infiltration (B)	Red earths – more fertile, Chocolate soils,	7.1
Slow (C)	Yellow Podzolic Soils, Brown Podzolic Soils,	80.2
Very slow (D)	Gleyed Podzolic soils, Weisenboden (ASC - Hydrosols); Soloths	0.8

Notes: 1.Based on Great Soil Group classes (Stace et al 1968).

3.5.5 Inherent soil fertility

The inherent fertility based on GSG mapping of the project area identifies soils ranging from Low (1) soil fertility through to Moderately High (4). The inherent fertility is based on GSG data (Stace et al 1968), from which a fertility value was derived using a lookup table modified from Charman (1978).

The fertility rankings are defined by OEH (2016d) as (Table 3.7):

- **Moderately high (4):** includes soils with high fertility in their virgin state but fertility can be significantly reduced after a few years of cultivation and amendments and fertilisers are required.

- **Moderate (3):** soils have low to moderate fertilities and usually require fertiliser and/or have some physical restriction for arable use.

- **Moderately low (2):** Includes soils with low fertilities, such that, generally, only plants suited to grazing can be supported. Large inputs of fertiliser are required to make the soils useable for arable purposes.

- **Low (1):** Includes soils which, due to their poor physical and/or chemical status only support plant growth. The maximum agricultural use of these soils is low intensity grazing.

Table 3.7 Inherent fertility of soil groups in project area

Fertility Ranking[1]	Landscape Units	% in project area
Moderately high (4)	Red earths – more fertile, Chocolate soils, Kraznosems	7.4
Moderate (3)	Brown Podzolic soils, Wiesenboden, Yellow Podzolic – more fertile	68.9
Moderately low (2)	Yellow Podzolic – less fertile, Soloths, Gleyed Podzolic soils	12.1
Low (1)	Earthy sands, Siliceous sands	11.6

Notes: 1.Based on Great Soil Group classes (Stace et al 1968).

3.5.6 eSPADE soil profiles

The eSPADE soil profile data base search identifies information on soil profiles surveyed in the greater Bowral area and submitted to the SALIS database (OEH 2016e). Seventeen profiles occur within the project area. Table 3.8 details the historic eSPADE soil profiles within the project area. Very few of these sites have a complete survey record.

Table 3.8 eSPADE historic soil profiles within the project area (2016g)

ASC[1]	Great Soil Group	pH	Surface Texture	ID	Location Description
Hydrosols	Gleyed Podzolic Soil	5	coarse sandy loam	33	Cherry tree/ High Swamp roads.
	Gleyed Podzolic Soil	5	Coarse loamy sand	34	Depot Back Road Belanglo SF
	Humic Gley	5.5	Light sandy clay loam	35	Bunnigalore Road (Moss Vale)
	Wiesenboden	5.5	Light clay	214	Oldbury Road/Medway Rivulet
Kandosols	Red Earth	5	Light silty clay	36	Old Hume Highway
	Yellow Earth	6	Sandy loam	114	Profile 114
Kurosols	Brown Podzolic soil	6	Silty loam	3	Profile 3
	Yellow podzolic soil	6	Fine sandy clay loam	115	Profile 115
Rudosols and Tenosols	Earthy Sand	5.5	Coarse sandy loam	32	Belanglo S.F. Belanglo Creek Rd.
	Earthy Sand	6	Coarse loamy sand	6	Belanglo Rep3 Plot2-Smb6
	Earthy Sand	5.5	Fine sandy loam	19	Belanglo Demo No4 - Smb11
	Earthy Sand	4.5	Fine light sandy clay loam	20	Belanglo Demo No4 - Smb12
	Earthy Sand	6	Coarse loamy sand	1	Belanglo Rep4 Plot4-Smb1
	Earthy Sand	6	Fine loamy sand	8	Belanglo Rep4 Plot1-Smb8
	Earthy Sand	6	Coarse loamy sand	7	Belanglo Rep3 Plot4-Smb7
	Unclassified	5.5	Clay loam	52	10 m from SW Boundary Rd.
	Unclassified	5.5	Light clay loam	53	20 m from Eastern cpt Rd.

Notes: 1.Australian Soil Classification equivalent.

3.6 Acid sulphate soil planning map

There are no acid sulphate soils in the project area, as per the *Guidelines for the Use of Acid Sulfate Soil Risk Maps* (DLWC, 1998). They are only found in coastal areas.

3.7 Regional land use and land capability

3.7.1 Land use

Approximately 75% of the project area is privately owned land. The predominant land use is agriculture due to the minimum lot size for most of the area being 40 ha. Many properties are much larger. Common land uses include lifestyle rural properties, broad acre grazing, equestrian properties, viticulture and cropping. There are a number of vineyards located in the project area, including Cherry Tree Hill and Eling Forest Vineyards. Given the generally mild climate and reliable rainfall, the region has a traditional agricultural base.

More recently there has been noticeable growth in population resulting from the regions' proximity to Sydney. Towns within the Southern Highlands have become popular weekend and holiday tourist attractions and retirement locations. The region also has a longstanding manufacturing industry including a cement works, brickworks, metal fabrication, mining equipment manufacture, quarrying and coal mining.

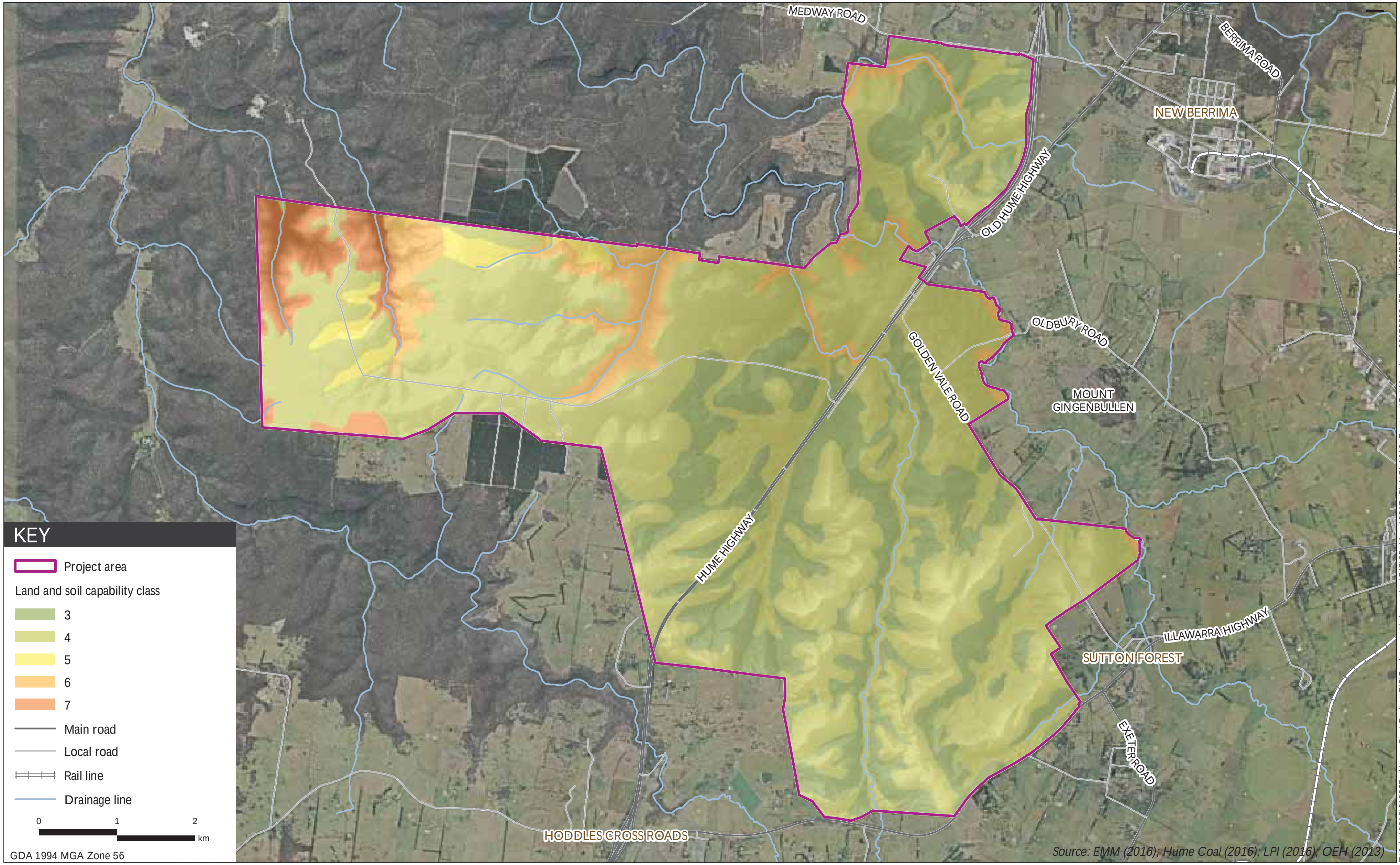
The remaining 25% of the project area is Belanglo State Forest. The Belango State Forest, located in the west of the project area, supports a commercial pine plantation which is processed at a local mill.

3.7.2 Land and soil capability classes

The project area is mapped by the *Land and Soil Capability Mapping of NSW* (OEH 2016e) as predominately Class 4 – Moderate capability and Class 3 – High capability, with small areas of Class 6 – Low capability and Class 7 – Very low capability (Figure 3.7). The LSC classes in the project area are matched with the relevant Soil Landscapes in Table 3.9. This mapping is not intended to be used for detailed rural capability assessment at the property scale which would require more intensive field investigation. A local scale assessment of land and soil capability has been conducted using the survey, and is summarised in Section 6 and presented in full in Appendix B.

Table 3.9 Regional land and soil capability classes (OEH 2016e) in the project area

LSC Class	Soil landscapes	Description	Area (Ha)	%
3	Moss Vale	**High capability land:** Land has moderate limitations and is capable of sustaining high-impact land uses, such as cropping with cultivation. However, careful management of limitations is required for cropping and intensive grazing to avoid land and environmental degradation.	1221.6	24
4	Kangaloon, Larkin, Lower Mittagong, Soapy Flat, Avoca Wingecarribee River var. A	**Moderate capability land:** Moderate to high limitations for high-impact land uses. It will restrict land management options for regular high-impact land uses such as cropping, high-intensity grazing and horticulture; and the limitations can only be managed by specialised management practices with a high level of knowledge, expertise, inputs, investment and technology.	3200.4	63
5	Wollondilly River;Soapy Flat var A	**Moderate-low capability land:** High limitations for high-impact land uses. Will largely restrict land use to grazing, some horticulture (orchards), forestry and nature conservation. The limitations need to be carefully managed to prevent long-term degradation.	88.8	2
6	Nattai Tablelands; Wingecarribee River	**Low capability land:** Very high limitations for high-impact land uses and is generally suitable for limited land uses such as grazing, forestry and nature conservation. Careful management of limitations is required to prevent severe land and environmental degradation.	340.3	7
7	Hawkesbury, Nattai Tablelands var. A, Kinnoul Hill	**Very low capability land:** Severe limitations that restrict most land uses and generally cannot be overcome. Generally suitable only for selective forestry and nature conservation.	199.9	4



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Soil and land capability (OEH mapping)

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Figure 3.7

3.7.3 Agricultural suitability assessment

The agricultural suitability assessment is a five class system (developed in 1979), which classifies land in terms of its suitability for general agricultural use (NSW DPI 2002). The classification system relies on the evaluation of biophysical, social and economic factors. It is a useful tool for government land use planning purposes, but is not used at a farm scale.

Class definitions for agricultural land classification are:

- **Class 1:** Arable land suitable for intensive cultivation where constraints to sustained high levels of agricultural production are minor or absent.

- **Class 2:** Arable land suitable for regular cultivation for crops, but not suited to continuous cultivation. It has a moderate to high suitability for agriculture but edaphic (soil factors) or environmental constraints reduce the overall level of production and may limit the cropping phase to a rotation with sown pastures.

- **Class 3:** Grazing land or land well suited to pasture improvement. It may be cultivated or cropped in rotation with sown pasture. The overall production level is moderate because of edaphic or environmental constraints. Erosion hazard, soil structural breakdown or other factors, including climate, may limit the capacity for cultivation and soil conservation or drainage works may be required.

- **Class 4:** Land suitable for grazing but not for cultivation. Agriculture is based on native pastures or improved pastures established using minimum tillage techniques. Production may be seasonally high but the overall production level is low as a result of major environmental constraints.

- **Class 5:** Land unsuitable for agriculture, or at best suited only to light grazing. Agricultural production is very low or zero as a result of severe constraints, including economic factors which prevent land improvement.

The 1:50000 scale Agricultural Land Classification Map - Moss Vale (Dept of Agriculture 1986), maps most of the project area as Land Class 3, with smaller areas of Class 4 and 5. There is no Class 1 or 2 land suitable for regular cultivation for crops.

3.7.4 Biophysical strategic agricultural land

The NSW Government has mapped BSAL across the whole of NSW, based on a desktop study, and the resultant maps accompany the Mining SEPP. The BSAL shown on the maps comprises land which meets criteria described in the Interim Protocol: access to a reliable water supply; and falls under soil fertility classes 'high' or 'moderately high' under the NSW OEH *Draft Inherent General Fertility of NSW,* where it is also present with land capability classes I, II or III under OEH's *Land and Soil Capability Mapping of NSW;* or falls under soil fertility classes 'moderate' under OEH's *Draft Inherent General Fertility of NSW,* where it is also present with land capability classes I or II under OEH's *Land and Soil Capability Mapping of NSW.*

The Strategic Agricultural Land Map prepared by OEH and presented in the Interim Protocol, indicates that there is no BSAL in the project area. These maps have generally not been verified by site investigations and site verification in accordance with the Interim Protocol is required to confirm whether or not land is actually BSAL. The project area has been assessed for BSAL which determined that no BSAL occurs within the project area. The full report is presented as Appendix A, with the summary of the results presented in Section 5.

4 Soil descriptions

4.1 Summary of units

The soil survey identified five major soil types within the project area (Table 4.1). The soil types identified are: Kandosols, Dermosols, Rudosols, Hydrosols, Tenosols. Figure 4.1 presents the spatial distribution of the soil types within the project area.

Yellow Kandosols are the dominant soil type of the project area (61%), followed by Rudosols (17%) and Tenosols (14%). A general description of the soil order is presented in Sections 4.1.1 to 4.1.5. A full description of the soil type in the project area, including tables showing soil chemistry data, are presented in Sections 4.2 to 4.6.

Table 4.1 Soil types in the project area

ASC order (Soil type)	Total area mapped within project area	
	(ha)	(%)
Kandosol	3076	61
Rudosol	852	17
Tenosol	714	14
Hydrosol	245	5
Dermosol	164	3
TOTAL	5051	

4.1.1 Kandosols

Kandosols are soils which lack strong texture contrast, have massive or only weakly structured B horizons, and are not calcareous throughout. The B2 horizon is generally well developed and has a maximum clay content in some part of the B2 horizon which exceeds 15%. In the project area Kandosols are associated with predominantly cleared, gently undulating grazing lands. The Kandosol described in the project area is further classified as Dystrophic Yellow Kandosol and is described in detail in Section 4.2.

4.1.2 Rudosols

Rudosols are usually young soils in the sense that soil forming factors have had little time to pedologically modify parent rocks or sediments. These are soils with negligible (rudimentary) pedologic organisation apart from a minimal development of an A1 horizon or possibly the presence of less than 10% of B horizon material, usually in fissures in the parent rock or saprolite. There are generally no pedological colour changes apart from the darkening of an A1 horizon. The Rudosol described in the project area is further classified as Lithic Leptic Rudosol and is described in detail in Section 4.3.

4.1.3 Tenosols

This soil order incorporates soils with generally weak pedologic organisation apart from the A horizons, encompassing a diverse range of soils. Tenosols generally have poor water retention, almost universal low fertility and occur in regions of low and erratic rainfall. They are mainly used for grazing based on native pastures. In better watered areas, such as the project area, limited areas support forestry. The Tenosol described in the project area is further classified as Paralithic Leptic Tenosol and is described in detail in Section 4.4.

4.1.4 Hydrosols

This order includes a range of seasonally or permanently wet soils which experience saturation of the greater part of the profile for prolonged periods (2-3 months). There is a large diversity in this soil group. The soils may or may not experience reducing conditions for all or part of the period of saturation, and thus manifestations of reduction and oxidation such as 'gley' colours and mottles may or may not be present. The Hydrosol described in the project area is further classified as Kandosolic Redoxic Hydrosol and is described in detail in Section 4.5.

4.1.5 Dermosols

Dermosols are moderately deep and well-drained soils of wetter areas in eastern Australia. They have B2 horizons with structure more developed than weak throughout the major part of the horizon, and do not have clear or abrupt textural B horizons. These soils can support a wide range of land uses including cattle and sheep grazing of native pastures, forestry and sugar cane. Cereal crops, especially wheat, are commonly grown on the more fertile Dermosols. The Dermosol described in the project area is further classified as Eutrophic Grey Dermosol and is described in detail in Section 4.6.

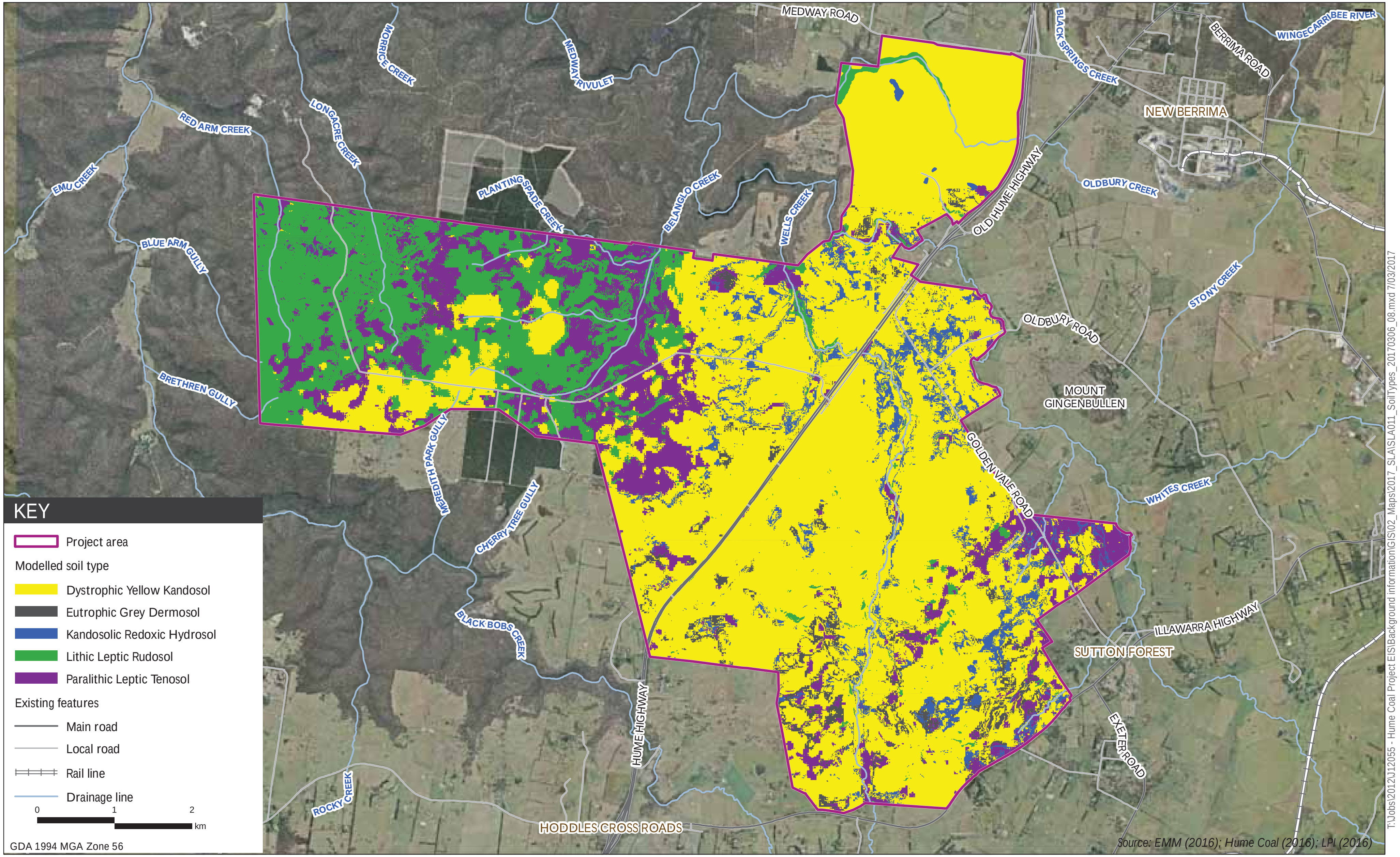
4.1.6 Soil and geology relationship

During the survey, observations of surface geology were made. Geology is an important determinant of soil characteristics and a strong relationship between the two has been identified.

Table 4.2 summarises soil types most commonly identified in association with each of the observed geological formations in the project area.

Table 4.2 Soil and geology relationships within the project area

Soil types	Surface geology (observed in the field)	Mapped geology (Moss Vale 1:100,000 Geological Sheet)
Paralithic Leptic Tenosol and Lithic Leptic Rudosol	Sandstone parent material	Hawkesbury Sandstone (Rh)
Dystrophic Yellow Kandosol	Shale parent material	Quaternary residual deposits (Qr), Basalt (Czb), Bringelly Shale (Rwb) and Ashfield Shale (Rwa)
Kandosolic Redoxic Hydrosol	Alluvium	Alluvium (Qa and Qap)
Eutrophic Grey Dermosol	Basalt parent material	Basalt (Czb) and Bringelly Shale (Rwb)



Soil types in the project area

Hume Coal Project

Soil and Land Assessment Report

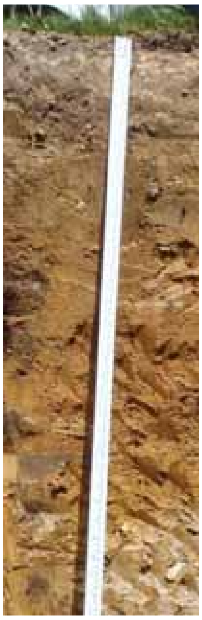
Figure 4.1

EMM HUMECOAL

4.2 Dystrophic Yellow Kandosol

The Dystrophic Yellow Kandosol soils are lacking strong texture contrast with silty clay loams over light clays, transitioning to medium clays at depth. The soil surface is mostly firm when dry and without surface coarse fragments. Topsoils have few coarse fragments and are without mottling. Subsoils have few coarse fragments, massive structure and are imperfectly drained. Mottling is common to many with colouring typically being orange or red. A soil profile description for a typical Dystrophic Yellow Kandosol is provided in Table 4.3.

Table 4.3 Dystrophic Yellow Kandosol typical soil profile summary

ASC:	Horizon name and average depth (m)	Colour, mottles and bleach	Moisture, laboratory pH (median) and drainage	Texture and structure	Coarse fragments, segregations and roots
	A1 0.0-0.19	Dark greyish brown, 10YR4/2 and no mottles or bleaching.	Moderately moist, pH 5.2 and well drained.	Silty loam and sub-angular blocky or massive.	No surface rock, few coarse fragments, no segregations and many roots.
	A2 0.19-0.36 (Sometimes A2e)	Pale brown, 10YR6/3 and no mottles or bleaching.	Moderately moist; pH 6.1 and well drained.	Clay loam sandy and sub-angular blocky or massive.	Few coarse fragments, no segregations and common roots.
	B21 0.36-0.53	Brownish yellow, 10YR6/8, common orange or red mottles and no bleaching.	Moist; pH 4.3 and imperfectly drained.	Light clay and massive.	Common coarse fragments, no segregations and few roots.
	B22 0.53-0.76	Brownish yellow, 10YR6/8, common to many orange or red mottles and no bleaching.	Moist to wet, pH 4.3 and imperfectly to poorly drained.	Medium clay and massive.	Common coarse fragments, no segregations and few to no roots.

Notes: *1. Description in accordance with the Australian Soil and Land Survey Field Handbook (NCST 2009).*
2. pH are laboratory results and the median values are presented.

Laboratory analysis of particle size was carried out on a representative soil profile, and the results are presented in Table 4.4.

Table 4.4 Particle size analysis - Dystrophic Yellow Kandosol (Site 388)

Horizon	Depth	Clay (<2 µm)	Silt (2-60 µm)	Sand (0.06-2.00 mm)	Gravel (>2mm)
	mm	%	%	%	%
A1	0-10	16	32	51	1
A1	10-20	15	29	52	4
A1	20-30	18	25	51	6
A2	42-50	21	23	50	6
B21	50-60	24	22	48	6
B22	70-75	39	21	37	3

The Dystrophic Yellow Kandosol soil unit occurs on all slopes and crests of low rolling hills on shale surface geology (see Photograph 4.1). Land within the project area that is characterised by this soil type is extensively cleared primarily for grazing of improved pastures and pine forestry. The Dystrophic Yellow Kandosol is more common across the eastern and central part of the project area where it is associated with shale surface geology of low rolling hills. It occurs less regularly within the Belanglo State Forest due to the increased presence of sandstone surface geology.

Two variations were noted, a shallow phase variation (10% of total occurrences) and a variation with a redder hue in the upper B2 horizon (10%). The shallow phase variation typically exists on steep slopes or hillcrests. Another variation exists on spurs and ridge lines with a redder hue in the upper B2 horizon. Laboratory testing using a citrate-dithionite extractable iron procedure confirmed that the percentage of free iron oxide is less than 5% and so the red variation is not a Ferrosol.

Photograph 4.1 Dystrophic Yellow Kandosol (site 688)

The Dystrophic Yellow Kandosol can be strongly acidic in the A1 horizon with pH values ranging from 3.8 to 6.2 (see Table 4.5). Out of the 73 sites which were tested for field pH in the A1 horizon, 68% were below pH 5.5, and 15% were below 4.5. These results were mirrored in the B horizon with 66% below pH5.5. The pH's of the majority of the soils in this soil unit are therefore generally unsuitable for cultivation, and restricted to grazing, forestry and nature conservation (EOH 2012). The soils with the more neutral pH may be suitable for some restricted cultivation and pasture cropping, depending on other factors such as slope.

The macronutrients (nitrogen, phosphorous, and potassium) and the micronutrients (copper, zinc, iron, manganese, boron) are mostly low which could restrict agriculture, although fertiliser could amend these concentrations. The cation exchange capacity (CEC) is also very low, which also may present some fertility issues.

All soil chemistry results are given in Table 4.5. The soil chemistry constituent values highlighted in the 'soil sufficiency' column are agricultural industry benchmarks (Baker and Eldershaw 1993; Department of the Environment and Resource Management (DERM) 2011; Peverill, Sparrow and Reuter 1999) and have been referenced in interpreting the laboratory results. The outcomes are presented in the comments column, and are in reference to the median values with increasing depth. A summary of the agricultural potential of Dystrophic Yellow Kandosol is given in Table 4.6.

Table 4.5 Dystrophic Yellow Kandosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.19	A2 0.19-0.36	B21 0.36-0.53	B22 0.53-0.76	Comments on median values (in increasing depth)
pH_{water}	pH units	6.0-7.5	5.2 (3.8-6.2)	6.1 (4.3-6.5)	4.3 (3.8-7.1)	4.3 (4.0-7.2)	Strong (top of A horizon) to extreme acidity (B horizon).
Electrical conductivity – saturated extract (EC_{se})	dS/m	<1.9	0.49 (0.16-4.63)	0.26 (0.23-0.66)	0.19 (0.09-1.17)	0.13 (0.07-1.51)	Very low soil salinity.
Chloride (Cl^-)	mg/kg	<800	30 (20-50)	50 (50-50)	20 (10-140)	105 (30-200)	Not restrictive.
Plant available water capacity (PAWC)	mm	>80	11.4 (L-ZCL)	13.6 (ZL-ZCL)	17.0 (LC-LMC)	27.6 (LMC-HC)	Small (total of 69.6).
Macronutrients							
Nitrite + Nitrate as N (Sol.)	mg/kg	>15	19.6 (0.1-333)	13.7 (12.9-14.5)	2.8 (0.1-12.2)	2.1 (0.8-6.8)	Moderate (top of A horizon) to very low (with depth).
Total Nitrogen as N	mg/kg	>1500	1485 (520-2680)	520 (390-940)	410 (200-960)	380 (110-530)	Deficient.
Phosphorous (P) (Colwell)	mg/kg	>10	3 (<2-46)	<2 (<2-5)	<2 (<2-24)	<2 (<2-26)	Very low (except in the A1 horizon).
Potassium (K) (Acid Extract)	mg/kg	>117	<100 (<100-300)	<100 (<100-<100)	<100 (<100-<100)	<100 (<100-200)	Insufficient.
K (Total)	mg/kg	>150	275 (200-790)	260 (220-320)	390 (140-610)	420 (170-830)	High (A horizon) to very high (B horizon).
Micronutrients							
Copper (Cu)	mg/kg	>0.3	<1.0 (<1.0-<1.0)	<1.0 (<1.0-<1.0)	<1.0 (<1.0-<1.0)	<1.0 (<1.0-<1.0)	Low (inconclusive).
Zinc (Zn)	mg/kg	>0.5 (pH<7) >0.8 (pH>7)	<1.0 (<1.0-8.1)	<1.0 (<1.0-<0.1)	<1.0 (<1.0-2.9)	<1.0 (<1.0-2.0)	Low (inconclusive).
Manganese (Mn)	mg/kg	>2	47.0 (<1.0-74)	21.0 (<1.0-44)	<1.0 (<1.0-14)	<1.0 (<1.0-9)	Moderate (A horizon) to very low (B horizon).
Boron (B)	mg/kg	>1	0.95 (<0.2-1.6)	0.50 (<0.2-0.7)	0.50 (<0.2-3.3)	0.50 (<0.2-1.7)	Low (A1 horizon) to very low (A2 and B horizons).

Table 4.5 Dystrophic Yellow Kandosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.19	A2 0.19-0.36	B21 0.36-0.53	B22 0.53-0.76	Comments on median values (in increasing depth)
Exchangeable cations							
Cation Exchange Capacity (CEC)	meq/ 100g	12-25	3.8 (0.6-11.8)	2.1 (1.4-3.5)	0.8 (0.1-3.9)	0.3 (0.04-4.3)	Very low.
Calcium (Ca)	meq/ 100g	>5	2.9 (0.3-8.4)	1.7 (0.7-4.7)	1.1 (<0.1-4.4)	1.0 (0.2-5.5)	Low (A horizon) to very low (B horizon).
Magnesium (Mg)	meq/ 100g	>1	0.8 (0.3-3.5)	0.8 (0.2-3.3)	0.7 (0.4-5.9)	1.6 (0.6-7.7)	Low (A and B1 horizons) to moderate.
Sodium (Na)	meq/ 100g	<0.7	<0.1 (<0.1-0.2)	<0.1 (<0.1-0.2)	<0.1 (<0.1-0.3)	<0.1 (<0.1-0.4)	Very low.
K	meq/ 100g	>0.3	0.3 (<0.1-1.2)	<0.1 (<0.1-0.1)	<0.1 (<0.1-0.2)	<0.1 (<0.1-0.4)	Low (A1 horizon) to very low (A2 and B horizons).
Exchangeable sodium percentage (ESP)	%	<6	<2.70* (1.7-16.7)	<3.90* (2.41-11.1)	4.35 (2.8-16.7)	3.60 (2.8-11.1)	Non-sodic.
Ca:Mg ratio		>2	3.40 (1.0-6)	2.10 (1.4-3.5)	0.83 (0.1-3.9)	0.30 (0.04-4.3)	Stable A horizon. Unstable B horizon.
Organic Carbon	%	>1.2	2.0 (<0.5-4.1)	<0.5 (<0.5-2.2)	<0.5 (<0.5-1.8)	<0.5 (<0.5-1.8)	Moderate (A1 horizon) to very low (A2 and B horizons).

Notes: *1. Plant sufficiency sources: Baker and Eldershaw (1993), DERM (2011) and Peverill, Sparrow and Reuter (1999).*
2. Values in brackets are the ranges measured.
** These values are an approximation based on calculations using the lowest measurable level.*

Table 4.6 Dystrophic Yellow Kandosol agricultural use summary

Elements	Comments
pH_{water}	Strongly acidic at the surface, progressing to extremely acidic with depth. Outside of the desirable range for agriculture throughout most of the profile. Would restrict agriculture.
EC	Very low salinity levels that would not restrict agriculture.
Cl	Acceptable chloride levels that would not restrict agriculture.
PAWC	At the upper limit of a low plant available water capacity, which would restrict agriculture.
Fertility	
Macronutrients	Mostly low levels of macronutrients, which present fertility issues. Would restrict agriculture.
Micronutrients	Mostly low to very low levels of micronutrients, which present fertility issues. Would restrict agriculture.
CEC	Very low CEC, which may present some fertility issues.
Fertility ranking	**Relative Fertility of ASC Classes (NSW Government 2013):** Moderately low - Kandosols (order), Any (sub-order), Dystrophic (Great Group) **EMM applied Relative Fertility of ASC Classes (lab and field data applied to Murphy et al. 2007):** Moderately low (Group 2) **Explanation (Murphy et al. 2007):** Low fertilities that generally only support plants suited to grazing. Generally deficient in nitrogen, phosphorus and many other elements.

Table 4.6 Dystrophic Yellow Kandosol agricultural use summary

Elements	Comments
ESP	Low ESP indicating a non-sodic soil, which would not restrict agriculture.
Ca:Mg ratio	A mostly stable Ca:Mg ratio in the topsoil, but decreasing with depth to levels that suggest strong soil instability.
Organic Carbon	Indicative of good structural condition and structural stability in the A1 horizon. Low levels below this horizon.
Major limitations to agriculture	PAWC Macronutrients (eg nitrate, total nitrogen, phosphorus, potassium extract) Micronutrients (eg boron, calcium, magnesium, sodium, potassium)

4.3 Lithic Leptic Rudosol

Lithic Leptic Rudosol soils are shallow and weakly developed sands (most commonly clayey sands) to a depth of approximately 0.18 m over weakly to highly weathered sandstone. The soil surface is loose with common surface coarse fragments and rock outcrops. Lithic Leptic Rudosols have few coarse fragments throughout, no mottling and are highly permeable and rapidly drained. These soils typically have low fertility, are strongly acidic, non-sodic and non-saline. A soil profile description for a typical Lithic Leptic Rudosol is presented in Table 4.7. It is noted that the laboratory pH values presented are median values.

Table 4.7 Lithic Leptic Rudosol typical soil profile summary

ASC:	Horizon name and depth (m) (average)	Colour, mottles and bleach	Moisture, laboratory pH (median value) and drainage	Texture, structure and consistence	Coarse fragments, segregations and roots
	O 0-0.02	Very dark brown, no mottles and no bleaching.	Dry, pH 4.4, rapidly drained.	Loamy sand, crumb or granular and very weak force.	Surface coarse fragments of 10-20% stones and boulders, few coarse fragments, very high organic matter, no segregations and common roots.
	A11 0.02-0.09	Dark greyish brown, no mottles and no bleaching.	Dry, pH 4.6, rapidly drained.	Sandy loam, crumb or granular and very weak force.	Few coarse fragments, high organic matter, no segregations and common roots.
	A12 0.09-0.18	Dark greyish brown, no mottles and no bleaching.	Dry, pH 4.75, rapidly drained.	Sandy loam, crumb or granular and very weak force.	2-10% gravel, no segregations and common roots.
	R 0.18+	Parent material - Hawkesbury Sandstone.			

Note: 1. Description in accordance with the Australian Soil and Land Survey Field Handbook (NCST 2009).

Laboratory analysis of particle size was carried out on a representative soil profile, and the results are presented in Table 4.4. The soil is predominantly gravel and sand.

Table 4.8 Particle size analysis – Lithic Leptic Rudosol (Site 474)

Horizon	Depth	Clay (<2 µm)	Silt (2-60 µm)	Sand (0.06-2.00 mm)	Gravel (>2mm)
	mm	%	%	%	%
A11	0-3	9	27	53	11
A12	3-10	11	14	70	5

The Lithic Leptic Rudosol is a shallow soil that occurs on the plateaus, scarps and benches of steep hills on Hawkesbury Sandstone (sandstone-quartz and shale). Slopes vary from very gently inclined on the plateaus to steeply inclined on scarps with an average gradient of around 17%. Within the project area, common land uses on this soil type are low intensity grazing on native pastures and forestry. Coverage of the Lithic Leptic Rudosols is limited to the steep slopes associated with sandstone surface geology most commonly found within Belanglo State Forest (see Photograph 4.2).

Photograph 4.2 Lithic Leptic Rudosol (site 352)

Lithic Leptic Rudosol is very strongly acidic throughout the profile and is outside the desirable range for agriculture throughout most of the profile. It is typically on steep slopes with loose soils with course fragments, that make it suited only to some grazing, forestry and nature conservation.

Soil chemistry results for the Lithic Leptic Rudosol are presented in Table 4.9 the soil chemistry constituent values highlighted in the 'soil sufficiency' column are agricultural industry benchmarks (Baker and Eldershaw 1993; Department of the Environment and Resource Management (DERM) 2011; Peverill, Sparrow and Reuter 1999) and have been referenced in interpreting the laboratory results. The outcomes are presented in the comments column, and are in reference to the median values with increasing depth. A summary of the agricultural potential of Lithic Leptic Rudosol is presented in Table 4.10.

Table 4.9 Lithic Leptic Rudosol soil chemistry results – median values (and ranges)

Constituents	Unit	Soil sufficiency[1]	A11 0.02-0.09	A12 0.09-0.18	Comments on median values (in increasing depth)
pH_{water}	pH units	6.0-7.5	4.60 (4.4-5.8)	4.75 (4.2-5.3)	Very strong acidity.
Electrical conductivity – saturated extract (EC_{se})	dS/m	<1.9	0.46 (0.21-0.46)	0.34 (0.24-0.44)	Very low soil salinity.
Chloride (Cl^-)	mg/kg	<800	30 (20-40)	30 (30-30)	Not restrictive.
Plant available water capacity (PAWC)	mm	>80	3.5 (CS-ZCL)	4.5 (CS-ZCL)	Very small (total of 8).
Macronutrients					
Nitrite + Nitrate as N (Sol.)	mg/kg	>15	0.20 (0.2-0.5)	0.35 (0.2-0.5)	Very low.
Total Nitrogen as N	mg/kg	>1500	1270 (1270-2700)	1215 (750-1680)	Deficient.
Phosphorous (P) (Colwell)	mg/kg	>10	<2 (<2-6)	<2 (<2-5)	Very low.
K (Acid Extract)	mg/kg	>117	100 (<100-100)	<100 (<100-<100)	Insufficient - low.
Potassium (K) (Acid Extract)	mg/kg	>150	150 (130-180)	165 (120-210)	Moderate.
Micronutrients					
Cu	mg/kg	>0.3	<1.0 (<1.0-<1.0)	<1.0 (<1.0-<1.0)	Inconclusive.
Zn	mg/kg	>0.5 (pH<7) >0.8 (pH>7)	<1.0 (<1.00-3.19)	<1.0 (<1.0-<0.1)	Inconclusive.
Mn	mg/kg	>2	<1.00 (<1.0-14.6)	2.79 (<1.00-4.57)	Very low (A11 horizon) to moderate (A12 horizon).
B	mg/kg	>1	<1.0 (<1.00-3.19)	<1.0 (<1.0-<1.0)	Low.
CEC	meq/ 100g	12-25	0.70 (0.6-7.5)	3.05 (0.4-5.7)	Very low.
Ca	meq/ 100g	>5	0.20 (0.1-6.1)	2.40 (<0.1-4.7)	Very low (A11 horizon) to low (A12 horizon).
Mg	meq/ 100g	>1	0.20 (0.1-1.2)	0.45 (<0.1-0.8)	Very low (A11 horizon) to low (A12 horizon).

Table 4.9 Lithic Leptic Rudosol soil chemistry results – median values (and ranges)

Constituents	Unit	Soil sufficiency[1]	A11 0.02-0.09	A12 0.09-0.18	Comments on median values (in increasing depth)
Na	meq/ 100g	<0.7	0.2 (<0.1-0.2)	<0.1 (<0.1-0.1)	Low (A11 horizon) to very low (A12 horizon).
K	meq/ 100g	>0.3	<0.1 (<0.1-0.2)	0.2 (<0.1-0.2)	Very low.
Exchangeable cations					
ESP	%	<6	0.33 (0.29-1.33*)	1.00* (0.25-1.75*)	Non-sodic.
Ca:Mg ratio		>2	1.00 (1.0-5.1)	3.44 (1.0-5.9)	Unstable (A11 horizon) to stable (A12 horizon).
Organic Carbon	%	>1.2	3.4 (2.9-7.0)	2.7 (1.8-3.9)	Very high.

Notes: 1. Sources: Baker and Eldershaw (1993), DERM (2011) and Peverill, Sparrow and Reuter (1999).
2. Values in brackets are the ranges measured.
** These values are an approximation based on calculations using the lowest measurable level.*

Table 4.10 Lithic Leptic Rudosol soil chemistry summary

Elements	Comments
pH_{water}	Very strongly acidic throughout the profile. Outside of the desirable range for agriculture throughout most of the profile. Would restrict agriculture.
EC	Very low soil salinity levels that would not restrict agriculture.
Cl	Acceptable chloride levels that would not restrict agriculture.
PAWC	A very small PAWC, which would restrict agriculture.
Fertility	
Macronutrients	Mostly low levels of macronutrients, which present fertility issues. Would restrict agriculture.
Micronutrients	Mostly low to very low levels of micronutrients, which present fertility issues. Would restrict agriculture.
CEC	Very low CEC, which may present some fertility issues.
Fertility ranking	**Relative Fertility of ASC Classes (NSW Government 2013):** Low - Rudosols (order), Leptic (sub-order), Any (Great Group) **EMM applied Relative Fertility of ASC Classes (lab and field data applied to Murphy et al. 2007):** Low (Group 1) **Explanation (Murphy et al. 2007):** Soils which, due to their poor physical and/or chemical status, only support limited agriculture. The maximum agricultural use of these soils is low intensity grazing. Include shallow and sandy soils which by virtue of their poor water retention characteristics can only support limited agriculture.
ESP	ESP indicating a non-sodic soil that would not restrict agriculture.
Ca:Mg ratio	Unstable Ca:Mg ratio in the topsoil, but increasing stability with depth to levels that suggest soil stability.
Organic Carbon	Indicative of good structural condition and structural stability. Very high levels throughout that would not restrict agriculture.

Table 4.10 Lithic Leptic Rudosol soil chemistry summary

Elements	Comments
Major limitations to agriculture	pH PAWC Macronutrients (eg nitrate, total nitrogen, phosphorus, potassium extract) Micronutrients (eg manganese, boron, calcium, magnesium, sodium, potassium)

4.4 Paralithic Leptic Tenosol

The Paralithic Leptic Tenosols soils are weakly developed with a slight increase in clay content and lightening of soil colour with depth. They are typically sandy in the A1 horizon and the A2 horizon is a sandy loam. The soil surface is without coarse fragments and of loose condition. Paralithic Leptic Tenosols have few coarse fragments, which are spread evenly throughout the profile. Subsoils typically have few orange mottles with no segregations. Paralithic Leptic Tenosols are typically extremely acidic, highly permeable, rapidly drained and non-saline. Generally the Tenosol sites were underlain by a hard material, usually weathered rock, which varied in depth between sites from <500 mm to approximately 750 mm. It is noted that using Isbell (2002), the subgroup would be Brown-Orthic rather than Leptic. This difference would not affect interpretation of the soil's characteristics or the BSAL assessment outcome. A soil profile description for a typical Paralithic Leptic Tenosol is presented in Table 4.11.

Table 4.11 Paralithic Leptic Tenosol typical soil profile summary

	Horizon name and depth (average) (m)	Colour, mottles and bleach	Moisture, lab pH (median) and drainage	Texture, structure and consistence	Coarse fragments, segregations and roots
	A11 0-0.12	Yellowish brownish, no mottles and no bleaching.	Dry, pH 4.6 and rapidly drained.	Clayey sand, granular and loose.	Few surface coarse fragments, few coarse fragments, no segregations and few roots.
	A12 0.12-0.31	Yellowish brownish, few orange mottles and no bleaching.	Dry, pH 4.4 and rapidly drained.	Clayey sand, granular and loose.	Few coarse fragments, no segregations and few roots.
	A21 0.31-0.53	Brownish yellow, few orange mottles and no bleaching.	Dry, pH 4.4 and rapidly drained.	Loamy sandy, granular and loose.	Few coarse fragments, no segregations and no roots.
	A21 0.53-0.74	Pale yellow, few orange mottles and no bleaching.	Dry, pH 4.4 and rapidly drained.	Loamy sandy, granular and loose.	Few coarse fragments, no segregations and no roots.

Note: 1. Description in accordance with the Australian Soil and Land Survey Field Handbook (NCST 2009).

Laboratory analysis of particle size was carried out on a representative soil profile, and the results are presented in Table 4.12.

Table 4.12 Particle size analysis – paralithic leptic tenosol (Site 287)

Horizon	Depth	Clay (<2 µm)	Silt (2-60 µm)	Sand (0.06-2.00 mm)	Gravel (>2mm)
	mm	%	%	%	%
A1	0-10	11	8	80	1
A1	10-20	12	10	78	<1
A2	20-30	15	10	75	<1
B2	50-60	16	11	73	<1
B2	70-75	19	11	70	<1

The Paralithic Leptic Tenosol soil unit occurs on rises and low hills on the Hawkesbury Sandstone formation (sandstone-quartz) and less commonly on depositional foot slopes on shale geology. Their location is independent of elevation, with Tenosols just as likely to be present on low gradient hilltops as in stable low lying areas. Within the project area, they are most commonly found within and immediately surrounding the Belanglo State Forest. A transitional Tenosol (grading to a Kandosol) was recorded on an isolated sandstone outcrop to the east of Belanglo State Forest. Within the project area, land use on this soil type is typically for native and pine forestry (see Photograph 4.3), with low intensity grazing in some locations.

Photograph 4.3 Paralithic Leptic Tenosol (site 300)

Paralithic Leptic Tenosols are typically extremely acidic, highly permeable, rapidly drained and non-saline.. The pH of the soils in this soil unit are below 5.5, and are therefore generally unsuitable for cultivation, and restricted to grazing, forestry and nature conservation (EOH 2012). The macronutrients (nitrogen, phosphorous, and potassium) and the micronutrients (copper, zinc, iron, manganese, boron) are mostly low which could restrict agriculture, although fertiliser could amend these concentrations. The cation exchange capacity (CEC) is also very low, which also may present some fertility issues.

All soil chemistry results are given in Table 4.13. The soil chemistry constituent values highlighted in the 'soil sufficiency' column are agricultural industry benchmarks (Baker and Eldershaw 1993; Department of the Environment and Resource Management (DERM) 2011; Peverill, Sparrow and Reuter 1999) and have been referenced in interpreting the laboratory results. The outcomes are presented in the comments column, and are in reference to the median values with increasing depth. A summary of the agricultural potential of Paralithic Leptic Tenosols is given in Table 4.14.

Table 4.13 Paralithic Leptic Tenosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A11 0-0.12	A12 0.12-0.31	A21 0.31-0.53	A22 0.53-0.74	Comments on median values (in increasing depth)
pH_{water}	pH units	6.0-7.5	4.6 (4.0-4.6)	4.4 (4.3-4.5)	4.4 (4.4-4.5)	4.4 (4.3-7.4)	Very strong (A11 horizon) to extreme acidity (below A11).
EC_{se}	dS/m	<1.9	1.17 (0.36-2.53)	0.39 (0.26-0.62)	0.26 (0.17-0.38)	0.17 (0.08-0.24)	Low (A11 horizon) to very low soil salinity (below A11 horizon).
Chloride (Cl^-)	mg/kg	<800	20 (20-50)	50 (30-110)	150 (50-880)	290 (50-1500)	Not restrictive.
PAWC	mm	>80	4.8 (S-ZL)	7.6 (LS-ZL)	8.8 (LS-CLS)	8.4 (LS-CLS)	Very small (total of 29.6).
Macronutrients							
Nitrite + Nitrate as N (Sol.)	mg/kg	>15	19.8 (0.4-87.1)	10.4 (1.4-13.0)	6.0 (1.2-9.9)	1.1 (0.6-2.8)	Moderate (A11 horizon) to very low (below A11 horizon).
Total Nitrogen as N	mg/kg	>1500	980 (270-2540)	550 (280-1150)	530 (280-740)	230 (140-320)	Deficient.
P (Colwell)	mg/kg	>10	11 (9-13)	3 (3-3)	2 (<2-2)	2 (<2-2)	Moderate (A11 horizon) to very low (below A11 horizon).
K (Acid Extract)	mg/kg	>117	<100 (<100-100)	<100 (<100-<100)	<100 (<100-<100)	<100 (<100-200)	Low (inconclusive).
K (Total)	mg/kg	>150	165 (60-310)	150 (80-160)	165 (80-240)	140 (80-280)	Moderate (A11 horizon) to low (gen. below A11 horizon).
Micronutrients							
Cu	mg/kg	>0.3	<1.0 (<1.0-<1.0)	<1.0 (<1.0-<1.0)	<1.0 (<1.0-<1.0)	<1.0 (<1.0-<1.0)	Low (inconclusive).
Zn	mg/kg	>0.5 (pH<7) >0.8 (pH>7)	<1.0 (<1.0-8.1)	<1.0 (<1.0-<0.1)	<1.0 (<1.0-2.9)	<1.0 (<1.0-2.0)	Low (inconclusive).
Mn	mg/kg	>2	7.7 (<1.0-19.3)	<1.0 (<1.0-1.5)	<1.0 (<1.0-<1.0)	<1.0 (<1.0-<1.0)	Moderate (A11 horizon) to very low (below A11 horizon).
B	mg/kg	>1	1.6 (0.4-5.0)	0.5 (0.4-3.4)	0.5 (0.5-3.0)	0.5 (0.4-2.6)	Moderate (A11 horizon) to very low (below A11 horizon).

Table 4.13 Paralithic Leptic Tenosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A11 0-0.12	A12 0.12-0.31	A21 0.31-0.53	A22 0.53-0.74	Comments on median values (in increasing depth)
Exchangeable cations							
CEC	meq/ 100g	12-25	2.15 (1.2-4.0)	1.40 (1.1-2.3)	0.85 (0.6-2.3)	0.60 (0.1-1.3)	Very low.
Ca	meq/ 100g	>5	3.2 (2.2-5.7)	3.0 (0.2-3.6)	2.7 (0.3-10.7)	2.2 (0.2-12.8)	Low.
Mg	meq/ 100g	>1	3.1 (1.7-4.7)	3.2 (0.4-4)	3.8 (0.5-12.7)	4.8 (1-19.8)	Moderate.
Na	meq/ 100g	<0.7	0.5 (0.5-0.5)	0.5 (0.1-0.5)	0.4 (0.1-1.1)	0.6 (0.2-2.1)	Very low.
K	meq/ 100g	>0.3	0.3 (0.2-0.3)	0.1 (0.1-0.1)	0.1 (0.1-0.3)	0.1 (0.1-0.2)	Very low.
ESP	%	<6	<2.38* (1.54-4.46)	<6.81* (1.45-12.5)	<4.44* (3.08-16.70)	5.89* (3.33-16.42)	Generally non-sodic though sodic in A12 horizon.
Ca:Mg ratio		>2	1.21 (1.03-1.29)	0.85 (0.5-1.1)	0.56 (0.2-0.84)	0.47 (0.2-0.65)	Moderate (A11 horizon) to strongly unstable (below A11).
Organic Carbon	%	>1.2	3.1 (2.4-5.0)	1.4 (0.6-1.9)	1.0 (0.5-4.5)	0.95 (0.8-1.1)	High (A11 horizon) to low (A21 and A22).

Notes: 1. Sources: Baker and Eldershaw (1993), DERM (2011) and Peverill, Sparrow and Reuter (1999).
2. Values in brackets are the ranges measured.
** These values are an approximation based on calculations using the lowest measurable level.*

Table 4.14 Paralithic Leptic Tenosol soil chemistry summary

Elements	Comments
pH_{water}	Very strongly acid at the surface, progressing to extreme acidity with depth. Outside of the desirable range for agriculture throughout most of the profile. Would restrict agriculture.
EC	Low to very low soil salinity levels that would not restrict agriculture.
Cl	Acceptable chloride levels that would not restrict agriculture.
PAWC	At the upper limit of a small PAWC, which would restrict agriculture.
Fertility	
Macronutrients	Moderate to mostly low levels of macronutrients, which present fertility issues. Would restrict agriculture.
Micronutrients	Mostly low to very low levels of micronutrients, which present fertility issues. Would restrict agriculture.
CEC	Very low CEC, which may present some fertility issues.
Fertility ranking	**Relative Fertility of ASC Classes (NSW Government 2013):** Low - Tenosols (order), Leptic (sub-order), Any (Great Group) **EMM applied Relative Fertility of ASC Classes (lab and field data applied to Murphy et al. 2007):** Low (Group 1) **Explanation (Murphy et al. 2007):** Soils which, due to their poor physical and/or chemical status, only support limited agriculture. The maximum agricultural use of these soils is low intensity grazing. Include sandy soils which by virtue of their poor water retention characteristics, can only support limited agriculture.

Table 4.14 Paralithic Leptic Tenosol soil chemistry summary

Elements	Comments
ESP	ESP indicating a sodic soil. The low sodium levels for all samples analysed make it difficult to be conclusive in the topsoil.
Ca:Mg ratio	A moderate Ca:Mg ratio in the topsoil, but decreasing with depth to levels that suggest soil instability.
Organic Carbon	Indicative of good structural condition and structural stability in the A1 horizons. Low levels below this horizon.
Major limitations to agriculture	pH PAWC Macronutrients (eg nitrate, total nitrogen, phosphorus, potassium extract) Micronutrients (eg manganese, boron, calcium, magnesium, sodium, potassium)

4.5 Kandosolic Redoxic Hydrosol

Kandosolic Redoxic Hydrosols are weakly to moderately developed, with variable textures and colour grades depending on the localised site morphology. A horizons are silty clay loam to light clay grading with depth towards medium to heavy clay B horizons. Surface condition is cracked and without coarse fragments. They have no coarse fragments throughout the profile. Orange mottles may be present at depth. Subsoils typically have no segregations. A soil profile description for a typical Kandosolic Redoxic Hydrosol is provided in Table 4.15.

Table 4.15 Kandosolic Redoxic Hydrosol typical soil profile summary

ASC:	Horizon name and depth (average) (m)	Colour, mottles and bleach	Moisture, laboratory pH (median value) and drainage	Texture, structure and consistence	Coarse fragments, segregations and roots
	A11 0-0.18	Yellowish brown, no mottles and no bleaching.	Moderately moist, pH 4.5 and poorly drained.	Light clay, sub-angular blocky and moderately weak force.	No surface coarse fragments, no coarse fragments, no segregations and many roots.
	A12 0.18-0.33	Yellowish brown, few orange mottles and no bleaching.	Moist, pH 5.2 and poorly drained.	Light clay, sub-angular blocky and moderately weak force.	No coarse fragments, no segregations and few roots.
	B21 0.33-0.58	Very dark greyish brown, few orange mottles and no bleaching.	Wet, pH 5.0 and poorly drained.	Light-medium clay, massive and moderately weak force.	No coarse fragments, no segregations and few roots.
	B22 0.58-0.80+	Dark greyish brown, common orange mottles and no bleaching.	Moist, pH 4.9 and poorly drained.	Medium-heavy clay, massive and very firm force.	No coarse fragments, no segregations and few roots.

Note: 1. Description in accordance with the Australian Soil and Land Survey Field Handbook (NCST 2009).

Kandosolic Redoxic Hydrosol have moderately low fertility, are strongly acidic, slowly permeable, poorly drained, sodic in the B horizon and are moderately saline in the A horizon. The soils in this soil unit are therefore generally unsuitable for cultivation, and restricted to grazing (EOH 2012).

All soil chemistry results are given in Table 4.16. The soil chemistry constituent values highlighted in the 'soil sufficiency' column are agricultural industry benchmarks (Baker and Eldershaw 1993; Department of the Environment and Resource Management (DERM) 2011; Peverill, Sparrow and Reuter 1999) and have been referenced in interpreting the laboratory results. The outcomes are presented in the comments column, and are in reference to the median values with increasing depth. A summary of the agricultural potential of Kandosolic Redoxic Hydrosol is given in Table 4.17.

The Kandosolic Redoxic Hydrosol is limited to drainage depressions and associated floodplains that experience regular inundation. This soil unit is spread throughout the project area and is directly associated with drainage lines and water bodies. Within the project area, land use on this soil type is generally for improved and native pastures (see Photograph 4.4).

Photograph 4.4 Kandosolic Redoxic Hydrosol (site 92)

Table 4.16 Kandosolic Redoxic Hydrosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A11 0-0.18	A12 0.18-0.33	B21 0.33-0.58	B22 0.58-0.80+	Comments on median values (in increasing depth)
pH_{water}	pH units	6.0-7.5	4.5 (3.7-5.2)	5.2 (3.8-5.2)	5.0 (4.0-5.1)	4.9 (4.3-6.5)	Extreme (A11 horizon) to very strong acidity (A12 and below).
EC_{se}	dS/m	<1.9	1.39 (0.89-4.46)	0.20 (0.19-1.02)	0.32 (0.13-3.27)	0.37 (0.13-5.53)	Low soil salinity.
Cl^-	mg/kg	<800	20 (20-50)	50 (30-110)	150 (50-880)	290 (50-1500)	Not restrictive.
PAWC	mm	>80	18.0 (ZL-MC)	15.0 (LC-LMC)	30.0 (LC-HC)	26.4 (LC-HC)	Moderate (total of 89.4).
Macronutrients							
Total Nitrogen as N	mg/kg	>1500	2540 (2320-2900)	1295 (670-1760)	890 (440-2000)	745 (400-1320)	Sufficient (A11 horizon) to deficient (below A12 horizon)
P (Colwell)	mg/kg	>10	11 (9-13)	2 (<2-3)	2 (<2-2)	2 (<2-2)	Moderate (A11 horizon) to very low (A12 and below).
K (Acid Extract)	mg/kg	>117	200 (100-200)	<100 (<100-<100)	<100 (<100-<100)	<100 (<100-100)	Moderate (A11 horizon) to low – insufficient (A12 horizon and below).
K (Total)	mg/kg	>150	490 (360-680)	380 (150-520)	450 (180-930)	455 (360-1040)	Very high.
Micronutrients							
Cu	mg/kg	>0.3	1.91 (<1-3.1)	1.78 (<1-2.5)	1.05 (<1-1.9)	1.10 (<1-1.8)	Moderate.
Zn	mg/kg	>0.5 (pH<7) >0.8 (pH>7)	2.3 (1.9-2.8)	<1.0 (<1.0-<0.1)	<1.0 (<1.0-1.1)	<1.0 (<1.0-<1.0)	High (A11 horizon) to low (inconclusive) (A12 and below).
Mn	mg/kg	>2	39.5 (31.4-123.0)	93.8 (4.25-138.0)	<1.0 (<1.0-78.8)	<1.0 (<1.0-17.9)	High (A horizon) to very low (B horizon).
B	mg/kg	>1	1.40 (1.4-1.6)	0.75 (0.6-1)	0.80 (0.6-1.8)	0.75 (0.3-1.8)	Moderate (A11 horizon) to low (A12 horizon and below).
Exchangeable cations							
CEC	meq/ 100g	12-25	6.50 (4.2-11.2)	7.00 (0.8-7.6)	6.50 (0.7-24.8)	7.95 (1.6-34.9)	Low.
Ca	meq/ 100g	>5	3.20 (2.2-5.7)	3.00 (0.2-3.6)	2.75 (0.3-10.7)	2.20 (0.2-12.8)	Low.
Mg	meq/ 100g	>1	3.10 (1.7-4.7)	3.25 (0.4-4.0)	3.80 (0.5-12.7)	4.80 (1.0-19.8)	High.
Na	meq/ 100g	<0.7	<0.10 (<0.1-0.5)	0.30 (<0.1-0.5)	0.40 (0.1-1.1)	0.50 (<0.1-2.1)	Low to moderate.
K	meq/ 100g	>0.3	0.3 (0.2-0.3)	0.1 (<0.1-0.1)	0.1 (<0.1-0.3)	0.1 (<0.1-0.2)	Low to very low.

Table 4.16 Kandosolic Redoxic Hydrosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A11 0-0.18	A12 0.18-0.33	B21 0.33-0.58	B22 0.58-0.80+	Comments on median values (in increasing depth)
ESP	%	<6	2.40 (<1.5*-4.5)	6.81 (1.5-<12.5*)	4.40 (3.1-16.7)	5.90 (<3.3*-16.4)	Non-sodic to sodic.
Ca:Mg ratio		>2	1.2 (1.0-1.3)	0.9 (0.5-1.1)	0.6 (0.2-0.8)	0.5 (0.2-0.7)	Unstable to strongly unstable.
Organic Carbon	%	>1.2	3.1 (2.4-5.0)	1.4 (0.6-1.9)	1.0 (<0.5-4.5)	0.9 (<0.5-1.1)	Very high to low.

Notes: 1. Sources: Baker and Eldershaw (1993), DERM (2011) and Peverill, Sparrow and Reuter (1999).
2. Values in brackets are the ranges measured.
** These values are an approximation based on calculations using the lowest measurable level.*

Table 4.17 Kandosolic Redoxic Hydrosol soil chemistry summary

Elements	Comments
pH_{water}	Varying from extremely to very strongly acidic throughout the profile. Outside of the desirable range for agriculture. Would restrict agriculture.
EC	Moderate to low soil salinity levels that would not restrict agriculture.
Cl	Acceptable chloride levels that would not restrict agriculture.
PAWC	A moderate PAWC, which would not restrict agriculture.
Fertility	
Macronutrients	Very high to very low levels of nitrogen in the A horizons. Moderate to low levels of phosphorus and potassium extract in the A horizons. Mostly low levels of macronutrients in the B horizons. Would restrict agriculture.
Micronutrients	Variable levels of macronutrients in the A horizons, ranging from high to low depending on the parameter, and generally decreasing to moderate to very low levels in the B horizons. Would restrict agriculture.
CEC	Low CEC levels throughout the soil. Would restrict agriculture.
Fertility ranking	**Relative Fertility of ASC Classes (NSW Government 2013):** Moderately low - Hydrosol (order), Redoxic (sub-order), any but some Sulfuric (Great Group) **EMM applied Relative Fertility of ASC Classes (lab and field data applied to Murphy et al. 2007):** Moderately low (Group 2) **Explanation (Murphy et al. 2007):** Low fertilities that generally only support plants suited to grazing. Large inputs of fertiliser are required to make soil usable for arable purposes. Generally deficient in nitrogen, phosphorus and many other elements.
ESP	ESP indicating sodic soils. Would restrict agriculture.
Ca:Mg ratio	Unstable Ca:Mg ratio indicating soil instability.
Organic Carbon	Indicative of good structural condition and structural stability in the upper A horizon, but reducing with depth to low levels. Would not restrict agriculture.
Major limitations to agriculture	pH Macronutrients (eg phosphorus, potassium extract) Micronutrients (eg boron, calcium, potassium) Sodicity

4.6 Eutrophic Grey Dermosol

Eutrophic Grey Dermosol soils are moderately to well developed, depending on the landform element with which they are associated. The soil lacks strong texture contrast and has increasing clay content with depth. A horizons are typically greyish brown silty loam over grey medium to heavy clay B horizons. The soil surface is mostly without coarse fragments and of firm to cracked condition. Eutrophic Grey Dermosols generally have few or no coarse fragments in the lower A and upper B horizons with coarse fragments more common in the lower B horizon. Subsoils commonly have red and orange mottling with no segregations. A soil profile description for a typical Eutrophic Grey Dermosols is provided in Table 4.18.

Table 4.18 Eutrophic Grey Dermosol typical soil profile summary

ASC:	Horizon name and depth (m) (average)	Colour, mottles and bleach	Moisture, laboratory pH (median value) and drainage	Texture, structure and consistence	Coarse fragments, segregations and roots
	A1 0-0.18	Dark greyish brown, no mottles and no bleaching.	Moist, pH 4.9 and moderately well drained.	Silty loam, sub-angular blocky and moderately weak force.	No surface coarse fragments, no coarse fragments, no segregations and many roots.
	A2 0.18-0.30	Dark greyish brown, few red mottles and no bleaching.	Moderately moist, pH 4.8 and imperfectly drained.	Silty clay loam, sub-angular blocky and very firm force.	No coarse fragments, no segregations and common roots.
	B21 0.30-0.50	Greyish brown, common orange mottles and no bleaching.	Moderately moist, pH 5.1 and imperfectly drained.	Medium heavy clay, sub-angular blocky and very firm force.	Few coarse fragments, no segregations and few roots.
	B22 0.50-0.67	Grey, many orange mottles and no bleaching.	Dry, pH 6.8 and poorly drained.	Heavy clay, sub-angular blocky and moderately strong force.	Few coarse fragments, no segregations and few roots.

Note: 1. Description in accordance with the Australian Soil and Land Survey Field Handbook (NCST 2009).

Eutrophic Grey Dermosols occur on gently to moderately inclined rolling low hills to rolling hills on small, randomly distributed, isolated basalt intrusions. Within the project area, land use on this soil type is for grazing of native and improved pastures (Photograph 4.5). Eutrophic Grey Dermosols appear to be limited to the small, randomly distributed, isolated basalt intrusions. They were not recorded away from these surface geology expressions.

Photograph 4.5 Eutrophic Grey Dermosol (site 632)

Eutrophic Grey Dermosols are of moderately high fertility, moderately permeable, poorly drained and have moderate to low salinity. They have sodic B horizons and very strongly acidic A horizons.

Soil chemistry results are given in Table 4.19, the soil chemistry constituent values highlighted in the 'soil sufficiency' column are agricultural industry benchmarks (Baker and Eldershaw 1993; Department of the Environment and Resource Management (DERM) 2011; Peverill, Sparrow and Reuter 1999) and have been referenced in interpreting the laboratory results. The outcomes are presented in the comments column, and are in reference to the median values with increasing depth. A summary of the agricultural potential of Eutrophic Grey Dermosols is given in Table 4.20.

Table 4.19 Eutrophic Grey Dermosol soil chemistry results – median values (and ranges)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.18	A2 0.18-0.30	B21 0.30-0.50	B22 0.50-0.67	Comments on median values (in increasing depth)
pH_{water}	pH units	6.0-7.5	4.9 (4.5-5.4)	4.8 (4.7-4.9)	5.1 (4.8-7.4)	6.8 (5.2-8.3)	Very strong acidity (A1 to B21 horizons) to neutral (B22).
EC_{se}	dS/m	<1.9	1.51 (0.26-2.37)	0.56 (0.13-0.98)	0.22 (0.07-1.10)	1.21 (0.05-2.36)	Moderate to low soil salinity.
Cl^-	mg/kg	<800	10 (<10-10)	10 (10-10)	20 (10-140)	105 (30-200)	Not restrictive.
PAWC	mm	>80	10.8 (ZL-ZCL)	9.6 (ZL-ZCL)	24.0 (MC-HC)	20.4 (MC-HC)	Small (total of 64.8).

Table 4.19 Eutrophic Grey Dermosol soil chemistry results – median values (and ranges)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.18	A2 0.18-0.30	B21 0.30-0.50	B22 0.50-0.67	Comments on median values (in increasing depth)
Macronutrients							
Nitrite + Nitrate as N (Sol.)	mg/kg	>15	104.70 (14-164)	36.60 (1.2-71.9)	1.60 (1.1-5.8)	0.35 (0.3-0.4)	Very high (A horizon) to very low (B horizon).
Total Nitrogen as N	mg/kg	>1500	3690 (1510-5650)	2645 (1240-4050)	990 (900-1330)	635 (560-710)	Sufficient (A) to deficient (B).
P (Colwell)	mg/kg	>10	12.0 (3.0-25.0)	8.5 (2.0-15.0)	<2.0 (<2.0-<2.0)	<2.0 (<2.0-<2.0)	Moderate (A1), low (A2) to very low (B).
K (Acid Extract)	mg/kg	>117	200 (100-400)	200 (<100-300)	<100 (<100-<100)	<100 (<100-100)	Moderate (A) to low - insufficient (B).
K (Total)	mg/kg	>150	595 (370-840)	515 (320-710)	570 (490-740)	570 (490-650)	Very high.
Micronutrients							
Cu	mg/kg	>0.3	1.51 (<1.00-1.71)	<1.00 (<1.00-<1.00)	<1.00 (<1.00-<1.00)	<1.00 (<1.00-<1.00)	Moderate (A1) to low -inconclusive (A2 horizon and below).
Zn	mg/kg	>0.5 (pH<7) >0.8 (pH>7)	<1.0 (<1.0-8.1)	<1.0 (<1.0-<0.1)	<1.0 (<1.0-<1.0)	<1.0 (<1.0-<1.0)	Low (inconclusive).
Mn	mg/kg	>2	45.10 (37.9-51.8)	31.30 (28.4-34.1)	1.23 (<1.0-1.46)	<1.00 (<1.0-<1.0)	Very high (A) to low (B21) to very low (B22).
B	mg/kg	>1	1.65 (0.8-2.4)	1.60 (1.2-2.0)	1.20 (0.7-1.7)	0.45 (0.4-0.5)	Moderate (A1 to B21) to very low (B22).
Exchangeable cations							
CEC	meq/ 100g	12-25	8.55 (6.9-10.4)	8.25 (6.6-9.9)	17.90 (12.0-21.0)	16.80 (12.6-21.0)	Low (A horizon) to moderate (B horizon).
Ca	meq/ 100g	>5	6.0 (5.0-6.9)	5.7 (4.4-6.9)	6.5 (5.4-7.1)	5.5 (4.7-6.2)	Moderate.
Mg	meq/ 100g	>1	2.1 (1.5-2.8)	2.1 (1.8-2.4)	10.6 (4.9-12.4)	9.9 (5.6-14.1)	Moderate (A horizon) to high (B horizon).
Na	meq/ 100g	<0.7	0.10 (<0.1-0.2)	0.15 (<0.1-0.2)	1.30 (0.4-1.4)	1.25 (0.4-2.1)	Low (A horizon) to moderate (B horizon).
K	meq/ 100g	>0.3	0.4 (0.2-0.6)	0.4 (0.2-0.6)	0.3 (0.2-0.5)	0.2 (0.1-0.3)	Moderate (A horizon) to low (B horizon).
ESP	%	<6	<1.20* (0.96-2.9)	2.00 (1.0-3.0)	6.19 (3.3-7.8)	6.60 (3.2-10.0)	Non-sodic (A horizon) to sodic (B horizon).
Ca:Mg ratio		>2	3.00 (2.5-3.4)	2.70 (2.4-2.9)	0.57 (0.5-1.3)	0.72 (0.3-1.1)	Stable (A horizon) to strongly unstable (B).
Organic Carbon	%	>1.2	3.75 (1.6-4.9)	2.80 (1.3-4.3)	1.00 (0.7-1.1)	<0.50 (<0.5-0.5)	Very high (A horizon) to very low (B).

Notes: 1. Sources: Baker and Eldershaw (1993), DERM (2011) and Peverill, Sparrow and Reuter (1999).
2. Values in brackets are the ranges measured.
** These values are an approximation based on calculations using the lowest measurable level.*

Table 4.20 Eutrophic Grey Dermosol soil chemistry summary

Elements	Comments
pH_{water}	Very strongly acidic at the surface grading to neutral in the subsoil. Outside of the desirable range for agriculture in the upper profile. Would restrict agriculture.
EC	Moderate to low soil salinity levels that would not restrict agriculture.
Cl	Acceptable chloride levels that would not restrict agriculture.
PAWC	A small PAWC, which would restrict agriculture.
Fertility	
Macronutrients	Moderate to high levels of macronutrients in the A horizon. Would not restrict agriculture. Note: there was evidence of recent cultivation at the detailed survey sites on this soil type and demonstrated field and laboratory signs of recent fertiliser application, including non-soil related white substance noted in the field and high nutrient levels in the A horizon.
Micronutrients	Moderate to low levels of micronutrients in the A horizon. Would not restrict agriculture.
CEC	Low CEC levels in the A horizon, which may present some fertility issues.
Fertility ranking	**Relative Fertility of ASC Classes (NSW Government 2013):** Moderately high - Dermosol (order), any (sub-order), Eutrophic (Great Group) **EMM applied Relative Fertility of ASC Classes (lab and field data applied to Murphy et al. 2007):** Moderate (Group 3) **Explanation (Murphy et al. 2007):** Soils have moderate fertility and usually require fertiliser and/or have some physical restrictions for arable use. Soils within this group are moderately deficient in nitrogen, phosphorus and some other elements. The grey, red and brown clays have a somewhat better chemical status than the other soils within this group. The high clay content and strongly coherent nature of some subsoils restrict water and root penetration. Note: The laboratory results class the soil as moderately high to high fertility, particularly with the very high nitrogen and total potassium levels recorded in the A horizon. However, the moderate to very low levels of most other macronutrients and micronutrients indicated by the laboratory results, particularly below 30 centimetres depth, suggest moderate natural fertility. Field and laboratory results suggest recent application of fertiliser.
ESP	ESP indicating a sodic subsoil that would restrict agriculture.
Ca:Mg ratio	Stable Ca:Mg ratio in the topsoil, but decreasing with depth to levels that suggest soil instability.
Organic Carbon	Indicative of good structural condition and structural stability in the A horizon, but reducing with depth to low levels. Would not restrict agriculture.
Major limitations to agriculture	Surface pH PAWC Subsoil sodicity

5 Biophysical strategic agricultural land assessment

5.1 Biophysical strategic agricultural land assessment results

A detailed BSAL assessment of the project area and surrounding buffer area was undertaken in accordance with the Interim protocol. The BSAL assessment determined that no BSAL occurs within the project area. The complete BSAL verification assessment report is presented as Appendix A. A Site Verification Certificate (SVC) was lodged on 17 August 2015 and issued on 22 April 2016.

Each soil type identified in the project area was assessed against the specified BSAL verification criteria and no type was found to satisfy the criteria, with most failing multiple physical and chemical soil criteria. In addition, an analysis of slope in the project area determined that some land failed the slope criterion. The result is that no BSAL is present in the project area, a conclusion that is consistent with the results of the broader scale NSW Government's BSAL mapping.

5.1.1 Exclusion criteria

For land to be classified as BSAL it must have access to a reliable water supply; meet all of the criterion; and be a contiguous area of at least 20 ha. Under the Interim Protocol if any individual criterion is not met, the site is not BSAL. The BSAL verification criteria have been evaluated for the project area, based on analysis of field, laboratory and remotely sensed data. The results for each criterion for the individual soil sites, grouped in soil type, are presented in Table 5.1.

i Slope

A slope assessment for the entire assessment area was conducted using a DEM and site observations were made using a hand held clinometer. Areas with slopes greater than 10% were identified as BSAL exclusion areas. Slopes (greater than 10%) occupy much of the western part of the project area, mainly associated with ridgelines and watercourses. A BSAL exclusion map (Figure 5.1) shows Lithic Leptic Rudosol was excluded based on slopes.

ii Rock outcrop

The area of rock outcrop at each site, estimated as a percentage of the site, was determined by visual inspection in the field and recorded on SALIS data cards. Sites with 30% or greater rock outcrop were identified as BSAL exclusion areas.

iii Surface rockiness

Rockiness refers to the presence of unattached coarse rock fragments and/or rock outcrops at the soil surface. The area of surface rockiness, estimated as a percentage of each survey site, as well as the physical characteristics and size of rock fragments, was determined in the field and recorded on SALIS data cards. Sites with greater than 20% coverage of unattached rock fragments, with diameters larger than 60 mm, were identified as BSAL exclusion areas.

iv Gilgai

Under the Interim Protocol, sites with average gilgai depressions deeper than 500 mm over more than 50% of the area are identified as BSAL exclusion areas. However, in the SVC application area no significant areas of gilgai were identified and thus no areas were excluded as BSAL on this basis.

v Soil fertility

Soil types with fertility less than 'moderate', based on the relative fertility of ASC classes presented in Appendix 2 of the Interim Protocol, were identified as BSAL exclusion areas. This was based on the soil type distribution map presented as Figure 4.1.

The soils that were excluded based on fertility were:

- Dystrophic Yellow Kandosol was excluded because of moderately low soil fertility;
- Kandosolic Redoxic Hydrosol was excluded because of moderately low soil fertility;
- Paralithic Leptic Tenosol was excluded because of low soil fertility; and
- Lithic Leptic Rudosol was excluded because of low fertility.

vi Effective rooting depth

Effective rooting depth refers to the depth of soil in which roots can function effectively. That is, above any physical or chemical barrier. Physical and chemical barriers were identified in the field and recorded on SALIS data cards, and/or by laboratory analysis. In the context of BSAL, the depth of soil from the surface to a physical barrier such as bedrock, weathered rock, hard pans or continuous gravel layers was noted during field surveys. Chemical barriers were identified based on laboratory analysis of soil profile samples, being where limiting values of soil pH, chloride content, electrical conductivity, exchangeable sodium percentage and/or the Ca:Mg ratio exist. Survey sites with a physical or chemical barrier to rooting depth at less than 750 mm were identified as BSAL exclusion areas.

vii Drainage

The hydrology at the sites was observed in the field and recorded on SALIS data cards. Poorly drained sites were identified as BSAL exclusion areas. Poorly drained sites were defined as those in low-lying landscapes with drainage restrictions and potential for waterlogging.

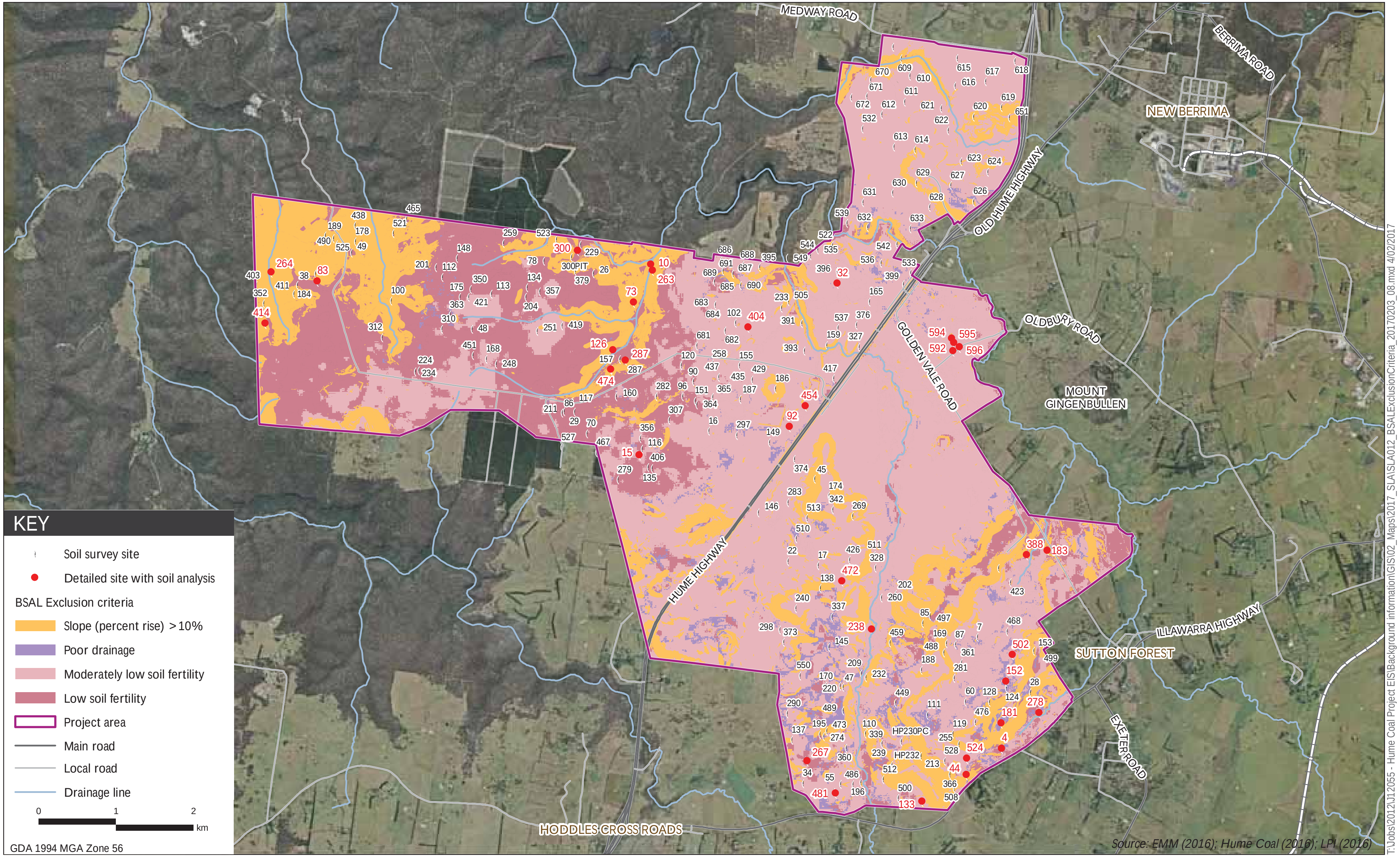
- Eutrophic Grey Dermosol was excluded because of poor drainage; and
- Kandosolic Redoxic Hydrosol was mostly excluded because of poor drainage.

viii Soil pH

Soil pH was measured in the laboratory and occasionally in the field. Sites where the pH in the uppermost 600 mm of the soil profile was outside of the range 5.0-8.9, measured in water, were identified as BSAL exclusion areas. Many of the sites were excluded based on pH.

ix Soil salinity

Soil salinity was measured in the laboratory. Sites where soil salinity in the uppermost 600 mm of the soil profile had EC > 4 deciSiemens per metre (dS/m); or the presence of chlorides at 800 milligrams/kilogram (mg/kg) or more, with gypsum present.



BSAL exclusion map (EMM mapping)

Hume Coal Project

Soil and Land Assessment Report

Figure 5.1

EMM HUMECOAL

Table 5.1 BSAL verification assessment by soil survey site

Site[1]	ASC soil type (to Great Group)	Water: Access to reliable water supply?	1: Slope ≤ 10%?	2: < 30% rock outcrop?	3: ≤ 20% of area has unattached rock fragments > 60 mm diameter?	4: ≤ 50% of the area has gilgais > 500 mm deep?	5: Slope < 5 %?	6: Nil rock outcrops?	7a: Moderate soil fertility?	7b: Moderately high or high soil fertility?	8: Effective rooting depth to physical barrier is ≥750 mm?	9: Soil drainage is better than poor?	10: pH 5-8.9 if measured in water or 4.5-8.1 if measured in calcium chloride, within the uppermost 600 mm of the soil profile?	11: Salinity is ≤ 4 dS/m or chlorides < 800 mg/kg when gypsum is present, within the uppermost 600 mm of the soil profile?	12: Effective rooting depth to a chemical barrier is ≥750 mm?	Area: Is the contiguous area ≥20 ha?	Is the site BSAL?
Dystrophic Yellow Kandosol																	
15	Acidic-Mottled Dystrophic Grey Kandosol	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	N	Y	No
32	Acidic Dystrophic Brown Kandosol	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	N	Y	N	Y	No
44	Bleached Mesotrophic Yellow Kandosol	Y	Y	Y	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	Y	No
133	Acidic-Mottled Dystrophic Yellow Kandosol	Y	N	Y	Y	Y	N	Y	N	N	Y	Y	N	Y	N	Y	No
183	Palic-Acidic Paralithic Leptic Tenosol	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	No
267	Acidic-Sodic Dystrophic Yellow Kandosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	N	Y	N	Y	No
388	Bleached-Mottled Dystrophic Yellow Kandosol	Y	Y	Y	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	Y	No
404	Acidic-Mottled Dystrophic Brown Kandosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	N	Y	N	Y	No
472	Acidic-Sodic Dystrophic Yellow Kandosol	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	N	N	N	Y	No
481	Acidic-Mottled Dystrophic Yellow Kandosol	Y	Y	Y	Y	Y	N	Y	N	N	Y	Y	N	Y	N	Y	No
502	Mottled Dystrophic Yellow Kandosol	Y	Y	Y	Y	Y	N	Y	N	N	N	Y	N	Y	N	Y	No
592	Haplic Dystrophic Red Kandosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	N	No
594	Mottled Dystrophic Yellow Kandosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	No
595	Haplic Dystrophic Red Kandosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	N	No
596	Mottled Dystrophic Yellow Kandosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	No

Table 5.1 BSAL verification assessment by soil survey site

Site[1]	ASC soil type (to Great Group)	BSAL verification criteria: Water – Access to reliable water supply?	1 – Slope ≤ 10%?	2 – < 30% rock outcrop?	3 – ≤ 20% of area has unattached rock fragments > 60 mm diameter?	4 – ≤ 50% of the area has gilgais > 500 mm deep?	5 – Slope < 5 %?	6 – Nil rock outcrops?	7a – Moderate soil fertility?	7b – Moderately high or high soil fertility?	8 – Effective rooting depth to physical barrier is ≥750 mm?	9 – Soil drainage is better than poor?	10 – pH 5-8.9 if measured in water or 4.5-8.1 if measured in calcium chloride, within the uppermost 600 mm of the soil profile?	11 – Salinity is ≤ 4 dS/m or chlorides < 800 mg/kg when gypsum is present, within the uppermost 600 mm of the soil profile?	12 – Effective rooting depth to a chemical barrier is ≥750 mm?	Area – Is the contiguous area ≥20 ha?	Is the site BSAL?
Paralithic Leptic Tenosol																	
73	Palic-Acidic Paralithic Leptic Tenosol	Y	N	Y	Y	Y	N	Y	N	N	Y	Y	N	Y	N	Y	No
83	Palic-Acidic Paralithic Leptic Tenosol	Y	Y	Y	Y	Y	N	Y	N	N	Y	Y	N	Y	N	Y	No
126	Palic-Acidic Paralithic Leptic Tenosol	Y	N	Y	Y	Y	N	Y	N	N	Y	Y	N	Y	N	Y	No
263	Palic-Acidic Paralithic Leptic Tenosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	N	Y	N	Y	No
287	Palic-Acidic Paralithic Leptic Tenosol	Y	Y	Y	Y	Y	N	Y	N	N	Y	Y	Y	Y	N	Y	No
300	Palic-Acidic Paralithic Leptic Tenosol	Y	Y	Y	Y	Y	N	Y	N	N	Y	Y	N	Y	N	Y	No
Kandosolic Redoxic Hydrosol																	
4	Acidic-Sodic Dermosolic Redoxic Hydrosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y	N	N	Y	No
10	Acidic-Sodic Tenosolic Oxyaquic Hydrosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	N	Y	N	Y	No
92	Acidic-Sodic Kandosolic Redoxic Hydrosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	N	Y	N	Y	No
238	Acidic-Sodic Kandosolic Redoxic Hydrosol	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	Y	N	Y	No
454	Acidic-Sodic Kandosolic Redoxic Hydrosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	N	Y	Y	Y	No
524	Acidic-Sodic Kandosolic Redoxic Hydrosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	N	Y	N	Y	No

Table 5.1 BSAL verification assessment by soil survey site

Site[1]	ASC soil type (to Great Group)	BSAL verification criteria: Water – Access to reliable water supply?	1 – Slope ≤ 10%?	2 – < 30% rock outcrop?	3 – ≤ 20% of area has unattached rock fragments > 60 mm diameter?	4 – ≤ 50% of the area has gilgais > 500 mm deep?	5 – Slope < 5 %?	6 – Nil rock outcrops?	7a – Moderate soil fertility?	7b – Moderately high or high soil fertility?	8 – Effective rooting depth to physical barrier is ≥750 mm?	9 – Soil drainage is better than poor?	10 – pH 5-8.9 if measured in water or 4.5-8.1 if measured in calcium chloride, within the uppermost 600 mm of the soil profile?	11 – Salinity is ≤ 4 dS/m or chlorides < 800 mg/kg when gypsum is present, within the uppermost 600 mm of the soil profile?	12 – Effective rooting depth to a chemical barrier is ≥750 mm?	Area – Is the contiguous area ≥20 ha?	Is the site BSAL?
Lithic Leptic Rudosol																	
264	Acidic Lithic Leptic Rudosol	Y	N	Y	N	Y	N	N	N	N	N	Y	N	N	N	Y	No
414	Acidic Lithic Leptic Rudosol	Y	N	N	N	Y	N	N	N	N	N	Y	N	Y	N	Y	No
474	Acidic Lithic Leptic Rudosol	Y	N	Y	Y	Y	N	N	N	N	N	Y	Y	Y	Y	Y	No
Eutrophic Grey Dermosol																	
152	Mottled-Sodic Eutrophic Grey Dermosol	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	N	No
181	Acidic-Sodic Eutrophic Brown Dermosol	Y	Y	Y	Y	Y	N	Y	Y	N	Y	N	N	Y	N	N	No
278	Acidic- Mottled Mesotrophic Grey Dermosol	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y	Y	N	No

Note: 1. Refer to Figure 2.1 for the locations of survey sites.

6 Land and soil capability assessment

6.1 Land and soil capability assessment system

The LSC classes of the project area were assessed in accordance with the requirements of the *Land and soil capability assessment scheme* (OEH 2012). The LSC class definitions are presented in Table 6.1. The assessment used the information collected during the survey and supplemented with information gathered during the desktop assessment.

The assessment classifies soils and landscape characteristics against eight decision tables that use landscape, soils and climate data on the various hazards or limitations to allocate land to an LSC class based on each hazard or limitation (OEH 2012). Each hazard is assigned one of eight LSC classes where Class 1 represents the least limitation and Class 8 represents the greatest limitation; each is assessed individually to develop a profile of hazards for the parcel of land being assessed. The final hazard assessment for a parcel of land is based on the highest hazard in that parcel of land (OEH 2012).

Table 6.1 Land and soil capability classes - general definitions (OEH 2012)

LSC class	General definition
Land capable of a wide variety of land uses (cropping, grazing, horticulture, forestry, nature conservation)	
1	**Extremely high capability land**: Land has no limitations. No special land management practices required. Land capable of all rural land uses and land management practices.
2	**Very high capability land**: Land has slight limitations. These can be managed by readily available, easily implemented management practices. Land is capable of most land uses and land management practices, including intensive cropping with cultivation.
3	**High capability land**: Land has moderate limitations and is capable of sustaining high-impact land uses, such as cropping with cultivation, using more intensive, readily available and widely accepted management practices. However, careful management of limitations is required for cropping and intensive grazing to avoid land and environmental degradation.
Land capable of a variety of land uses (cropping with restricted cultivation, pasture cropping, grazing, some horticulture, forestry, nature conservation)	
4	**Moderate capability land**: Land has moderate to high limitations for high-impact land uses. Will restrict land management options for regular high-impact land uses such as cropping, high-intensity grazing and horticulture. These limitations can only be managed by specialised management practices with a high level of knowledge, expertise, inputs, investment and technology.
5	**Moderate–low capability land**: Land has high limitations for high-impact land uses. Will largely restrict land use to grazing, some horticulture (orchards), forestry and nature conservation. The limitations need to be carefully managed to prevent long-term degradation.
Land capable for a limited set of land uses (grazing, forestry and nature conservation	
6	**Low capability land**: Land has very high limitations for high-impact land uses. Land use restricted to low-impact land uses such as grazing, forestry and nature conservation. Careful management of limitations is required to prevent severe land and environmental degradation.
Land generally incapable of agricultural land use (selective forestry and nature conservation)	
7	**Very low capability land**: Land has severe limitations that restrict most land uses and generally cannot be overcome. On-site and off-site impacts of land management practices can be extremely severe if limitations not managed. There should be minimal disturbance of native vegetation.
8	**Extremely low capability land**: Limitations are so severe that the land is incapable of sustaining any land use apart from nature conservation. There should be no disturbance of native vegetation.

6.2 Land and soil capability assessment and results

Data for the assessment was sourced from field survey observations, desktop analysis and soil laboratory analysis. There was pH data for 90 of the 244 sites assessed for LSC. The sites with no pH data were assigned a pH range which represented the median pH of the sites with pH data (soil acidification classes indicated with an asterisk*). The soil acidification class for the soils with no pH data were classed as 2, 3, 4 or 5, based on soil texture, and would be higher if the pH was lower than average. However, only eight of these sites (with no pH data) which had a soil acidification class of 2 or 3, had an overall LSC classification that was Class 3. Only three sites which had a soil acidification class of 4, had an overall LSC classification that was Class 4. All of the other 143 sites with no pH data had an overall LSC class that was higher (than the soil acidification class) due to other limiting factors such as steep slopes, waterlogging or soil shallowness. The results for each site that was assessed are presented in Table 6.2. Appendix B presents the detailed LSC assessment.

Table 6.2 Summary of LSC classes across the project area

SMUs	Water Erosion LSC class	Wind Erosion LSC class	Soil structural decline LSC class	Soil acidification LSC class	Salinity LSC class	Waterlogging LSC class	Shallow soils and rockiness LSC class	Mass movement LSC class	Overall LSC class
Dermosol									
124	3	3	3	3*	1	3	4	1	4
152	3	2	3	3	1	4	4	1	4
181	3	4	3	5	1	5	3	1	5
278	2	2	3	4	1	5	3	1	5
620	4	3	3	3*	1	1	7	1	7
632	3	3	3	3	1	2	4	1	4
Hydrosol									
4	2	2	3	3	1	6	4	1	6
10	2	5	3	6	1	6	3	1	6
92	2	3	3	5	1	6	3	1	6
111	2	2	3	4	1	6	3	1	6
238	2	2	3	5	1	6	3	1	6
454	2	2	3	3	1	6	3	1	6
524	2	2	3	5	1	6	3	1	6
611	2	3	3	3*	1	6	3	1	6
697	3	4	3	5	1	6	4	1	6
Kandosol									
7	3	2	3	3	1	4	4	1	4
15	3	2	3	4	1	4	4	1	4
16	3	2	3	3*	1	3	3	1	3
17	6	4	3	3	1	4	3	1	6
22	2	2	3	2*	1	5	4	1	5
28	4	3	3	3*	1	5	3	1	5
32	3	3	3	5	1	2	4	1	5
34	3	4	3	3*	1	4	3	1	4

Table 6.2 Summary of LSC classes across the project area

SMUs	Water Erosion LSC class	Wind Erosion LSC class	Soil structural decline LSC class	Soil acidification LSC class	Salinity LSC class	Waterlogging LSC class	Shallow soils and rockiness LSC class	Mass movement LSC class	Overall LSC class
44	3	3	3	4	1	4	3	1	4
45	4	3	3	3*	1	3	3	1	4
47	3	3	3	4	1	4	3	1	4
48	3	4	3	3*	1	4	6	1	6
55	3	2	3	3*	1	4	3	1	4
70	3	4	3	3*	1	2	6	1	6
87	3	4	3	3*	1	2	3	1	4
99	3	3	3	3*	1	4	3	1	4
110	4	2	3	3*	1	2	3	1	4
116	2	4	3	5*	1	1	3	1	5
120	2	4	3	4*	1	1	3	1	4
133	4	4	3	5	1	4	3	1	5
135	3	3	3	3*	1	3	4	1	4
137	3	4	3	3*	1	3	3	1	4
138	6	3	3	3*	1	4	4	1	6
145	3	3	3	4	1	2	4	1	4
146	2	2	3	4	1	4	3	1	4
149	2	2	3	3*	1	4	3	1	4
151	3	3	3	3*	1	2	4	1	4
153	4	3	3	3*	1	2	4	1	4
155	2	3	3	3*	1	3	4	1	4
160	2	2	3	5	1	3	3	1	5
168	2	3	3	3*	1	2	3	1	3
170	3	3	3	4	1	4	3	1	4
175	3	3	3	3*	1	3	4	1	4
186	2	4	3	3*	1	2	3	1	4
187	3	3	3	3*	1	4	4	1	4
188	3	3	3	3*	1	4	4	1	4
195	3	2	3	4	1	3	3	1	4
202	3	3	3	3*	1	4	3	1	4
209	3	2	3	3	1	2	4	1	4
211	2	4	3	3*	1	2	6	1	6
213	6	4	3	3*	1	2	6	1	6
220	4	3	3	4	1	2	3	1	4
230	3	3	3	3*	1	4	3	1	4
232	3	2	3	3*	1	4	3	1	4
235	4	4	3	3*	1	2	6	1	6
236	3	3	3	3*	1	4	4	1	4
240	3	3	3	3*	1	2	3	1	4

Table 6.2 Summary of LSC classes across the project area

SMUs	Water Erosion LSC class	Wind Erosion LSC class	Soil structural decline LSC class	Soil acidification LSC class	Salinity LSC class	Waterlogging LSC class	Shallow soils and rockiness LSC class	Mass movement LSC class	Overall LSC class
248	2	3	3	3*	1	2	4	1	4
251	3	2	3	3*	1	2	7	1	7
255	6	4	3	3*	1	1	6	1	6
258	3	2	3	3*	1	3	4	1	4
260	3	3	3	3	1	2	4	1	4
267	2	4	3	5	1	5	3	1	5
269	3	4	3	3*	1	3	6	1	6
274	3	2	3	3	1	4	3	1	4
279	3	2	3	4	1	4	3	1	4
281	3	3	3	4	1	4	3	1	4
282	3	6	3	6	1	3	3	1	6
283	3	2	3	4	1	3	3	1	4
290	3	3	3	4	1	3	4	1	4
297	2	2	3	3*	1	4	6	1	6
298	3	3	3	3*	1	5	3	1	5
308	3	2	3	3*	1	5	3	1	5
310	3	3	3	3*	1	3	4	1	4
328	3	2	3	3*	1	2	3	1	3
337	3	4	3	4	1	4	3	1	4
339	6	2	3	3*	1	4	4	1	6
342	2	4	3	3*	1	4	3	1	4
356	2	4	3	5	1	2	4	1	5
360	4	2	3	3*	1	3	7	1	7
361	3	2	3	3*	1	4	4	1	4
363	3	4	3	3*	1	3	4	1	4
365	3	2	3	3*	1	3	6	1	6
366	3	3	3	4	1	4	6	1	6
373	3	2	3	3*	1	5	3	1	5
374	3	2	3	3*	1	4	3	1	4
388	3	2	3	3	1	4	3	1	4
391	3	3	3	3*	1	3	3	1	6
396	3	3	3	3*	1	2	6	1	6
404	3	4	3	5	1	2	3	1	5
406	3	2	3	3*	1	3	3	1	3
417	3	3	3	3*	1	2	6	1	6
419	3	2	3	3*	1	4	4	1	4
421	3	3	3	3*	1	3	4	1	4
423	1	2	3	2*	1	3	3	1	3
426	2	4	3	3	1	2	6	1	6

Table 6.2 Summary of LSC classes across the project area

SMUs	Water Erosion LSC class	Wind Erosion LSC class	Soil structural decline LSC class	Soil acidification LSC class	Salinity LSC class	Waterlogging LSC class	Shallow soils and rockiness LSC class	Mass movement LSC class	Overall LSC class
429	3	3	3	3*	1	3	4	1	4
435	3	3	3	3*	1	4	3	1	4
437	3	2	3	3*	1	4	4	1	4
449	3	3	3	3*	1	4	3	1	4
451	2	3	3	3*	1	3	6	1	6
459	4	3	3	3*	1	4	3	1	4
468	3	2	3	5	1	5	3	1	5
472	3	4	3	5	1	3	4	1	5
473	4	3	3	4	1	4	4	1	4
481	3	4	3	5	1	3	3	1	5
486	3	5	3	4	1	4	6	1	6
488	4	3	3	4	1	3	3	1	4
489	3	3	3	4	1	2	4	1	4
499	4	3	3	4	1	4	3	1	4
500	3	3	3	4	1	4	4	1	4
502	3	3	3	4	1	2	3	1	4
505	3	3	3	3*	1	3	6	1	6
508	4	3	3	4	1	4	3	1	4
510	2	4	3	3	1	3	6	1	6
511	3	3	3	3*	1	4	3	1	4
512	4	2	3	4	1	3	3	1	4
528	4	2	3	3*	1	4	3	1	4
535	3	3	3	3*	1	2	4	1	4
536	3	3	3	3*	1	1	6	1	6
537	3	4	3	3*	1	2	6	1	6
539	4	4	3	3*	1	2	4	1	4
544	3	3	3	3*	1	2	4	1	4
545	2	3	3	3*	1	2	4	1	4
550	3	3	3	3*	1	5	3	1	5
592	2	3	3	4	1	2	3	1	4
594	3	2	3	3	1	3	3	1	3
595	3	3	3	3	1	2	3	1	3
596	3	3	3	3	1	3	3	1	3
601	2	3	3	3*	1	3	4	1	4
602	2	3	3	3*	1	3	4	1	4
603	3	4	3	3*	1	4	3	1	4
606	2	3	3	3*	1	4	4	1	4
607	2	4	3	3*	1	5	4	1	5
610	2	3	3	4	1	3	3	1	4

Table 6.2 Summary of LSC classes across the project area

SMUs	Water Erosion LSC class	Wind Erosion LSC class	Soil structural decline LSC class	Soil acidification LSC class	Salinity LSC class	Waterlogging LSC class	Shallow soils and rockiness LSC class	Mass movement LSC class	Overall LSC class
612	3	3	3	3*	1	2	6	1	6
613	2	3	3	3*	1	2	7	1	7
614	4	3	3	2*	1	3	6	1	6
615	3	3	3	3*	1	2	6	1	6
616	3	3	3	3*	1	2	3	1	3
617	3	3	3	2*	1	5	3	1	5
618	2	4	3	3*	1	4	4	1	4
619	4	3	3	5	1	5	3	1	5
621	3	2	3	3*	1	3	4	1	4
622	2	2	3	3*	1	2	3	1	3
623	3	2	3	3*	1	3	3	1	3
624	3	4	3	3*	1	4	3	1	4
625	3	4	3	3*	1	4	3	1	4
626	4	4	3	3*	1	3	6	1	6
627	3	4	3	3*	1	5	4	1	5
628	3	2	3	3*	1	4	3	1	4
629	4	3	3	2*	1	2	6	1	6
630	3	2	3	2*	1	5	4	1	5
631	3	3	3	2*	1	5	3	1	5
633	2	2	3	3*	1	3	4	1	4
670	3	5	3	5	1	5	4	1	5
671	2	2	3	3	1	4	3	1	4
672	3	5	3	3*	1	5	7	1	7
681	2	5	3	4	1	5	3	1	5
682	3	5	3	4*	1	5	3	1	5
683	2	4	3	5*	1	5	4	1	5
684	3	3	3	5*	1	5	6	1	6
686	3	5	3	5	1	5	3	1	5
687	3	4	3	6	1	5	4	1	6
688	3	3	3	5	1	5	6	1	6
690	3	2	3	5	1	5	4	1	5
691	3	3	3	5	1	5	4	1	5
692	8	2	3	4	1	5	3	1	8
698	3	2	3	3	1	5	3	1	5
699	3	3	3	4	1	3	3	1	4
700	3	4	3	3*	1	3	4	1	4
701	3	4	3	3*	1	3	4	1	4
702	3	3	3	5	1	3	4	1	5
703	3	3	3	4	1	4	4	1	4

Table 6.2 Summary of LSC classes across the project area

SMUs	Water Erosion LSC class	Wind Erosion LSC class	Soil structural decline LSC class	Soil acidification LSC class	Salinity LSC class	Waterlogging LSC class	Shallow soils and rockiness LSC class	Mass movement LSC class	Overall LSC class
704	2	3	3	3*	1	3	7	1	7
Rudosol									
38	3	4	3	3*	1	1	7	1	7
49	2	7	3	4*	1	1	7	1	7
100	3	3	3	3*	1	1	6	1	6
113	3	3	3	5*	1	1	6	1	6
117	2	3	3	4*	1	1	6	1	6
148	3	3	3	5*	1	1	6	1	6
159	4	3	3	3*	1	1	7	1	7
178	3	6	3	4*	1	1	7	1	7
189	4	6	3	4*	1	1	4	1	6
204	3	5	3	4*	1	1	7	1	7
259	3	4	3	3*	1	1	6	1	6
264	8	5	3	6	1	1	7	1	8
312	2	6	3	4*	1	1	7	1	7
350	3	3	3	3*	1	2	6	1	6
352	6	6	3	4	1	1	7	1	7
357	3	4	3	3*	1	1	6	1	6
393	3	3	3	3*	1	1	6	1	6
403	4	6	3	4	1	1	6	1	6
411	7	6	3	4*	1	1	7	1	7
414	6	7	3	6	1	1	7	1	7
438	4	3	3	3*	1	1	7	1	7
465	4	6	3	4*	1	1	7	1	7
474	4	4	3	5	1	1	7	1	7
490	6	6	1	5*	1	1	6	1	6
521	6	4	3	4*	1	1	7	1	7
525	7	6	3	4*	1	1	7	1	7
609	6	4	3	4*	1	1	7	1	7
Tenosol									
26	3	4	3	3*	1	1	6	1	6
29	2	5	3	5*	1	2	3	1	5
73	4	5	3	6	1	1	3	1	6
83	3	6	3	6	1	1	3	1	6
90	2	5	3	4*	1	1	3	1	5
112	2	5	3	4*	1	1	4	1	5
119	4	3	3	3*	1	1	6	1	6
126	3	5	3	6	1	1	3	1	6
128	4	3	3	4	1	1	7	1	7

Table 6.2 Summary of LSC classes across the project area

SMUs	Water Erosion LSC class	Wind Erosion LSC class	Soil structural decline LSC class	Soil acidification LSC class	Salinity LSC class	Waterlogging LSC class	Shallow soils and rockiness LSC class	Mass movement LSC class	Overall LSC class
157	3	3	3	5*	1	1	3	1	5
174	3	4	3	3*	1	1	6	1	6
183	3	3	3	4	1	2	7	1	7
196	3	3	3	4	1	1	3	1	4
201	3	4	3	4*	1	2	6	1	6
224	3	2	3	3*	1	1	6	1	6
229	3	5	3	4*	1	1	7	1	7
234	2	5	3	4*	1	1	4	1	5
239	4	4	3	3*	1	1	6	1	6
263	6	3	3	5	1	1	3	1	6
287	3	4	3	5	1	1	3	1	5
300	3	6	1	6	1	1	3	1	6
307	3	3	3	3*	1	1	6	1	6
327	2	3	3	3*	1	2	6	1	6
364	3	5	3	4	1	3	3	1	5
376	3	4	3	3*	1	2	6	1	6
379	3	6	3	4*	1	1	4	1	6
467	3	6	3	4*	1	1	3	1	6
513	3	4	3	4	1	1	6	1	6
522	4	6	3	4*	1	1	7	1	7
523	4	4	3	5*	1	1	4	1	5
532	3	4	3	4*	1	1	3	1	4
600	2	6	3	4*	1	1	6	1	6
604	3	3	3	5*	1	1	4	1	5
605	3	4	3	4*	1	1	4	1	4
608	2	3	3	3*	1	2	6	1	6
685	3	4	3	5	1	5	7	1	7
689	3	4	3	5	1	5	6	1	6

6.2.1 Land and soil capability assessment conclusions

i Relationship between soil type and LSC classes

The Kandosol and Dermosol soils have generally been classified as Class 4 or 5. These soils are therefore capable of cropping with restricted cultivation, pasture cropping and grazing. The sites which were Class 5 were either poorly drained or slightly acidic. Some sites were classified as Class 6 due to shallow soil depths. Eleven of the Kandosol soil sites were Class 3, however incomplete data for surface pH means eight of these sites are conservatively classified (without soil pH) and may be Class 4 or 5.

The Hydrosols have been classified as Class 6, based on being waterlogged for several months of the year.

The Rudosols have been generally classified as Class 6 or 7, based on the rockiness and/or shallowness of the soils. Therefore the Rudosols are generally suitable for forestry or nature conservation, with some limited areas that may be able to support grazing (Class 6). These soils are limited to the steep slopes associated with sandstone surface geology most commonly found within Belanglo State Forest. Within the project area, common land uses on this soil type are low intensity grazing on native pastures and forestry.

The Tenosols have been generally classified as Class 5, 6 or 7, based on a low surface soil pH, shallow soils, or sites subject to wind erosion. Therefore the Tenosols are generally suited to either grazing, forestry or nature conservation. They are most commonly found within and immediately surrounding the Belanglo State Forest, and land use on this soil type is typically for native and pine forestry.

ii Distribution of LSC classes

The LSC assessment has mapped 58% of the project area as moderate (Class 4 – 44%) to moderate-low (Class 5 – 14%) capability land. This means that the land has moderate to high limitations for high – impact land uses, which will restrict cropping, high intensity grazing and horticulture (OEH 2012). These limitations can only be managed with the implementation of suitable soil conservation measures.

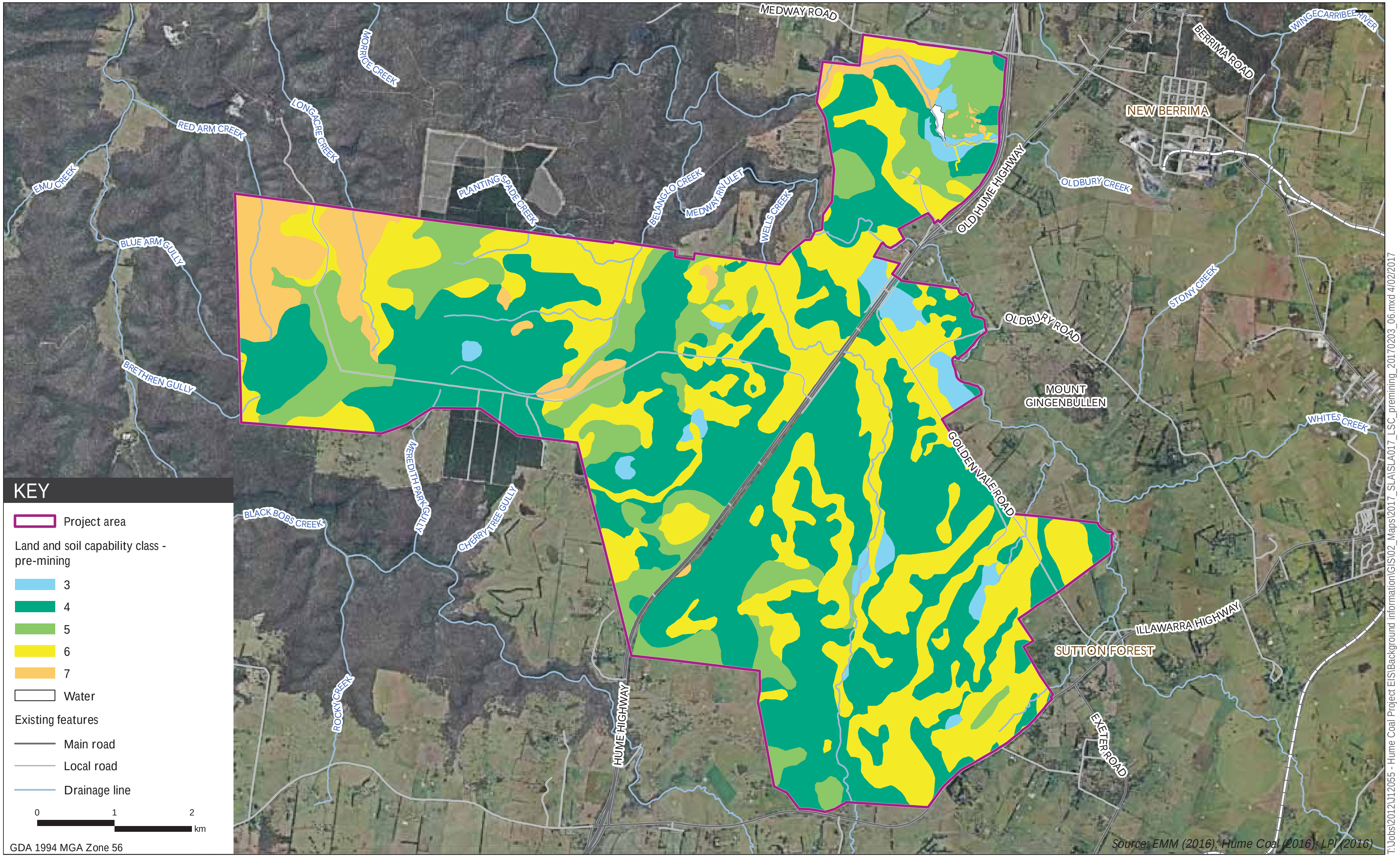
32% of the project area is mapped as low capability (Class 6) – suitable for a limited set of land uses such as grazing, forestry and nature conservation. Very low capability land is mapped across 6% of the project area, suitable for selective forestry and nature conservation.

High capability land is mapped on 3% of the project area. None of the individual areas mapped as Class 3 are greater than 20 ha. OEH state that 20 ha is the minimum area required for commercial food production and therefore, use this as a requirement for defining BSAL in the interim protocol (DP&E 2015).

A map has been produced that shows the spatial distribution of the LSC classes (Figure 6.1), and Table 6.3 shows the number of hectares of each land class in the project area.

Table 6.3 Land and soil capability classes in the project area – pre-mining

Class	Capability	Soil type in the project area	Hectares (ha)	%
Land capable of a wide variety of land uses (cropping, grazing, horticulture, forestry, nature conservation)				
1	Extremely high	None	0	
2	Very high	None	0	
3	High	Kandosols (areas restricted in size)	144	3%
Land capable of a variety of land uses (cropping with restricted cultivation, pasture cropping, grazing, some horticulture, forestry, nature conservation)				
4	Moderate	Kandosols, Dermosols	2221	44%
5	Moderate–low	Poorly drained Kandosols, slightly acidic Tenosols and Kandosols, imperfectly drained Dermosols	704	14%
Land capable for a limited set of land uses (grazing, forestry and nature conservation)				
6	Low	Hydrosols, acidic Tenososls Soils with steep slopes or shallow soils	1641	32%
Land generally incapable of agricultural land use (selective forestry and nature conservation)				
7	Very low	Shallow soils (mostly Rudosols and Tenosols)	300	6%
8	Extremely low	Very steep ground (>50%).		
	None	Waterbody, Hume Highway, etc	41	1%



Land and soil capability class - pre-mining (EMM mapping)

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Figure 6.1

7 Impact assessment

7.1 General risks to soil resources

7.1.1 Soil degradation

Soil resources can be degraded by a number of processes, which can reduce the agricultural potential of the affected land. General mechanisms by which this degradation can occur are as follows:

Nutrient decline: A decline in nutrient content could occur while the soil is stored in stockpiles. This would decrease fertility, and may mean the rehabilitated land using the returned soil would support less plant growth and would reduce the agricultural potential of the land. This can be amended by adding fertilisers to the returned soil (Keipert 2005).

Structural decline: Structural decline of the soil refers to the breakdown of the aggregates (or peds), resulting in soil particles becoming more randomly and closely packed together with little pore space compared to the original structure (DLWC 2000). Structural decline is caused by compaction by heavy vehicles and machinery during the removal, stockpiling and re-spreading process. Soil permeability, water-holding capacity, aeration and microfauna presence decreases and the affected soils are less favourable for plant growth. Therefore, management practices need to minimise the risk of compaction wherever practicable.

Acidification: A gradual increase in acidity of the soil could lead to a decline in pasture growth. It can occur on agricultural land as a result of long-term application of nitrogenous fertilisers, and the increased leaching processes following the loss of deep-rooted vegetation (DLWC 2000). The land in the majority of the project area has been extensively cleared of deep-rooted vegetation, and has been used for pasture for many decades. The pH of the surface soil in some parts of the project area is currently slightly acidic and may need soil amendments (ie lime) to increase the pH to help plant growth.

7.1.2 Loss of soil resource

The soil will be stripped from the direct disturbance footprint of the project, and stored in stockpiles for later use in rehabilitation. Some soil is always lost during handling (ie stripping, stockpiling and spreading), and poor site selection for stockpiles may further decrease the available soil, particularly if the stockpile has to be relocated. Accurately calculating the soil needed for stripping lowers the risk that not enough soil will be stripped for effective rehabilitation.

7.1.3 Soil erosion and sediment transport

Erosion results in loss of soil from the landscape and then the land's productive capacity and its capacity to perform ecosystem functions can deteriorate. The potential for soils to erode determines which management measures should be used and whether the soils are appropriate to use for rehabilitation.

7.1.4 Subsidence related impacts on soil resources

There is a negligible risk of subsidence-related impacts occurring above the underground mine, due to the first workings mining method to be utilised, which retains pillars of rock to support the overlying strata. Mine Advice (2016) has assessed the predicted maximum subsidence associated with the proposed mine method and layout and predicts that it is "negligible".

7.1.5 Soil contamination

In the surface infrastructure areas there is a risk that land could be contaminated from hydrocarbon spills, storage of fuel and chemicals, refuelling activities, sewage, etc. Also there will be temporary storage of drift spoil during the early phase of mining which could result in leachate of minerals from the overburden. However, this risk is very low as the geochemical testing has shown these materials are benign (RGS Environmental 2016). Contamination could also occur from the coal product stockpiles which have some potential to produce acidic runoff (RGS Environmental 2016).

The topsoil will not be impacted by these potential sources of contamination as it will have been stripped beforehand.

Small areas of soil contamination could occur from hydrocarbon spills during soil stripping and construction activities (eg burst hydraulic hose); although the likelihood of occurrence is considered to be low.

7.2 Land subject to potential impacts

The project's potential impacts on soil resources are associated with: temporary loss of land due to construction and operation of mine infrastructure (eg surface facilities); and during rehabilitation and closure activities. The assessment focuses on the disturbance footprint within the project area. Activities during the life of the mine may impact on soil physical and chemical properties and post-mining land use. These potential impacts are addressed in the following sections.

Surface infrastructure is proposed to be developed on predominately cleared land owned by Hume Coal, or land for which there are appropriate access agreements in place with the landowner, and where the land is relatively free from environmental and other constraints. The project design integrates with the existing topography and landform and is set back from sensitive receptors where possible, to minimise the potential for visual, noise, dust and amenity impacts. Nevertheless, land used to accommodate buildings and structures will be disturbed requiring management and rehabilitation.

Disturbance of soil could increase erosion, depending on slope, and mix lower class soils and subsoils with better quality soils. Machinery used in the construction phase could also degrade soil quality as a result of compaction when creating topsoil stockpiles, and on areas used for temporary construction (eg. access tracks, laydown areas).

Due to the underground nature and first workings coal extraction method to be employed, impacts to soil resources are not expected to be significant during the operational phases and because only very localised land clearing will occur and subsidence will be negligible.

During decommissioning works, soils may be disturbed temporarily while infrastructure is dismantled, and access and internal roads and other supporting infrastructure are removed. All disturbed land will be rehabilitated with stockpiled soil, and the pre-mining land use returned.

Mitigation measures for the potential impacts to soil resources are described Section 8.

7.2.1 Disturbance footprint

Land disturbance will be mainly associated with the development and use of surface infrastructure (ie coal handling infrastructure, mining infrastructure, roads, dams and stockpiles), and will have a direct disturbance footprint of approximately 117 hectares of land (details given in Table 7.1).

Table 7.1 Surface Infrastructure disturbance area

Surface infrastructure	Description	Area (ha)
Mining infrastructure	Drifts, ventilation shafts	64
Coal handling infrastructure	ROM overland conveyor system, coal preparation plant, product coal overland conveyor system and coal loading facility	
General infrastructure	access roads, offices, bathhouse, carparking, temporary accommodation and construction facilities, workshop and utilities	
Mine Water Dams (MWD)	primary water dam, product stockpile water dam and CPP/ROM water dam	44
Stockpiled material	Drift spoil stockpile, ROM stockpile, product stockpiles, temporary coal reject stockpile, topsoil stockpiles	9
Total		117

7.2.2 Soil types disturbed

The majority of the proposed surface infrastructure area is positioned over one soil type, Dystrophic Yellow Kandosol soils (see Figure 7.1). The Dystrophic Yellow Kandosol soils are associated with gently undulating landscapes which have been predominantly cleared and replaced with pasture grasses.

Small patches of Kandosolic Redoxic Hydrosol have been mapped in the disturbance footprint. The conveyor corridor crosses Oldbury Creek where it is expected to encounter Kandosolic Redoxic Hydrosol, or very wet soils.

The Dystrophic Yellow Kandosol soil type will be the most useful for rehabilitation purposes due to its structure and depth. The Paralithic Leptic Tenosol soils are generally shallow and not expected to provide a significant volume of useable material. Kandosolic Redoxic Hydrosols are not considered suitable for use in rehabilitation. These soils are typically wet which would lead to them compacting and breaking down during stripping operations.

The LSC classes to be disturbed are shown in Figure 7.2

Table 7.2 Soil types to be disturbed

Soil type	Disturbance area	
	Ha	%
Dystrophic Yellow Kandosol	110.3	94.3
Eutrophic Grey Dermosol	1.1	0.9
Kandosolic Redoxic Hydrosol	3.6	3.1
Paralithic Leptic Tenosol	1.6	1.4
Lithic Leptic Rudosol	0.4	0.3
TOTAL	**117**	**100%**

Notes: 1. Based on EMM assessment (Feb 2016).