APPENDIX I

AGRICULTURAL RESOURCE ASSESSMENT

June 2013

Agricultural Resource Assessment: "Wilpinjong Coal Mine Modification", Wollar, NSW

Prepared for Wilpinjong Coal Pty Ltd

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Orange NSW

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1.0 INTRODUCTION

1.1 Background

The Wilpinjong Coal Mine is an existing open cut coal mining operation situated approximately 40 kilometres (km) north-east of Mudgee, near the Village of Wollar, within the Mid-Western Regional Council Local Government Area, in central New South Wales (NSW) (Figure 1).

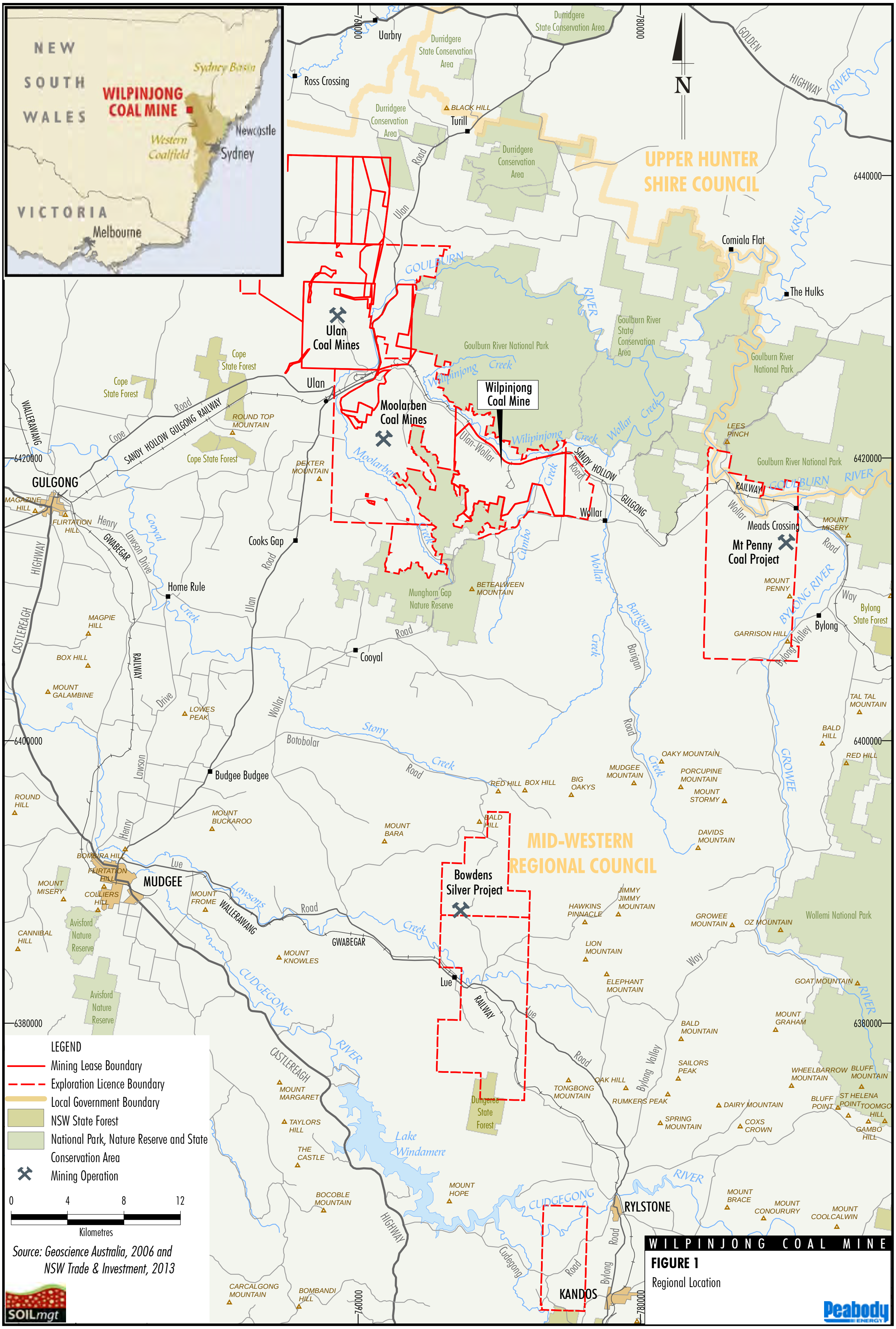
The Wilpinjong Coal Mine is owned and operated by Wilpinjong Coal Pty Limited (WCPL), a wholly owned subsidiary of Peabody Energy Australia Pty Limited. Mining is undertaken within Mining Lease (ML) 1573 and the approved open cut and contained infrastructure area at the Wilpinjong Coal Mine comprises approximately 1,920 hectares (ha) (Figure 2).

The Wilpinjong Coal Mine was approved under Part 3A of the NSW *Environmental Planning and Assessment Act, 1979* (EP&A Act) by the NSW Minister for Planning in February 2006 (Project Approval 05-0021). The mine has been operating since 2006, and is approved to produce up to 15 million tonnes per annum (Mtpa) of run-of-mine (ROM) coal from six open cut pits (Figure 2).

The Wilpinjong Coal Mine produces both washed and unwashed coal products. The coal handling and processing infrastructure has been designed to accommodate the processing of raw coal and the handling of raw (bypass) and washed product coal. The Project Approval currently allows for the beneficiation of up to 8.5 Mtpa of ROM coal in the Coal Handling and Preparation Plant (CHPP) and up to 12.5 Mtpa of thermal coal products from the Wilpinjong Coal Mine are transported by rail to domestic customers for use in electricity generation and to port for export.

Following a review of mine planning, CHPP capacity, waste rock bulking factors, planned building and demolition works and light vehicle servicing requirements, WCPL has determined that a number of minor alterations to the approved Wilpinjong Coal Mine are required, including:

- development of incremental extensions to the existing open cut pits (Figure 3) that would extend the open cuts by approximately 70 ha and would result in the recovery of approximately 3 million tonnes of additional ROM coal;
- higher rates of annual waste rock production (from 28 million bank cubic metres [Mbcm] up to approximately 33.3 Mbcm) in order to maintain approved ROM coal production;
- minor CHPP upgrades to improve fine coal reject management (installation of a belt press filter) and an increase in the rate of ROM coal beneficiation in the CHPP to approximately 9 Mtpa;
- upgrade of the existing Reverse Osmosis Plant to a Water Treatment Facility with the addition of pre-filtration and flocculation/dosing facilities to improve plant efficiency;
- amendment of the waste emplacement strategy to include:
  - development of an elevated waste rock emplacement landform (up to approximately 450 metres [m] Australian Height Datum[AHD]) within the footprint of Pit 2 (Figure 3);
  - disposal of some inert building and demolition waste that is produced from off-site building demolition in the approved mine waste rock emplacements;
  - co-disposal of fine coal reject material produced by the belt press filter with coarse rejects; and
- operation of a light vehicle servicing workshop at an existing farm shed that is located in the north of the Project area (Figure 3).



WILPINJONG COAL MINE

FIGURE 1

Regional Location

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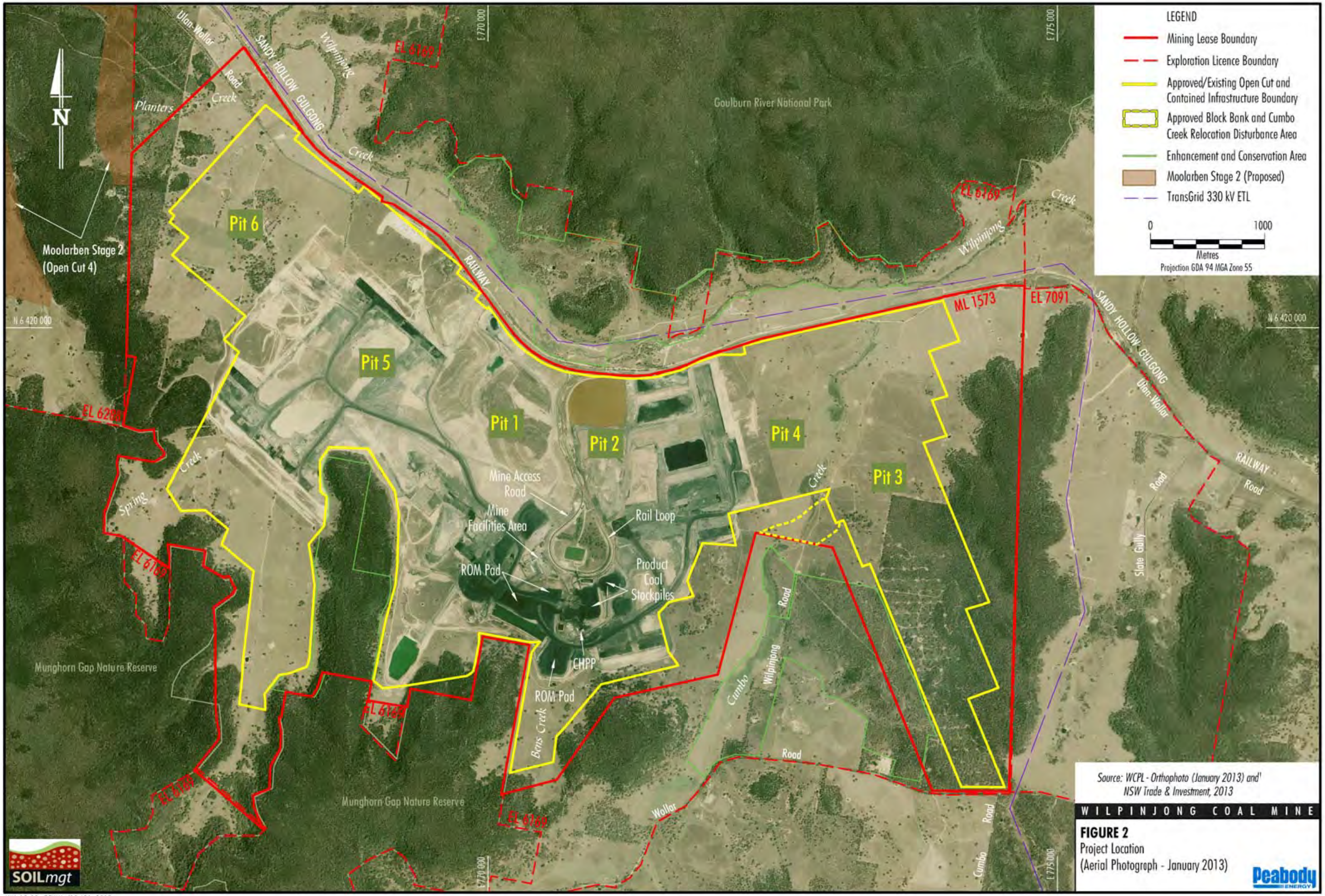

FIGURE 2
Project Location
(Aerial Photograph - January 2013)

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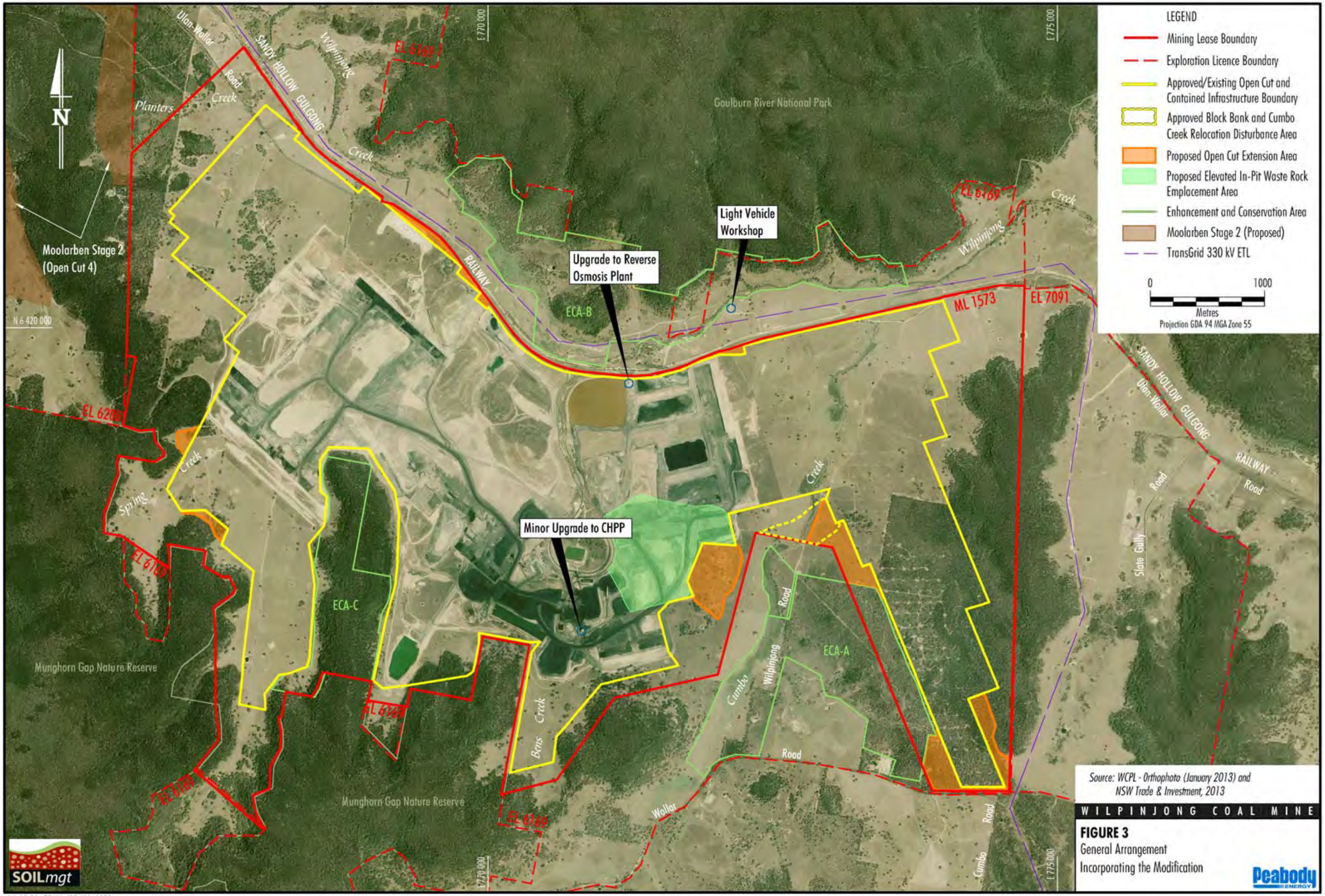

WILPINJONG COAL MINE

FIGURE 3
General Arrangement
Incorporating the Modification

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Construction of the belt press filter and augmentation of the existing Reverse Osmosis Plant may require a temporary construction workforce of up to 20 people for periods in 2014.

These variations to the Wilpinjong Coal Mine are being sought via a Modification under section 75W of the EP&A Act (the Modification).

It should be noted that no changes are proposed to the approved rates of production of ROM coal (15 Mtpa) or product coal (12.5 Mtpa) and the current owner-operator mobile fleet would not require augmentation. In addition, the Modification would not require any significant alteration to the existing approved Wilpinjong Coal Mine mining operations and general supporting infrastructure, or the current operational workforce of approximately 550 staff and contractors.

1.2 Scope and Objectives

This Agricultural Resource Assessment has been prepared to support an application to undertake the Modification.

The objectives of this assessment were to:

- Describe the agricultural resources (focusing on soil resources) and enterprises of the lands associated with the Modification open cut extension areas (total of about 70 ha).
- Recommend management measures for agricultural resources, with emphasis on soil assessment and management in the open cut extension areas.
- Assess the potential impacts on agricultural enterprises and productivity as a result of the Modification.

2.0 DESCRIPTION OF THE MODIFICATION AREA

The Wilpinjong Coal Mine site is located in the Upper Hunter Valley region of NSW. Landforms at the site consist of gently sloping colluvium and undulating foothills adjacent to north-flowing tributary creeks of Wilpinjong Creek (part of the Goulburn River Catchment). Steep timbered ridges exist to the south, west and east of the mine site. Wilpinjong Creek is located to the north of the mining lease (Figure 3).

The Moolarben Coal Mines are located to the west of the Wilpinjong Coal Mine, the Goulburn River National Park lies to the north and the Munghorn Nature Reserve is located to the south (Figures 1 and 3).

Elevations in the vicinity of Wilpinjong Coal Mine range from approximately 350 m AHD at Wilpinjong Creek to approximately 610 m AHD on ridges to the immediate south of ML 1573.

Land use in the proposed open cut extension areas includes mining-related infrastructure, remnant vegetation and cleared grazing land (Figure 3). The cleared grazing land is under unimproved pasture. No grazing is currently conducted in most of these areas, however, some limited grazing is undertaken in the south of Pit 5 and this includes the two small open cut extension areas (Figures 2 and 3). Some dryland cropping has occurred in previous decades in the north western Modification open cut extension area in the vicinity of Ulan-Wollar Road (L. Coleman, pers. comm.).

The Wilpinjong area experiences a temperate climate with an average annual rainfall of approximately 600 millimetres (mm). Long-term historical rainfall data is available from numerous established Bureau of Meteorology stations in the surrounding region. The closest station with a long-term record is located in Wollar (Barigan St) (station number 62032 with records available from 1901).

3.0 SOIL RESOURCES

3.1 Review of Existing Information

The following existing information relevant to the Modification area was reviewed for this agricultural resources assessment:

- Soil Profile Attribute Data Environment (SPADE) soil profiles (part of the NSW Natural Resource Atlas);
- soil type and landscape mapping (Murphy and Lawrie 1998);
- Western Coalfield Geology Map (Department of Mineral Resources 1998);
- Biophysical Strategic Agricultural Land (BSAL) mapping (NSW Government 2012);
- Critical Industry Cluster mapping (NSW Government 2012);
- Land and Soil Capability (LSC) mapping (Office of Environment and Heritage 2012a); and
- soil survey for Wilpinjong Coal Project Soils, Rural Land Capability and Agricultural Suitability Assessment (Jammel Environmental & Planning Services Pty Ltd [Jammel] 2004).

A brief summary of relevant information from these sources is provided in the following subsections.

SPADE Soil Profile Database

A search of the NSW Government's SPADE website (part of the NSW Natural Resource Atlas) was conducted to identify any existing soil profile information in the open cut extension areas. No SPADE soil profiles with adequate profile descriptions or laboratory analyses could be found in these areas.

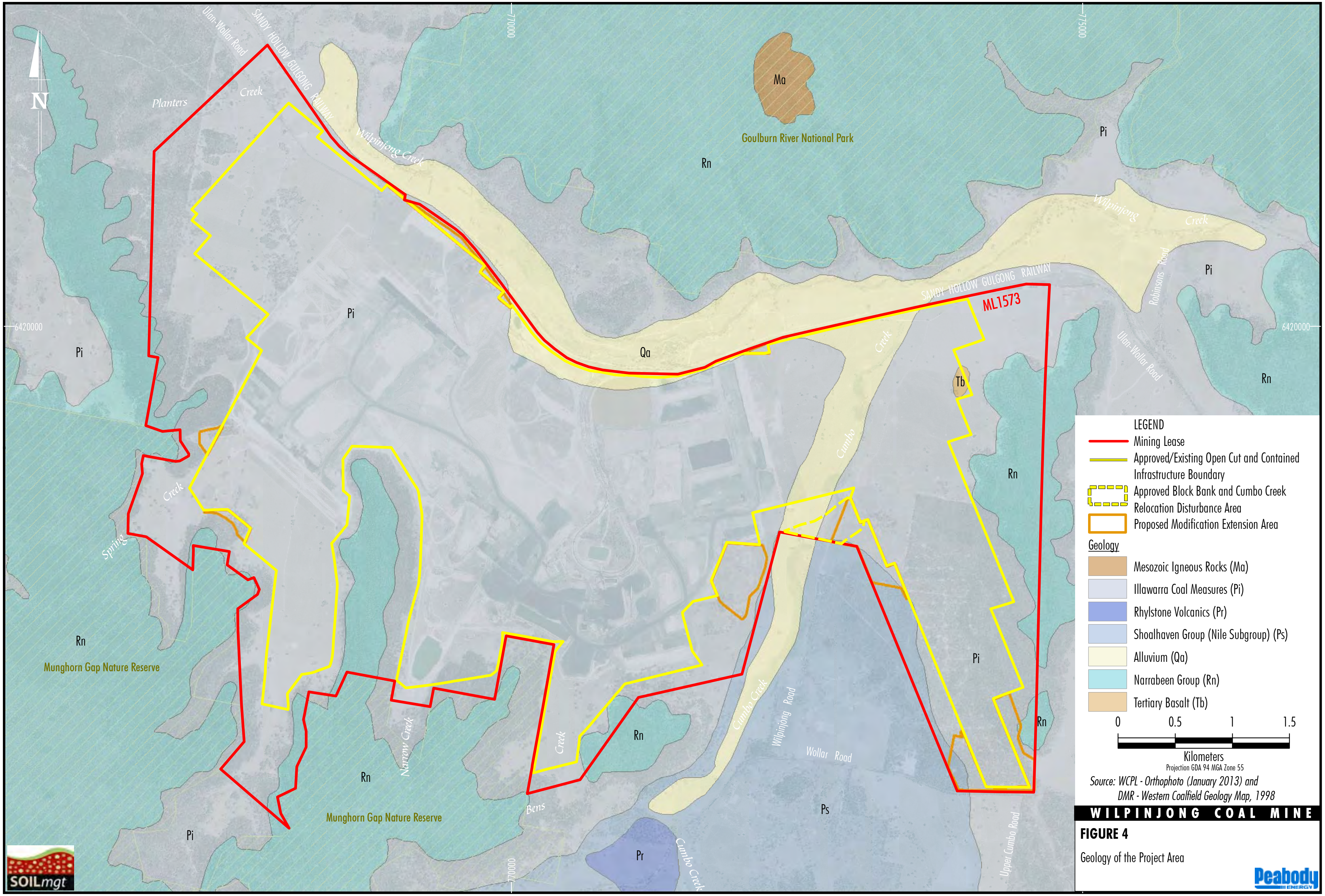
Geology/Parent Materials for Soil Formation

Rock types that are the parent material for soil formation in the vicinity of the open cut extension areas are shown in Figure 4. The main geological unit is the Permian 'Illawarra Coal Measures' consisting of shale, sandstone, conglomerate and coal. It is overlaid by Triassic sandstone and mudstone parent material that lies beneath the nearby rocky ridge lines.

Soil Types and Landscapes

Appendixes 1 and 2 show the location of soil landscape units as mapped and described by Murphy and Lawrie (1998) in the vicinity of the Wilpinjong Coal Mine, and modified by Jammel (2004). The descriptions of these units indicate the presence of soil conditions that generally are sub-optimal for plant growth (Table 1).

The 'Ulan' Soil Landscape unit is dominant across much of the Wilpinjong Coal Mine, however, the 'Barigan Creek' unit is dominant in the Cumbo Creek corridor and the 'Lees Pinch' unit is associated with ridgelines in the south (Appendix 1).



WILPINJONG COAL MINE

FIGURE 4

Geology of the Project Area

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Table 1. Soil landscape units (Murphy and Lawrie 1998) in the vicinity of the Modification area

Soil landscape unit	Soil types present	Likely constraints for agricultural production based on these descriptions
Ulan (**ul**)	Yellow Podzolic Soils on lower slopes and drainage lines with patches of yellow Solodic Soils Solonetz in association with salt scalds. Yellow and Brown Earths on footslopes with minor areas of Earthy Sands.	Seasonal waterlogging on lower slopes; moderate to high erosion hazard under cultivation; moderate available water holding capacity.
Barigan Creek (**bc**)	Yellow Podzolic Soils are common on lower slopes and along drainage lines. Red Podzolic Soils on colluvial slopes, benches and rises.	High erosion hazard under cropping or where there is low surface cover; salinity in localized areas in drainage depressions.
Lees Pinch (**lp**)	Slopes 15-40 percent (%); shallow sandy soils with extensive rock outcrop, boulder debris slopes and sandstone cliffs.	Steep slopes, very low fertility, very low waterholding capacity.

The Jammel (2004) study included 46 soil pits across the Wilpinjong Mine Site. Because many of the soil samples were bulked across several sampling sites and the sampling depths lack the required resolution against current guidelines, this study does not provide information that is suitable for contemporary agricultural resource assessment purposes.

Strategic Agricultural Land

The *Upper Hunter Strategic Regional Land Use Plan* (SRLUP) (NSW Government 2012) includes mapping of lands identified as Strategic Agricultural Lands. Strategic Agricultural Lands include BSAL and Critical Industry Clusters. BSAL is classified as land with reliable water of suitable quality, with a soil fertility of 'high' or 'moderately high' (Draft Inherent General Fertility of NSW) and Class I, II or III LSC, or a soil fertility of 'moderate' and Class I or II LSC (NSW Government 2012). The SRLUP does not map any BSAL in the vicinity of the Wilpinjong Coal Mine. The nearest BSAL is located approximately 15.5 km east of the Wilpinjong Coal Mine.

The SRLUP includes mapping of lands identified as Viticulture and Equine Critical Industry Clusters. None of these areas are mapped in the SRLUP within the Wilpinjong Coal Mine. The nearest Viticulture and Equine Critical Industry Clusters are located approximately 52.5 km and 14.5 km east respectively.

Land and Soil Capability Classes

The NSW Government estimate of LSC in the vicinity of the Wilpinjong Coal Mine is shown in Appendix 3. Based on the mapping in Appendix 3, all of the Modification open cut extension areas have a LSC rating of 5, with the exception of one area that is rated 7, in the south-east of Pit 3.

These classes are defined as follows (Office of Environment and Heritage, 2012b):

> ***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.*
>
> ***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.*

3.2 Methodology

A soil survey was conducted to characterise and assess the soils in the Modification open cut extension areas. This section provides a description of the soil survey methodology and outcomes.

The following soil information is regarded by Ward (1998) as being important for soil and overburden assessment associated with mine site reclamation:

- Classification (structure, texture, etc.); allows existing data and experience on managing similar soils elsewhere to be applied.
- Dispersion index and particle size analysis; indicates soil structural stability and erodibility.
- pH; need to identify extreme ranges for treatment of lime or selection of suitable plant species.
- Electrical conductivity (EC); indicates soluble salt status.
- Macro- and micro-nutrients.

More specifically, Elliott and Reynolds (2007) suggest that the following soil factors need to be considered when assessing suitability of topdressing materials for mine site reclamation:

- Structure grade, which affects the ability of water and oxygen to enter soil.
- The ability of a soil to maintain structure grade following mechanical work associated with the extraction, transportation and spreading of topdressing material.
- The ability of soil peds to resist deflocculation when moist.
- Macrostructure; where soil peds are larger than 100 mm in the subsoil, they are likely to slake or be hardsetting and prone to surface sealing.
- Mottling; its presence may indicate reducing conditions and poor soil aeration.
- Texture; soil with textures equal to or coarser than sandy loam are considered unsuitable as topdressing materials because they are extremely erodible and have low waterholding capacities.
- Material with a gravel and sand content greater than 60% is unsuitable.
- Saline material is unsuitable.

These soil factors have been taken into account when planning the soil assessment methodology, in conjunction with soil survey methodology for intensive agricultural developments described by McKenzie *et al.* (2008).

The assessment has also been prepared with regard to a sampling intensity recommended by Gallant *et al.* (2008) for detailed project planning i.e. 'Moderately High (Detailed) Intensity Level' (approximately 1 pit per 10 ha).

Field Survey

A site inspection and soil survey was conducted as part of this Agricultural Resource Assessment. The field work was carried out on 4-5 February 2013. Seven backhoe pits (approx. 1.4 m deep; shallower where hard rock was encountered) were assessed across the Modification open cut extension areas. The soil pit locations (labeled A to G) are shown on Map 1. The pits were located in a way that covered the major variations in elevation and landforms, although steep areas were avoided because of safety precautions. The seven soil pits over approximately 70 ha (1 pit per 10 ha) provides an intensity of sampling that is consistent with the sampling density nominated in *Interim Protocol for site verification and mapping of biophysical strategic agricultural land* (NSW Government 2013) (the Protocol) of 1 site per 5 – 25 ha for intensive developments such as open cut coal mines.

Characteristics of each of the key open cut extension disturbance areas represented respectively by Pits A to G (Map 1), general locational photographs are shown in Table 2 and slopes in the open cut extension areas are shown on Map 2.

Table 2. Landforms represented by the seven soil pits and general location photographs

Soil pit*	Landform variations present in the vicinity of the pit	Zone represented by the pit	General photograph of soil pit location
A	Mix of approximately 70% cleared pasture and 30% timbered areas; mostly <10% slope.	Representative of the majority of this Modification open cut extension area.	
B	Mostly timbered with a large range of slope variation.	Approx. 6% slope; small area of pasture in between clumps of trees.	
C	Cleared pasture country <10% slope, grading into steeper forested areas >10% slope.	Approx. 8% slope; small area of pasture in between clumps of trees.	
D	Mix of approximately 80% cleared pasture and 20% degraded timbered areas; major slope variations.	Approx. 9% slope; pasture with easterly aspect.	

Table 2. Landforms represented by the seven soil pits and general location photographs (Continued)

Soil pit	Landform variations present	Zone represented by the pit	General photograph of soil pit location
E	Mostly pasture <5% slope	Representative of the majority of this Modification open cut extension area	
F	Timbered area, <5% slope	Representative of the majority of this Modification open cut extension area	
G	Lower slope (<5% slope) but with undulations	Slight rises	

* Refer Maps 1 and 2

A Garmin '*GPSmap 62S*' instrument with an accuracy of about ±4 m was used to record the pit coordinates (Appendix 4).

The field description methods were as described in the '*Australian Soil and Land Survey Field Handbook*' (National Committee on Soil and Terrain 2009) and the '*Guidelines for Surveying Soil and Land Resources, Chapter 29*' (McKenzie *et al*. 2008). The soil profiles have been classified (Appendix 4) according to the Australian Soil Classification (Isbell 2002).

Field Soil Observations/Testing

The soil pits were trimmed with a geological pick to allow photography and description of the undisturbed structure and root growth.

The following characteristics were assessed for the layers identified in each of the soil profiles:

- thickness of each layer (horizon);
- soil moisture status at the time of sampling;
- pH (using Raupach test kit);

- colour of moistened soil (using Munsell reference colours);
- pedality of the soil aggregates;
- amount and type of coarse fragments (gravel, rock, manganese oxide nodules);
- texture (proportions of sand, silt and clay), estimated by hand;
- presence/absence of free lime and gypsum;
- root frequency; and
- dispersibility and the degree of slaking in deionised water (after 10 minutes).

Field observations for each pit are presented in Appendices 5 and 6.

The soil structure information (Appendix 6) has been summarised to give SOILpak 'compaction severity' scores (McKenzie 2001). This allows deep tillage recommendations to be made from the structure observations. The score is on a scale of 0.0 to 2.0, with a score of 0.0 indicating very poor structure for crop root growth and water entry/storage. Ideally, the SOILpak score of the root zone should be in the range 1.5 to 2.0.

Hand texturing (National Committee on Soil and Terrain 2009) provides an approximation of the clay content of a soil. In conjunction with the estimation of coarse fragment (gravel) content, it provides a low-cost alternative to particle size analysis.

Total available water (TAW) for the upper 1 m of soil has been estimated using texture, structural form and coarse fragment content data (McKenzie *et al*. 2008).

Laboratory Soil Testing

All of the pits were sampled for laboratory analysis. The sampling intervals for laboratory analysis were 0 to 15 centimetres (cm); 15 to 30 cm; 30 to 60 cm and 60 to 90 cm.

The soil was analysed by Incitec-Pivot Laboratory, Werribee Victoria for exchangeable cations, pH, EC, chlorides, nutrient status (nitrate-nitrogen, phosphorus, sulfur, zinc, copper and boron) and organic matter content. An ammonium acetate method was used for the extraction of exchangeable cations. The cation exchange capacity (CEC) values are the sum of exchangeable sodium, potassium, calcium, magnesium and aluminium. Phosphorus was determined using the Colwell method, sulphur by the CPC method, boron by a calcium chloride ($CaCl_2$) extraction and zinc/copper by a DTPA extraction (see Rayment and Lyons [2011] for further details).

Soil dispersibility, as measured by the Aggregate Stability in Water (ASWAT) test (Field *et al.* 1997), was assessed by McKenzie Soil Management in Orange. The results are presented in Appendix 7. The ASWAT test has been related to the well known Emerson aggregate stability test by Hazelton and Murphy (2007) (Table 3). An advantage of the ASWAT test is that the results can be linked with management issues such as the need for gypsum application and avoidance of wet working.

Table 3. The relationship between the Emerson aggregate stability test and the ASWAT test that assess the severity of dispersion when soil aggregates are added to water

Dispersibility	Emerson Aggregate Classes	Probable Score for the ASWAT Test (Field *et al.* 1997)
Very high	1 and 2(3)	12-16
High	2(2)	10-12
High to moderate	2(1)	9-10
Moderate	3(4) and 3(3)	5-8
Slight	3(2), 3(1) and 5	0-4
Negligible/aggregated	4, 6, 7, 8	0

The conversion factors of Slavich and Petterson (1993) allowed the electrical conductivity of saturated paste extracts (EC_e) to be calculated from the EC of 1:5 soil:water suspensions ($EC_{1:5}$) and texture.

3.3 Soil Types

The Australian Soil Classification (Isbell 2002) has been used to determine soil types at each of the seven pits (Table 4, Map 3).

Table 4. Soil types according to the Australian Soil Classification and Great Soil Groups

Soil Pit	Australian Soil Classification	Great Soil Group
A	Brown Dermosol	Brown & Yellow Podzolics
B	Red Kurosol	Red Podzolic
C	Brown Kurosol	Yellow Podzolic
D	Red Dermosol	Red Podzolic
E	Brown Dermosol	Brown & Yellow Podzolics
F	Brown Dermosol	Brown & Yellow Podzolics
G	Red Kurosol	Red Podzolic

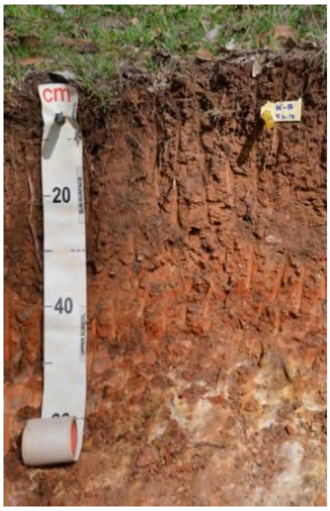
The soil types identified have the following characteristics:

- Dermosols are characterised by a lack of strong texture contrast between the topsoil and subsoil and moderately to strongly structured subsoil (McKenzie *et al*. 2004).
- Kurosols have a clear or abrupt textural subsoil, the upper 0.2 m of which is strongly acidic.

Photographs of the soils in the soil pit sites are presented in Figure 5.

Soil Landscape Units associated with these soil types are presented in Figure 6 (based on the terminology of Murphy and Lawrie 1998). It is noted that six of the seven pits were classified as being most aligned with the Barigan Creek Soil Landscape Unit based on the results of the field observations and laboratory soil testing, which contrasts with the Ulan Soil Landscape shown for these locations based on the regional mapping by Murphy and Lawrie (1998) (Appendix 1). However, the regional mapping would have had limited data in the Wilpinjong Coal Mine area because very few soil profile measurements were available at the time. The current study shows that areas of the Barigan Creek unit occur within the Ulan unit that was mapped at a regional scale.


Pit A: Brown Dermosol


Pit B: Red Kurosol


Pit C: Brown Kurosol

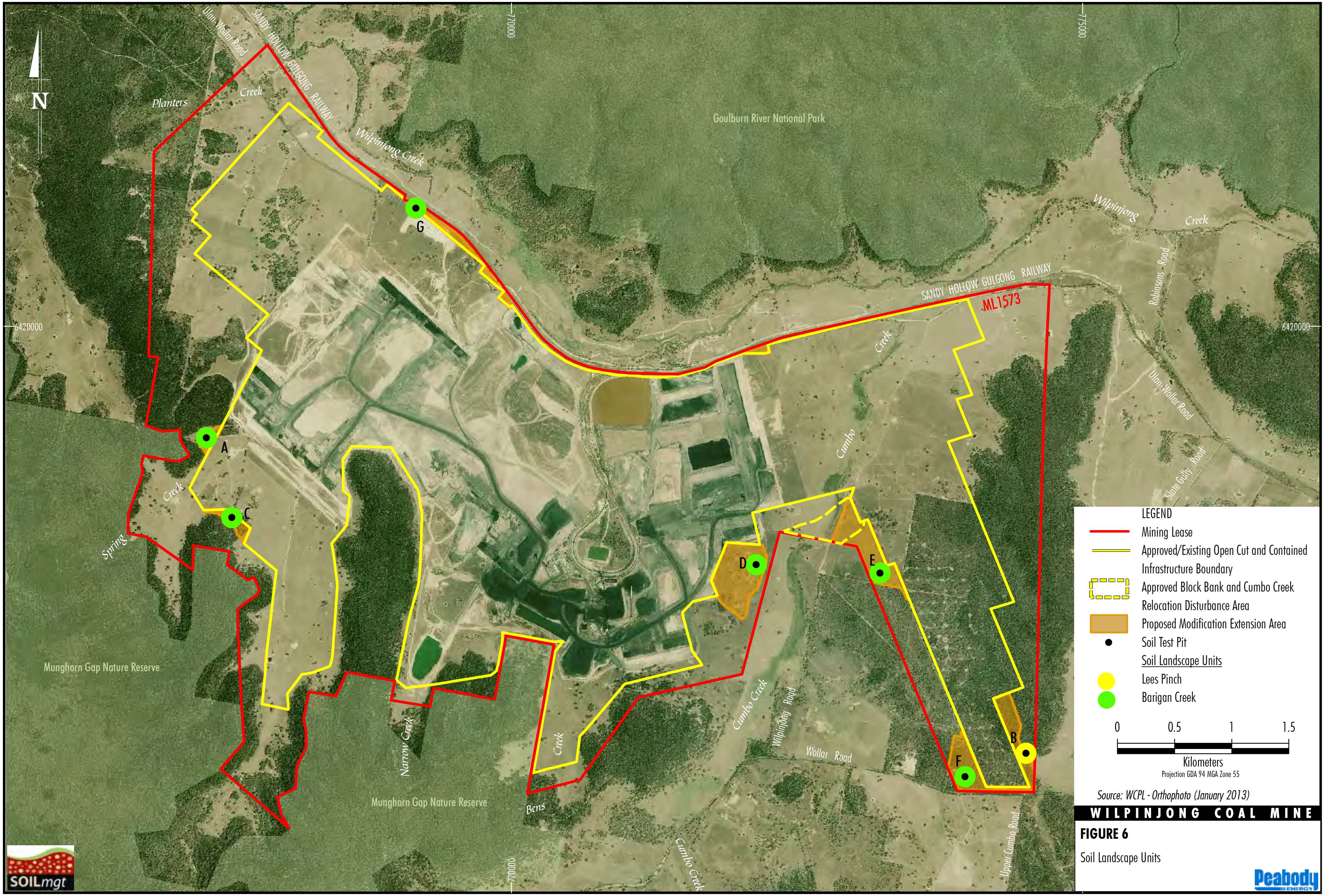

Pit D: Red Dermosol


Pit E: Brown Dermosol


Pit F: Brown Dermosol


Pit G: Red Kurosol

Figure 5. Photographs of Soil Types Identified during the Survey



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There are also some variations between the Great Soil Group mapping completed by Jammel (2004) (Appendix 2), and the Great Soil Groups that are identified for the recent seven soil pits (Table 4). This variation is to be expected given the differences in soil pit positions in the original study.

3.4 Soil Conditions for Plant Growth

The suitability of the soils for plant growth and rehabilitation has been determined based on a comparison of the results of the soil survey observations and laboratory analytical results against the criteria outlined in Table 5.

Table 5. Target Soil Conditions

Parameter	Woodland	Grazing	Cropping
Compaction Severity (SOILpak score)	Topsoil: >1.5 Subsoil: >1.0	Topsoil: >1.5 Subsoil: >1.0	Topsoil: .>1.5 Subsoil: >1.0
Exchangable Sodium Percentage	Topsoil: <2 Subsoil: <6	Topsoil: <2 Subsoil: <6	Topsoil: <2 Subsoil: <6
Acidity (pH $CaCl_2$)	As per native condition*	>5.0, <8.5	>5.5, <8.0
Salinity (ECe, dS/m)	As per native condition*	<1.5	<1.5
CEC (meq/100 g)	As per native condition*	>15 if possible	>15 if possible
Phosphorus (Colwell; mg/kg)	As per native condition*	>20	>30
Depth	As per native condition*	As deep as possible (preferably >1m)	As deep as possible (preferably >1m)

* To be assessed under natural stands of the selected woodland plant community

Note: dS/m – deciSiemens per metre

meq/100 g – milliequivalent of hydrogen per 100 grams

mg/kg – milligrams per kilogram

The sections below provide a description of the soil conditions within the Modification open cut extension areas as sampled by the soil pits, and measures which are traditionally implemented to improve identified constraints. These soil conditions, constraints and amelioration measures may not be applicable to the greater Wilpinjong Coal Mine and it is therefore recommended that the Rehabilitation Management Plan be revised to include some selective laboratory analysis to identify applicability of these soil management measures to soils in other areas (as a component of soil characterization).

Soil Depth, Texture and Waterholding Capacity

As soil becomes shallower, stonier and/or sandier, its ability to store water declines (White 2006).

The shallowest soil in the Modification area was in Pit B and depth to rock is shown on Map 4. The impact of profile shallowness/stoniness and sandiness on the ability of the soil to store plant available water (measured as TAW) is shown in Appendix 4 and on Map 5.

Plants are more likely to suffer drought stress where soil has a poor water storage capacity, particularly in hot weather with extended dry periods between rainfall events. In the open cut extension areas, the lack of water holding capacity in shallow soils is a major constraint to agricultural productivity.

Waterlogging Hazard

When soil is waterlogged, several adverse processes take place (Batey 1988):

- The lack of oxygen reduces the ability of plant roots to function properly.
- Anaerobic conditions can cause large losses of soil nitrogen to the atmosphere.
- Near-surface waterlogging is associated with inefficient storage of water due to excessive evaporation losses.

All pits, apart from Pit D, had evidence of waterlogging, i.e. subsoil mottling (Appendix 5, Map 6).

pH Imbalance

Topsoil acidity was widespread across the open cut extension areas (Appendix 5) and was associated with the presence of exchangeable aluminium (Appendix 7). The low CEC values (see below) in the topsoil (Appendix 7) indicate a low buffering capacity. Deep subsoil acidity was a major limitation at Pits C and F. Topsoil acidity problems can be overcome through the use of agricultural lime, but treatment of subsoil acidity is slow and expensive.

Soil Stability in Water – Dispersion and Slaking

Dispersion is the separation of soil micro-aggregates into sand, silt and clay particles, which tend to block soil pores and create problems with poor aeration (Levy 2000). Excessive hardness is a problem when the soil is dry. Dispersion is a process with the potential to reduce root growth and adversely affect profitability of most crop and pasture enterprises.

Dispersion may be associated with slaking, which is the collapse of soil aggregates to form micro-aggregates under moist conditions (So and Aylmore 1995). Slaking is associated with a lack of organic matter, which is important for the binding of soil micro-aggregates.

Soil prone to slaking, and particularly dispersion, is much more likely to be lost by water erosion than stable soil. This is because the soil tends to seal over under moist conditions and lose water as runoff, rather than taking in the water for storage in the subsoil (So and Aylmore 1995).

All of the soil pits had dispersive subsoil. However, these dispersion problems can be overcome in a cost-effective manner through the use of gypsum application and/or lime application. Typical application rates for the dispersive subsoil conditions identified in the seven pits would be approximately 3 tonnes per hectare (t/ha) of coarse grade gypsum and 2 to 10 t/ha of lime.

The main chemical factors influencing the behaviour of clay particles in these unstable soils are significant amounts of exchangeable sodium, aggravated by very low electrolyte concentrations and elevated exchangeable magnesium concentrations (calcium/magnesium ratios >1; see Appendix 7) (Levy 2000). Exchangeable aluminium, however, is a trivalent cation that tends to minimise dispersion.

Compaction Status

Compaction can strongly restrict plant growth because of poor water entry, poor efficiency of water storage, waterlogging when moist, and poor access to nutrients by plant roots (McKenzie 1998).

Compaction was assessed in this study using the SOILpak scoring system (Appendix 6). It was not a serious problem at any of the soil pits.

Structure Self-repair Ability

The ability of a soil to overcome compaction through shrinking and swelling induced by wet-dry cycles (soil structural resilience) can be estimated via CEC values (McKenzie 1998). The topsoil generally had a poor shrink-swell capacity, so the rate of recovery from compaction damage would be expected to be slow.

Salt Concentrations

Topsoil in the Modification open cut extension areas was non-saline. However, the subsoil below a depth of 60 cm at Pit C (>3 dS/m) (Appendix 7) was sufficiently saline to reduce the water uptake of most crop and pasture species (Table 5).

Nutrients

The soil was deficient (from an agricultural perspective [Table 5]) in phosphorus in the Modification open cut extension areas (<10 mg/kg Colwell-P) (Appendix 7). Sulfur deficiency was also widespread (Appendix 7). The typical remediation measure to improve phosphorous levels in soils is through the application of a phosphorous fertilizer such as superphosphate. Application of gypsum to improve dispersive soil conditions (as described above) increases sulfur levels in the soil, as does the sulfur component of superphosphate.

As the sum of exchangeable cations (an approximation of CEC) increases, the ability of soil to hold cation nutrients such as calcium, magnesium and potassium becomes greater (White 2006). CEC values for the Modification open cut extension areas (ranging from 2.0 to 13.4 meq/100 g) (Appendix 7) show only a moderate ability for the soil profiles to store cation nutrients (Table 5).

Soil Carbon and Soil Biological Health

The favourable organic carbon concentrations in the topsoil (0 to 15 cm) at Pits A and C (2.2% and 3.7%) (Appendix 7) provide beneficial soil organisms with a ready supply of food.

Summary of Soil Constraints

A broad range of soil physical and chemical constraints for agricultural land use have been identified in the Modification open cut extension areas including:

- **Soil acidity and associated aluminium toxicity** is a major constraint to agricultural productivity. Acidic soil lacks versatility in terms of agricultural management as many plant species do not thrive with this chemical constraint to crop/pasture production. Agricultural lime can be used to overcome acidity, but the required mechanical incorporation of the lime would be difficult to achieve *in-situ* and would leave the soil prone to erosion losses.
- **A lack of waterholding capacity** where there is a large stone content in the soil and/or bedrock close to the soil surface and/or a sandy texture; poor subsoil structure limits root growth and creates a similar effect. This is not a major concern when irrigation water and/or frequent showers of rain are applied to soil, but prolonged dry spells will induce drought stress in plants when they are grown in shallow and/or stony and/or sandy soil (e.g. Pit B).
- **Dispersive subsoil** due mainly to a lack of electrolyte and excessive exchangeable magnesium percentage. Dispersion induces waterlogging stress under moist conditions and excessive hardness when the soil is dry.
- **Subsoil salinity** in one of the seven pits (Pit C). Some pasture species, particularly legumes, have a poor ability to extract water from the soil when soil salinity is elevated.

- **Nutrient deficiencies**, particularly phosphorus, limit the growth of pasture and crop species even when other essential requirements such as water and adequate aeration are present in the soil.

4.0 LAND AND SOIL CAPABILITY CLASSES

All of the seven pits in the Modification open cut extension areas have a LSC rating of 4 (Figure 7), according to Office of Environment and Heritage (2012b) classification system. It is noted that this LSC rating is better than the regional NSW Government mapping would suggest (Appendix 3), however, it indicates that significant limitations are present. It is likely that the pre-existing LSC rating of 5 for these areas was based on the assumption that much of the Wilpinjong Coal Mine area was part of the Ulan Soil Landscape Unit (see Section 3.3).

This class is defined as follows (Office of Environment and Heritage 2012b):

> ***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.*

Reasons for this classification are outlined in Appendix 8.

5.0 STRATEGIC AGRICULTURAL LAND ASSESSMENT

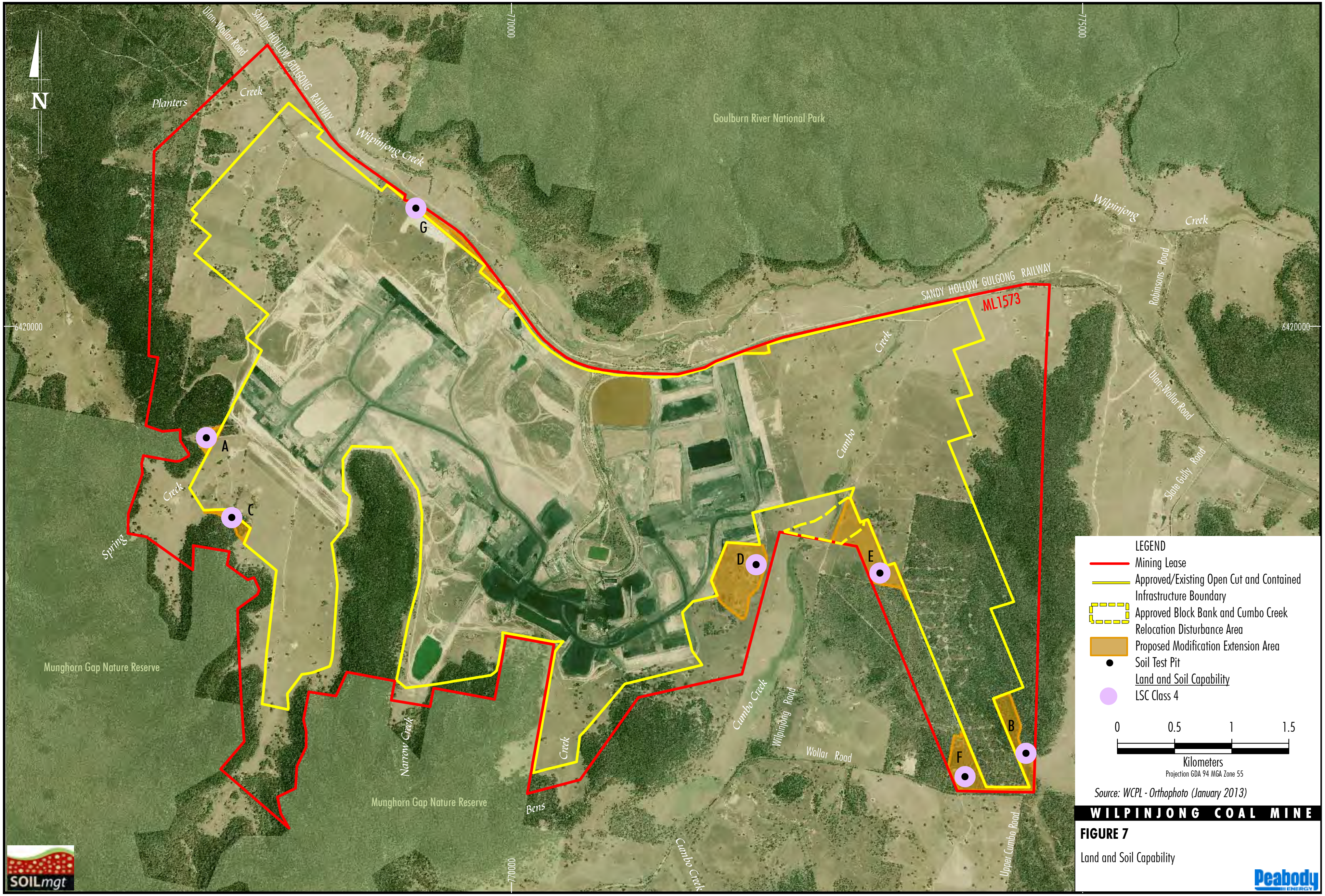
While the Modification open cut extension areas are not considered to be highly productive agricultural land (Sections 4 and 6), three of the seven pits (Pits A, C and D) have potential to conform to BSAL status (Figure 8), if in fact the areas represented by these pits were to exceed an area of 20 ha. A discussion of the physical and land use context of each of these pit locations is provided below.

<u>Pit A</u>

Pit A is located in a small valley head area on an upper mid-slope between the approved open cut of the Wilpinjong Coal Mine and a treed ridgeline to the west. The pit is located on a slope of approximately 8%. Due to the proximity of the approved open cut of the Wilpinjong Coal Mine and slopes greater than 10% to the west (Map 2), this area is effectively isolated by the approved mine and would not comprise 20 ha in area. A general location photograph provided in Table 2 illustrates the nature of the site and the landform.

<u>Pit C</u>

Pit C is located on an upper mid-slope at the base of a ridgeline that extends north from the Munghorn Gap Nature Reserve and is similarly surrounded by steeply sloping lands to the south and the approved open cut of the Wilpinjong Coal Mine. Due to the proximity of the open cut of the Wilpinjong Coal Mine and slopes greater than 10% that form the majority of this minor extension area (Map 2), this also would not comprise 20 ha in area. A general location photograph provided in Table 2 illustrates the nature of the site and the landform.



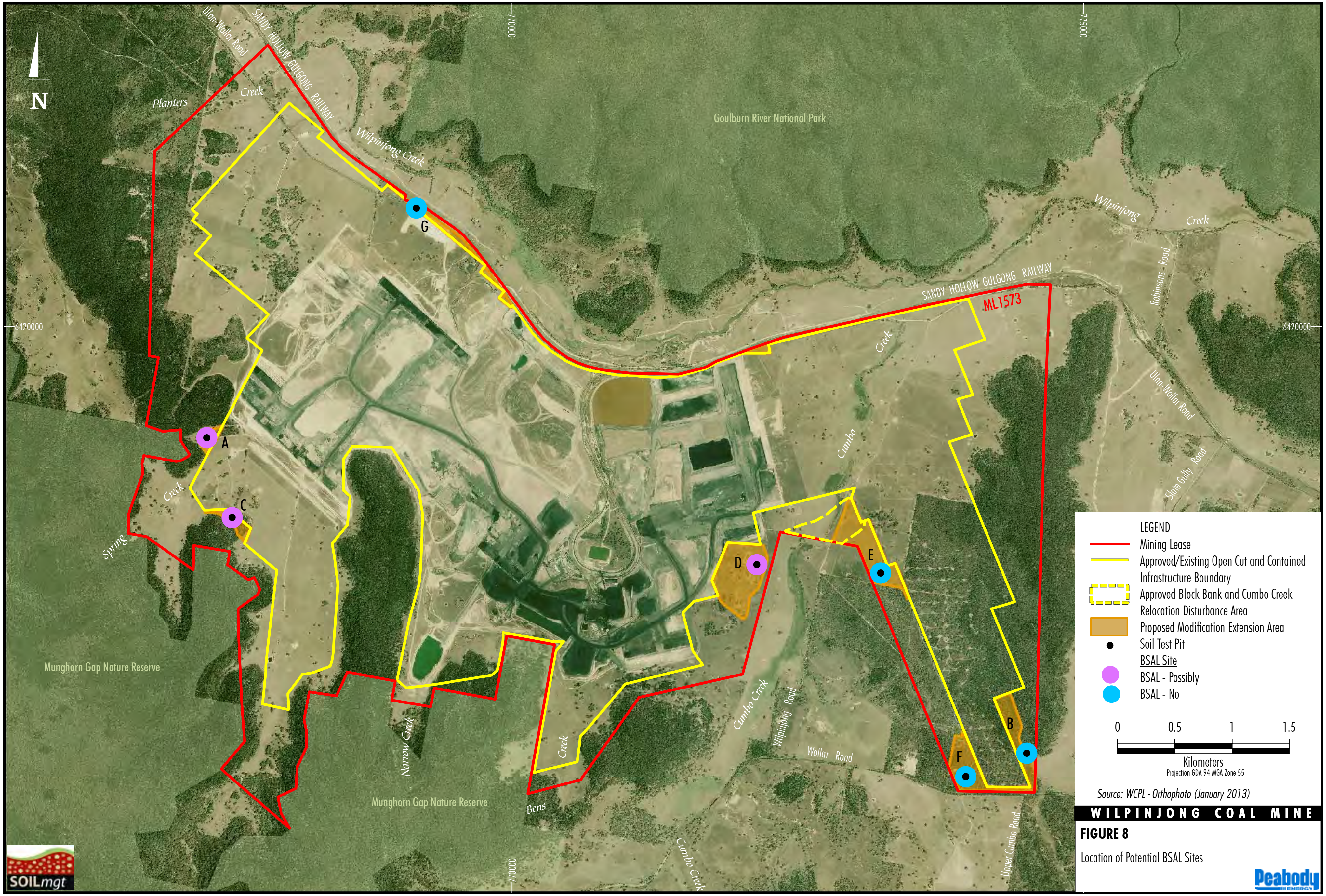
WILPINJONG COAL MINE

FIGURE 7

Land and Soil Capability

Peabody ENERGY

WIL-12-12_75WMod12_ARA_204B



WILPINJONG COAL MINE

FIGURE 8

Location of Potential BSAL Sites

WIL-12-12_75WMod12_ARA_202B

Pit D

Pit D is located on an upper mid-slope to the east of a small elevated ridgeline that runs approximately north-south to the west of Cumbo Creek. The majority of the Modification open cut extension area in which this pit is located comprises greater than 10% slope (Map 2) (i.e. does not meet BSAL criteria), however, the pit is located in an area of approximately 9% slope (and, therefore, meets the BSAL criteria).

The more gently sloping lands associated with Cumbo Creek are located to the east (beyond the extent of ML 1573). A portion of Cumbo Creek and a large area of land to the east of Cumbo Creek are contained within the approved Enhancement and Conservation Area of the Wilpinjong Coal Mine (Figure 3) and this area is protected by a Voluntary Conservation Agreement (i.e. excluded from future agricultural production).

Pit D may be indicative of a larger area with potential to conform to BSAL criteria, however, this is of little relevance to the current proposal as the majority of the open cut extension area in which Pit D is located is of greater than 10% slope and therefore would not meet BSAL criteria (Map 2).

The location of these sites within an existing ML and adjoining an active major open cut coal mine, means that the potential for BSAL status is of little relevance to decision making, and the small areas where BSAL potential has been identified do not warrant any further investigation. As discussed in Section 2, these areas are not currently used for agricultural production apart from some limited light grazing, due to their proximity to the approved Wilpinjong Coal Mine.

Reasons for BSAL conclusions are shown in Appendix 8. The latest version of the Protocol has been used to carry out this assessment (NSW Government 2013). It is noted that under the SRLUP (NSW Government 2012) none of these pits would meet BSAL criteria, as they do not fall within the LSC classification 1, 2 or 3.

6.0 AGRICULTURAL PRODUCTIVITY IMPACTS OF THE OPEN CUT EXTENSION AREAS

6.1 Current Agricultural Productivity

Agricultural enterprises known to have been conducted on the open cut extension areas include cattle grazing for beef production on rain-fed unimproved pastures and some opportunistic dryland cropping in the vicinity of Pit G.

The NSW Department of Primary Industries (2012) *Gross Margin Budget for 'North Coast Weaners – Unimproved Land'* provides an estimate of productivity in the open cut extension areas. The estimated productivity is summarised in Table 6.

Table 6. Approximate productivity of the open cut extension areas

Enterprise	Stocking Rate (DSE/ha)	Gross Margin ($/ha/year)
Beef cattle grazing (weaners) on unimproved pastures or low productivity improved pastures.	**3**	**53.06**

Note: DSE - Dry Sheep Equivalent

Given the serious soil limitations for plant growth (Appendix 8) and the previous agricultural activities conducted (beef cattle production on rain-fed unimproved pasture), the open cut extension areas are not considered to be highly productive agricultural land. It is also noted that these areas adjoin a major open cut mine and are located wholly within an existing ML. In addition, WCPL has advised that these areas are currently not subject to agricultural use apart for some limited light grazing, due to their proximity to the approved operations of the Wilpinjong Coal Mine.

6.2 Potential Impacts to Agricultural Productivity

The proposed Modification open cut extension area comprises eight small parcels of land covering a total of approximately 70 ha that would be disturbed by open cut mining. This is a very small area in relation to the adjacent open cut mine, and is wholly within the active Wilpinjong Coal Mine ML.

Three of the seven soil pits (A, C and D) were shown to have BSAL potential however, they had limitations that led to a LSC rating of 4. Pits A and C are located between ridgelines and the approved open cuts of the Wilpinjong Coal Mine and these areas would not comprise 20 ha in size. Pits C and D had a sandy loam texture that is considered sub-optimal for use as a rehabilitation material, and the deep subsoil (60-90 cm) at Pit C was saline. The majority of the Modification open cut extensions areas in which Pits C and D are located would not meet the BSAL criteria as they are too steep, i.e. slope > 10% (Map 2). It is noted that under the SRLUP (NSW Government 2012) none of these pits would meet BSAL criteria, as they do not fall within the LSC classification 1, 2 or 3.

It can be concluded from this evidence that agricultural potential of all of the soil examined in this study, in its current state, is poor and hence potential impacts on agricultural enterprise as a result of the modest open cut extensions would be minimal.

7.0 REHABILITATION AND SOIL MANAGEMENT

The Rehabilitation Management Plan for the Wilpinjong Coal Mine (2011) refers to the need for addition of ameliorants such as gypsum to make soil in the rehabilitated areas more suitable for plant growth and less prone to water erosion. This approach would also have to be applied to soils stripped from the Modification open cut extension areas examined in this study, although lime or a gypsum-lime blend is likely to be the most effective ameliorant.

In accordance with the Wilpinjong Coal Mine Mining Operations Plan (MOP) soils should continue to be stripped following vegetation clearance and suitable stripping depths in the Modification open cut extension areas should be assessed at the time of stripping to maximise suitable soil material for rehabilitation. Additional soil testing is recommended as part of this phase given the variations in topography that exist between the existing soil sampling sites. Soil stockpile and rehabilitation management measures are currently detailed in the MOP and Rehabilitation Management Plan to maintain stripped soil viability and suitability for rehabilitation.

Application of best practice techniques to strip, stockpile, ameliorate, re-apply and revegetate the topsoil and subsoil has the potential to boost agricultural productivity in the open cut extension areas, relative to its current status. Recommended general best practice soil resource management measures are described in the subsections below.

7.1 Soil Resource Management Measures

General soil resource management practices, where surface development is proposed within the Modification open cut extension areas, should involve the stripping and stockpiling of soil resources prior to any mine-related disturbance, other than clearing vegetation. The general strategy should be for disturbance areas to be rehabilitated progressively.

The objectives of soil resource management for the Modification open cut extension are to:

- Identify and quantify potential soil resources for rehabilitation.
- Optimise the recovery of useable topsoil and subsoil during stripping operations.
- Manage topsoil and subsoil reserves so as not to degrade the resource when stockpiled.
- Establish effective soil amelioration procedures to maximise the availability of soil reserves for future rehabilitation works. Take into account the need to provide soil conditions that minimise the risk of soil loss via wind and water erosion during and after rehabilitation.

Stripping

The following management measures should be implemented during the stripping of soils:

- Areas of disturbance are to be stripped progressively, as required, to reduce potential erosion and sediment generation, and to minimise the extent of topsoil stockpiles and the period of soil storage.
- Areas of disturbance requiring soil stripping are to be clearly defined following vegetation clearing.
- Topsoil and subsoil stripping during periods of high soil moisture content (i.e. following heavy rain) is to be avoided to reduce the likelihood of damage to soil structure.

The degree of success of a stripping and stockpiling program is strongly influenced by soil water content. Attempts to strip soil under moist conditions with inappropriate machinery settings can aggravate structural degradation problems. Excessive compaction and/or remoulding of the soil by heavy machinery under wet conditions also can be a major problem.

Where soil dispersion problems are aggravated by stripping during periods of high moisture content, extra gypsum (approximately 1 t/ha) should be applied to encourage re-stabilisation of the stripped soil.

Stockpile Management

The following management measures should be implemented during the stockpiling/storage of soils:

- Topsoil and subsoil stockpiles should be retained at a height of no more than 3 m, with slopes no greater than 1:2 (vertical to horizontal) and a slightly roughened surface to minimise erosion.
- Construct topsoil stockpiles in a way that minimises erosion, encourages drainage, and promotes revegetation.
- Where ameliorants such as lime, gypsum, biosolids and/or fertiliser are needed to improve the condition of cut soil, they should be applied to the stockpiles in-between the application of separate layers from the scrapers. Another option is to apply soil ameliorants such as lime prior to stripping so that reaction times and mixing are maximized.
- All topsoil and subsoil stockpiles should be seeded with a non-persistent cover crop to reduce erosion potential as soon as practicable after completion of stockpiling. Where seasonal conditions preclude adequate development of a cover crop, stockpiles should be treated with a straw/vegetative mulch to improve stability.
- Grow deep-rooting vegetation to encourage organic matter accumulation and maintain microbial activity. Minimising stockpile height maximises the chances of plenty of plant roots reaching the base of the stockpile as it awaits redistribution.
- There should be no vehicle access on soil stockpiles, except when soil quality monitoring or weed spraying is required.
- Soil stockpiles should be located in positions to avoid surface water flows. Silt stop fencing would be placed immediately down-slope of stockpiles until stable vegetation cover is established.
- In the event that unacceptable weed generation is observed on soil stockpiles, a weed eradication program should be implemented.
- An inventory of soil resources (available and stripped) on the mine site should be maintained and regularly reconciled with rehabilitation requirements.
- In preference to stockpiling, wherever practicable, stripped topsoil and subsoil should be directly replaced on completed sections of the final landform.

7.2 Application of Soil on Rehabilitated Landforms

The following management measures should be implemented during the application of soils on rehabilitated landforms:

- Topsoil and subsoil placement shall only proceed once the final landform and major drainage works (i.e. graded banks, drainage channels and rock waterways if required) have been completed.
- Where possible, cross-rip the upper 30 cm of the waste rock to minimise particle size and therefore boost water holding capacity.
- Topsoil and subsoil placement is to be undertaken from the top of slopes or top of sub drainage catchment to minimise erosion damage created by storm run-off from bare upslope areas.
- Topsoil and subsoil placement is to be conducted along the general run of the contour to minimise the incidence of erosion.
- Topsoil and subsoil is not to be placed in the invert of drainage lines or drainage works.
- Spread topsoil/subsoil profile thickness and quality is to be evaluated prior to sowing.

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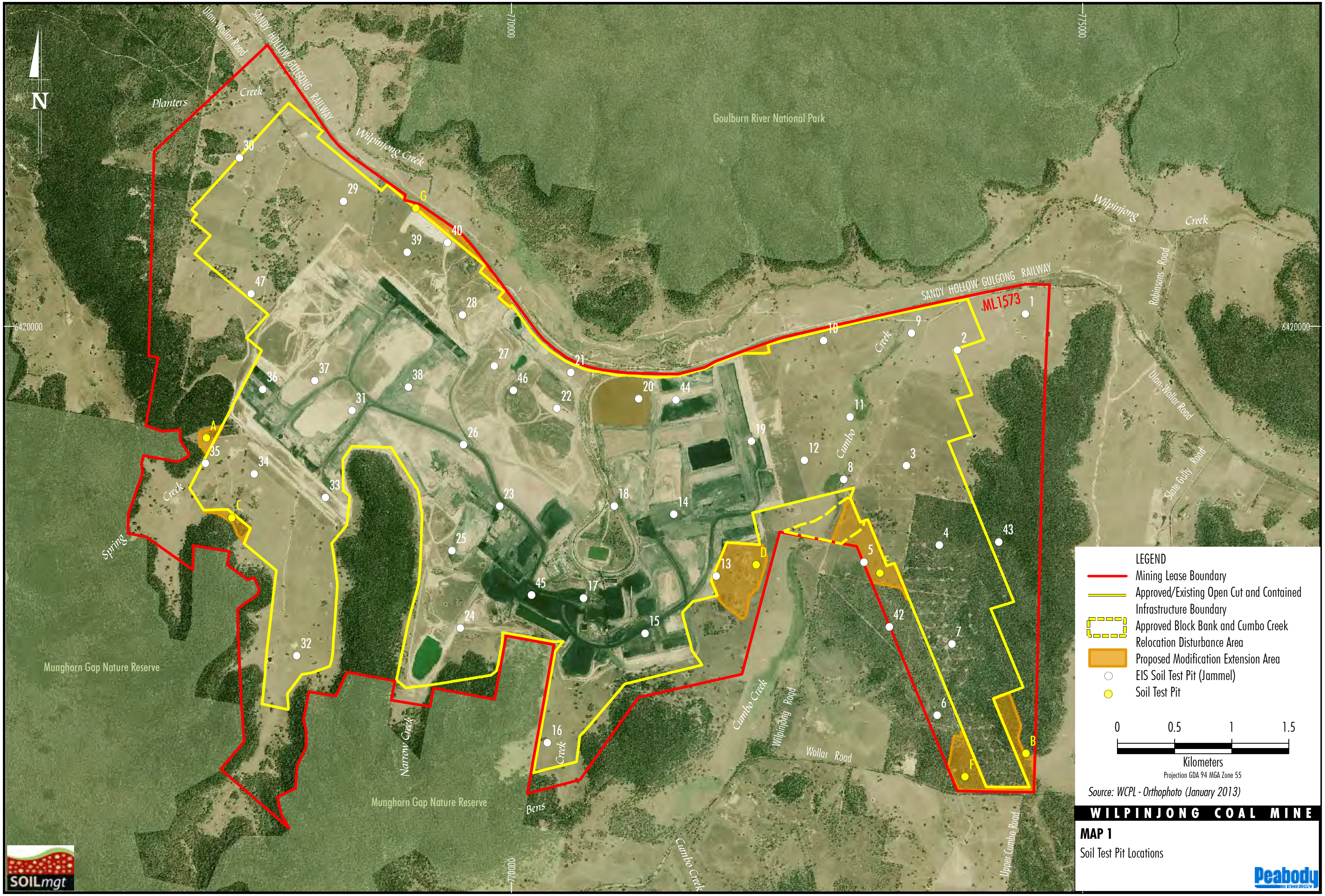
Maps



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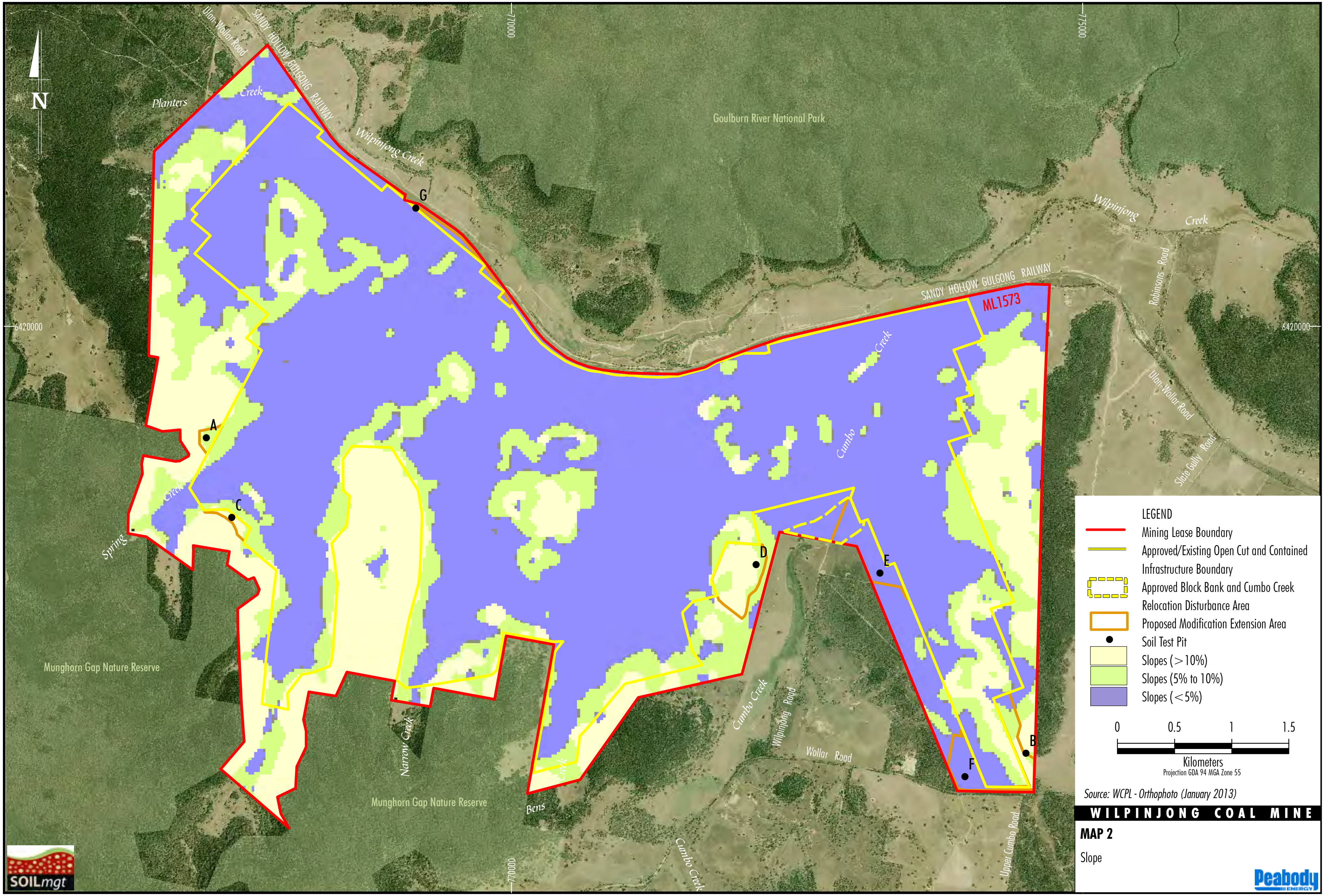

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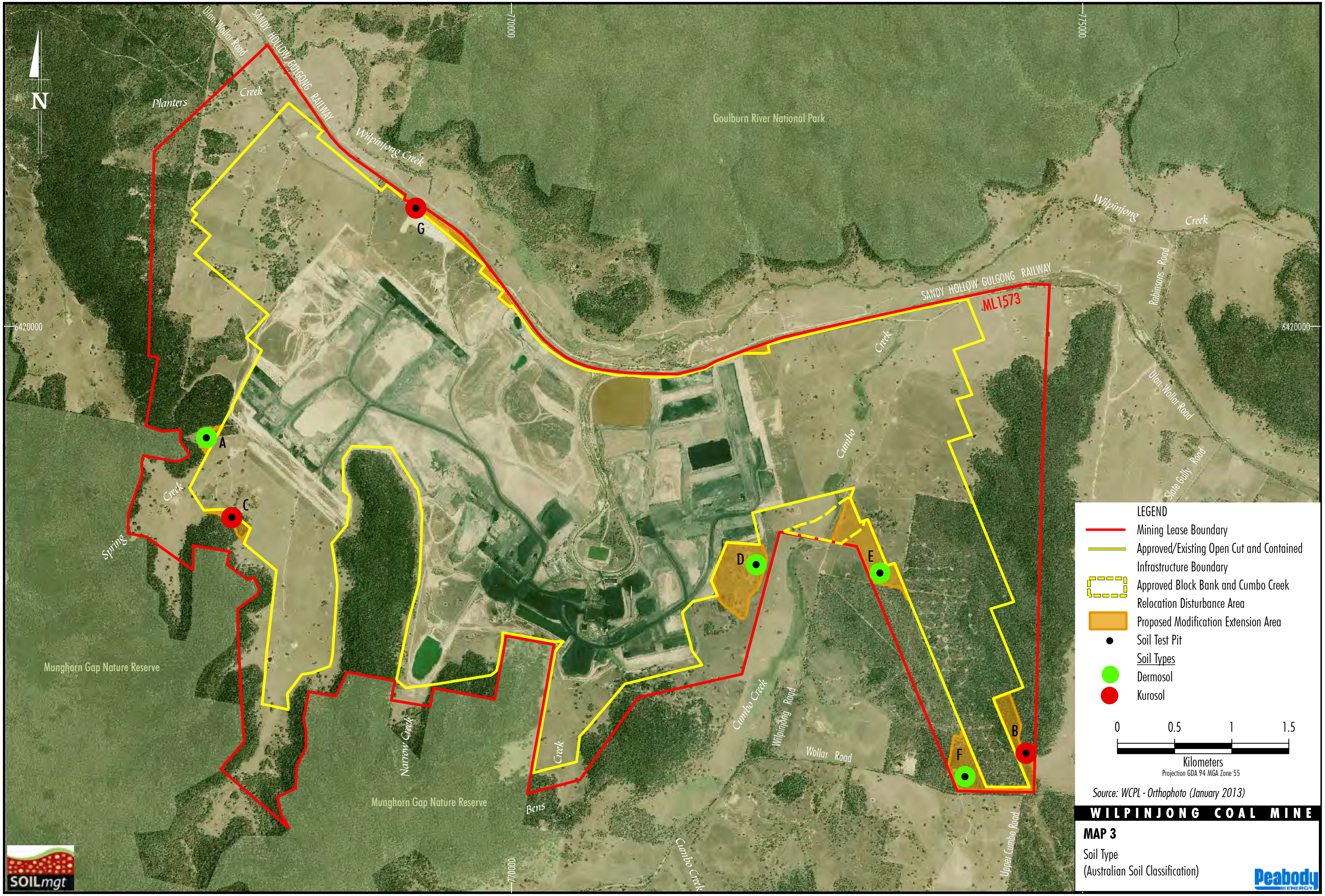

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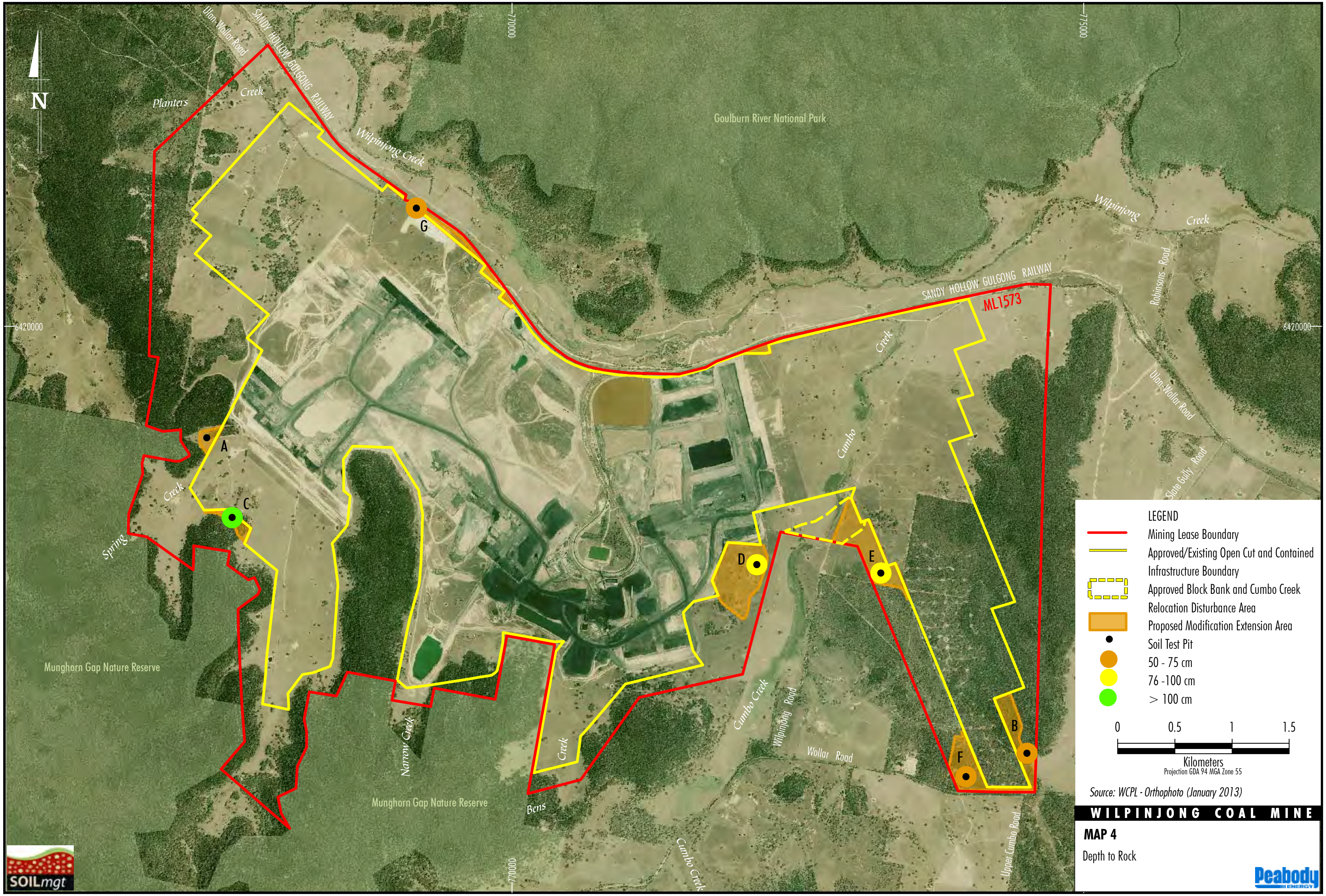


WIL-12-12_ARA Maps_203B

LEGEND
Mining Lease Boundary
Approved/Existing Open Cut and Contained Infrastructure Boundary
Approved Block Bank and Cumbo Creek Relocation Disturbance Area
Proposed Modification Extension Area
Soil Test Pit
76 -100 mm/m
> 100 mm/m

0 0.5 1 1.5
Kilometers
Projection GDA 94 MGA Zone 55

Source: WCPL - Orthophoto (January 2013)

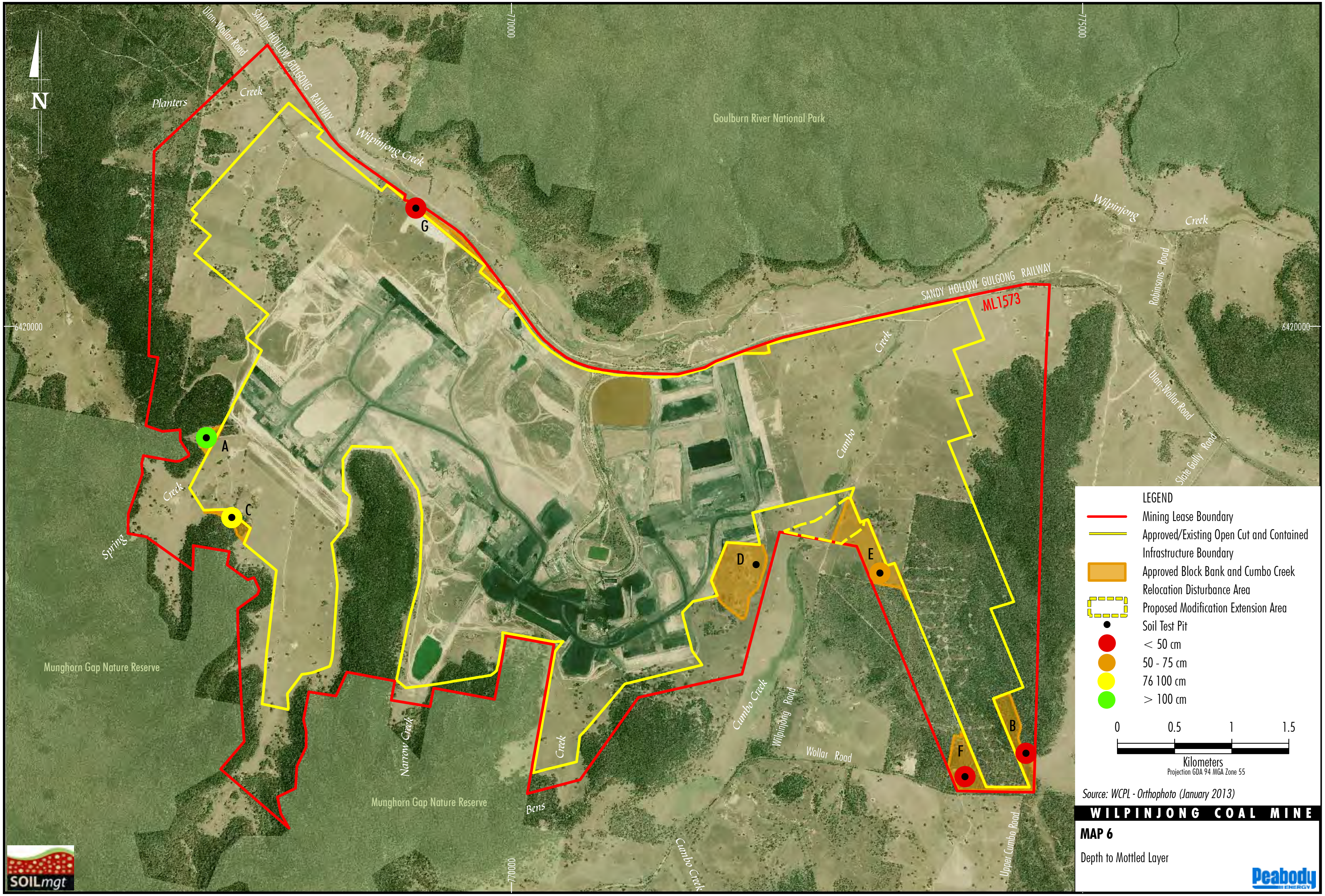
WILPINJONG COAL MINE

MAP 5

Plant Available Water (TAW)

Peabody ENERGY

WIL-12-12_ARA Maps_204B



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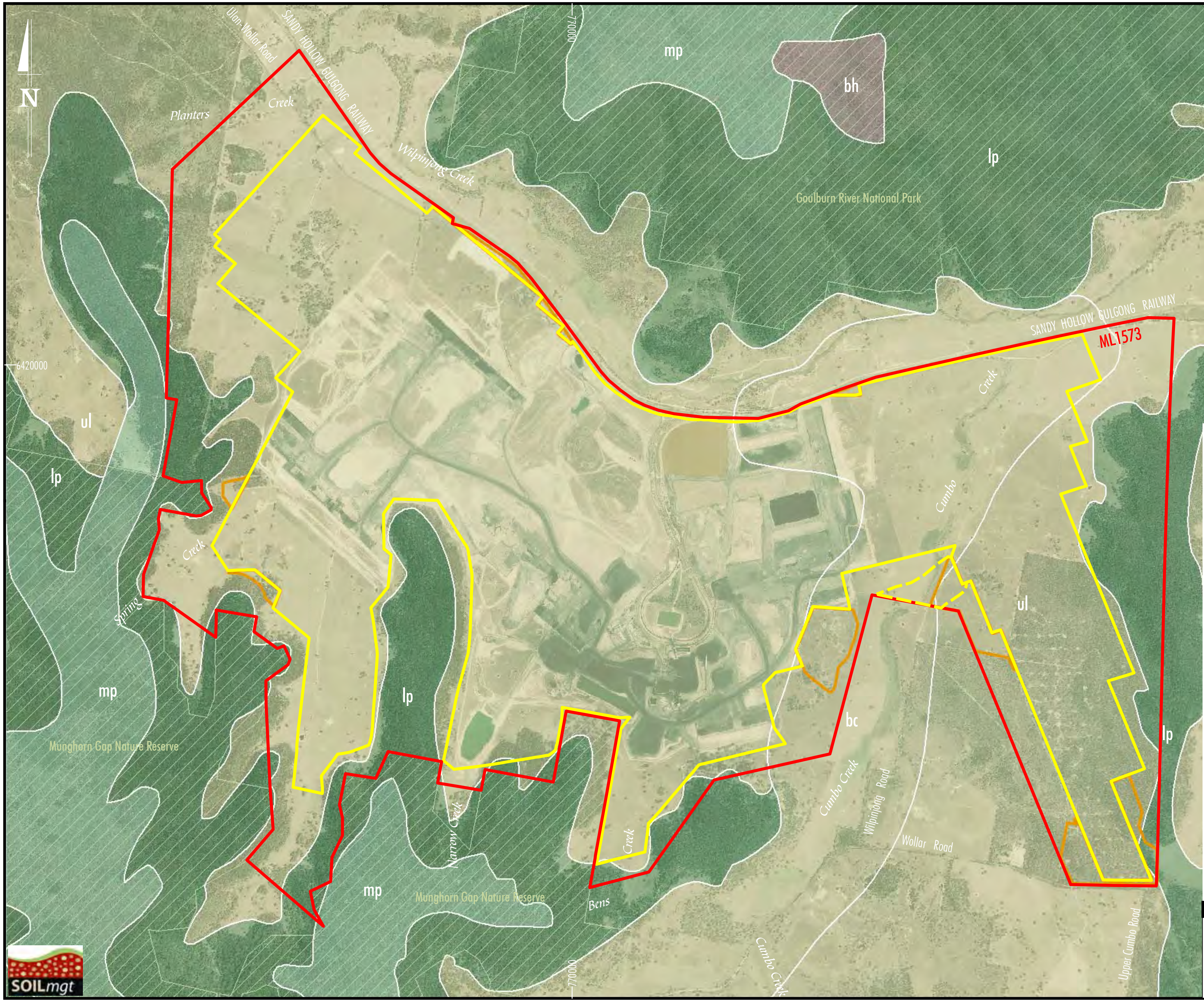
Appendix 1. Dubbo Soil Landscapes



WILPINJONG COAL MINE

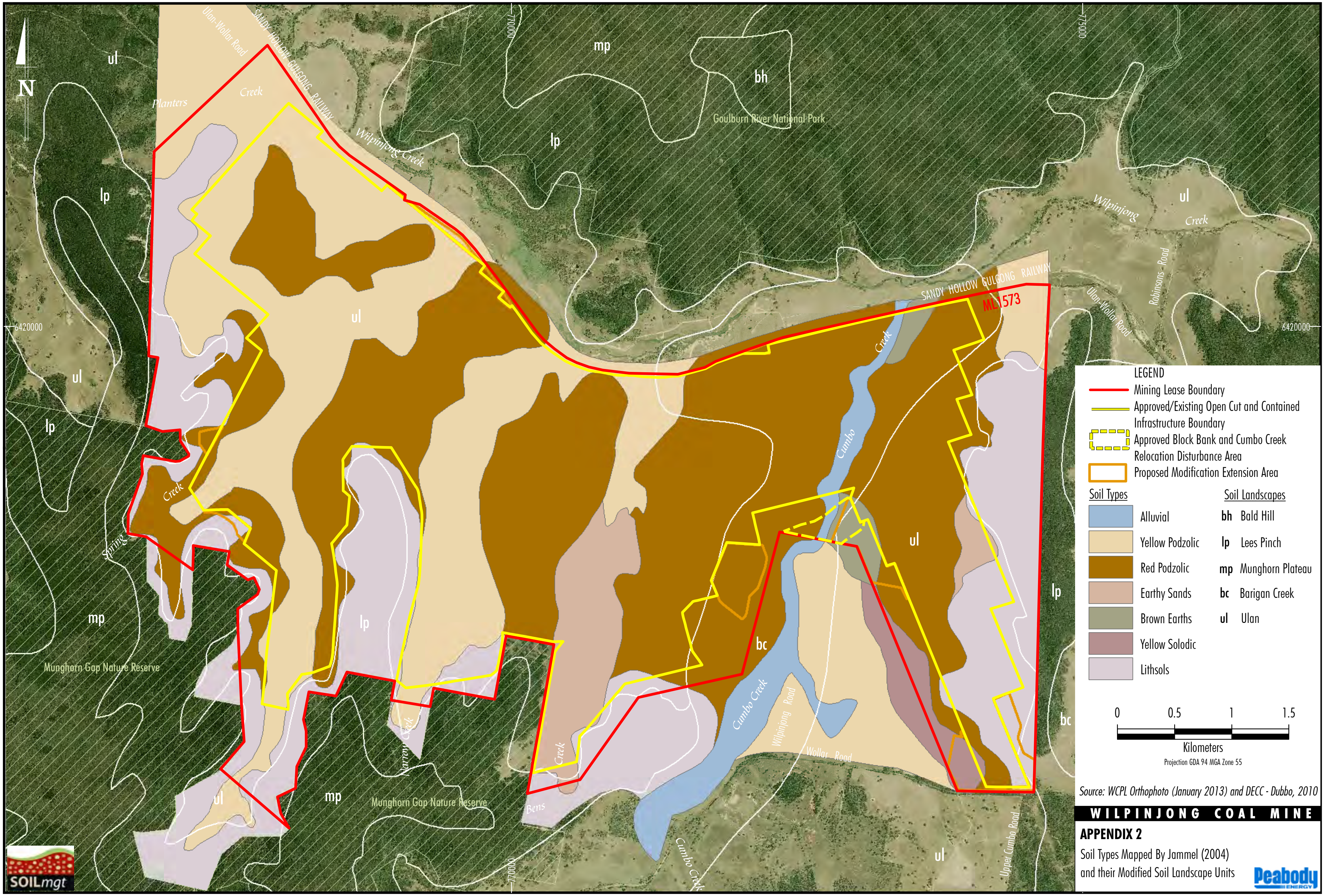
APPENDIX 1

Dubbo Soil Landscapes

Peabody ENERGY

WIL-12-12_75WMod12_ARA Apd_201B

Appendix 2. Soil types mapped by Jammel (2004) and their Modified Soil Landscape Units



WILPINJONG COAL MINE

APPENDIX 2

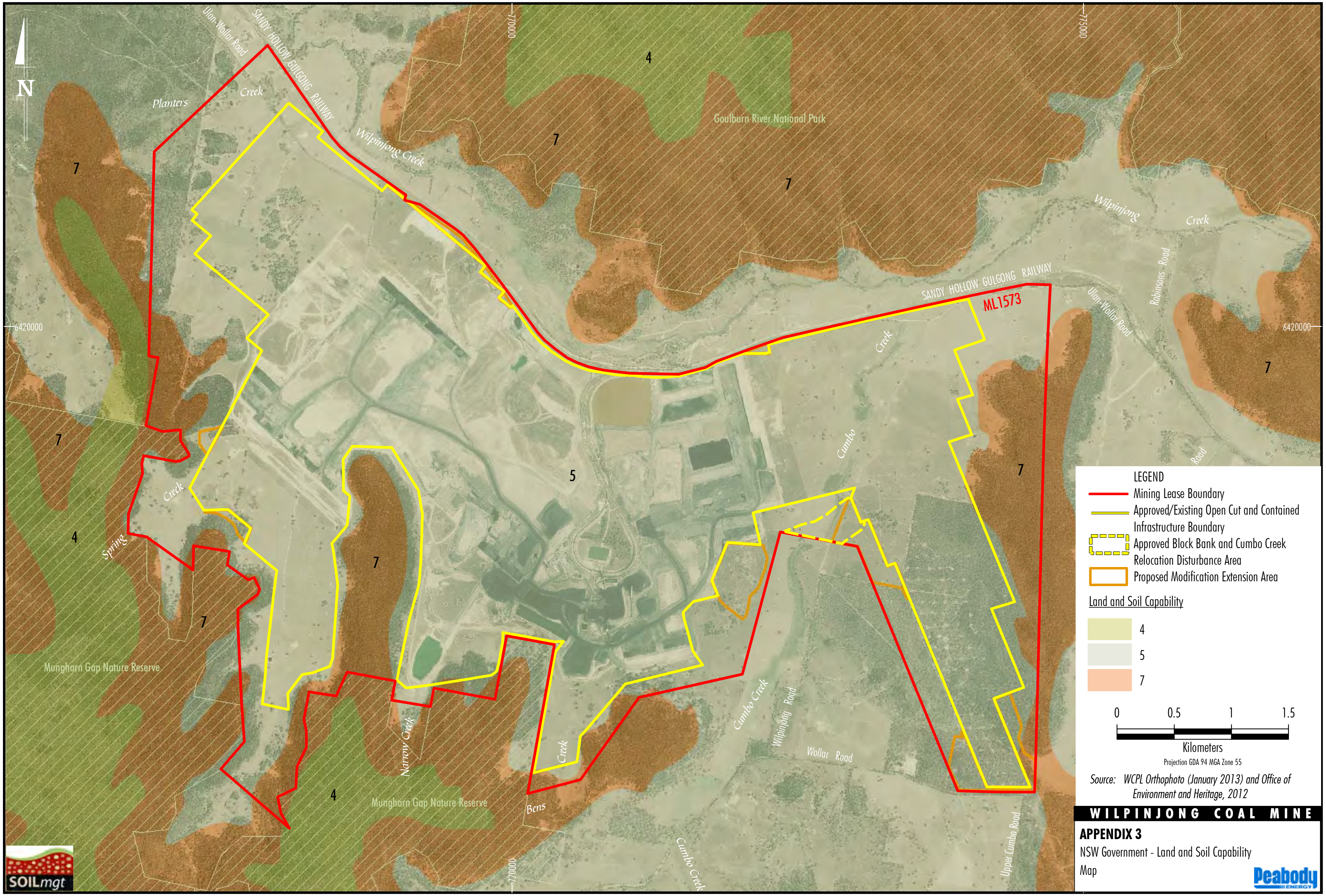
Soil Types Mapped By Jammel (2004) and their Modified Soil Landscape Units

SOILmgt

Peabody ENERGY

WIL-12-12_75WMod12_ARA Apd_202B

Appendix 3. NSW Government-Land and Soil Capability Map



WILPINJONG COAL MINE

APPENDIX 3

NSW Government - Land and Soil Capability Map

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Appendix 4. Overview Data

Overview Data

Sampling Site	Photo Sequence	Easting m WGS84	Northing m WGS84	Landuse Feb. 2013	Position in Landscape	Depth to rock (cm)	Depth to mottles (cm)	Australian Soil Classification	Total plant available water (mm/m)
A	2	767330	6419028	Rough pasture near woodland	Upper mid-slope	–	120	Brown Dermosol	143
B	5	774504	6416266	Rough pasture/woodland	Upper slope	50	30	Red Kurosol	90
C	1	767553	6418326	Rough pasture near woodland	Upper mid-slope	110	80	Brown Kurosol	133
D	6	772142	6417915	Mod. vigour pasture	Upper mid-slope	100	–	Red Dermosol	157
E	3	773227	6417842	Rough pasture	Colluvial outwash	90	50	Brown Dermosol	126
F	4	773971	6416061	Woodland	Gentle upper slope	72	40	Brown Dermosol	129
G	7	769164	6421036	Mod. vigour pasture	Lower slope	75	25	Red Kurosol	145

cm = centimetres
mm = millimetres
mm/m = millimetres per metre

Appendix 5. Layer Data

Layer Data

Pit (field)	Horizon	Lower depth (cm)	Texture	pH water	Moist soil colour (Munsell)		Mottles	SOILpak compaction score	Gravel Fragments (%)	Dispersion 10 minutes	Moisture	Lime		Root score
												%	Type	
A	A11	18	Coarse sandy clay loam	5.0	7.5YR3/2	Dark brown	–	1.8	–	0	M	–	–	4
	A12	32	Coarse sandy clay loam	5.5	7.5YR4/2	Brown	–	1.6	2 (GV)	0	M	–	–	3
	A31	65	Coarse sandy clay loam	5.5	7.5YR4/3	Brown	–	1.6	5 (GV)	1	M	–	–	2
	A32	125	Coarse sandy loam	6.0	7.5YR5/3	Brown	–	1.3	15 (GV)	2	D	–	–	1
	B1	140+	Light clay	6.0	7.5YR5/4	Brown	grey	0.8	–	1	D	–	–	–
B	A11	10	Sandy clay loam	5.5	7.5YR3/2	Dark brown	–	1.7	–	2	M	–	–	4
	A12	30	Sandy clay loam	5.5	7.5YR5/4	Brown	–	1.5	2 (GV)	2	M	–	–	3
	B2	50	Sandy light medium clay	5.0	2.5YR5/6	Red	grey	1	–	3	S	–	–	2
	C	60+	**PALE SANDSTONE**											
C	A11	20	Coarse sandy loam	5.0	7.5YR3/2	Dark brown	–	1.8	–	0	M	–	–	4
	A12	45	Coarse sandy loam	5.0	7.5YR4/2	Brown	–	1.5	–	0	M	–	–	2
	B2	80	Sandy clay loam	6.0	7.5YR5/4	Brown	–	1.1	5 (GV)	2	M(50), D	–	–	1
	BC	110	Sandy light clay	4.5	2.5YR4/6	Red	grey	0.9	15 (GV)	0	D	–	–	0
	C	115+	**SHALE**											
D	A11	15	Sandy loam	5.0	5YR4/3	Reddish brown	–	1.8	–	1	M	–	–	3
	A12	40	Fine sandy clay loam	5.5	5YR4/3	Reddish brown	–	1.6	–	1	M	–	–	3
	B1	100	Sandy clay loam	6.0	5YR5/4	Reddish brown	–	1.1	5 (GV)	3	D	–	–	2
	C	140+	**COAL**											1 (125)
E	A11	15	Fine sandy clay loam	5.0	7.5YR4/2	Brown	–	1.4	–	1	M	–	–	3
	A12	30	Fine sandy clay loam	5.0	7.5YR5/3	Brown	–	1.3	–	3	M	–	–	1
	B21	50	Light clay	5.0	10YR5/4	Yellowish brown	–	1.4	–	2	M	–	–	1
	B22	90	Light clay	5.5	10YR5/4	Yellowish brown	grey	0.7	–	0	D	–	–	0.5 (75)
	C	95+	**CONGLOMERATE**											
F	A1	18	Fine sandy clay loam	5.0	7.5YR3/2	Dark brown	–	1.7	–	0	M	–	–	3
	B21	40	Light clay	4.5	7.5YR4/3	Brown	–	1.4	2 (GV)	1	S	–	–	3
	B22	72	Light clay	4.5	7.5YR4/4	Brown	grey	1.1	15 (GV)	2	S	–	–	2
	C	85+	**COAL**											1
G	A11	11	Sandy clay loam	4.5	7.5YR4/3	Brown	–	1.6	–	0	M	–	–	3
	A12	25	Sandy clay loam	4.5	7.5YR5/4	Brown	–	1.4	–	3	M	–	–	3
	B21	45	Medium heavy clay	4.5	5YR4/6	Yellowish red	sl. grey	1.8	–	0	M	–	–	3
	B22	75	Medium heavy clay	4.5	5YR4/6	Yellowish red	grey	1.3	10 (GV)	0	M	–	–	2
	C	90+	**BLACK SHALE**											

cm = centimetres
% = percent

Appendix 6. Layer Data – Soil Structure Details

Layer Data – Soil Structure Details

Pit (field)	Horizon	Lower depth (cm)	Pedality			Fabric	Consistence	SOILpak compaction
			Grade	Type	Size			
A	A11	18	M	SB	10	E	1	1.8
	A12	32	M	PO	10	E	1	1.6
	A31	65	W	PO	10	E	1	1.6
	A32	125	W	B/LE	12	E	2	1.3
	B1	140+	M	B/LE	12	E	5	0.8
B	A11	10	M	SB	7	E	1	1.7
	A12	30	M	PO	7	E	1	1.5
	B2	50	S	B/LE	12	RP	4	1
	C	60+						
C	A11	20	M	SB	5	E	1	1.8
	A12	45	M	PO	8	E	1	1.5
	B2	80	M	B	12	E	3	1.1
	BC	110	M	B/LE	10	RP	5	0.9
	C	115+						
D	A11	15	S	SB	5	E	1	1.8
	A12	40	M	PO	8	E	2	1.6
	B1	100	M	LE	12	RP	4	1.1
	C	140+						
E	A11	15	S	PO	7	E	2	1.4
	A12	30	M	PO	10	E	2	1.3
	B21	50	M	PO	8	E	2	1.4
	B22	90	S	B	15	RP	5	0.7
	C	95+						
F	A1	18	S	SB	7	E	1	1.7
	B21	40	M	PO	10	E	2	1.4
	B22	72	S	B	15	RP	3	1.1
	C	85+						
G	A11	11	M	P	10	E	1	1.6
	A12	25	M	PO	12	E	2	1.4
	B21	45	S	PO	5	RP	1	1.8
	B22	75	W	B/LE	10	RP	2	1.3
	C	90+						

cm = centimetres

Appendix 7. Laboratory Data

Laboratory Data

Site	Depth (cm)	pH CaCl2	EC 1:5 (dS/m)	ECe (dS/m)	Chloride (mg/kg)	Exchangeable cations, meq/100 g						ESP	ESI	ESI v2	Ca/Mg	ASWAT score	NO_3-N (mg/kg)	Colwell-P (mg/kg)	SO_4-S (mg/kg)	DTPA-Zn (mg/kg)	DTPA-Cu (mg/kg)	Boron (mg/kg)	Org. C (%)
						Ca	Mg	K	Na	Al	CEC												
A	15	4.6	0.07	0.67	<10	6.5	1.8	0.9	0.01	0.1	9.3	0.1	0.65	7.0	3.6	0	18	7	4.6	0.69	2.3	0.38	2.2
	30	4.9	0.03	0.29	<10	5.0	2.0	0.4	0.02	0.1	7.5	0.3	0.11	1.5	2.5	0	3	<5	3	0.72	0.28	0.25	1.1
	60	5.3	0.02	0.19	<10	2.5	3.2	0.3	0.03	0.1	6.1	0.5	0.04	0.7	0.8	12	1	<5	1	0.81	0.08	0.16	0.3
	90	5.6	0.01	0.14	<10	1.8	3.4	0.3	0.03	0.0	5.5	0.5	0.02	0.3	0.5	12	<1	<5	<1	0.46	0.07	0.11	0.2
B	15	5.3	0.04	0.38	<10	5.5	1.2	0.7	0.01	0.1	7.5	0.1	0.30	4.0	4.6	1	6	<5	2	0.38	3.60	0.34	1.3
	30	4.9	0.02	0.19	<10	2.7	0.8	0.5	0.07	0.1	4.2	1.7	0.01	0.3	3.3	11	2	<5	1	0.27	0.19	0.28	0.3
	50	5.2	0.04	0.34	18	4.3	2.2	0.8	0.06	0.1	7.5	0.8	0.05	0.7	2.0	13	2	<5	3	0.42	0.20	0.44	0.3
C	15	5.0	0.14	1.93	16	10.0	2.0	1.3	0.01	0.1	13.4	0.1	1.88	14.0	5.0	0	36	9	6	0.39	6.00	0.74	3.7
	30	5.0	0.06	0.83	17	5.5	1.5	0.6	0.02	0.1	7.7	0.3	0.23	3.0	3.7	1	10	<5	4	0.31	0.37	0.36	0.8
	60	6.0	0.04	0.55	15	3.7	2.5	0.4	0.05	0.0	6.7	0.7	0.05	0.8	1.5	12	3	<5	5	0.44	0.03	0.31	0.3
	90	4.1	0.36	3.42	400	2.7	5.5	0.3	0.65	1.9	11.0	5.9	0.06	0.6	0.5	0	40	<5	3	0.52	0.15	0.15	<0.2
D	15	5.0	0.06	0.83	18	5.5	1.4	0.5	0.01	0.1	7.6	0.1	0.45	6.0	3.9	1	8	<5	3	0.57	1.00	0.30	1.0
	30	5.5	0.02	0.19	<10	4.8	1.2	0.3	0.01	0.0	6.3	0.2	0.13	2.0	4.0	10	1	<5	-	0.64	0.05	0.31	0.4
	60	6.0	0.02	0.19	<10	3.8	1.6	0.1	0.02	0.0	5.6	0.4	0.06	1.0	2.4	13	<1	<5	<1	0.62	0.05	0.33	0.2
	90	6.1	0.02	0.19	<10	3.2	3.6	0.1	0.06	0.0	7.0	0.9	0.02	0.3	0.9	13	<1	<5	<1	0.59	0.09	0.51	0.2
E	15	5.1	0.05	0.48	<10	3.6	0.9	0.8	0.01	0.1	5.4	0.2	0.27	5.0	4.0	3	6	5	4	0.48	3.70	0.38	1.3
	30	5.2	0.02	0.19	<10	2.5	0.8	0.4	0.01	0.1	3.8	0.3	0.08	2.0	3.0	14	<1	<5	<1	0.64	0.29	0.21	0.4
	50	5.1	0.02	0.17	<10	2.9	2.1	0.3	0.03	0.1	5.4	0.6	0.04	0.7	1.4	11	<1	<5	<1	0.75	0.12	0.26	0.2
	90	5.0	0.02	0.17	11	3.6	3.3	0.4	0.11	0.1	7.5	1.5	0.01	0.2	1.1	1	<1	<5	5	0.81	0.11	0.33	0.2
F	15	4.5	0.02	0.19	<10	1.8	1.6	0.5	0.04	0.9	4.7	0.8	0.02	0.5	1.1	4	<1	<5	3	0.48	1.10	0.27	1.2
	30	4.1	0.02	0.17	11	0.4	1.2	0.3	0.07	2.4	4.3	1.6	0.01	0.3	0.3	11	<1	<5	3	0.37	0.54	0.21	0.5
	60	4.0	0.02	0.17	<10	0.1	1.2	0.1	0.12	3.2	4.7	2.5	0.01	0.2	0.1	12	1	<5	2	0.39	0.58	0.12	0.3
G	15	4.6	0.05	0.48	20	1.3	0.7	0.5	0.09	0.1	2.7	3.4	0.01	0.6	2.0	4	4	7	4	0.33	2.20	0.17	1.2
	25	4.6	0.03	0.29	<10	0.9	0.5	0.3	0.05	0.2	2.0	2.5	0.01	0.6	1.7	12	1	<5	3	0.16	0.63	0.14	0.4
	60	4.5	0.05	0.38	32	2.9	3.5	0.4	0.17	1.0	7.9	2.1	0.02	0.3	0.8	2	<1	<5	5	0.80	0.10	0.33	0.4
	75	4.6	0.21	1.58	250	2.9	4.6	0.3	0.65	0.6	9.0	7.2	0.03	0.3	0.6	0	<1	<5	13	0.98	0.16	0.23	0.2

cm = centimetres EC = electrical conductivity dS/m = deciSiemens per metre
ECe = EC of the saturation extract; a measure of the salinity of a soil sample. It is assessed using a 1:5 soil:water extract, then multiplied by a conversion factor that takes into account the influence of texture (clay content) on the response of plants to salinity.

mg/kg = milligrams per kilogram
meq/100 g = milliequivalent of hydrogen per 100 grams.
CEC: Cation Exchange Capacity (sum of exchangeable cations); exchangeable cations are positively charged ions held loosely on negatively charged soil particles, and readily exchanged with other ions in the soil solution.
ESP: The quantity of exchangeable sodium ions as a percentage of all exchangeable cations held by soil. The critical ESP above which dispersion occurs ranges from 2 to 15, depending on the amount of electrolyte in soil solution.
ESI: Electrochemical Stability Index; EC1:5 (dS/m) divided by ESP; it is a measure of soil stability in water; aim for values greater than 0.05. ESI v2 = EC1:5, dS/m ÷ exch. Na, meq/100 g
ASWAT = aggregate stability in water.
DTPA = Diethylene triamine pentaacetic acid.
Ca – Calcium
Mg – Magnesium
K – Potassium
Na – Sodium
Al – Aluminium
NO_3 – N – Nitrate as Nitrogen
SO_4 – S – Sulphate as Sulphur
Zn – Zinc
Cu – Copper
$CaCl_2$ – Calcium chloride

Appendix 8. Land and Soil Capability Classes

Land and Soil Capability Classes

Pit	LSC soil constraints	Land and Soil Capability classification
A	Acidic topsoil	Class 4
B	Rocky near surface	Class 4
C	Acidic topsoil; low buffering capacity	Class 4
D	Acidic topsoil; low buffering capacity	Class 4
E	Waterlogged subsoil (mottled)	Class 4
F	Acidic topsoil; rocky near surface	Class 4
G	Acidic topsoil	Class 4

Source: Office of Environment and Heritage (2012b)

Appendix 9. BSAL Assessment

BSAL Assessment

Sampling Site	Slope (%)	Depth to Rock (cm)	Depth to Mottles (cm)	pH CaCl2			ESP			Salinity (ECe, dS/m)			Australian Soil Classification: Fertility Status	Potential to Conform to BSAL
				0-15cm	15-30cm	30-60cm	0-15cm	15-30cm	30-60cm	0-15cm	15-30cm	30-60cm		
A		–	120	4.6	4.9	5.3	0.1	0.3	0.5	0.67	0.29	0.19	Brown Dermosol	YES (if >20 ha)
B		50	30	5.3	4.9	5.2	0.1	1.7	0.8	0.38	0.19	0.34	Red Kurosol	NO
C		110	80	5.0	5.0	6.0	0.1	0.3	0.7	1.93	0.83	0.55	Brown Kurosol	YES (if >20 ha)
D		100	–	5.0	5.5	6.0	0.1	0.2	0.4	0.83	0.19	0.19	Red Dermosol	YES (if >20 ha)
E		90	50	5.1	5.2	5.1	0.2	0.3	0.6	0.48	0.19	0.17	Brown Dermosol	NO
F		72	40	4.5	4.1	4.0	0.8	1.6	2.5	0.19	0.17	0.17	Brown Dermosol	NO
G		75	25	4.6	4.6	4.5	3.4	2.5	2.1	0.48	0.29	0.38	Red Kurosol	NO
	< 10%												>= Moderate Fertility status	

Source: NSW Government (2013)

Note: cm - centimetres

ECe - Electrical conductivity of the saturation extract; a measure of the salinity of a soil sample. It is assessed using a 1:5 soil:water extract, then multiplied by a conversion factor that takes into account the influence of texture (clay content) on the response of plants to salinity.

dS/m - deciSiemens per metre

BSAL – Biophysical Strategic Agricultural Land

$CaCl_2$ – calcium chloride

% - percent