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Site Verification Report: "Wilpinjong Coal Mine" Wollar, NSW

Prepared for Peabody Energy; in conjunction with Resource Strategies Pty Ltd

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INFORMATION SOURCES AND REFERENCING

This report was derived from an extensive range of information sources including literature review and discussions with colleagues and landholders. The author has sought to ensure that sources for his use of text, diagrams, maps and images are provided in the report. If the author inadvertently has failed to adequately acknowledge a source of material used, he would appreciate prompt notification so that the matter can be corrected in the electronic version of the document and a full acknowledgement provided.

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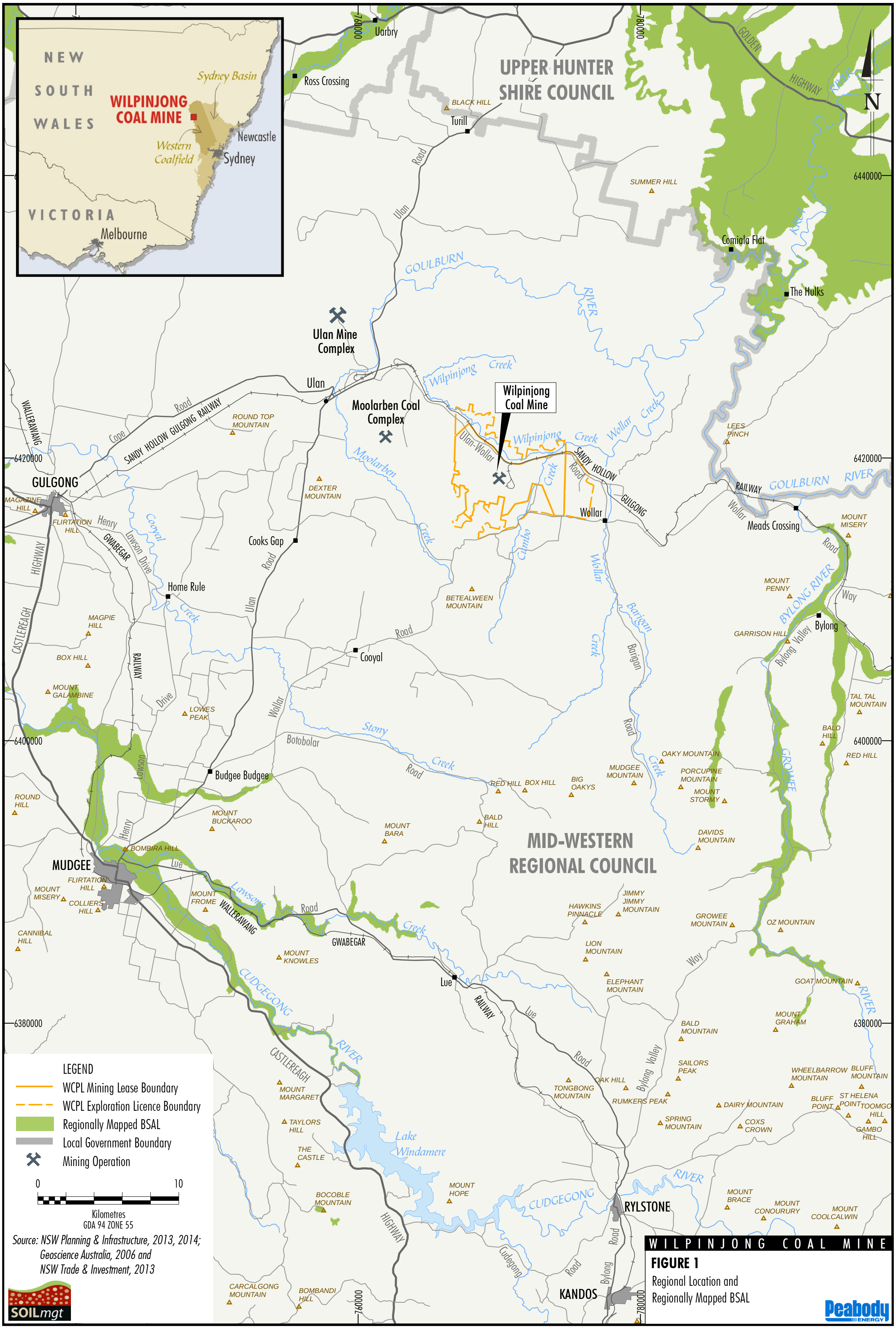
1 INTRODUCTION

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 Local Government Area, in central New South Wales (NSW) (Figure 1).

Construction of the Wilpinjong Coal Mine commenced in February 2006, and the mine is currently approved to produce up to 15 million tonnes per annum (Mtpa) of run-of-mine coal. 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.

Wilpinjong Coal Pty Ltd (WCPL) is seeking a Site Verification Certificate (SVC) for parts of Exploration Licences (EL) 7091 and 6169 where future mining development may be proposed (herein referred to as the SVC Application Area) (Figure 2). This Site Verification Report has been prepared in accordance with the *Interim Protocol for Site Verification and Mapping of Biophysical Strategic Agricultural Land* (NSW Government 2013a) (Interim Protocol) to accompany the SVC application.



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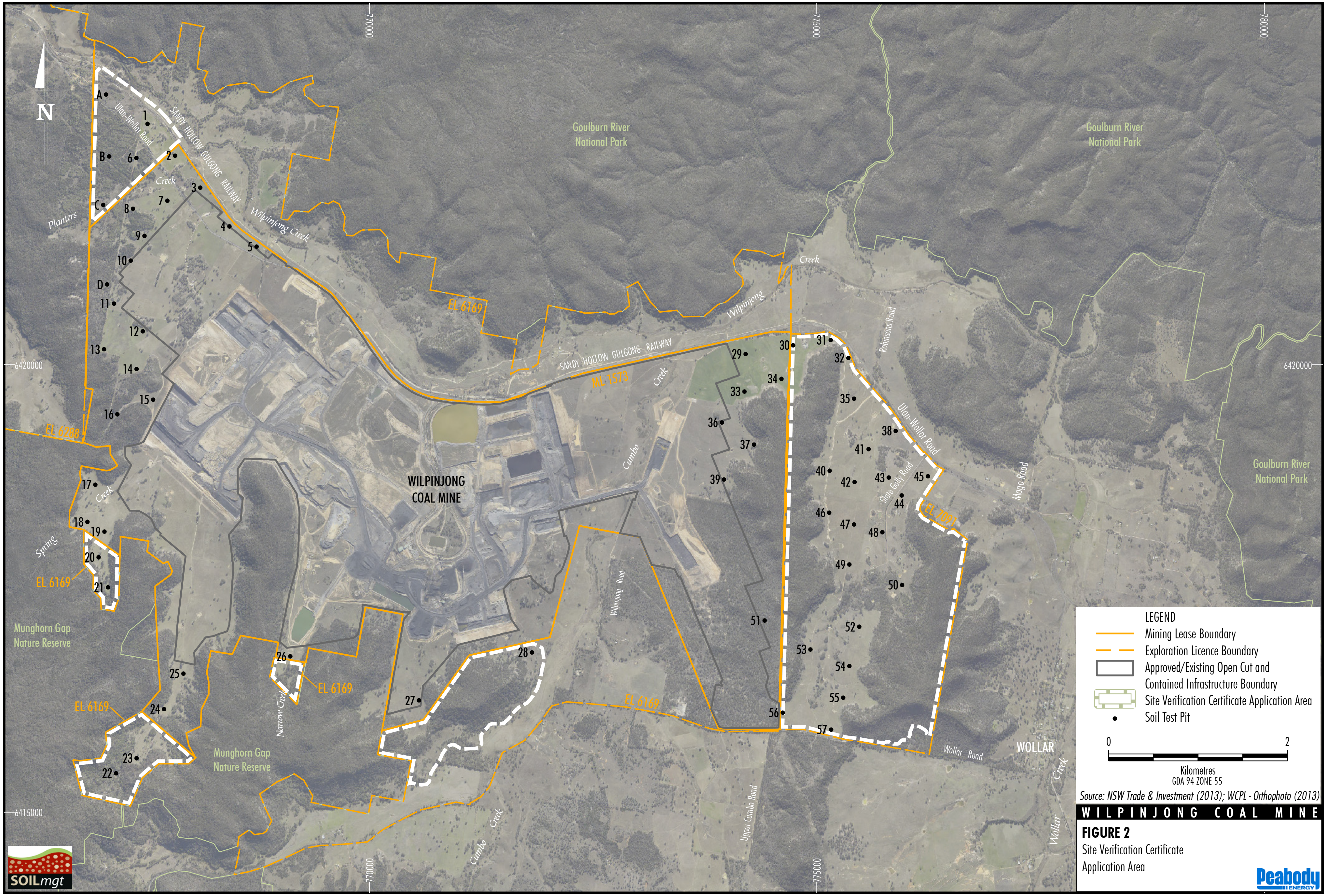

FIGURE 2

Site Verification Certificate Application Area

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2 SITE DESCRIPTION

The Wilpinjong Coal Mine 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 tributaries 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 Mining Lease (ML) 1573 (Figure 2).

The Moolarben Coal Mine is 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 southwest (Figures 1 and 2).

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

Land use in the vicinity of the SVC Application Area is characterised by a combination of coal mining operations, agricultural land uses (primarily grazing) and rural residential development (evident in the local villages of Wollar, Ulan and the localities of Cumbo, Slate Gully and Araluen) (Figure 1). The cleared grazing land is under unimproved pasture utilized by cattle and sheep. Some dryland cropping has occurred in previous decades in the north-western part of the SVC Application 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).

The NSW Government's regional Biophysical Strategic Agricultural Land (BSAL) mapping (NSW Government 2013b, 2014) shows no BSAL or critical industry clusters in the vicinity of the SVC Application Area. The nearest BSAL is located approximately 18 km southeast of the Wilpinjong Coal Mine (Figure 1).

3 SOIL RESOURCES

3.1 Review of Existing Information

The following existing information was reviewed as part of this 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 1:100 000 (Department of Mineral Resources 1998);
- Regional BSAL mapping (NSW Government 2013b, 2014);
- Critical Industry Cluster mapping (NSW Government 2012);
- Land and Soil Capability mapping (Office of Environment and Heritage 2012);
- Soil survey for Wilpinjong Coal Project Soils, Rural Land Capability and Agricultural Suitability Assessment (Jammel Environmental & Planning Services Pty Ltd 2004); and
- Agricultural Resource Assessment: "Wilpinjong Coal Mine Modification", Wollar, NSW (McKenzie Soil Management 2013).

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

eSPADE Soil Profile Database

A search of the NSW Government's 'eSPADE' website (part of the NSW Natural Resource Atlas) was conducted to identify any existing soil profile information in the survey areas. No eSPADE 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 Wilpinjong Coal Mine are shown in Figure 3. 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

Appendices 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.

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

The Jammel (2004) study included 46 soil pits across the Wilpinjong Coal Mine site (Appendix 2). 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 BSAL site verification purposes.

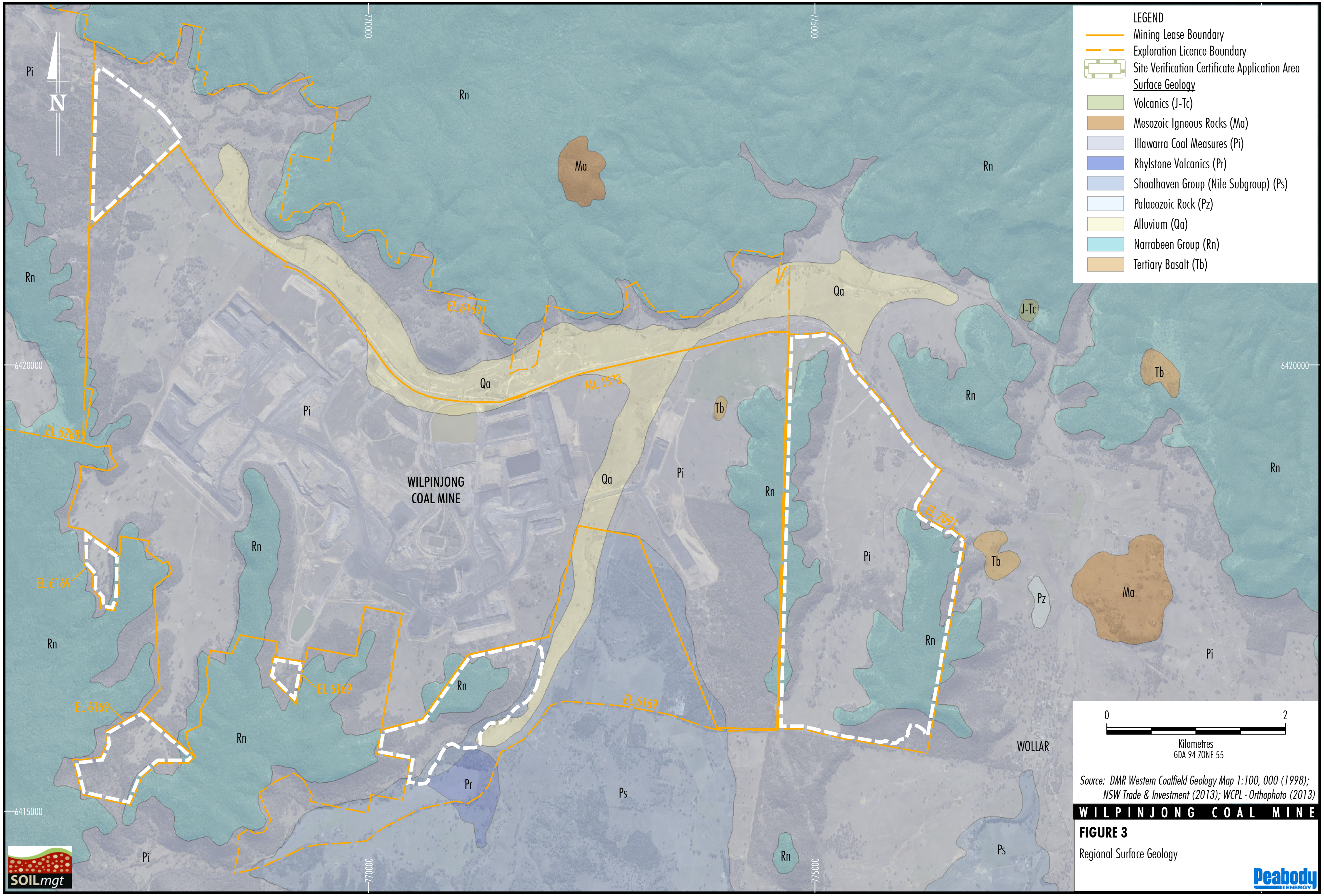

FIGURE 3
Regional Surface Geology

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3.2 Soil Survey Methodology

WCPL commissioned McKenzie Soil Management to conduct an Agricultural Resources Assessment for areas surrounding the currently approved extent of Wilpinjong Coal Mine operations within ML 1573, EL 7091 and EL 6169. A soil survey was conducted by McKenzie Soil Management under very dry conditions in early-2014.

A significant aim of this study has been to identify BSAL within the SVC Application Area (Figure 2). BSAL verification within the SVC Application Area has been conducted in accordance with the Interim Protocol (as discussed in Section 5). However, the following soil information is regarded by Ward (1998) as being important for soil assessment associated with mine site reclamation, and has been incorporated into the methodology for this assessment:

- 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 soil 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 hard-setting 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 water holding capacities.
- Material with a gravel and sand content greater than 60% is unsuitable.
- Saline material is unsuitable.

Because the NSW Government now requires proponents of new mining and coal seam gas projects in NSW to consider the potential impacts of projects on agricultural resources up-front in the project assessment process, existing soil profiles have to be described in a way that allows the productivity of crops, pasture and trees to be predicted accurately, as well as assisting with prediction of impacts of mining on agriculture, and provision of information about soil materials that will assist with any mine rehabilitation activities that are required. Therefore, in addition to following the BSAL identification process described in the Interim Protocol, the soil survey methodology for intensive agricultural developments described by McKenzie *et al.* (2008) and McKenzie (2013) also has been taken into account when planning the Agricultural Resource Assessment. The combination of techniques from this variety of sources, and its compatibility with requirements of the Interim Protocol, is described in the following sections.

Field Survey

The Agricultural Resource Assessment involved a survey of 57 detailed soil pit profiles dug with an excavator (approximately 1.4 m deep; shallower where hard rock was encountered) and four spade/auger profiles (check sites) (approximately 90 centimetres [cm] deep, labelled A to D on Figure 2). 32 of these sites are located within the SVC Application Area and 29 sites are located outside the SVC Application Area (within ML 1573) (Table 1). As shown on Figure 2, the survey areas within ML 1573 are contiguous with, and sample the soil landscape units between, the currently approved extent of the Wilpinjong Coal Mine and the SVC Application Area.

Table 1. Location of Soil Survey Sites (refer to Figure 2)

Soil Survey Sites Within SVC Application Area							
A	6	23	32	41	45	49	54
B	20	28	35	42	46	50	55
C	21	30	38	43	47	52	56
1	22	31	40	44	48	53	57
Soil Survey Sites Outside SVC Application Area							
D	5	10	14	18	26	34	51
2	7	11	15	19	27	36	
3	8	12	16	24	29	37	
4	9	13	17	25	33	39	

The soil survey was carried out by Dr David McKenzie. He has Certified Professional Soil Scientist Stage 3 accreditation (http://www.cpss.com.au/) from Soil Science Australia and a PhD in soil science. Dr McKenzie also has 'Chartered Scientist' accreditation with British Society of Soil Science.

The soil pits were located in a way that covered as many of the major variations in elevation and landforms as possible. The pits in the areas with slope <10% were positioned on a flexible grid spacing of approximately 400 m (approximately 1 pit per 16 hectares [ha] within the Application Area). This provided an intensity of sampling (1:25 000) that satisfied the Interim Protocol (NSW Government 2013a) nominated sampling density of 1 site per 5 – 25 ha for intensive mining developments (see Gallant *et al.* 2008).

More importantly, the pit spacing allowed an assessment of the size of an area of BSAL to determine whether it met the minimum area requirement of 20 ha, as described in the Interim Protocol:

- One pit on its own that satisfied Steps 1 to 12 of the BSAL criteria (Section 5) – represents approximately 16 ha, i.e. not above the BSAL threshold of 20 ha.
- Two pits together that satisfied Steps 1 to 12 of the BSAL criteria (Section 5) – represents approximately 30 ha, i.e. almost certainly above the BSAL threshold of 20 ha.

This meant that all of the <10% slope field sites with a soil depth >75 cm required laboratory analysis to determine whether or not each site actually had BSAL characteristics. Key soil factors such as salinity, pH ($CaCl_2$), sodicity and cation exchange capacity (CEC) cannot be measured or predicted accurately in the field.

A limited number of detailed sites were inspected in the steeper 'exclusion zones' (>10% slope, where BSAL status can only be negative) to inform the Agricultural Resource Assessment of soil conditions in those areas.

The slope information used to assist with locating observation sites and defining BSAL exclusion zones is shown in Map 1. Slope was interpreted using detailed LiDAR data obtained by Peabody Energy.

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

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 according to the ASC (Isbell 2002).

Field Soil Observations/Testing

The 1.4 m deep pit profiles were dug with an excavator and trimmed with a geological pick to allow high resolution 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) and mottle characteristics;
- 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).

Site factors noted included current land use, landform, slope (measured with a SUUNTO clinometer), aspect, and surface rock. Outcropping bedrock was always under consideration, but its occurrence was negligible in this study. No gilgai features were observed.

Field observations for each pit are presented in Attachments A, B and C.

The soil structure information (Attachment C) 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 (Attachment A) has been estimated using texture, structural form and coarse fragment content data (McKenzie *et al*. 2008).

Laboratory Soil Testing

All of the pits on land <10% slope and >75 cm soil depth (i.e. sites with the potential to be BSAL) were sampled for laboratory analysis. The sampling intervals for laboratory analysis were as per the Interim Protocol, i.e. 0 to 5 cm; 5 to 15 cm; 15 to 30 cm; 30 to 60 cm; and 60 to 100 cm. Where important horizon boundaries did not coincide with these depth intervals, extra samples were taken to ensure that distinctive horizons (e.g. A2 horizons) were kept separate for analysis.

The soil was analysed by Incitec-Pivot Laboratory, Werribee Victoria for exchangeable cations, pH, EC, chlorides, nutrient status (nitrate-nitrogen, phosphorus, sulfur, zinc, copper, boron) and organic matter content (Attachment D). An ammonium acetate method was used for the extraction of exchangeable cations. The CEC values are the sum of exchangeable sodium, potassium, calcium, magnesium and aluminium; exchangeable sodium data are presented as exchangeable sodium percentage (ESP). 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). These methods are compatible with the key components of the Interim Protocol.

Soil dispersibility, as measured by the Aggregate Stability in Water (ASWAT) test (Field *et al.* 1997), was assessed by McKenzie Soil Management in Orange, NSW. The results are presented in Attachment D. The ASWAT test has been related to the well-known Emerson aggregate stability test by Hazelton and Murphy (2007) – see Table 2. 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 (McKenzie 2013) (Figure 4). 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.

Table 2. The Relationship Between the Emerson Aggregate Stability Test and the ASWAT Test

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

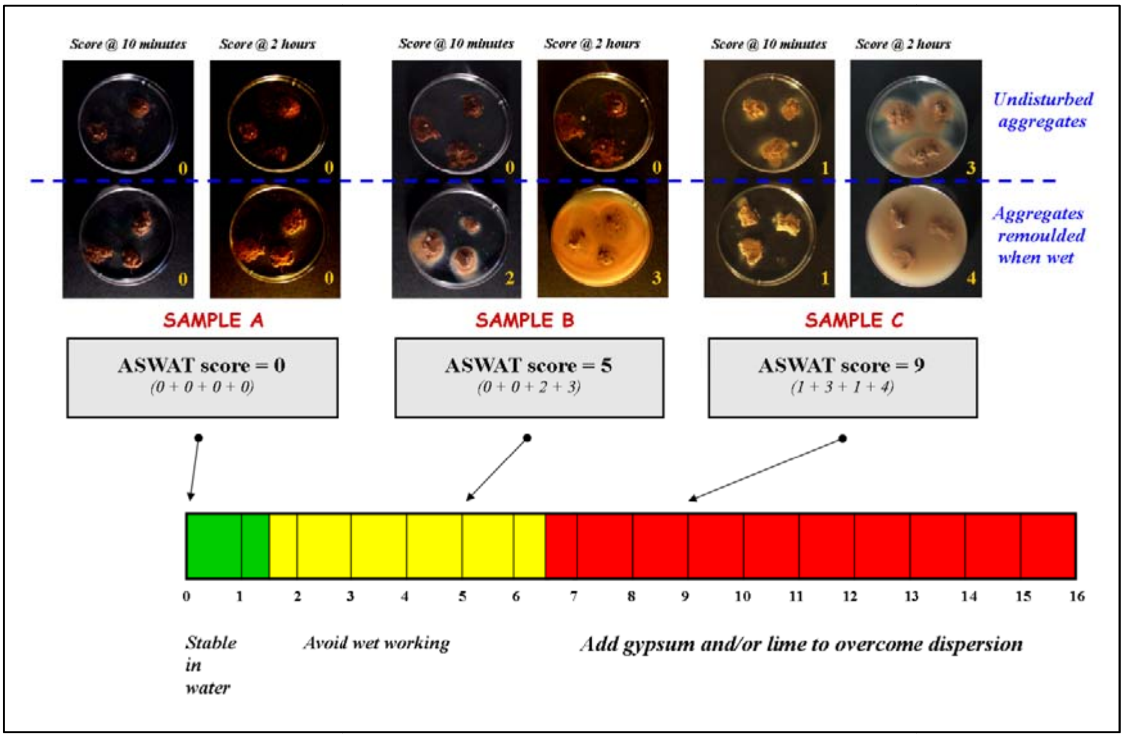


Figure 4. The Link between ASWAT Results and Soil Management Options

The following key soil factors are attached in the form of colour coded maps:

Map 1. BSAL Slope Categories.

Map 2. Soil Types (Australian Soil Classification).

Map 3. Depth to Rock.

Map 4. Plant Available Water (TAW).

Map 5. Depth to Mottled Layer.

Map 6. Depth to Layer with Lime.

Map 7a. Dispersion (ASWAT score).

Map 7b. Dispersion (ESP Value).

Map 7c. Dispersion (ESI Value).

Map 8. Compaction Severity (SOILpak Score).

Map 9. Cation Exchange Capacity (CEC).

Map 10. Salinity (Electrical Conductivity [ECe]).

Map 11. pH ($CaCl_2$).

Map 12. Phosphorus (Colwell P).

Map 13. Organic Carbon (%).

3.3 Soil Types and Mapping

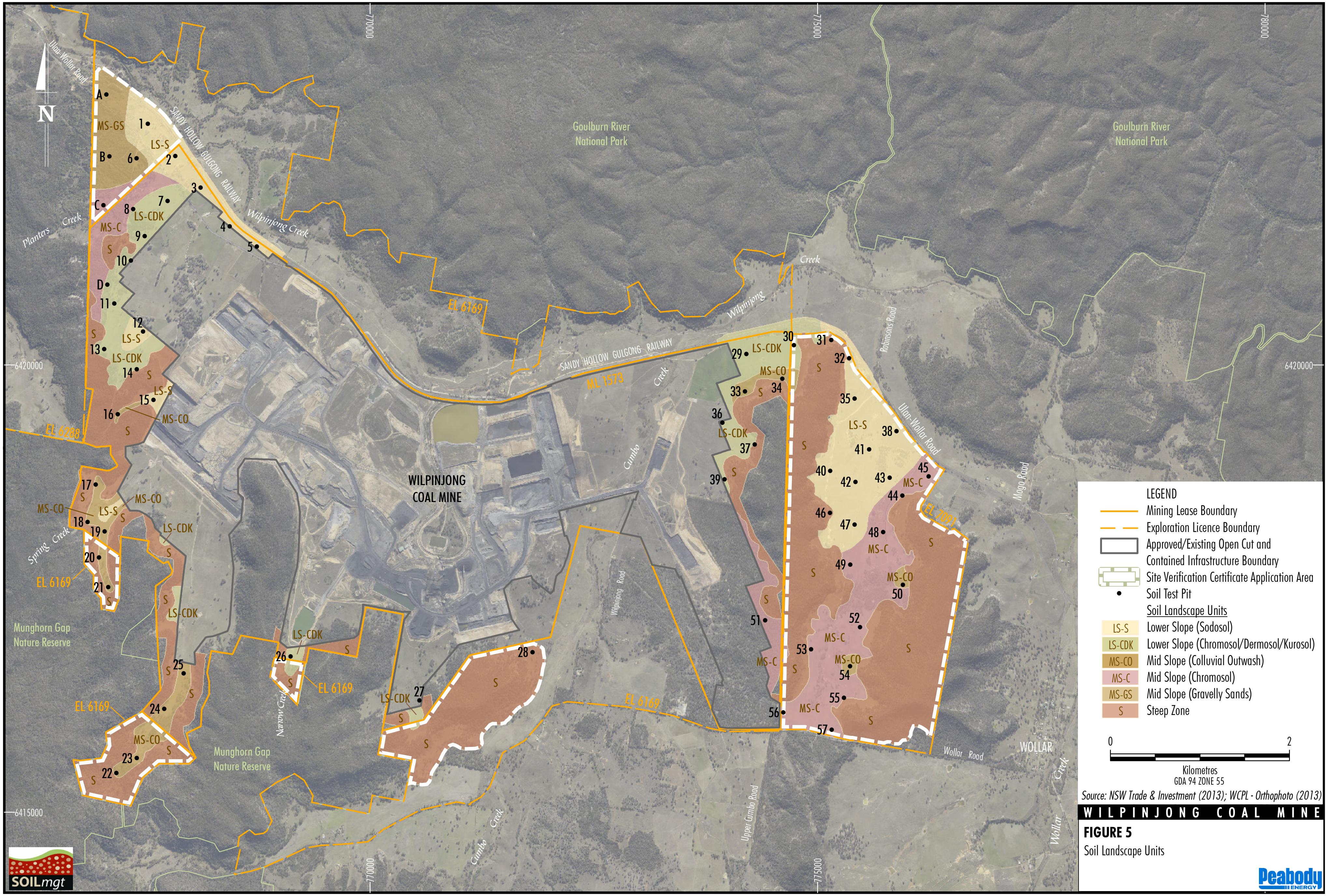
Soil Landscape Units

Soil Landscape Units identified during the Agricultural Resource Assessment that host the soil types described in the next section are described in Table 3 and presented in Figure 5. Soil Landscape Units are associations of soils described and delineated by means of landforms (Dent and Young 1981).

Table 3. Soil Types Associated with the Soil Landscape Units

Soil Landscape Unit	**Number of sites**[1]	**Map code**	**Dominant soil types**	**Sub-dominant soil types**	**Additional comments**
Lower Slope (Sodosol)	14	LS-S	Sodosol	Chromosol	Poor root growth in subsoil due to sodicity
Lower Slope (Chromosol/Dermosol/ Kurosol)	13	LS-CDK	Chromosol, Dermosol, Kurosol	Rudosol	-
Midslope (Colluvial Outwash)	14	MS-CO	Rudosol	Kandosol	Deep young soil with favourable subsoil conditions for root growth
Midslope (Chromosol)	11	MS-C	Chromosol	Rudosol	-
Midslope (Gravelly Sands)	3	MS-GS	Rudosol	-	Poor water holding capacity
Steep Zone	6	S	One of each of the following soil types: Chromosol, Dermosol, Kandosol, Kurosol, Rudosol, Tenosol		Large proportion of shallow soil with poor water holding capacity

[1] Refer to Figure 5.



WILPINJONG COAL MINE

FIGURE 5

Soil Landscape Units

WIL-12-12_BSAL SV App_205E

ASC Soil Types

The ASC (Isbell 2002) has been used to determine soil types at each of the 61 observation sites (Map 2). Photographs of representative soil profiles identified during the survey are presented in Figures 6 and 7 (for each Soil Landscape Unit and ASC soil type described below). All of the sites have three to four photographs to record the following: a) Landscape view, b) Trimmed soil profile, c) Rehabilitation of the pit site following infilling, and d) Close-up view of soil surface and associated vegetation where required.

This comprehensive collection of soil profile photographs is provided in Attachment E.

Total numbers of the contrasting ASC soil types, and the equivalent Great Soil Group (Stace et al. 1968) terminologies, are shown in Table 4.

Table 4. Soil Types Identified; Classified According to the ASC and Great Soil Groups

ASC Soil Type	Number of Sites	Great Soil Group Equivalent
Rudosol	19	Alluvial Soils
Chromosol	12	Red-Brown Earths, Non-calcic brown soils
Sodosol	11	Solodic Soils
Dermosol	6	Chocolate Soils, Red Podzolics
Kurosol	6	Podzolic Soils and Soloths
Kandosol	4	Calcareous Red Earths
Tenosol	3	Lithosols

The soil types in Table 4 have the following characteristics:

- Rudosols are derived from recently deposited materials that have only minimal profile development.
- Chromosols have strong texture contrast (Isbell 2002) between the A and B horizons, and a non-sodic subsoil with pH_{water} greater than 5.5.
- Sodosols have strong texture contrast between topsoil and subsoil, and the B horizon is sodic (ESP of 6 or greater).
- Dermosols lack a strong texture contrast between the A and B horizons and have moderately to strongly structured B2 horizons.
- Kurosols have strong texture contrast between topsoil and subsoil, and the B horizon is strongly acidic (pH_{water} less than 5.5).
- Kandosols lack strong textural contrast and have a massive or only weakly structured B horizon.
- Tenosols at this location are shallow and have only weak pedological development.

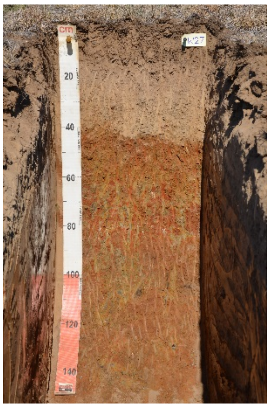
Soil Landscape Unit (Table 3)	Soil Profile Photographs (Dominant ASC Profiles)		
Lower Slope – Sodosol **(LS-S)**	Pit 4: Sodosol 	Pit 15: Sodosol 	
Lower Slope – Chromosol/Dermosol /Kurosol **(LS-CDK)**	Pit 8: Chromosol 	Pit 26: Dermosol 	Pit 30: Kurosol 
Midslope – Colluvial Outwash **(MS-CO)**	Pit 19: Rudosol 	Pit 21: Rudosol 	

Figure 6. Photographs of Soil Types – Dominant ASC Orders

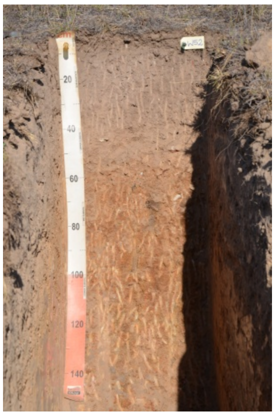
Soil Landscape Unit (Table 3)	**Soil Profile Photographs (Dominant ASC Profiles)**		
Midslope – Chromosol **(MS-C)**	Pit 45: Chromosol 	Pit 48: Chromosol 	
Midslope – Gravelly Sands **(MS-GS)**	Pit 6: Rudosol 		
Steep Zone **(S)**	Pit 27: Kandosol 	Pit 31: Chromosol 	

Figure 6. Photographs of Soil Types – Dominant ASC Orders (continued)

Soil Landscape Unit (Table 3)	Soil Profile Photographs (Sub-Dominant ASC Profiles)		
Lower Slope – Sodosol **(LS-S)**	Pit 41: Chromosol 		
Lower Slope – Chromosol/Dermosol /Kurosol **(LS-CDK)**	Pit 11: Rudosol 		
Midslope – Colluvial Outwash **(MS-CO)**	Pit 23: Kandosol 		

Figure 7. Photographs of Soil Types – Sub-Dominant ASC Orders

Soil Landscape Unit (Table 3)	Soil Profile Photographs (Sub-Dominant ASC Profiles)		
Midslope – Chromosol **(MS-C)**	Pit 57: Rudosol 		
Midslope – Gravelly Sands **(MS-GS)**	No sub-dominant ASC profile was identified in this Soil Landscape Unit		
Steep Zone **(S)**	Pit 32: Tenosol 	Pit 37: Kurosol 	

Figure 7. Photographs of Soil Types – Sub-Dominant ASC Orders (continued)

3.4 Soil Conditions for Plant Growth

Soil Depth, Texture and Waterholding Capacity

The impact across the site of profile shallowness/stoniness and sandiness on the ability of the soil to store plant available water (measured as TAW) is shown in Attachment A and on Map 4. As soil becomes shallower, stonier and/or sandier, its ability to store water declines (White 2006).

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. Within the SVC Application Area, the lack of water holding capacity in shallow/stony soils is a significant constraint to agricultural productivity.

The deeper soil tended to have very good water holding capacity because of a combination of moderate clay content, minimal coarse fragments and favourable soil structure.

Waterlogging Hazard

Much of the subsoil showed signs of waterlogging. 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.

An indicator of waterlogging in the field is the presence of mottling (Map 5). Mottles are blotches of sub-dominant colours different from the matrix colour; for example, grey or yellow blotches within a reddish-brown subsoil. The impedance of internal drainage that creates mottling is usually caused either by impermeable rock close to the surface or dispersive subsoil. Mottling sometimes is associated with the presence of black manganiferous nodules or concretions.

Soil Stability in Water – Dispersion and Slaking

Poor soil structure in the survey area was associated with instability in water caused by dispersion. 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 then becomes 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).

Three maps relating to soil stability in water are presented (Maps 7a, 7b and 7c). The ASWAT score (Map 7) shows how prone the soil is to dispersion under conditions that existed when the soil was sampled (Field *et al*. 1997). The 'working when wet' procedure that is part of the ASWAT test is a simulation of processes such as raindrop impact on wet soil and the cutting/stockpiling of moist soil. Dispersion was evident in the sub-surface (15-30 cm) across much of the site (Maps 7a, 7b and 7c). The dispersion problems can be overcome in a cost-effective manner through gypsum application, or by use of gypsum-lime blends where soil pH is acidic or neutral.

The main chemical factor influencing the behaviour of clay particles in unstable soils is moderate amounts of ESP (Map 7b), aggravated by low electrolyte concentrations (Levy 2000). Map 7c (ESI, electrochemical stability index; EC÷ESP) highlights sites affected by this process.

Compaction Status

Compaction was assessed in this study using the SOILpak scoring system (Map 8). Much of the soil had subsoil compaction problems, caused apparently by the natural dispersion problems.

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).

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 (Map 9) (McKenzie 1998). The soil in this study did not have a favourable capacity for self-repair capacity via shrink-swell processes.

Salt Concentrations

Subsoil salinity (Map 10) was only a minor issue in the upper one metre of soil.

pH Imbalance

Much of the topsoil and some subsoil was acidic (Map 11) and is likely to respond well to lime application.

Nutrients

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). Poor CEC values (Map 9) therefore are unfavourable from a nutritional perspective. The topsoil and subsoil was deficient (from an agricultural point of view) in phosphorus (Map 12).

Soil Carbon and Soil Biological Health

The relatively high organic carbon concentrations in much of the topsoil (0-5 cm) (Map 13) provide beneficial soil organisms with a ready supply of food. However, organic carbon content of deeper layers was poor.

4 BIOPHYSICAL STRATEGIC AGRICULTURAL LAND ASSESSMENT

The Interim Protocol (NSW Government 2013a) was used to verify the presence of BSAL within the SVC Application Area. A flow chart showing the Interim Protocol BSAL assessment criteria (Steps 1 to 12) is provided in Figure 8.

An assessment of each observation site within the SVC Application Area has been conducted against the BSAL assessment criteria, with the results presented in Table 5. The limiting factors in the BSAL verification process are highlighted via a colour-coded matrix in Table 5.

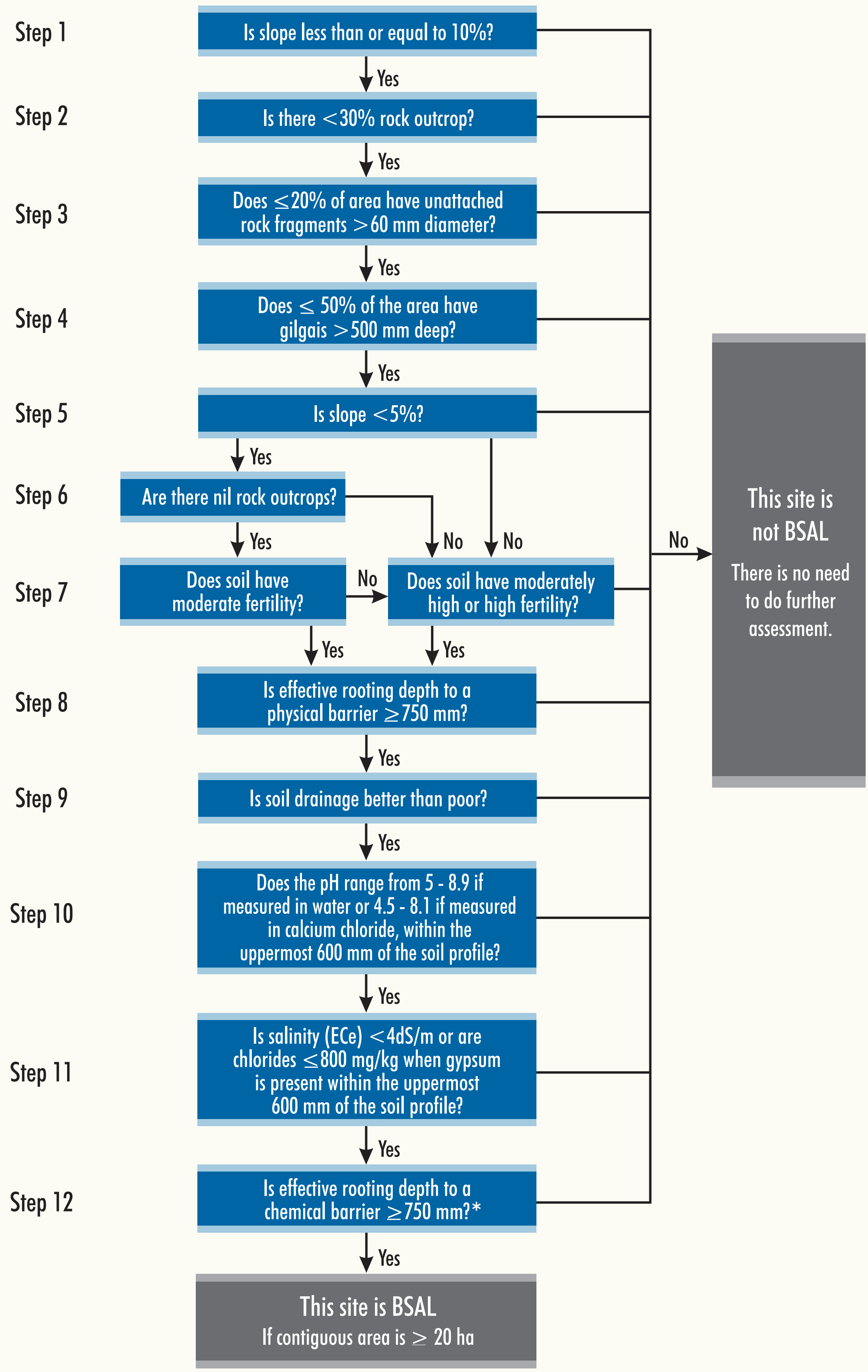
The following description outlines how particular factors in the BSAL flow chart were interpreted for this study:

- "Physical barrier" (Step 8) - defined as 'hard rock' or a layer with >90% coarse fragments.
- "Soil drainage better than poor" (Step 9) - poor drainage for the purpose of this report is determined by visual assessment of waterlogging indicators, i.e. the presence of mottling (>10%) and/or black manganiferous nodules or concretions (>20%) within the depth interval 0-750 mm.
- pH (Step 10) - Soil pH is measured most accurately by using the pH (1:5 $CaCl_2$) technique rather than pH (1:5 water). Therefore, BSAL assessment is based exclusively on examination of pH (1:5 $CaCl_2$) data.
- "Chemical barrier" (Step 12) - defined as ESP>6.

Two individual sites within the SVC Application Area (Pits 50 and 55 [Figure 9]) meet Steps 1 to 12 of the BSAL assessment criteria, however as no adjacent test pits also meet the criteria, the contiguous area is less than 20 ha. The land around Pit 50 is part of a small colluvial fan that covered an area of approximately 5 ha. A similar colluvial fan landscape covering an area of approximately 3 ha was present in the zone represented by Pit 55. Photographs of these two sites are shown in Figure 10.

Figure 9 also shows the exclusion zones within the SVC Application Area where slope is greater than 10%. Besides slope, the key factor limiting the BSAL status of soils within the SVC Application Area is poor soil drainage (as assessed by waterlogging indicators) (Table 5).

It is concluded that the land within the SVC Application Area is not BSAL. This finding is consistent with the NSW Government's regional BSAL mapping.



* In accordance with Section 6.10 of the Interim Protocol

Source: After NSW Government (2013)

WILPINJONG COAL MINE

FIGURE 8

Flow Chart for Site Verification of BSAL

Peabody ENERGY

SOILmgt

WIL-12-12_BSAL SV App_001A

Table 5 BSAL Assessment Matrix for SVC Application Area

Map ID	Slope (%)	Physical Barrier	Waterlogging			Chemical Barrier												Australian Soil Classification		
						pH CaCl2				ESP				Salinity (ECe, dS/m)						
		Depth Rock (cm)	Depth Mottles (cm)	Depth to Mn (cm)	Depth water-logged layer	0-5 cm	5-15 cm	15-30 cm	30-60 cm	0-5 cm	5-15 cm	15-30 cm	30-60 cm	0-5 cm	5-15 cm	15-30 cm	30-60 cm	ASC: Fertility Status	Subgroup, Great group	Pit BSAL Status[1]
1	5	-	40	-	40	5.8	4.5	5.7	7.5	0.4	3.0	7.6	16.6	1.2	0.7	0.9	3.0	Brown Sodosol, AH, FO	Eutrophic, Mottled-Mesonatric	No
6	4	-	-	-	-	5.6	4.8	4.3	4.3	0.3	0.9	1.2	0.9	0.7	0.5	0.2	0.2	Clastic Rudosol, AI, HI	Acidic, Colluvic	No
20	6	-	-	-	-	5.3	5.2	5.7	5.9	0.1	0.1	0.1	0.1	3.2	1.6	0.9	0.7	Clastic Rudosol, AR, HI	Basic, Colluvic	No
21	4	-	-	-	-	5.4	4.7	5.1	5.5	0.1	0.1	0.1	0.2	2.7	1.4	0.7	0.5	Stratic Rudosol, AR	Basic	No
22	3	-	-	-	-	5.8	5.3	5.8	6.3	0.1	0.1	0.1	0.1	0.8	0.5	0.3	0.3	Stratic Rudosol, AR	Basic	No
23	9	-	-	-	-	5.2	5.2	5.5	6.3	0.1	0.1	0.1	0.2	0.8	0.6	0.4	0.2	Brown Kandosol, CD, AH	Haplic, Eutrophic	No
28	6	80	32	-	32	4.9	4.7	4.9	4.5	0.3	0.4	1.6	3.6	0.8	0.5	0.2	0.2	Brown Dermosol, AZ, AH	Bleached-Mottled, Eutrophic	No
30	4	80	25	-	25	4.8	4.1	4.3	4.5	1.5	0.9	0.5	3.3	4.3	1.1	0.7	0.3	Yellow Kurosol, DQ, AH	Mottled, Eutrophic	No
31	12	90	28	-	28	-	-	-	-	-	-	-	-	-	-	-	-	Brown Chromosol, DQ, AH	Mottled, Eutrophic	No
32	10	55	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Bleached-Orthic Tenosol, AR, CZ	Basic, Lithic	No
35	5	57	22	-	22	-	-	-	-	-	-	-	-	-	-	-	-	Grey Sodosol, AH, FN	Eutrophic, Mottled-Subnatric	No
38	3	-	70	*	70	5.5	5.7	5.8	5.7	0.1	0.2	0.3	1.0	0.8	0.7	0.2	0.3	Yellow Dermosol, AZ, AH	Bleached-Mottled, Eutrophic	No
40	5	90	20	-	20	5.0	4.8	5.2	5.5	0.7	2.0	5.6	8.1	1.2	0.6	0.5	0.8	Brown Sodosol, AH, FN	Eutrophic, Mottled-Subnatric	No
41	5	90	50	-	50	4.8	4.6	5.1	6.4	0.6	1.6	1.5	4.3	1.6	0.7	0.5	0.3	Yellow Chromosol, AZ, AH	Bleached-Mottled, Eutrophic	No
42	4	-	15	-	15	5.2	5.2	6.0	6.5	0.3	4.2	4.3	6.1	1.2	0.8	0.4	0.6	Yellow Sodosol, AH, FN	Eutrophic, Mottled-Subnatric	No
43	3	105	80	-	80	5.0	5.1	5.2	4.4	0.6	1.2	3.3	10.7	0.7	0.6	0.6	1.0	Brown Sodosol, AH, FN	Eutrophic, Mottled-Subnatric	No
44	5	65	**	*	**	-	-	-	-	-	-	-	-	-	-	-	-	Red Chromosol, At, AH	Bleached, Eutrophic	No
45	5	-	55	*	55	5.9	5.2	4.8	5.5	0.2	0.5	0.2	0.6	1.7	1.0	0.4	0.2	Red Chromosol, DQ, AH	Mottled, Eutrophic	No
46	11	-	60	-	60	-	-	-	-	-	-	-	-	-	-	-	-	Stratic Rudosol, AR	Basic	No
47	3	-	62	-	62	5.1	5.1	6.4	6.9	0.1	1.3	3.1	6.9	1.1	1.4	0.5	0.7	Brown Sodosol, AH, FN	Eutrophic, Mottled-Subnatric	No
48	3	-	30	*	30	5.2	5.5	6.2	7.0	0.5	0.8	1.7	4.6	0.6	0.6	0.3	0.5	Brown Chromosol, AZ, AH	Bleached-Mottled, Eutrophic	No
49	5	-	60	-	60	4.7	5.4	6.5	6.9	0.2	0.9	2.0	3.6	0.9	0.4	0.6	0.8	Brown Chromosol, AZ, BD	Bleached-Mottled, Calcic	No
50	4	-	**	-	**	6.1	5.5	5.8	6.0	0.1	0.1	0.1	0.3	1.0	0.5	0.3	0.2	Grey Kandosol, CD, AH	Haplic, Eutrophic	Yes
52	3	-	30	-	30	4.7	5.1	5.4	6.8	0.4	0.5	1.1	4.9	1.0	0.5	0.4	0.7	Brown Chromosol, AZ, AH	Bleached-Mottled, Eutrophic	No
53	6	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Leptic Rudosol,AI, CZ	Acidic, Lithic	No
54	3	-	30	*	30	4.8	5.2	5.5	7.2	0.1	0.1	0.1	0.3	0.7	0.6	0.3	0.4	Red Dermosol, AZ, AH	Bleached-Mottled, Eutrophic	No
55	7	-	90	-	90	5.0	4.9	5.2	5.7	0.1	0.1	0.2	0.9	1.4	1.1	0.4	0.3	Red Chromosol, AT, AH	Bleached, Eutrophic	Yes
56	2	35	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Bleached-Leptic Tenosol, AR, CZ	Basic, Lithic	No
57	3	70	38	-	38	-	-	-	-	-	-	-	-	-	-	-	-	Arenic Rudosol, AI	Acidic	No
A	3		65		65	4.9	5.1	5.0	5.3	0.7	1.5	2.2	2.6	0.5	0.5	0.2	0.2	Arenic Rudosol, AR	Basic	No
B	6					4.5	4.2	4.3	4.3	0.7	2.9	1.7	0.9	1.1	0.9	0.5	0.5	Clastic Rudosol, AI, HI	Acidic, Colluvic	No
C	3		40		40	5.1	5.0	5.3	5.6	0.1	1.0	1.5	3.3	0.9	0.2	0.2	0.3	Grey Kandosol, AZ, AH	Bleached-Mottled, Eutrophic	No
D	5					5.6	4.7	4.4	4.8	0.2	0.2	1.2	1.4	1.0	0.4	0.3	0.3	Brown-Orthic Tenosol, AI, CZ	Acidic, Lithic	No

[1] Indicates whether the observation site meet the Interim Protocol BSAL Assessment Criteria Steps 1 to 12 (Figure 8).

* = Mn present but <20%.

** = Mottling present but <10%.

Colour Codes:

Slope		Physical Barrier		Waterlogging		pH		ESP		Salinity		ASC: Fertility Status		Pit BSAL Status	
	<5%		<75 cm		<75 cm		<4.5, >8.1		>6		>4		Low/Moderately Low		Yes
	5-10%	No shading	>75 cm	No shading	>75 cm	No shading	4.5 > 8.1	No shading	<6	No shading	<4		Moderate		No
	>10%												Moderately High/High		

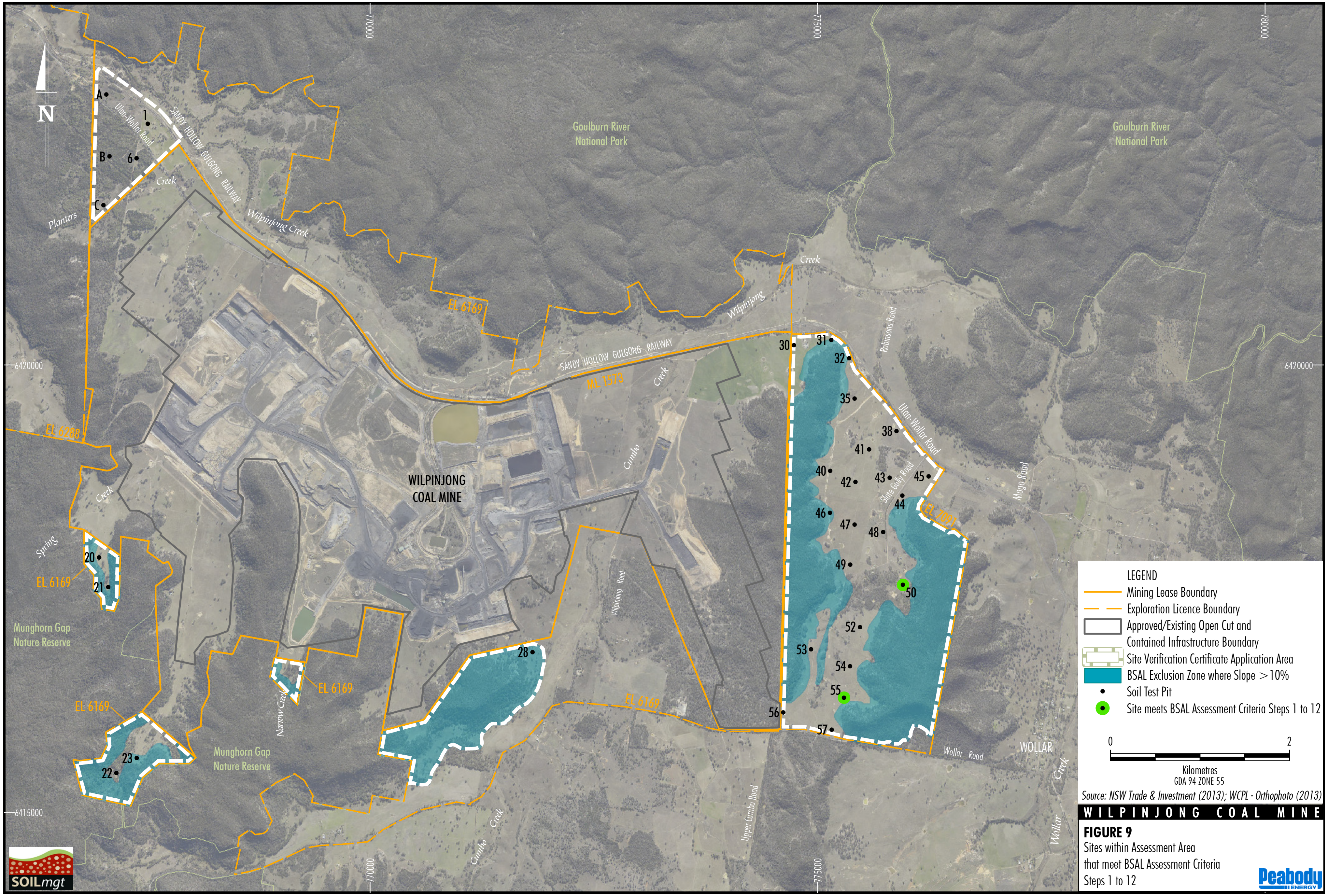


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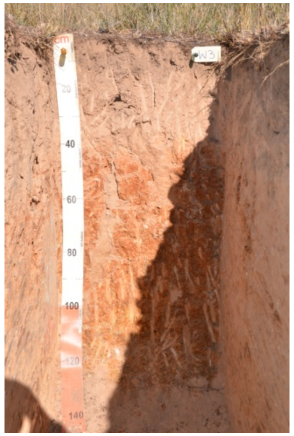
Figure 10 Photographs of Areas Surrounding Pits 50 and 55

Pit 50



Pit 55



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