ATTACHMENT A

AGRICULTURAL RESOURCE ASSESSMENT
(McKenzie Soil Management, 2012)

October 2012

Agricultural Resource Assessment: "Vickery Coal Project", Gunnedah NSW

Prepared for Whitehaven Coal Limited

SOILmgt

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1 INTRODUCTION

1.1 Background

Whitehaven Coal Limited (Whitehaven) proposes to develop an open cut mining operation known as the Vickery Coal Project (the Project) approximately 25 kilometres (km) north of Gunnedah in New South Wales (NSW) (Figure 1).

The Project is located at the site of the former Vickery Coal Mine which was operated during the 1980s and 1990s. Mining operations at the Vickery Coal Mine ceased in May 1998. Since mining ceased, rehabilitation activities have been completed and the site is currently under care and maintenance.

The Project general arrangement is shown on Figures 2a and 2b. A detailed description of the Project is provided in Section 2 in the Main Report of the Environmental Impact Statement (EIS).

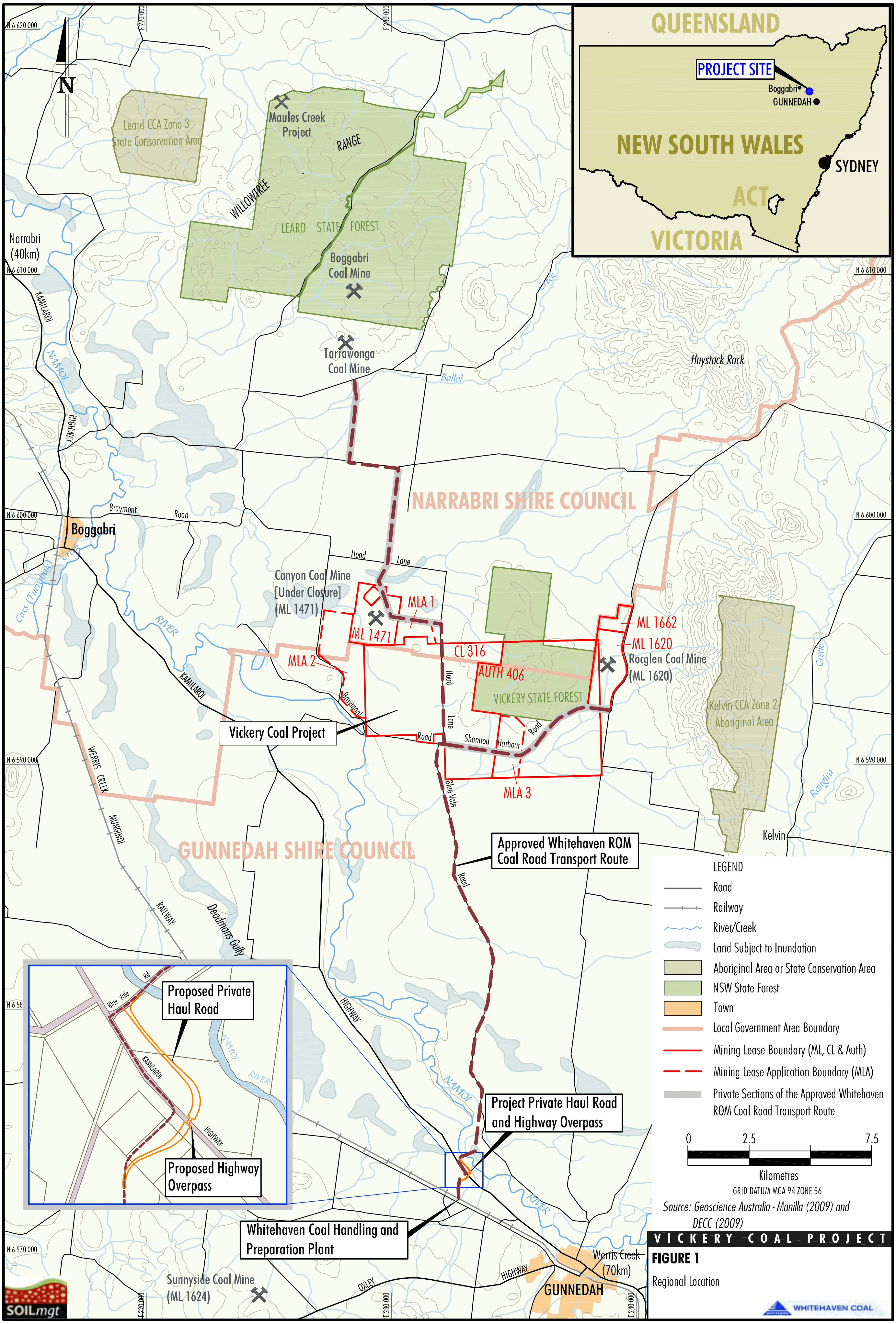
1.2 Scope and Objectives

This assessment has been prepared to assist with addressing of the following components of the Director-General's Requirements for the Project:

***Land Resources** – including a detailed description and assessment of impacts on:*

- *soils, land capability…;*
- *landforms and topography;*
- *land use, including agricultural, forestry, conservation and recreational use, with particular reference to agricultural land use and Vickery State Forest;*
- *agricultural resources and/or enterprises of the local area, with particular reference to highly productive alluvial soils that may be impacted directly or indirectly by the project, and including:*
    - *pre-mining and post-mining agricultural assessment and mapping (including land capability and agricultural suitability mapping) of soil characteristics, across all proposed disturbance areas, and an assessment of their value and rehabilitation limitations;*
    - *any change in land-use arising from the creation of biodiversity offsets;*
    - *a detailed description of the measures that would be implemented to avoid, reduce or mitigate impacts of the development on local agricultural resources and/or enterprises; and*
    - *justification for any significant long term changes to agricultural resources, particularly highly productive soils potentially affected by the development.*

Additional detail on the water resources used or capable of being used for agriculture is provided in the Groundwater Assessment (Heritage Computing 2012) (Appendix A of the EIS), Surface Water Assessment (Evans & Peck 2012) (Appendix B of the EIS) and the Agricultural Assessment (Resource Strategies 2012) (Appendix G of EIS).



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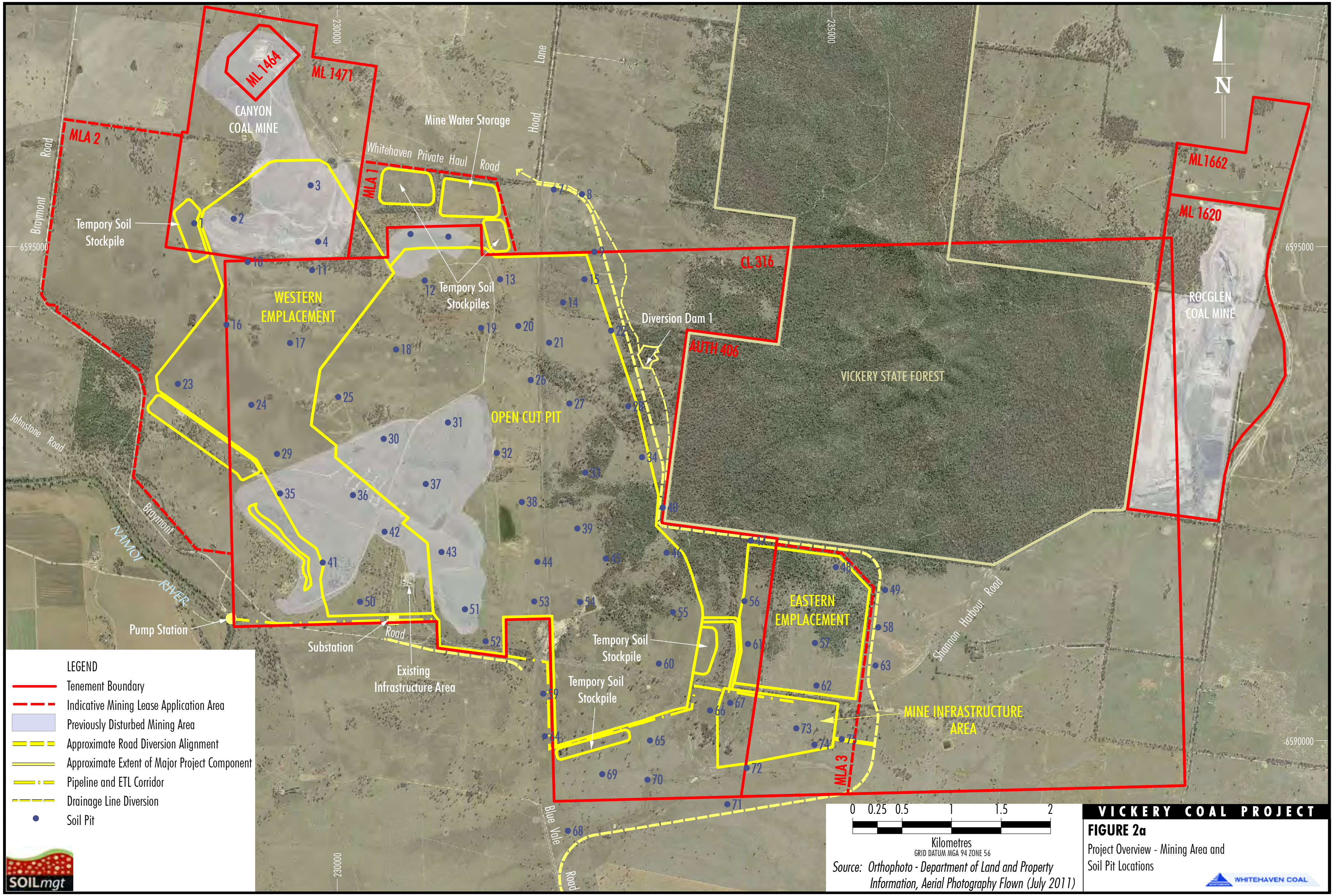

VICKERY COAL PROJECT

FIGURE 2a

Project Overview - Mining Area and Soil Pit Locations

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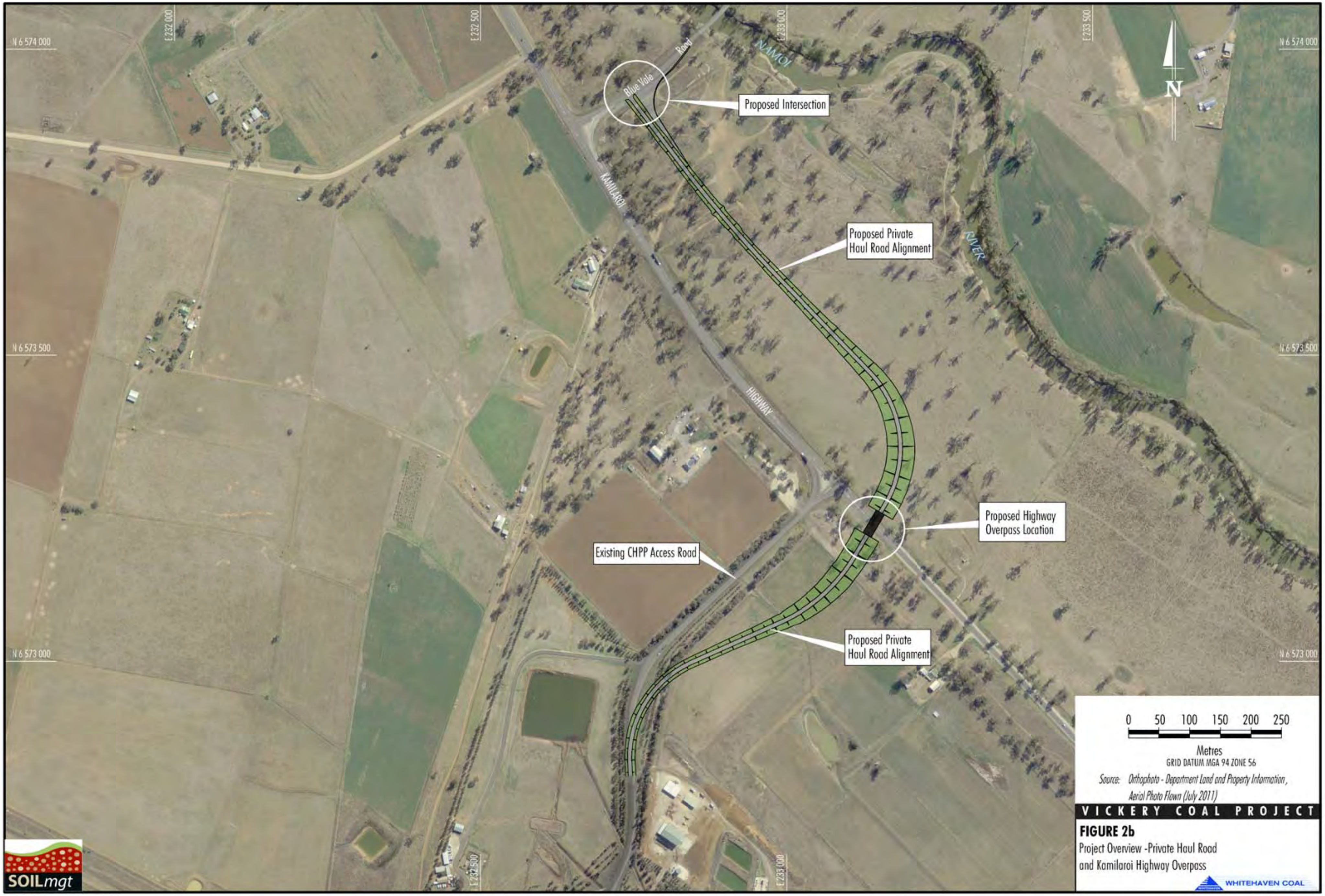

VICKERY COAL PROJECT

FIGURE 2b

Project Overview -Private Haul Road and Kamilaroi Highway Overpass

WHITEHAVEN COAL

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The objectives of this study were to:

- Describe the agriculture resources and enterprises of the lands associated with the Project site.
- Estimate the post-mining agriculture resources of the lands associated with the Project site.
- Recommend management measures for agriculture resources.

2 PROJECT OVERVIEW

The proposed life of the Project is 30 years. The main activities associated with the development of the Project would include (Figures 2a and 2b):

- development and operation of an open cut mine within Coal Lease (CL) 316, Authorisation 406, Mining Lease 1471, Mining Lease Application (MLA) 1, MLA 2 and MLA 3;
- use of conventional mining equipment, haul trucks and excavators to remove up to 4.5 million tonnes per annum of run–of-mine (ROM) coal and approximately 48 million bank cubic metres of waste rock per annum from the planned open cut;
- placement of waste rock (i.e. overburden and interburden/partings) within external emplacements to the west and east of the planned open cut (i.e. Western Emplacement and Eastern Emplacement) and within mined-out voids;
- construction and use of a mine infrastructure area (MIA), including on-site coal crushing, screening and handling facilities to produce sized ROM coal, workshops, offices and services;
- transport of ROM coal by haulage trucks to the Whitehaven Coal Handling and Processing Plant (CHPP) on the outskirts of Gunnedah (approximately 20 km to the south of the Project open cut for processing);
- use of an on-site mobile crusher for coal crushing and screening of up to 150,000 tonnes of domestic specification coal per annum for direct collection by customers at the Project site;
- use of an on-site mobile crusher to produce up to approximately 90,000 cubic metres (m^3) of gravel materials per annum for direct collection by customers at the Project site;
- construction and use of water supply bores and a surface water extraction point on the bank of the Namoi River and associated pump and pipeline systems;
- construction and use of new dams, sediment basins, channels, dewatering bores and other water management infrastructure required to operate the mine;
- construction and use of new soil stockpile areas, laydown areas and gravel/borrow areas;
- construction of a 66 kilovolt (kV)/11 kV electricity substation and 11 kV electricity transmission line;
- transport of coarse rejects generated at the Whitehaven CHPP via truck to the Project for emplacement within an in-pit emplacement area;
- Transport of tailings (i.e. the rejects) generated within the Whitehaven CHPP via truck to the Project for emplacement within co-disposal storage areas in the open cut and/or disposal in existing off-site licensed facilities (e.g. the Brickworks Pit);

- realignment of sections of Blue Vale Road and Shannon Harbour Road and Hoad Lane to the east and south of the open cut (referred to as the Blue Vale Road realignment);
- realignment of the southern extent of Braymont Road to the south of the open cut;
- construction of an approximately 1 km long section of private haul road (including an overpass over the Kamilaroi Highway) between Blue Vale Road and the Whitehaven CHPP (referred to as the private haul road and Kamilaroi Highway overpass);
- ongoing exploration, monitoring and rehabilitation activities; and
- construction and use of other associated minor infrastructure, plant, equipment and mine service facilities.

3 PROJECT SITE DESCRIPTION

The Project site is located on undulating foothills and ridges to the east of the Namoi River approximately 25 km north of Gunnedah. The Project site adjoins grazing land to the south and north, and the Vickery State Forest to the east. Approximately 20% of the Project site (465 hectares [ha]) has been disturbed as a result of previous mining activities and has subsequently been rehabilitated (Figure 2a).

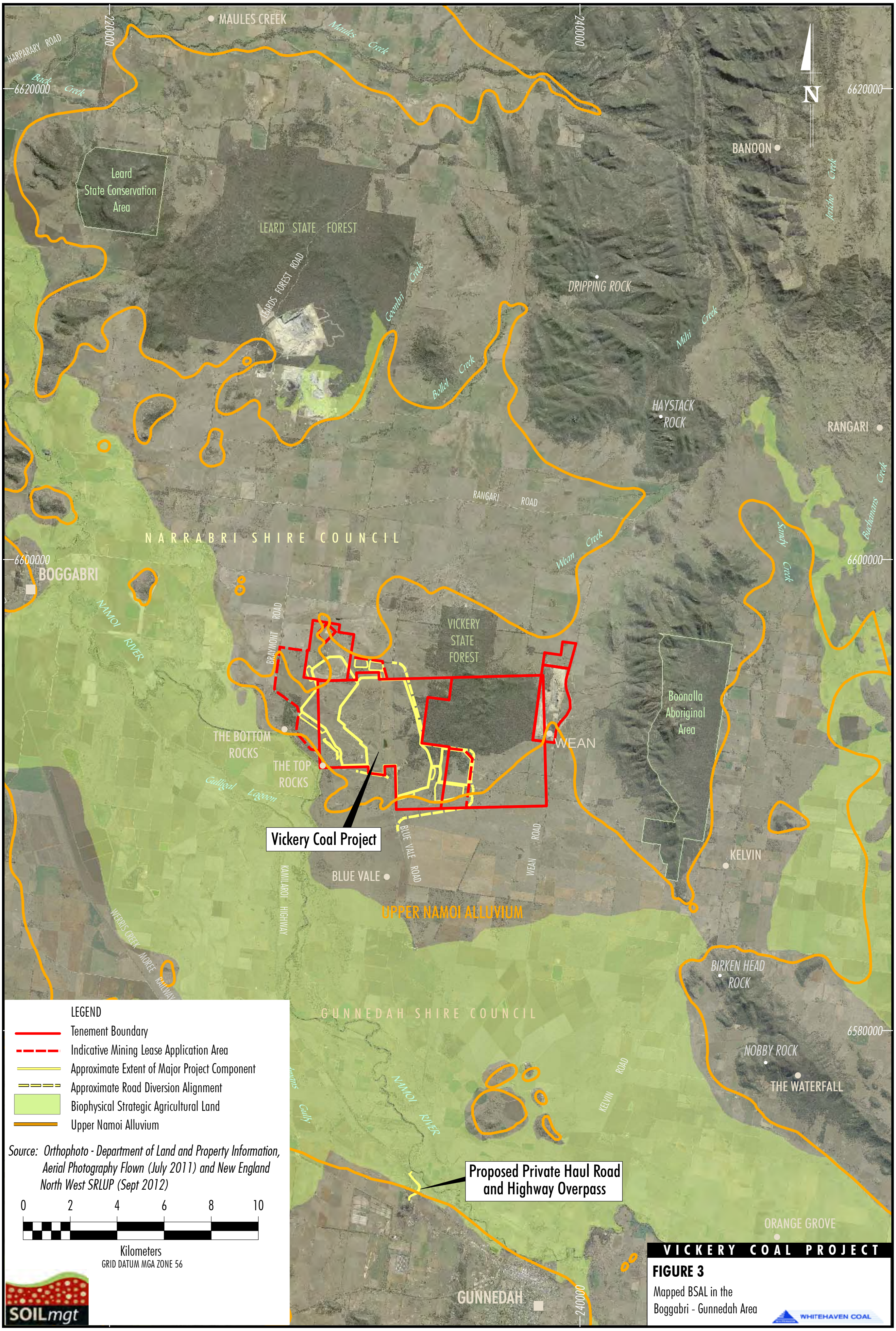
An aerial image of the Project site is shown on Figure 2a. Topographical data for the existing landscape (elevation and slope) supplied by Whitehaven are shown on **Map 1**.

The geomorphology of the Project site has been described by Fluvial Systems (2012) (Appendix A to Appendix B of the EIS). South Creek has its headwaters in the Vickery State Forest. The northern drainage line has its headwaters in the north-western section of the State Forest and is a tributary of Driggle Draggle Creek. The north-western and western drainage lines have much richer soil derived from basalt underlying Red Hill and in the vicinity of Soil Test Pits 23, 24, 29 and 36 (Figure 2a). The basalt is likely to be the remains of a Tertiary valley flow, but it could also be a plug. Regional geological mapping for the Project site lacked the detail required to be useful for soil boundary definition, however, the native vegetation mapping developed by Niche Environment and Heritage (2012) (Appendix E to the EIS) was considered during the development of soil boundaries (Section 4.3).

Elevations in the vicinity of the Project range from approximately 250 metres (m) Australian Height Datum (AHD) on a drainage line in the north-west to approximately 325 m AHD at a hilltop near the south-western corner of Vickery State Forest. Elevations in the rehabilitated areas range from approximately 260 m AHD in the main void to approximately 300 m AHD on the high points of the rehabilitated landscape (**Map 1**).

Land use within the Project site includes areas of native woodland vegetation, cleared grazing land on unimproved pastures and previously disturbed mining areas (Figure 3). The cleared grazing land is under unimproved pasture. There was no evidence of recent cropping activities within the Project site. However, Miller (1982) noted cultivation 30 years ago on the south-western slopes of Red Hill, and on the western and southern footslopes below the hills of the Vickery State Forest. Agricultural productivity data for the region and Project area is presented in the Agricultural Assessment (Resource Strategies 2012).

Mean annual rainfall over a period of approx 136 years at Gunnedah is 621 millimetres (mm) (range = 248 to 1,138 mm) (Bureau of Meteorology, 2012).



LEGEND

- Tenement Boundary
- Indicative Mining Lease Application Area
- Approximate Extent of Major Project Component
- Approximate Road Diversion Alignment
- Biophysical Strategic Agricultural Land
- Upper Namoi Alluvium

Source: Orthophoto - Department of Land and Property Information, Aerial Photography Flown (July 2011) and New England North West SRLUP (Sept 2012)

0 2 4 6 8 10

Kilometers

GRID DATUM MGA ZONE 56

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VICKERY COAL PROJECT

FIGURE 3

Mapped BSAL in the Boggabri - Gunnedah Area

WHITEHAVEN COAL

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4 SOIL RESOURCES

4.1 Existing Information

The following existing information relevant to the Project site was available for this assessment:

- *Soil Landscapes of the Boggabri 1:100 000 Sheet (Boggabri, Gunnedah, Maules Creek, Carroll)* (Banks and King in press); and
- *Miller (1982) Soil Survey Report* for the original Vickery Coal Mine EIS.

A brief summary of relevant information from the reports above is provided below.

Soil Landscapes of the Boggabri 1:100 000 Sheet

Banks and King conducted a Soil Landscapes study across the region in 2004. The report remains unpublished ('in press'), but was made available by Robert Banks (pers. comm.). The soil profile data used in their study are available from the NSW Government Soil Profile Attribute Data Environment (SPADE) Website (part of the NSW Natural Resource Atlas).

Three soil profiles descriptions in the Project site are available from this and associated studies. Their locations are shown on **Map 1**. A sub-set of the Soil Landscapes map prepared by Banks and King (in press) is shown in Appendix 1a. Features of the Soil Landscape units are described in Appendix 1b. Soil profile information from the SPADE database is presented in Appendix 1c; only one of the three profile descriptions had associated laboratory data.

Miller (1982) Soil Survey

The Vickery Soil Map prepared by Dr Stuart Miller (1982) is shown in Appendix 2. It showed a large area of rich volcanic soil (Kraznozems and Euchrozems) in the western part of the study area that was not recognised by Banks and King.

The review of previous studies indicated that very little information about soil condition was available for CL 316, MLA 1, MLA 2 and MLA3, and the two modest pre-existing studies had contradictory results. There was a clear need for new soil survey information.

4.2 Methodology

A soil survey was conducted to characterise and assess the soils in the survey area (Figure 3). 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; 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 water holding 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 procedures for the Project.

Field Survey

The field work was carried out over eleven days between 14 and 22 November 2011 and 19 to 22 December 2011. Seventy-five backhoe pits (approximately 1.4 m deep; shallower where hard rock was encountered) were assessed and the locations are shown on Figure 2a. The pits were located in a way that covered the main variations in topography, geology, land use and vegetation type. Where possible, extra pits were dug more deeply (and immediately refilled) within 15 m of the 1.4 m deep pits to allow collection of deeper soil samples, where possible, to a depth of 3 m.

The use of 75 soil pits over the 2,400 ha study area gave a sampling intensity of one pit per 32 ha. This corresponds to a soil survey with a "medium (semi-detailed) intensity level" according to the *Guidelines for Surveying Soil and Land Resources* (Gallant *et al.* 2008), i.e. a publication scale of approximately 1:50 000. This represents a study that is considered by Gallant *et al. (2008)* to be useful for "semi-detailed project planning".

It is anticipated that extra soil sampling would be required prior to the commencement of topsoil stripping to inform detailed rehabilitation planning. The survey intensity level for future investigations will be determined in consultation with the NSW Department of Primary Industries (DPI) and would form a component of the Rehabilitation Management Plan for the Project.

A 'Magellan Explorist 210' GPS instrument with an accuracy of approximately ±4 m was used to record the pit coordinates (Appendix 3).

The soil was examined using the 1.4 m deep backhoe pits. They were trimmed with a geological pick to allow photography and description of the undisturbed structure and root growth.

The field description methods were as described in the '*Australian Soil and Land Survey Field Handbook*' (The National Committee on Soil and Terrain 2009) and the '*Guidelines for Surveying Soil and Land Resources, Chapter 29*' (McKenzie 2008). The soil profiles have been classified (Appendix 3) according to the Australian Soil Classification (Isbell 2002).

An electromagnetic induction (EM) survey was carried out in December 2011 by Terrabyte Services Wagga Wagga. A quad-bike with the EM instruments was driven along transects with a spacing of 100 m. Two depth intervals were considered simultaneously; to a depth of approximately 5 m (EM31 map) and to a depth of about 1.5 m (EM38 map) (Appendix 4). The EM survey was carried out soon after prolonged and heavy rainfall, meaning that one of the three major variables affecting soil electrical conductivity (soil moisture content) was relatively uniform across the study site, therefore allowing variations in soil salinity and profile clay content to be assessed. The results are shown in Appendix 4.

Field Soil Observations/Testing

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 3, 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 1.5–2.0.

Hand texturing (The 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.

Laboratory Soil Testing

A total of 325 × 1 kilogram (kg) soil samples were collected from 75 pits:

- 0-15 centimetres (cm): 75 samples;
- 15-30 cm: 71 samples (some of the rehabilitation sites had waste rock below 30 cm);
- 30-60 cm: 68 samples;
- 60-90 cm: 61 samples (some of the hill sites had hard rock below 60 cm);
- 90-120 cm: 26 samples (only collected where a contrasting/important layer of soil was observed below 90 cm);
- 120-150 cm: 2 samples (only collected where a contrasting/important layer of soil was observed below 120 cm);
- 2 m: 11 samples (mainly alluvial sites); and
- 3 m: 11 samples (mainly alluvial sites).

Where an important horizon had to be kept separate for analysis and it did not fit in with the set sampling depths, adjustments were made; for example in Pit 21, the first depth interval (0-15 cm) became 0-8 cm and the second (15-30 cm) became 8-20 cm.

The soil was analysed by Incitec-Pivot Laboratory, Werribee Victoria for exchangeable cations, pH, electrical conductivity, 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, and magnesium. 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) – see Table 1. 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 (Figure 4).

Table 1. 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

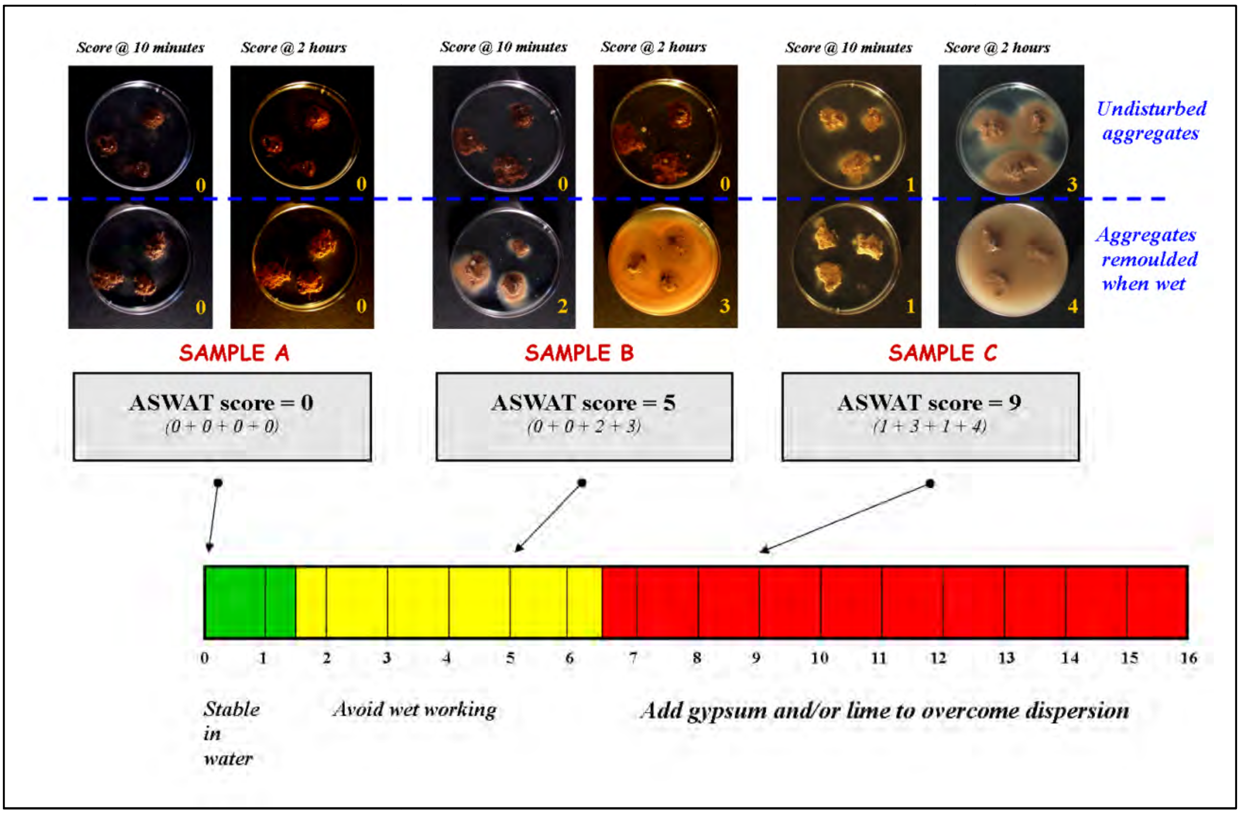


Figure 4. The Link between ASWAT Results and Soil Management Options (McKenzie 2012)

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

Twelve calibration samples (2 kg samples from Field Pit 49 (0-15 cm, 15-30 cm, 30-60 cm, 60-90 cm), Pit 63 (0-15 cm, 15-30 cm, 30-60 cm, 60-90 cm), and Field Pit 72 (0-15 cm, 15-30 cm, 30-60 cm, 60-90 cm)[1] were analysed by NSW Soil Conservation Service (SCS) Laboratory for the following analyses, which are part of the 'Erosion and Sediment Control' package (Appendix 8):

- Dispersion percentage.
- Emerson Aggregate Stability Test.
- Organic carbon.
- Particle size analysis.
- Particle size analysis – mechanical dispersion.
- Soil erodibility factor (K factor).

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

Map 2. Soil types (Australian Soil Classification).
Map 3. Depth to rock.
Map 4. Depth to gravel/sand layers in alluvium/colluvium.
Map 5. Plant available water (TAW).
Map 6. Depth of waterlogged (mottled) layer.
Map 7. Dispersion (ASWAT) scores.
Map 8. Dispersion (Exchangeable sodium percentage [ESP] values).
Map 9. Compaction severity (SOILpak score).
Map 10. CEC.
Map 11. Salinity (electrical conductivity [ECe]).
Map 12. pH ($CaCl_2$).
Map 13. Phosphorus (Colwell P).
Map 14. Organic carbon (%).

4.3 Soil Types and Mapping

General Description of Soil Types

The Australian Soil Classification (Isbell 2002) has been used to determine soil types at each of the 75 pits (**Map 2**). Vegetation mapping developed by Niche Environment and Heritage (2012) as part of the Project Ecological Assessment (Appendix E to the EIS) was considered during the description of the extent of the soil types. A summary of the soil types observed during the survey is shown in Table 2.

[1] Field Pit 49 = **Map Pit 55**, Field Pit 63 = **Map Pit 69** and Field Pit 72 = **Map Pit 24**.

Table 2. Soil Types According to the Australian Soil Classification

Soil Groupings	Australian Soil Classification Orders	Australian Soil Classification Suborders	Number of Soil Profiles in Each Category
Lacking strong texture contrast between topsoil and subsoil – loam topsoil (24)	Ferrosol (3)	Red	3
	Dermosol (19)	Red	6
		Brown	11
		Grey	2
	Kandosol (2)	Red	1
		Brown	1
Strong texture contrast – loam topsoil, clay-rich subsoil (21)	Sodosol (16)	Red	3
		Brown	8
		Yellow	2
		Grey	3
	Chromosol (5)	Red	1
		Brown	3
		Grey	1
Rehabilitated soil (12)	Anthroposol	Spolic	12
Cracking clays (8)	Vertosol (8)	Red	1
		Brown	6
		Grey	1
Deep recent alluvium (6)	Rudosol	Stratic	6
Shallow stony soil (4)	Tenosol	Leptic	4

The main soil types were Dermosols (25%) and Sodosols (21%). Anthroposols (all Spolic) (16%), Vertosols (11%), Rudosols (all Stratic) (8%), Chromosols (7%), Ferrosols (4%), Tenosols (5%) and Kandosols (3%) were also observed:

- Dermosols lack strong texture contrast between topsoil and subsoil, and have structured B horizons.
- Sodosols have a strong texture contrast between topsoil and sodic (ESP of 6 or greater) subsoil (B horizon) which is not strongly acidic.
- Anthroposols are soil types strongly modified by the activities of humans.
- Vertosols are clay-rich soils that exhibit cracking when dry.
- Stratic Rudosols are characterised by a number of alluvial depositional layers that have been little altered by pedogenic processes except at or near the surface. The uppermost depositional layers may be as young as recent floods (McKenzie *et al.* 2004).
- Chromosols are duplex, i.e. a strong contrast in texture between topsoil and subsoil. They have subsoil which is not strongly acidic and not sodic.

- Ferrosols have subsoils that are high in free iron oxide, and which lack strong texture contrast between topsoil and subsoil.
- Tenosols are shallow stony soils with only weak pedological development.
- Kandosols lack strong texture contrast and have poorly structured massive subsoils.

Approximate correlations between the Australian Soil Classification (Isbell 2002) and the superseded Great Soil Group (Stace *et al.* 1968) terminology are shown in Table 3.

Table 3. Association between Australian Soil Classification and Great Soil Groups

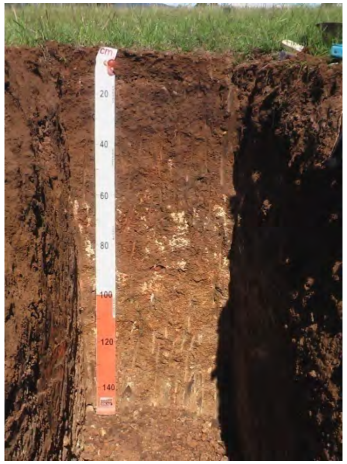
Australian Soil Classification	Great Soil Group
Dermosols	Prairie soils, chocolate soils, some red and yellow podzolic soils
Sodosols	Solodized solonetz and solodic soils, some soloths and red-brown earths
Anthroposols	n/a
Vertosols	Black Vertosols = Black Earths Red, Brown & Grey Vertosols = Red, Brown & Grey Clays
Stratic Rudosol	Alluvial soils
Chromosols	Non-calcic brown soils, some red-brown earths and a range of podzolic soils
Ferrosols	Kraznozems and Euchrozems
Tenosols	Lithosols, silicious and earthy sands
Kandosols	Red, yellow and grey earths, calcareous red earths

Photos of representative soil profiles identified during the survey are presented in Figures 5a and 5b.

The Soil Landscape Units that contain groupings of these soil types identified during the survey are shown in Figure 6. Their descriptions are as follows:

- **Rehabilitated Land** – Disturbed mining lands with a broad range of slopes; Anthroposols.
- **Drainage Line Variant a** - Ancient clay-rich plains and recent colluvium; strongly saline in low-lying areas; mainly in the area near Stratford Creek (Fluvial Systems 2012); dominated by Brown and Grey Vertosols and Brown Dermosols; Sodosols and Stratic Rudosols sub-dominant.
- **Drainage Line Variant b** – Sand-dominated recent drainage-line-deposits in the northern drainage line; mainly Stratic Rudosols with saline subsoils.
- **Drainage Line Variant c** – Recent drainage-line-deposits and colluvium derived from a mix of basic volcanic and sedimentary parent materials (north-western and western drainage lines); dominated by Dermosols; Vertosols and Sodosols sub-dominant in upper reaches of north-western drainage line); Chromosols and Kandosols sub-dominant west of Hoad Lane.


Red Dermosol– Pit 24


Brown Dermosol – Pit 53


Red Ferrosol – Pit 19


Red Vertosol – Pit 12


Brown Vertosol – Pit 70


Brown Chromosol – Pit 54


Stratic Rudosol – Pit 9


Brown Sodosol – Pit 57


Grey Sodosol – Pit 33


Leptic Tenosol – Pit 48

Figure 5a. Examples of the Soil Types Identified during the Survey

Anthroposol – Pit 3

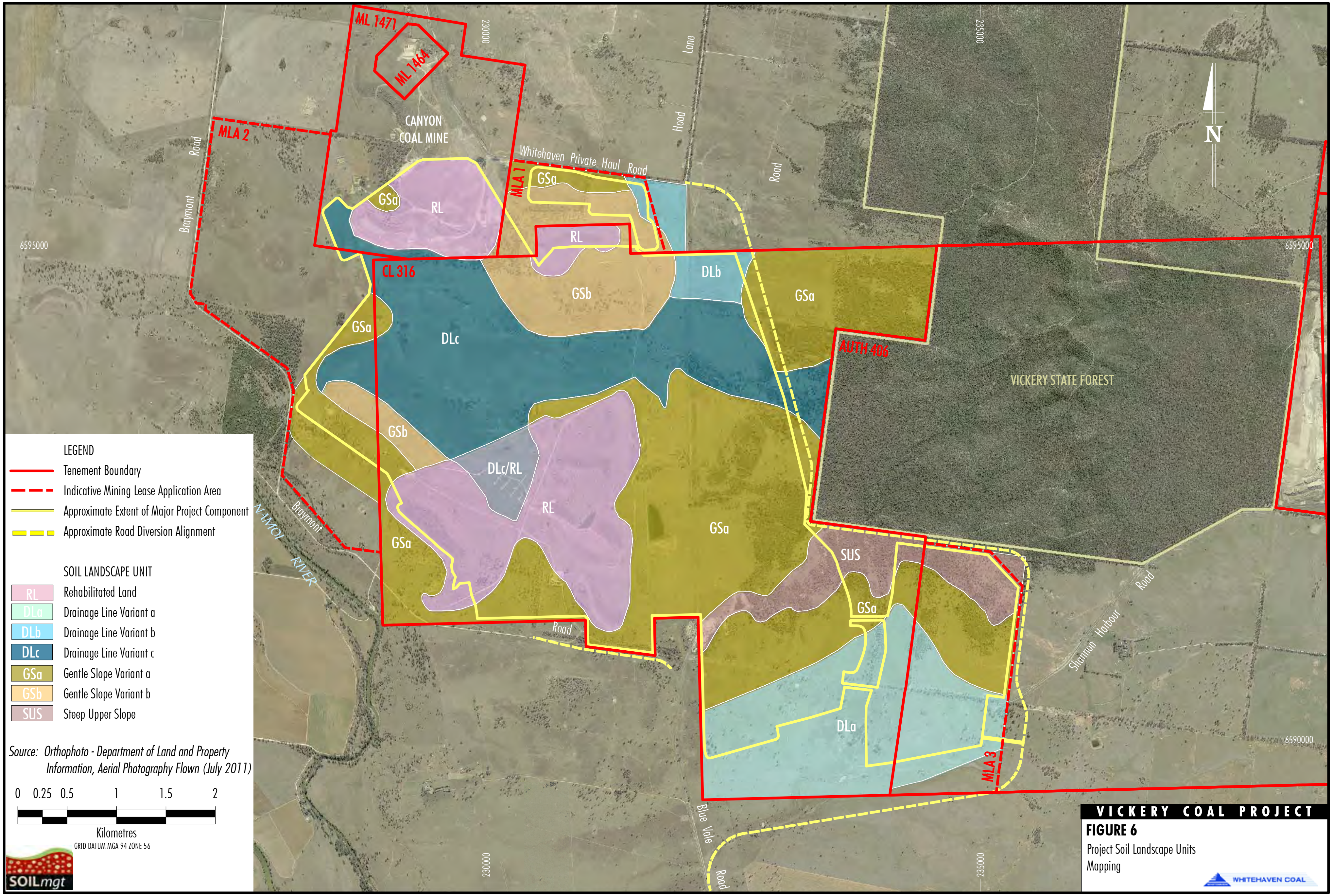
Anthroposol – Pit 37

Anthroposol – Pit 5

Anthroposol – Pit 51

Anthroposol – Pit 2

Figure 5b. Examples of Soil Profiles Observed in the Rehabilitated Areas



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- **Gentle Slopes Variant a** – 3-10% slope on sedimentary parent material (sandstone, siltstone, conglomerate); mosaic of Sodosols, Vertosols (possibly aeolian origins), Chromosols and Dermosols.
- **Gentle Slopes Variant b** – 3-10% slope on basaltic parent material; Red Ferrosols, Red Dermosols and Red Vertosols.
- **Upper Slopes** – >10% slope on sedimentary parent material; dominated by Tenosols.

4.4 Soil Conditions for Plant Growth

Soil Depth, Texture and Water Holding Capacity

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

Map 3 shows the decrease in soil depth that tends to occur moving up the hill from the drainage lines at the survey site. The shallow areas are associated with steeper slopes under the native vegetation on this steep infertile land would have prevented the development of deep soil profiles. With the surface texture being sandy loam and lighter at some of the hilly sites, wind erosion is likely to have occurred, in addition to erosion by water.

Shallow stony soil was most evident, however, on the rehabilitated sites. Photos of representative profiles are shown on Figure 5b.

Some of the soil on the drainage-line-deposits is underlain by coarse sand and/or water-worn gravel (**Map 4**) (Figure 5a, Pit 9).

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. At the Project site, the lack of waterholding capacity (**Map 5**) in shallow soils on the slopes (bedrock close to the surface) – and on drainage-line-deposit soils with coarse gravel close to the surface – is a major constraint to agricultural productivity.

Waterlogging Hazard Associated with Soil Instability in Water (Dispersion/Sodicity)

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 6**). Mottles are blotches of sub-dominant colours different from the matrix colour; for example, grey or yellow blotches within a reddish-brown subsoil.

The main causes of waterlogging in the Gunnedah-Boggabri area under rainfed conditions (e.g. at the Project site) are likely to be soil instability in water (dispersion), and compaction by farm machinery and, to a lesser extent, by large grazing animals (McKenzie and McGarry 2000).

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). It 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).

Two maps relating to soil stability in water are presented. 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. Much of the topsoil and subsoil in the survey area is prone to dispersion, particularly after being worked when wet.

ESP values (**Map 8**) are mostly lower than expected for such dispersive soil (as indicated by the ASWAT scores). The Electrochemical Stability Index values (Appendix 7), however, are very low indicating that most of the soil in the survey area has aggravation of dispersion because of very low electrolyte concentrations. Nevertheless, soil derived from the volcanic parent material in the west of the study area is less dispersive than soil on the sedimentary rock.

The main chemical factors influencing the behaviour of clay particles in sodic soils are exchangeable sodium and electrolyte concentration, but elevated exchangeable magnesium concentrations also can make clay particles in soil less stable in water (Levy 2000). On the non-volcanic areas, there were some very low 'exchangeable calcium' –'exchangeable magnesium' ratios that would contribute to dispersion problems.

Laboratory analysis results for soil erosion hazard are shown in Appendix 8 for three of the pits (Pits 24, 55 and 69 [field pit numbers 72, 49 and 63, respectively]).

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). The topsoil mostly was not compacted, except on sodic Vertosols along Stratford Creek (**Map 9**). Subsoil compaction was widespread, due apparently to residual damage from heavy machinery used in the previous mine disturbance area, and possibly because of farming operations that occurred in previous decades.

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 10**) (McKenzie 1998).

Much of the topsoil had a poor shrink-swell capacity, so the rate of recovery from compaction damage would be slow. The clay-rich Vertosols at the site (mainly in the south) have favourable self-repair capacity via shrink-swell processes, although structural form tends to quickly decline again because of structural instability associated with sodicity.

Salt Concentrations

Salinity at concentrations high enough to adversely affect most crops and pastures was evident in much of the subsoil derived from sedimentary parent material, but it was not a constraint in the well-drained volcanic soil (**Map 11**). Boundaries of the saline areas can be seen on the EM maps (Appendix 4).

pH Imbalance

Topsoil acidity was widespread across the area surveyed (**Map 12**) and was associated with the presence of exchangeable aluminium (Appendix 7). However, the acidity only extended deeply into the subsoil in the volcanic areas.

Nutrients

Much of the soil was deficient (from an agricultural perspective) in phosphorus in the survey area (**Map 13**). The only exception was on shallow soil of the rehabilitated areas. Sulfur deficiency (Appendix 7) was widespread in the non-saline parts of the survey area. There was evidence of zinc deficiency across most of the site.

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 (**Map 10**) show CEC trends across the area surveyed.

Soil Carbon and Soil Biological Health

At the time of sampling, organic matter content of the soil was poor, particularly below a depth of 15 cm (**Map 14**).

5 RURAL LAND CAPABILITY ASSESSMENT

5.1 Background

The Rural Land Capability classification in NSW was developed by the NSW SCS (Emery 1986). It was derived from the scheme of Klingebiel and Montgomery (1961).

Land is allocated to one of eight classes, with emphasis on the erosion hazards in the use of the land. The Rural Land Capability classes are as follows (Emery 1986; Sonter and Lawrie 2007):

Land Suitable for Regular Cultivation / Cropping

Class I: No special soil conservation works or practices necessary.

Class II: Soil conservation practices such as strip cropping, conservation tillage and adequate crop rotations are necessary.

Class III: Soil conservation practices such as graded banks and waterways are necessary, together with all the soil conservation practices as in Class II.

Land Suitable Mainly for Grazing

Class IV: Soil conservation practices such as pasture improvement, stock control, application of fertiliser, minimal cultivation for the establishment or re-establishment of permanent pasture and maintenance of good ground cover.

Class V: Soil conservation works such as diversion banks and contour ripping, in addition to the practices in Class IV.

Land Suitable for Grazing

Class VI: Not capable of cultivation. Soil conservation practices include limitation of stock, broadcasting of seed and fertiliser, promotion of native pasture regeneration, prevention of fire, destruction of vermin, maintenance of good ground cover and possibly some structural works.

Land Suitable for Tree Cover

Class VII: Land best protected by trees.

Land Unsuitable for Agriculture

Class VIII: Cliffs, lakes or swamps where it is impractical to grow crops or graze pasture.

5.2 Existing Information

Pre-existing Rural Land Capability mapping for the Project area, buffer area and the proposed biodiversity offset area from the NSW Office of Environment and Heritage (OEH) is shown in Appendix 9. It indicates that the Land Capability of the Project area and offset area range from Class II to Class VI and Class V to Class VIII respectively.

5.3 Rural Land Capability Classification

Rural Land Capability mapping was prepared for the Project disturbance area based on the results of the soil survey conducted in 2011 (Section 4).

Land slope is a primary determinant of Rural Land Capability because erosion hazard increases with slope steepness and because slope steepness imposes physical limits on many types of land usage (Sonter and Lawrie 2007). The slope categories in Table 1 of Murphy and Taylor (2008) assisted in determining the class allocation.

Estimates of Rural Land Capability across the Project site based on the site investigation are shown on Figure 7. Values ranged from Class II, in the relatively flat zone dominated by volcanic material, to Class VI. The major factor influencing the classification was land slope. The slope of the land ranged from approximately 0.5% in the Class II areas to approximately 20% on the steepest hillsides with a Class VI classification.

The presence – across the site – of soil with a strong potential to disperse, topsoil acidity, subsoil salinity and major nutrient deficiencies prevented the allotment of Rural Land Capability categories that were more favourable. All of these factors reduce a landholder's ability to create and maintain organic material to protect soil surfaces from water and wind erosion.

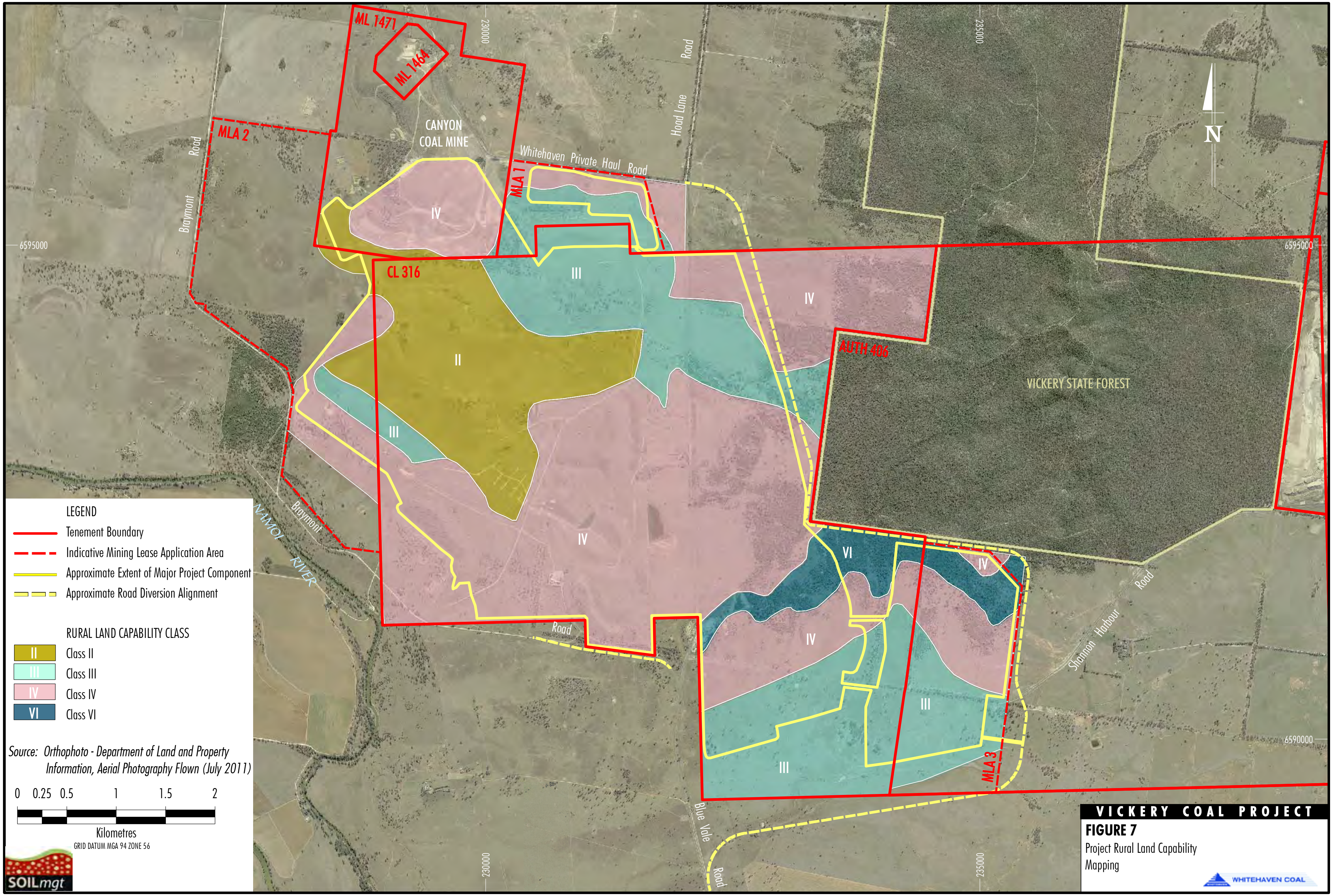

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FIGURE 7

Project Rural Land Capability Mapping

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6 AGRICULTURAL SUITABILITY ASSESSMENT

6.1 Background

This five class system used by NSW Agriculture classifies land in terms of its suitability for general agricultural use (Hulme *et al*. 2002). It was developed specifically to meet the objectives of the NSW *Environmental Planning and Assessment Act, 1979*.

Agricultural land is classified by evaluating biophysical, social and economic factors that may constrain the use of land for agriculture. In general terms, the fewer the constraints on the land, the greater its value for agriculture (Hulme *et al*. 2002). Higher quality lands (Classes 1 and 2) have fewer constraints and a greater versatility for agriculture than poorer quality lands. The essential characteristics of the five classes are as follows (Hulme *et al*. 2002):

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

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

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

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

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

Hulme *et al.* (2002) recognised that agriculture suitability classification maps have a limited life because of changes in social and economic factors. They also note that agricultural land classification maps produced at small scales (1:50 000 to 1:100 000) are inappropriate for making decisions about individual Development Applications because of a lack of detail.

6.2 Existing Information

Pre-existing Agricultural Suitability Mapping from the OEH for the Project area, buffer area and the proposed biodiversity offset area is shown in Appendix 9. It indicates that Agricultural Suitability of the Project area and offset area ranges from Class 2 to Class 4 and Class 4 to Class 5 respectively.

6.3 Agricultural Suitability Classification

Agricultural Suitability mapping for the Project disturbance area was prepared based on the results of the soil survey conducted in 2011 (Section 4).

Agricultural Suitability classes identified across the site ranged from Class 2 to the dominant Class 4 (Figure 8). The volcanic soil in the west of the study area had the best ratings, however, it is noted that the limited area of Class 2 land within the Project disturbance area may not be suitable for modern broad acre farming equipment.

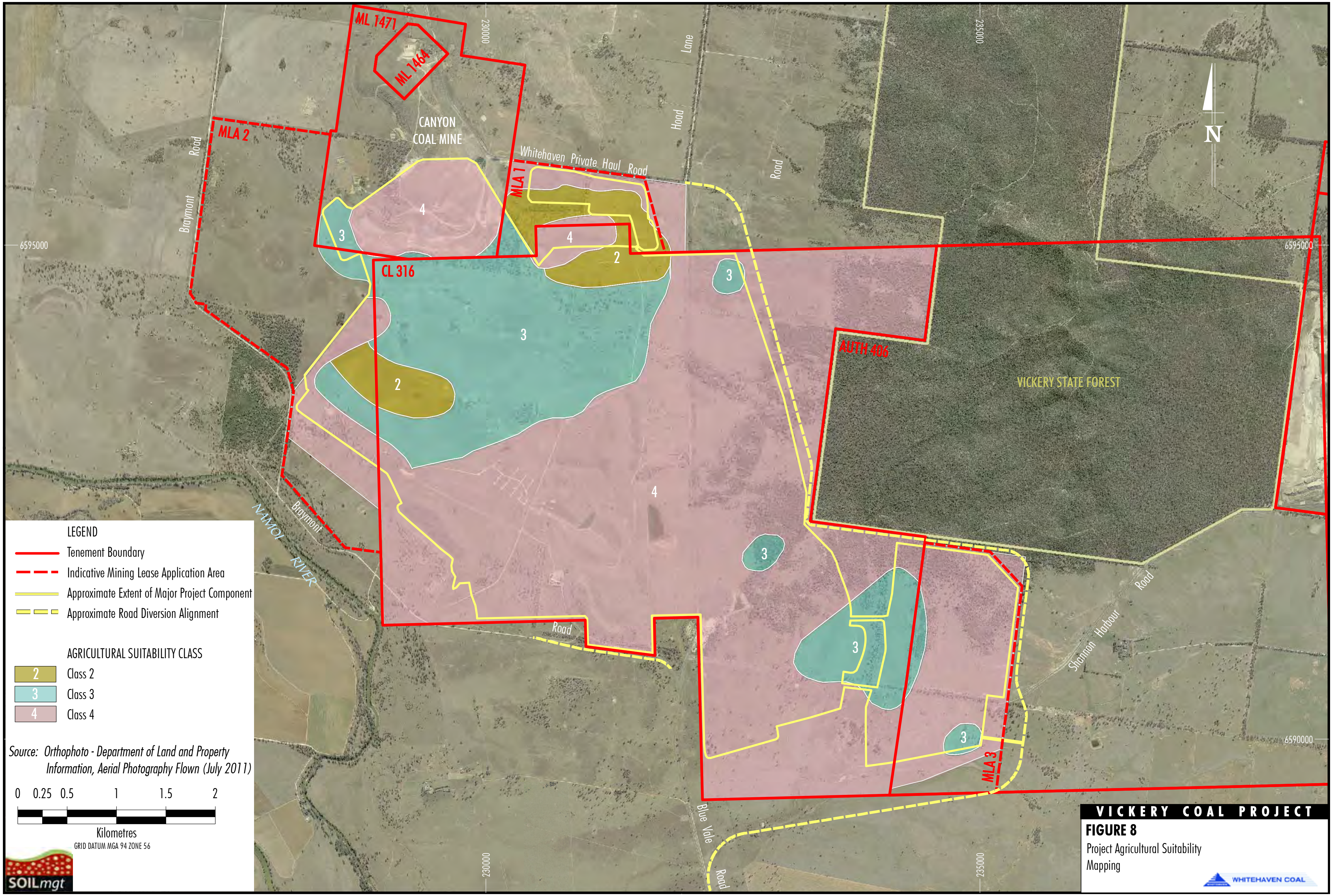
To illustrate how the Agricultural Suitability of the Project site was determined, the 9 soil related factors considered at eight of the 75 locations across the Project site are shown in Appendix 10.

The analysis shows that almost all parts of the Project area had at least one soil physical/chemical fertility constraint when examined in late 2011.

Land slope had a major bearing on the Agricultural Suitability of the Project site. Terracing is used to overcome slope and soil shallowness limitations in other parts of the world, but usually is not economically viable under Australian conditions. In contrast, topsoil limitations such as dispersion, compaction, acidity and nutrient deficiency can be overcome in a cost-effective manner through improved soil management.

Sites 18, 19 and 25 could be converted from Class 3 agricultural land to Class 2 through a lime application program to overcome soil acidity limitations. The rating of much of the sodic soil could be improved through a gypsum amelioration program.

Nutrient limitations were not emphasised in the assessment because they can be dealt with easily and routinely as part of crop/pasture planting operations.



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7 BIOPHYSICAL STRATEGIC AGRICULTURAL LAND

The *New England and North West Strategic Regional Land Use Plan* (SRLUP) (OEH, 2012) forms a component of the NSW Government's broader Strategic Regional Land Use Policy which aims to address land use conflicts in regional areas.

The SRLUP provides a framework to assess the presence of highly productive agricultural land (i.e. Biophysical Strategic Agricultural Land [BSAL]) using a set of criteria including draft 'Inherent General Soil Fertility' and 'Land and Soil Capability' mapping developed at a regional scale (Appendix 11).

An assessment against the BSAL criteria (Inherent General Soil Fertility, Land and Soil Capability and reliable water supply) based on interpretations against data collected during investigations at the Project site (Section 4) has been conducted and is presented in Appendix 11.

8 REHABILITATION AND SOIL MANAGEMENT

8.1 Proposed Rehabilitation Strategy

The Project site currently is dominated by cleared agricultural land used for pasture production for livestock. The Project would be progressively rehabilitated in a manner that provides a sustainable balance between this existing land use and woodland areas. The Project final landform and land uses following completion and closure of the Project are presented on Figure 9.

The final landform concept includes the establishment of a woodland vegetation corridor that would link the Vickery State Forest to existing woodland vegetation to the west of the Project and subsequently the riparian areas associated with the Namoi River. As shown on Figure 9, the northern portion of the final landform would comprise woodland vegetation to provide the east-west vegetation corridor. The Eastern Emplacement would also be rehabilitated to woodland vegetation.

The southern portion of the final landform, including the MIA, would be rehabilitated to pasture suitable for grazing, of comparable Agricultural Suitability to the majority of the existing rehabilitated and agricultural land within the Project area (i.e. Class 3 or Class 4 Agricultural Suitability).

The details of the proposed rehabilitation strategy for the Project are presented in Section 5 in the Main Report of the EIS.

8.2 Soil Resource Estimate

The available soil resource for rehabilitation at the Project has been estimated. The stripping depths have been selected such that only soils suitable for use as plant growth media for drought-tolerant improved pasture would be stripped.

The suitability of the soils for this purpose 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 4. It has also been assumed that appropriate management practices (Section 8.4) are implemented during soil handling and relevant amelioration measures (Section 8.3) are applied where necessary[2].

[2] Soil materials for mine site rehabilitation can be ameliorated for physical and chemical attributes that might otherwise preclude their general use (Elliot and Reynolds 2007).

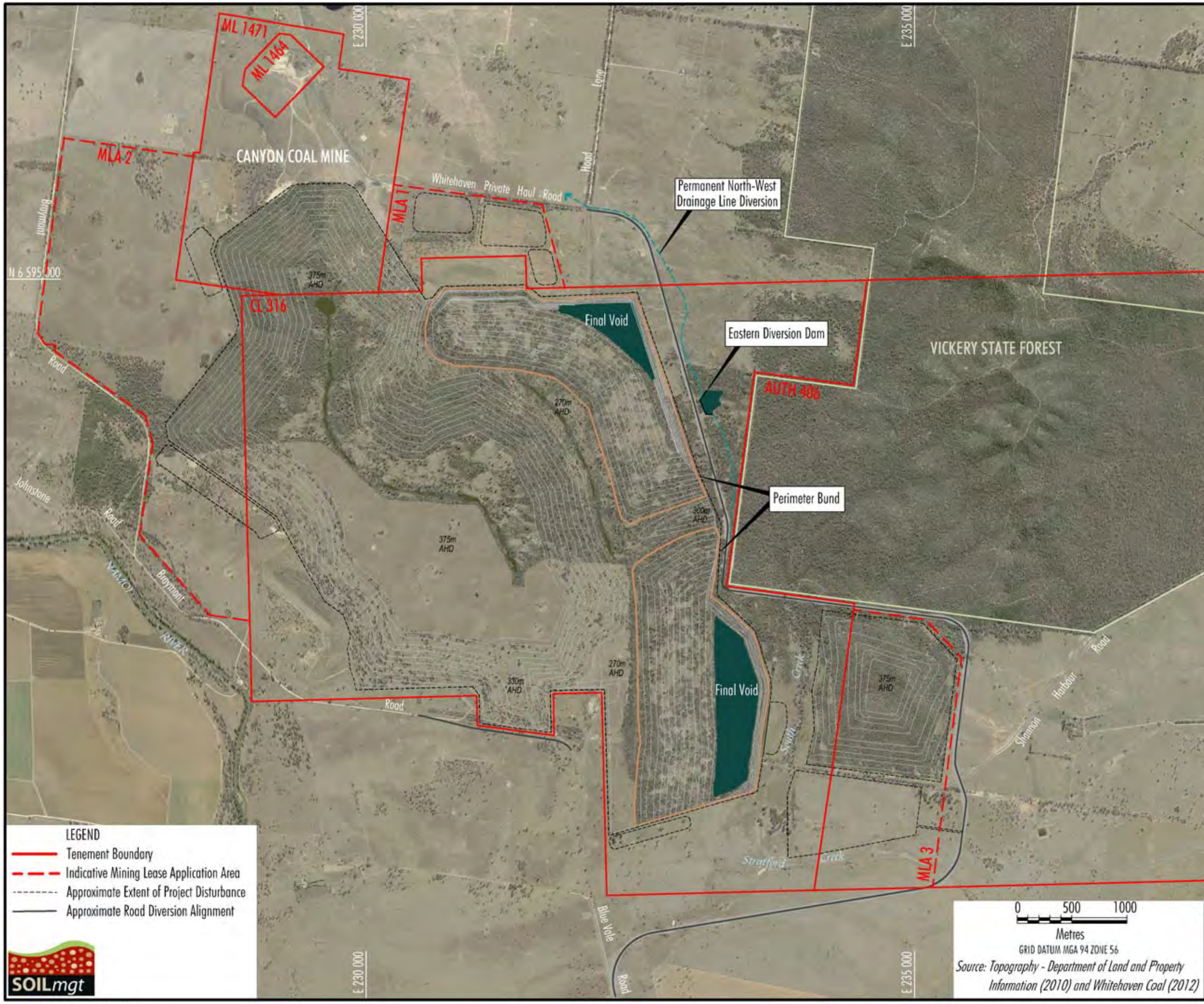

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FIGURE 9

Conceptual Final Landform

Table 4. Soil Suitability Criteria

Parameter	Cropping/Grazing targets
Compaction severity (SOILpak score)	Topsoil: >1.5 Subsoil >1.0
Exchangeable Sodium Percentage	Topsoil: <2 Subsoil <6
Acidity (pH $CaCl_2$)	>5.5, <8.0
Salinity (ECe, dS/m)	<1.5
CEC (meq/100 g)	>15 if possible
Phosphorus (Colwell; mg/kg)	>30
Depth	Root zone depth ranging from up to 90 cm (pasture) to 30 cm (woodland), on top of waste rock broken up as finely as possible, to maximise soil water storage and therefore minimise the adverse impacts of drought.

dS/m = deciSiemens per metre.
mg/kg = milligrams per kilogram
meq/100g = milliequivalent of hydrogen 100grams.

Two soil stripping maps are presented. Figure 10 shows recommended topsoil stripping depths. Some of this material is acidic and requires lime application, but otherwise it is low sodicity/low salinity and from the depths with maximum organic matter contents. There are favourable volumes of rehabilitation material in the volcanic zones. However, the soil on sedimentary rock just to the west and south of the Vickery State Forest is much less suitable as a material for rehabilitation. The Stratic Rudosols along the northern drainage line are very sandy with saline subsoil, so their potential as a material for rehabilitation is poor.

Given that there are likely to be shortages of "topsoil" for rehabilitation in the non-volcanic areas, a companion stripping map has been prepared (Figure 11) that shows where extra cutting can occur to pick up sodic subsoil which has the potential to be ameliorated through the use of gypsum. Strongly sodic subsoil (i.e. ESP >10) and saline subsoil (ECe > 1.5) has been avoided.

Prior to commencement of topsoil stripping in the areas with the greatest potential for provision of rehabilitation materials (i.e. the soil on the volcanic parent materials), extra field testing (sodicity/dispersion/acidity focus) would be conducted in these areas to refine the soil stripping maps. The survey intensity level for these investigations will be determined in consultation with the DPI and would form a component of the Rehabilitation Management Plan for the Project. It was anticipated that the EM survey (Appendix 4) would help to improve accuracy of the stripping maps, but unfortunately much of the poor soil derived from sedimentary rock had a similar EM signal to that of soil on the volcanic parent material.

The approximate volume of soil that would be available for rehabilitation purposes based on the mapping included on Figures 10 and 11 is provided in Tables 5 and 6.

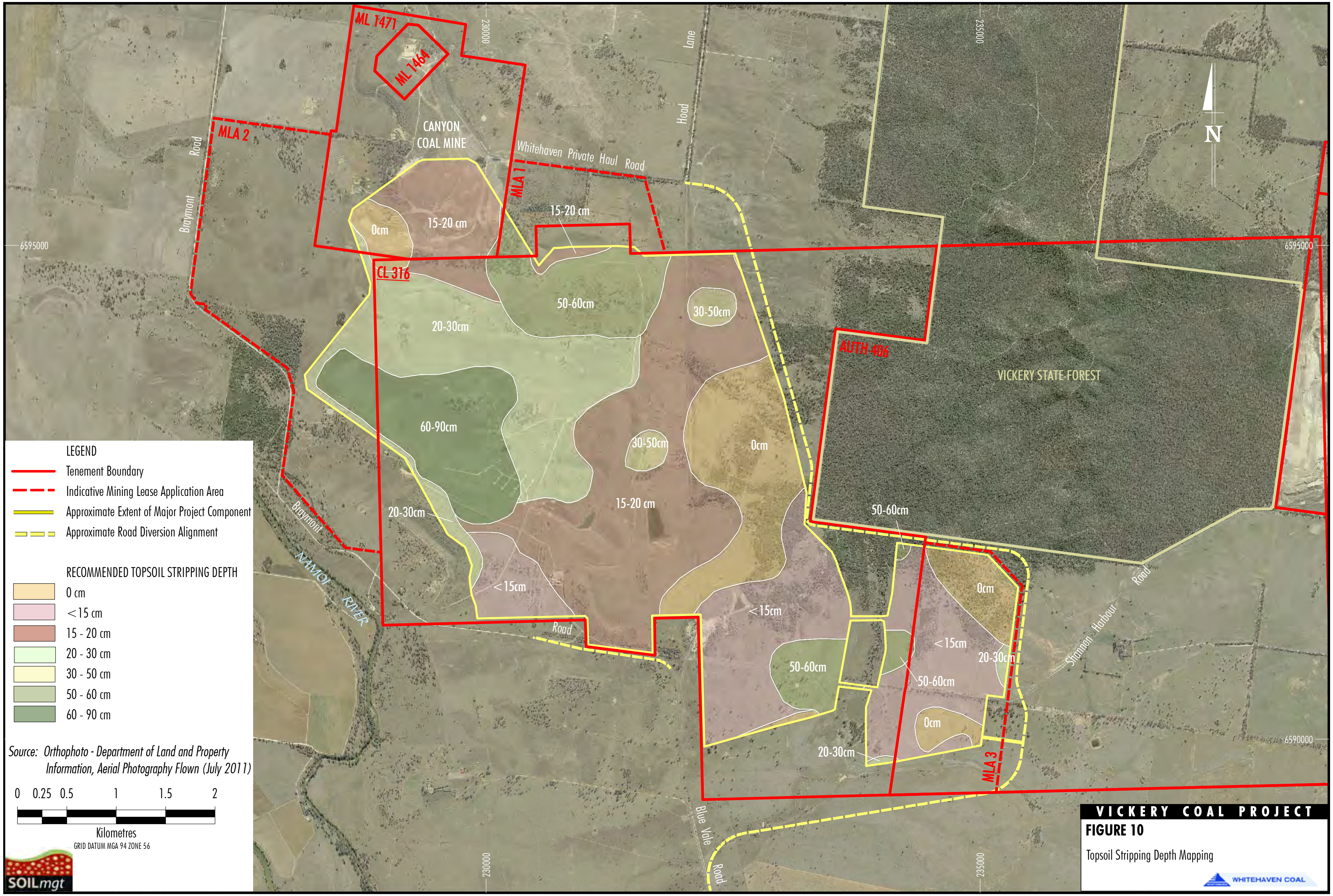

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FIGURE 10
Topsoil Stripping Depth Mapping

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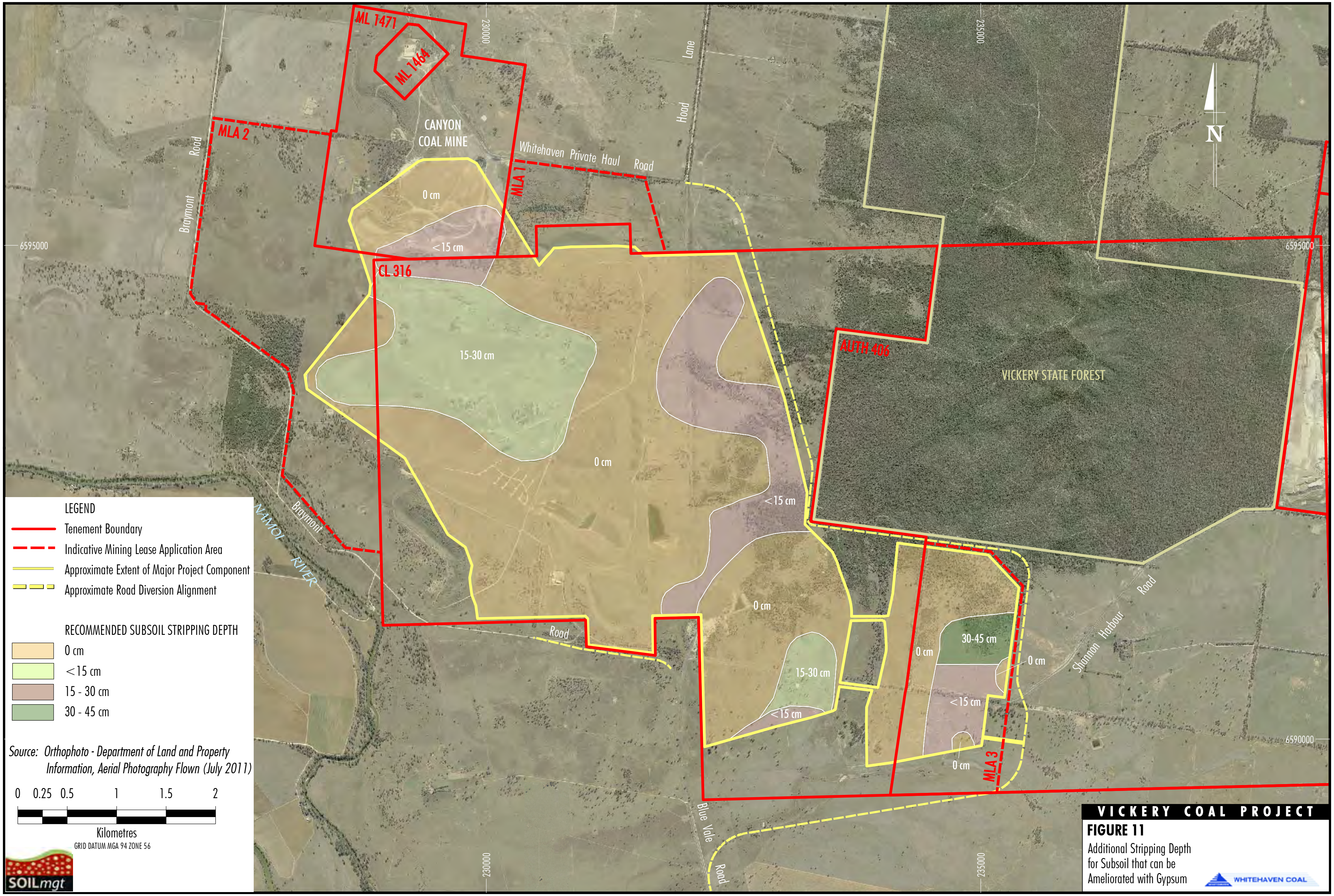

FIGURE 11
Additional Stripping Depth for Subsoil that can be Ameliorated with Gypsum

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Table 5. Soil Resource Availability

Recommended Stripping Depth (cm) (refer Figure 10)	Approximate Stripping Area (ha)	Approximate Volume (m^3)
< 15	408	611,480
15 – 20	570	1,139,850
20 – 30	321	961,790
30 – 50	30	147,730
50 – 60	195	1,171,490
60 - 90	210	1,893,900
Total	**1,734**	**5,926,240**

Table 6. Additional Soil Resource Availability Following Deeper Excavation and Gypsum Treatment

Recommended Stripping Depth (cm) (refer Figure 11)	Approximate Stripping Area (ha)	Approximate Volume (m^3)
< 15	658	947,500
15 – 30	652	1,956,890
30 – 45	34	154,800
Total	**1,344**	**3,059,190**

Preliminary material balance calculations based on the recommended soil stripping depths outlined in Tables 5 and 6 indicate an approximate topsoil/subsoil volume of 8,985,430 m^3 would be available from the Project disturbance area for use during future rehabilitation.

The available soil resource outlined in Tables 5 and 6 is sufficient to allow for soil re-application to a depth of up to approximately 90 cm (i.e. re-establishment of a full soil profile) on 780 ha of rehabilitated agricultural (grazing) areas and for up to approximately 30 cm to be used on other Project mine landforms to create woodland areas.

The mine plan has been used to determine the volume of topsoil that would be stripped, used in rehabilitation, or stockpiled over the life of the Project. This topsoil inventory is shown in Table 7.

Table 7. Topsoil Inventory

	Approximate Topsoil Volume Stripped (m^3)	Approximate Volume Used in Rehabilitation (m^3)	Approximate volume in Stockpiles (m^3)	Approximate Stockpile Area[1] (ha)
Years 1-2	3,015,230	654,110	2,361,120	79
Years 2-7	2,152,040	983,970	3,529,190	118
Years 7-17	1,697,500	1,655,160	3,571,530	119
Years 17-26	1,763,390	1,178,560	4,156,360	139
Year 26 - mine closure	357,270	4,516,360	0	0

[1] Assumes topsoil stockpile height of 3 m.

8.3 Soil Ameliorants

In the areas cleared for agriculture, a broad range of soil physical and chemical constraints have been identified (Section 4.4).

Much of the cleared land had evidence of structural limitations. Compaction caused by livestock trampling and heavy machinery is one of the issues. The other is dispersion, an inherent problem caused by an excess of exchangeable sodium on the clay particles.

A decline in organic matter content because of soil disturbance, and cultivation at moisture contents that were either too wet or too dry, appears to have made the soil more prone to instability in water.

Topsoil and sub-surface acidity was observed across the survey area. This appears to be an inherent problem, but it would have likely been aggravated by decades of export of agricultural produce without a counter-balance via lime application.

Notwithstanding the above, cost-effective methods are available to improve the soil for optimal production. Extension products such as the DPI SOILpak manuals (e.g. McKenzie 1998) are available to systematically assist farmers and graziers with the identification and treatment of problems such as soil structural constraints, acidification and salinity.

A summary of the soil constraints and measures which could be implemented to ameliorate the constraints is provided in Table 8. The estimated application rates and associated costs are also provided in Table 8.

It is important to note that a large proportion of the soil east of Hoad Lane has strongly saline subsoil (see **Map 11**, 60-90 cm). This is a constraint not readily corrected under dryland crops and pastures. The main option available for land managers is to select pasture/crop types/varieties that have a natural ability to cope with the elevated salt concentrations.

There are no cost effective management measures to ameliorate the presence of bedrock and/or coarse gravel close to the surface. The drought susceptibility associated with the poor water-holding capacity of shallow stony soil is unavoidable.

Table 8. Summary of Soil Constraints at the Project Site and Possible Ameliorants

Soil Constraint	Ameliorants	Application Details	Estimated Cost
Dispersion	Application of coarse-grade (20 mm-50 mm) recycled gypsum on the soil that is sodic in the 0-15 cm and/or 15-30 cm layers. Gypsum has a two-fold effect – it reduces sodicity through the displacement of exchangeable sodium and magnesium by calcium, and provides a mildly saline soil solution that creates a beneficial electrolyte effect.	Rate = 2.5 tonnes per hectare (t/ha); So and McKenzie (1984)[1].	$225 per ha. Cost includes purchase price (delivered to Gunnedah) and spreading; McKenzie *et al.* (1995) data[2].
Compaction	Mechanical loosening with an implement such as an agrowplow across all of the farming and grazing land. Procedures to minimise the risk of re-compaction, e.g. GPS guidance of farm machinery, and avoidance – where possible – of grazing under moist conditions, would have to be implemented.	Shatter compacted layers to a depth of approximately 25 cm with a once-only agrow-plowing (carried out, if possible, with soil water content at or just below the 'plastic limit').	$55 per ha. This estimate is only approximate; the cost of mechanical loosening is strongly influenced by soil water content, stubble cover and machinery availability.
Acidity	Application of finely-ground Attunga limestone ('lime'); incorporated via agrowplowing. Most of the cleared areas would benefit from 1 t/ha lime; areas with volcanic parent material require about triple this rate.	Rate = 1 t/ha; Fenton (2003) calculations.	$82-$246 per ha. Cost includes purchase price (delivered to Gunnedah), and spreading; McKenzie *et al.* (1995) data[2].
Organic Carbon	Application of organic amendments is effective, but unlikely to be economically viable under dryland cropping/farming in the Boggabri area. Instead, maximise soil organic matter via conservation of organic residues produced by cash crops and pasture.	n/a	n/a

1 Follow-up applications may be needed if very wet weather rapidly leaches the dissolved gypsum.

2 Estimated supply and delivery costs verified with Landmark, Gunnedah in August 2011.

8.4 Soil Resource Management Measures

General soil resource management practices, where surface development is proposed within the Project area, 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 those disturbance areas to be rehabilitated progressively.

The objectives of soil resource management for the Project 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 at the Project:

- 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.

When the moderately sodic subsoil material described in Table 6 is excavated, it needs to be laid down in a way that allows easy application of gypsum and rapid leaching of the sodium salts that are generated. Rates of gypsum application will depend on the exchangeable sodium concentrations, with quantities estimated using the equation of Awad and Abbott (1976). For example, the 15-30 cm layer from Pit 39 would require 2 t/ha gypsum.

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 at the Project:

- 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 [V:H]) and a slightly roughened surface to minimise erosion.
- Construct topsoil stockpiles in a way that minimises erosion, encourages drainage, and promotes revegetation.
- Where amendments such as lime, gypsum and 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.
- Wherever practicable, soil should not be trafficked, deep ripped or removed in wet conditions to avoid breakdown in soil structure.
- 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. Stockpile height can be excessive because of limited space at mine sites, but try to keep it as low as possible. This 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 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 Project 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.

Application of Soil on Rehabilitated Landforms

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

- 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.

Rehabilitation Management Plan

It is recommended that a Rehabilitation Management Plan for the Project be prepared by a suitability qualified expert to detail the soil resource management measures outlined in the sections above. The Rehabilitation Management Plan should be progressively updated to cater for the site-specific management requirements of soils as the Project progresses.

8.5 Rehabilitation – Agricultural Land Uses

Chemical and physical assessment of the soil properties of the area surveyed indicate that the soil resources quantified in Tables 5 and 6 would be suitable for rehabilitation purposes provided appropriate management practices (Section 8.4) are implemented during handling and relevant amelioration measures (Section 8.3) are applied where necessary. This section focuses on the rehabilitation of lands proposed for agricultural land uses post-mining.

Based on the soil quantities detailed in Table 5 and Table 6 and a soil profile of 0.9 m, up to approximately 780 ha of agricultural land capable of grazing could be re-established post-mining with soil profile specification as described in Table 4.

Successful soil profile reconstruction following major earthworks has been conducted in the Boggabri district previously. Cutting and filling operations (including soil profile reconstruction) associated with the landforming of nearby alluvial soil for irrigated cotton production has been very successful, despite some early challenges with soil structural degradation (McKenzie 1998). Soil structural problems induced by landforming for irrigated cotton have been addressed via a range of site-specific approaches that include deep ripping, gypsum spreading, nutrient application, and *in-situ* production of organic mulches. Effective restoration of subsoils following mining in the United Kingdom has been described by Ramsay (1986).

The soil profile described above would provide rootzone chemical and physical conditions that are at least as favourable pasture and crop production as the existing agricultural areas.

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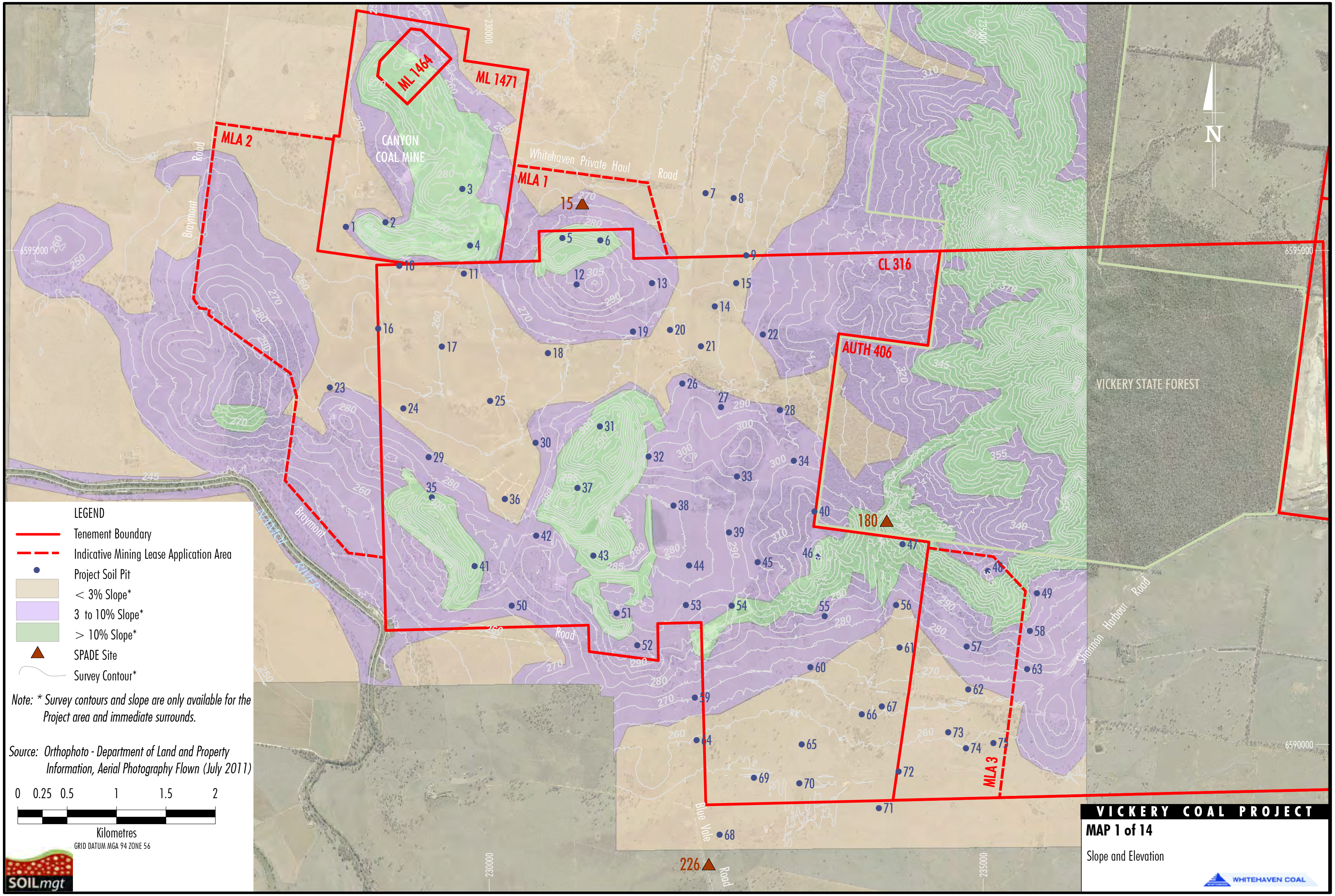
Soil Maps



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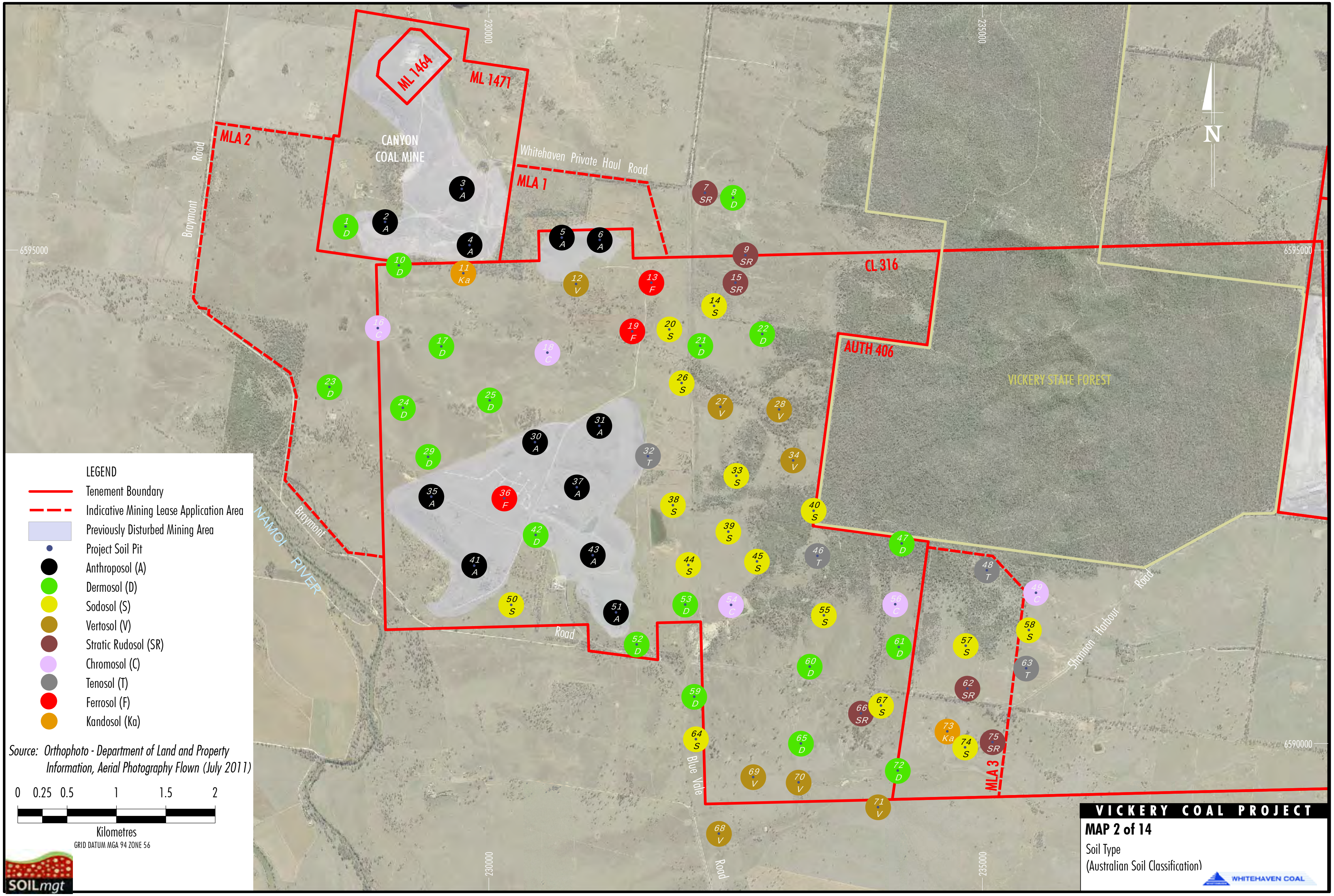

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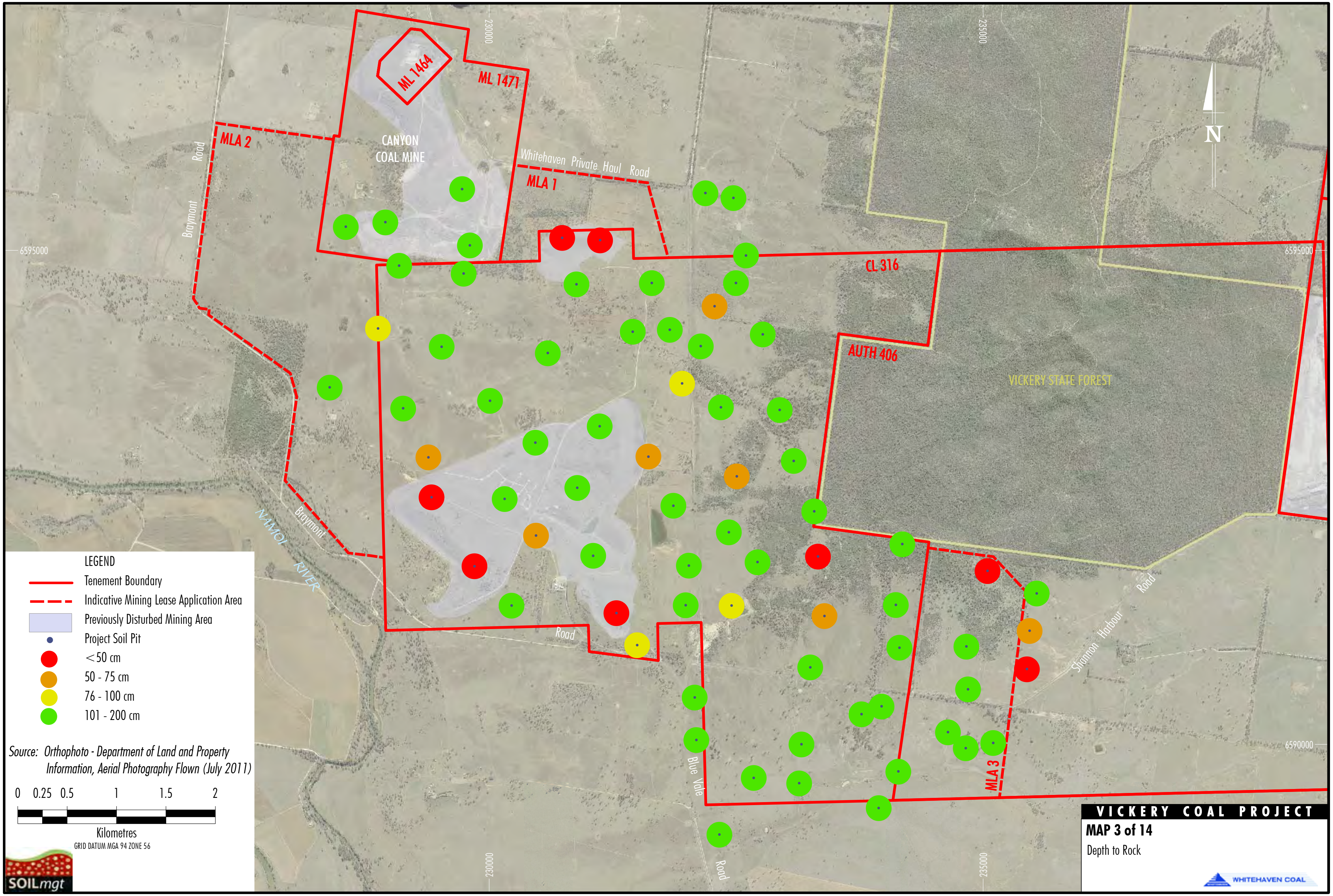

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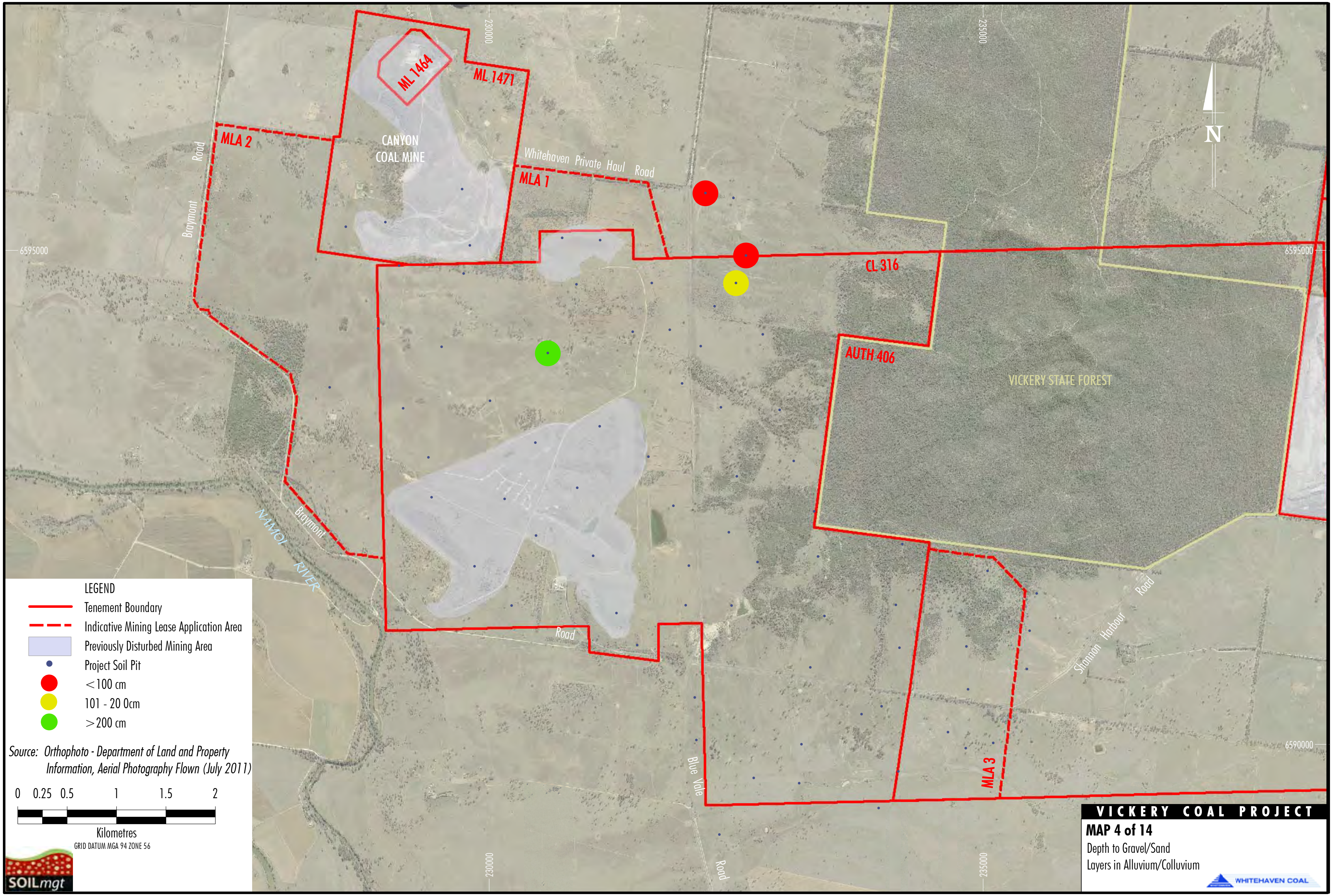

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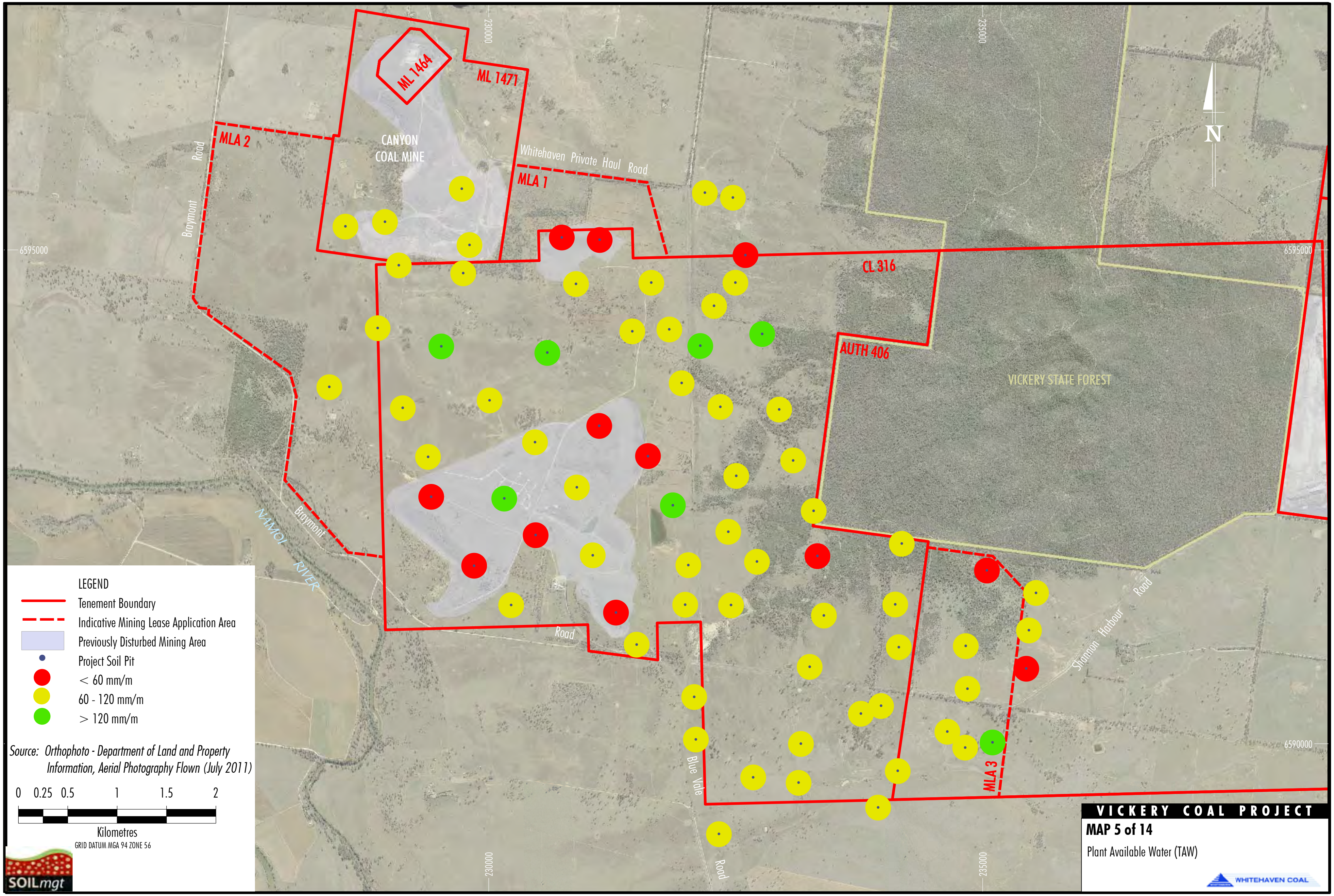

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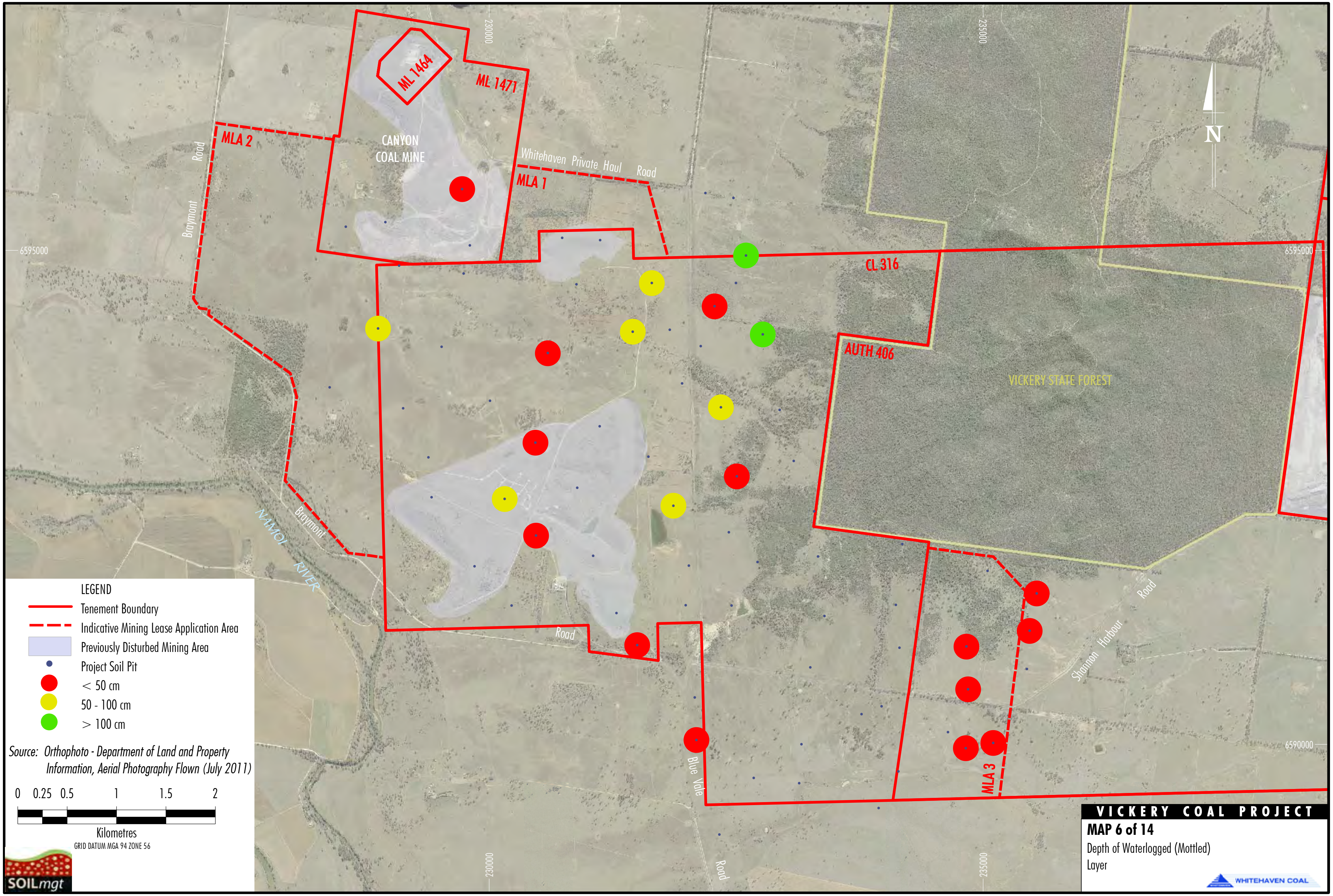

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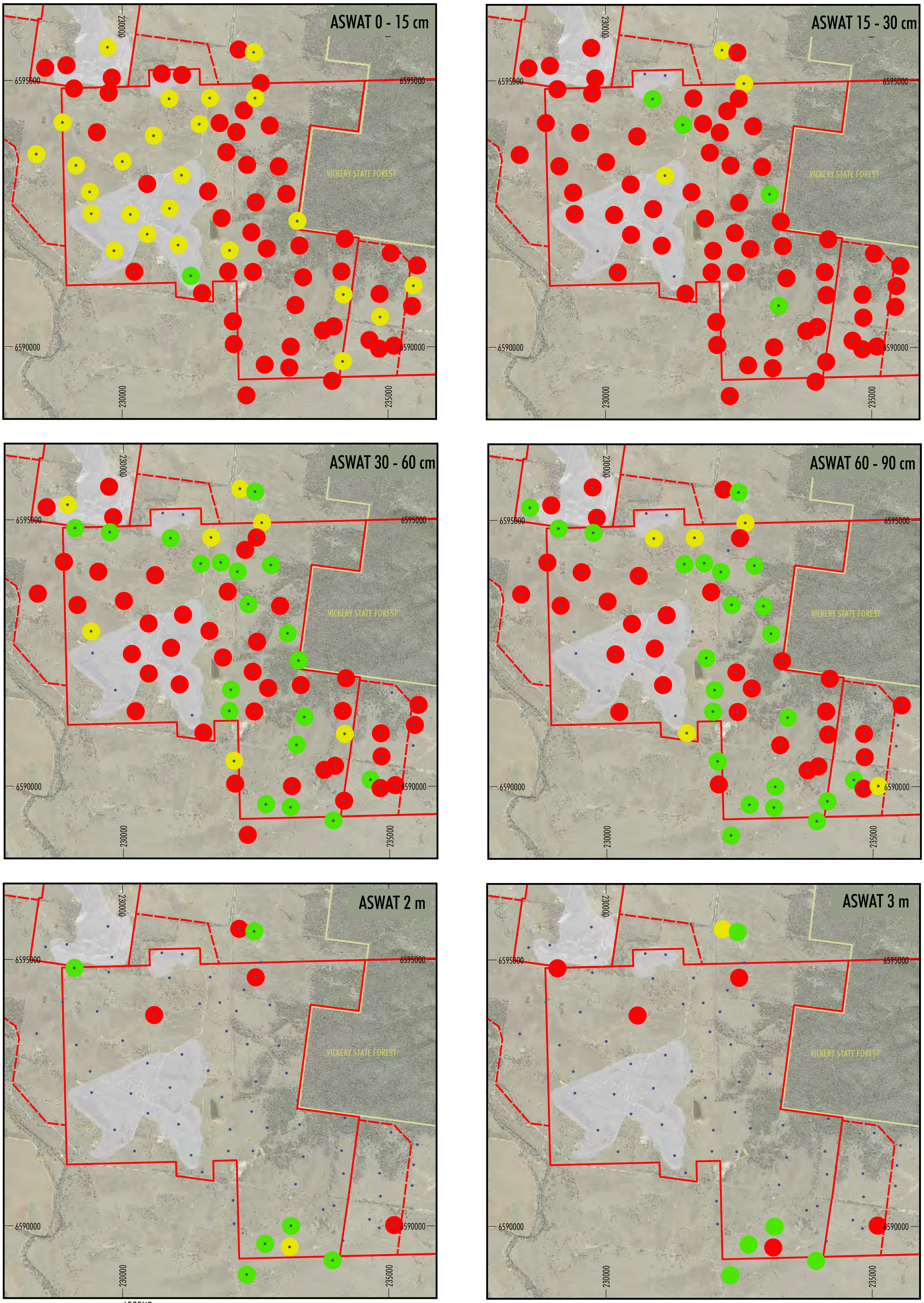


LEGEND

- Tenement Boundary
- Indicative Mining Lease Application Area
- Previously Disturbed Mining Area
- Project Soil Pit

- > 6
- 2 - 6
- < 2

0 0.5 1 2 3 4

Kilometres

GRID DATUM MGA 94 ZONE 56

Source: Orthophoto - Department of Land and Property Information, Aerial Photography Flown (July 2011)

SOILmgt

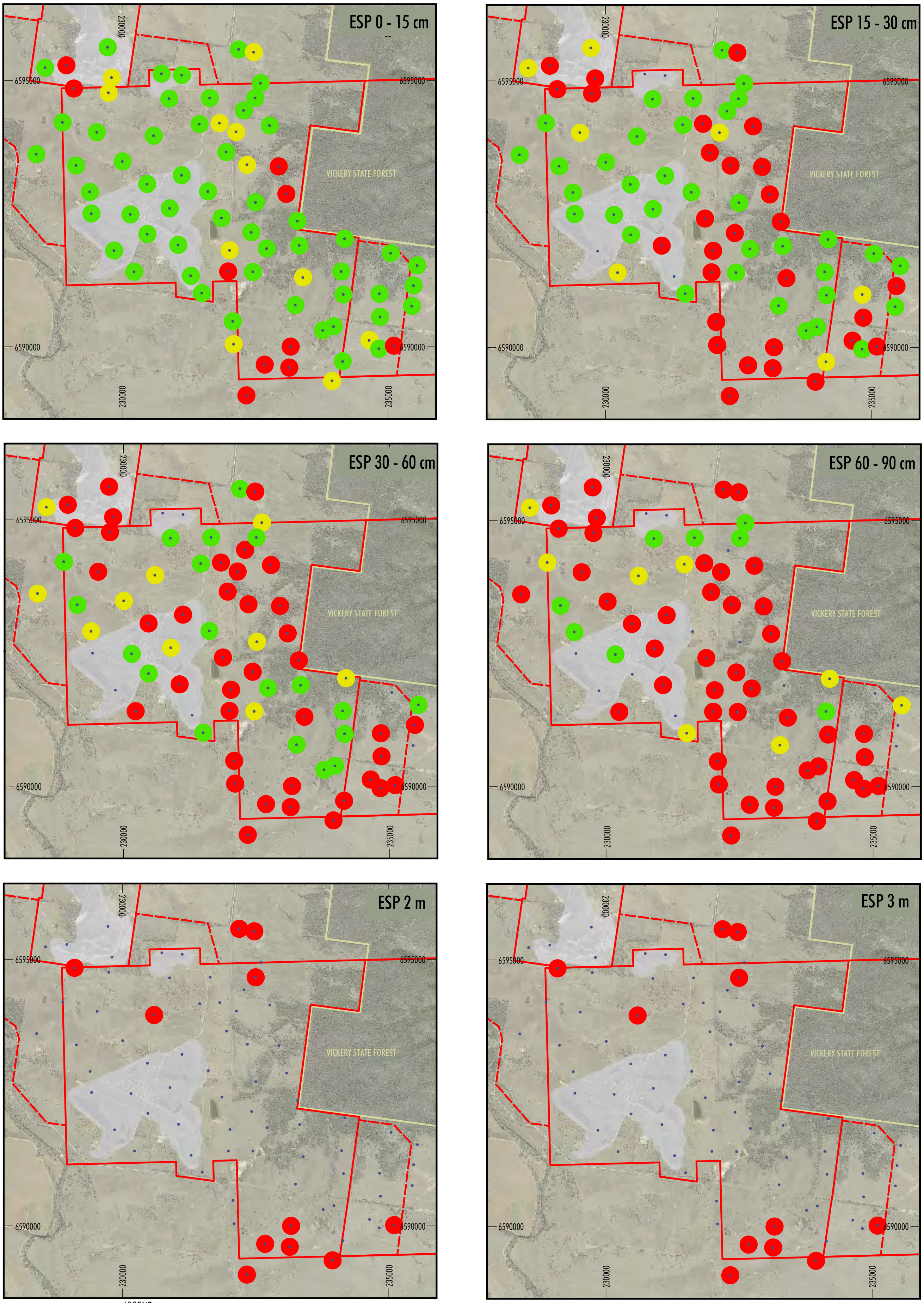
VICKERY COAL PROJECT

MAP 7 of 14

Dispersion (ASWAT scores)

WHITEHAVEN COAL

WHC-10-03 EIS_App AIA AM_206D



LEGEND

- Tenement Boundary
- Indicative Mining Lease Application Area
- Previously Disturbed Mining Area
- Project Soil Pit
- > 6
- 3 - 6
- < 3

0 0.5 1 2 3 4

Kilometres

GRID DATUM MGA 94 ZONE 56

Source: Orthophoto - Department of Land and Property Information, Aerial Photography Flown (July 2011)

SOILmgt

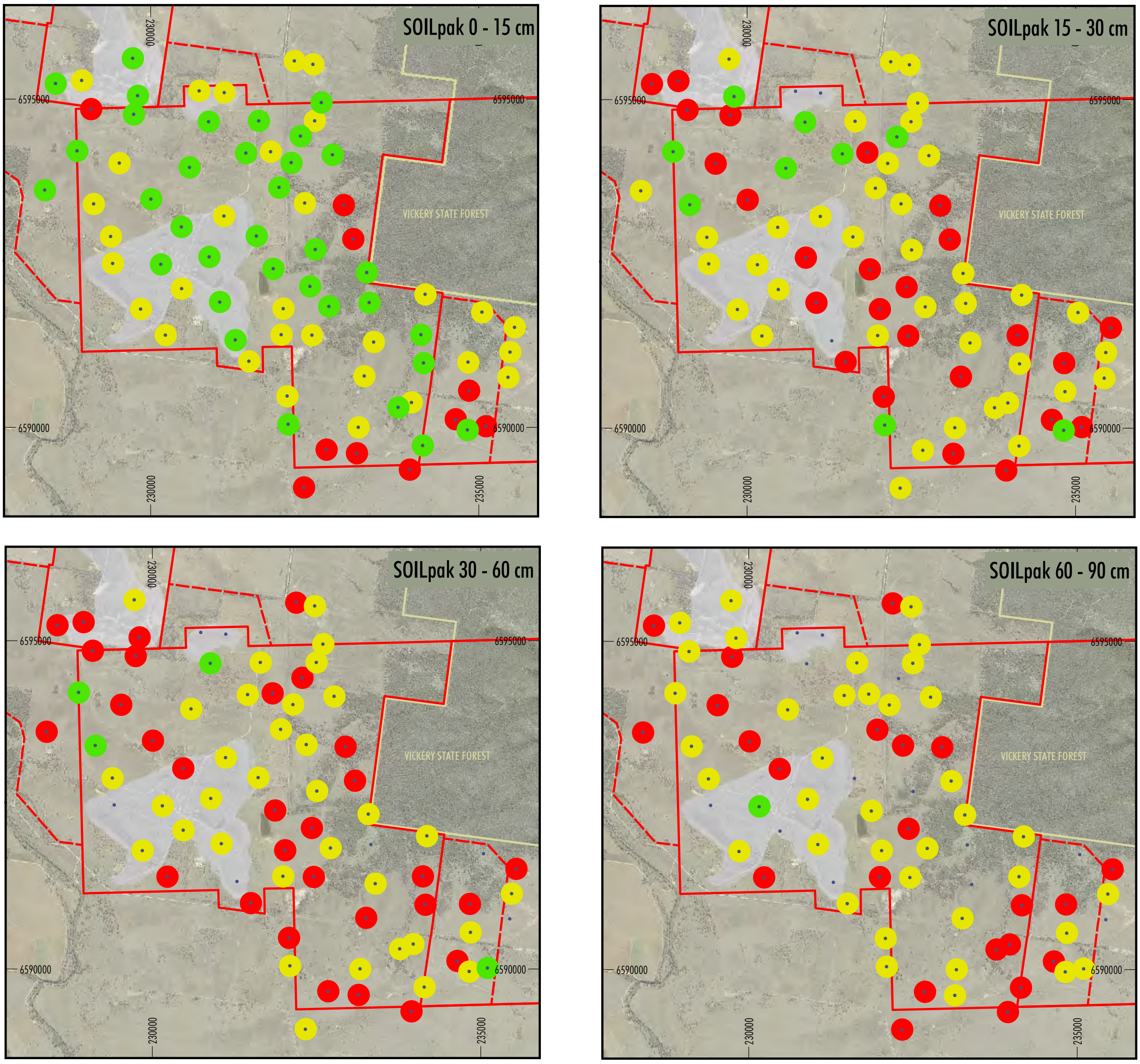
VICKERY COAL PROJECT

MAP 8 of 14

Dispersion (ESP Values)

WHITEHAVEN COAL

WHC-10-03 EIS_App AIA AM_207D



LEGEND

- Tenement Boundary
- Indicative Mining Lease Application Area
- Previously Disturbed Mining Area
- Project Soil Pit

- < 1.0
- 1.0 – 1.5
- > 1.5

0 0.5 1 2 3 4

Kilometres

GRID DATUM MGA 94 ZONE 56

Source: Orthophoto - Department of Land and Property Information, Aerial Photography Flown (July 2011)

VICKERY COAL PROJECT

MAP 9 of 14

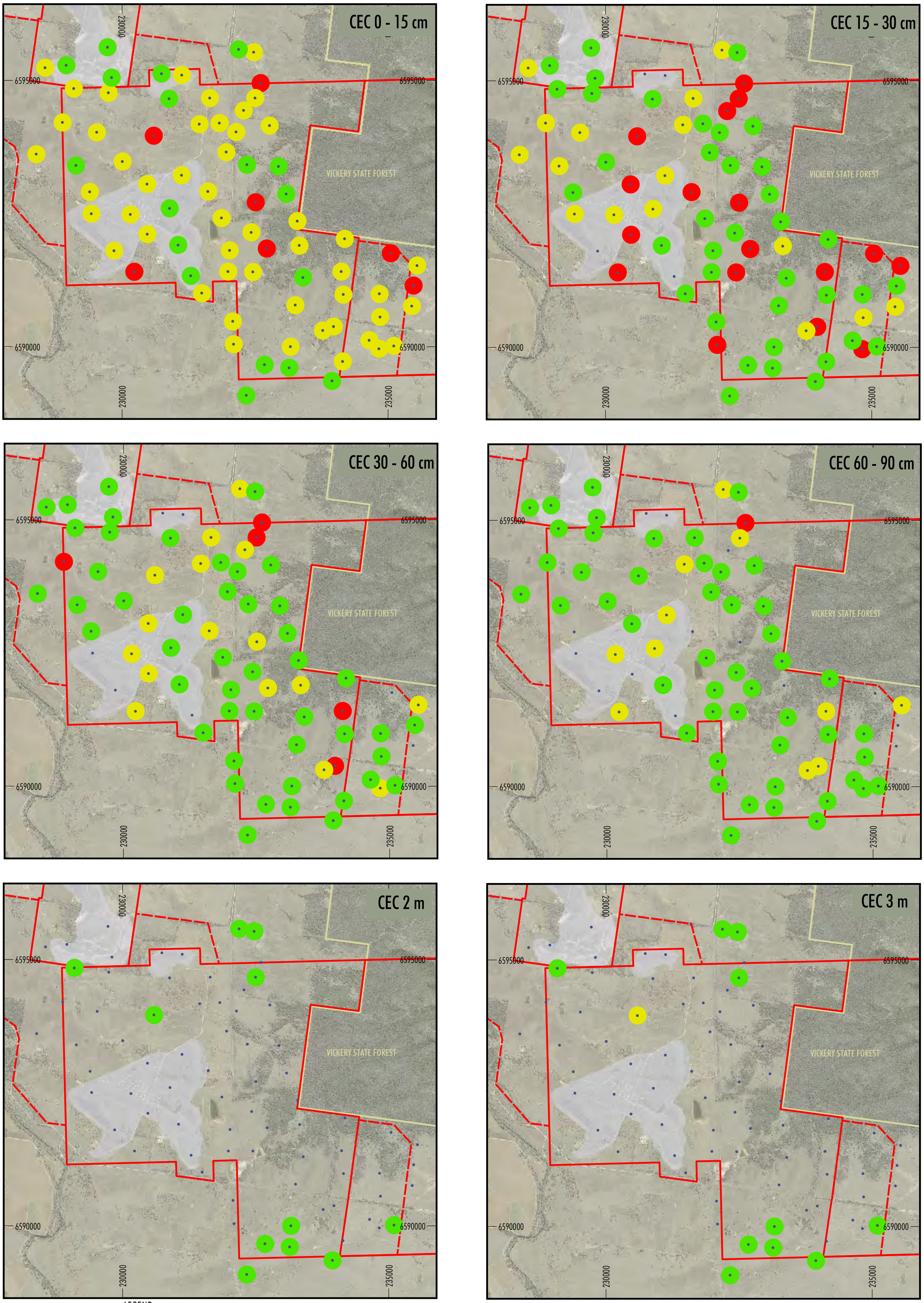
Compaction Severity

(SOILpak Score)

WHITEHAVEN COAL

SOILmgt

WHC-10-03 EIS_App AIA AM_208D



LEGEND

- Tenement Boundary
- Indicative Mining Lease Application Area
- Previously Disturbed Mining Area
- Project Soil Pit
- < 5 (meq/100g)
- 5 - 15 (meq/100g)
- > 15 (meq/100g)

0 0.5 1 2 3 4

Kilometres

GRID DATUM MGA 94 ZONE 56

Source: Orthophoto - Department of Land and Property Information, Aerial Photography Flown (July 2011)

SOILmgt

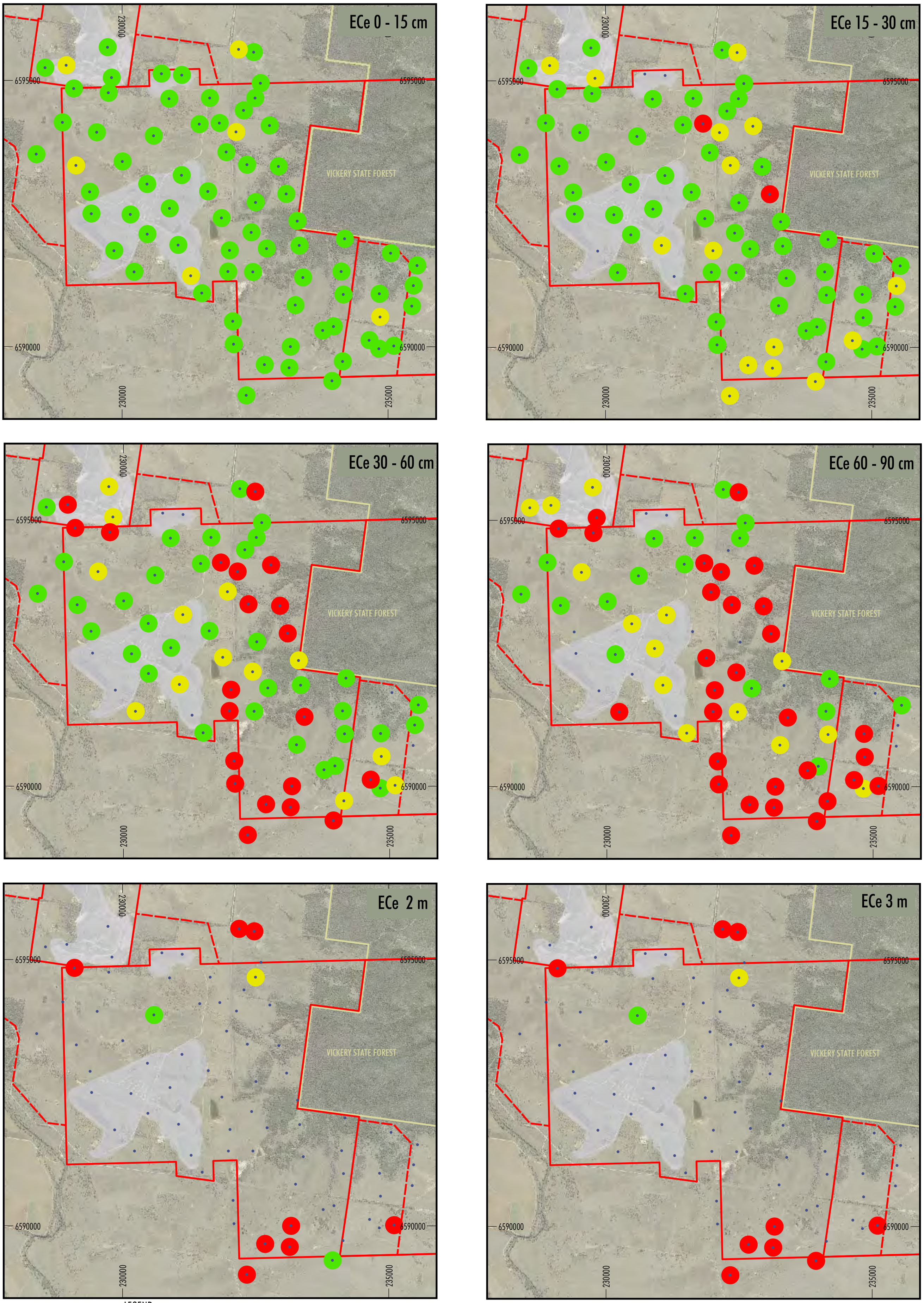
VICKERY COAL PROJECT

MAP 10 of 14

Cation Exchange Capacity

WHITEHAVEN COAL

WHC-10-03 EIS_App AIA AM_209D



LEGEND

- Tenement Boundary
- Indicative Mining Lease Application Area
- Previously Disturbed Mining Area
- Project Soil Pit

- > 3.0 dS/m
- 1.5 – 3.0 dS/m
- < 1.5 dS/m

0 0.5 1 2 3 4

Kilometres

GRID DATUM MGA 94 ZONE 56

Source: Orthophoto - Department of Land and Property Information, Aerial Photography Flown (July 2011)

SOILmgt

VICKERY COAL PROJECT

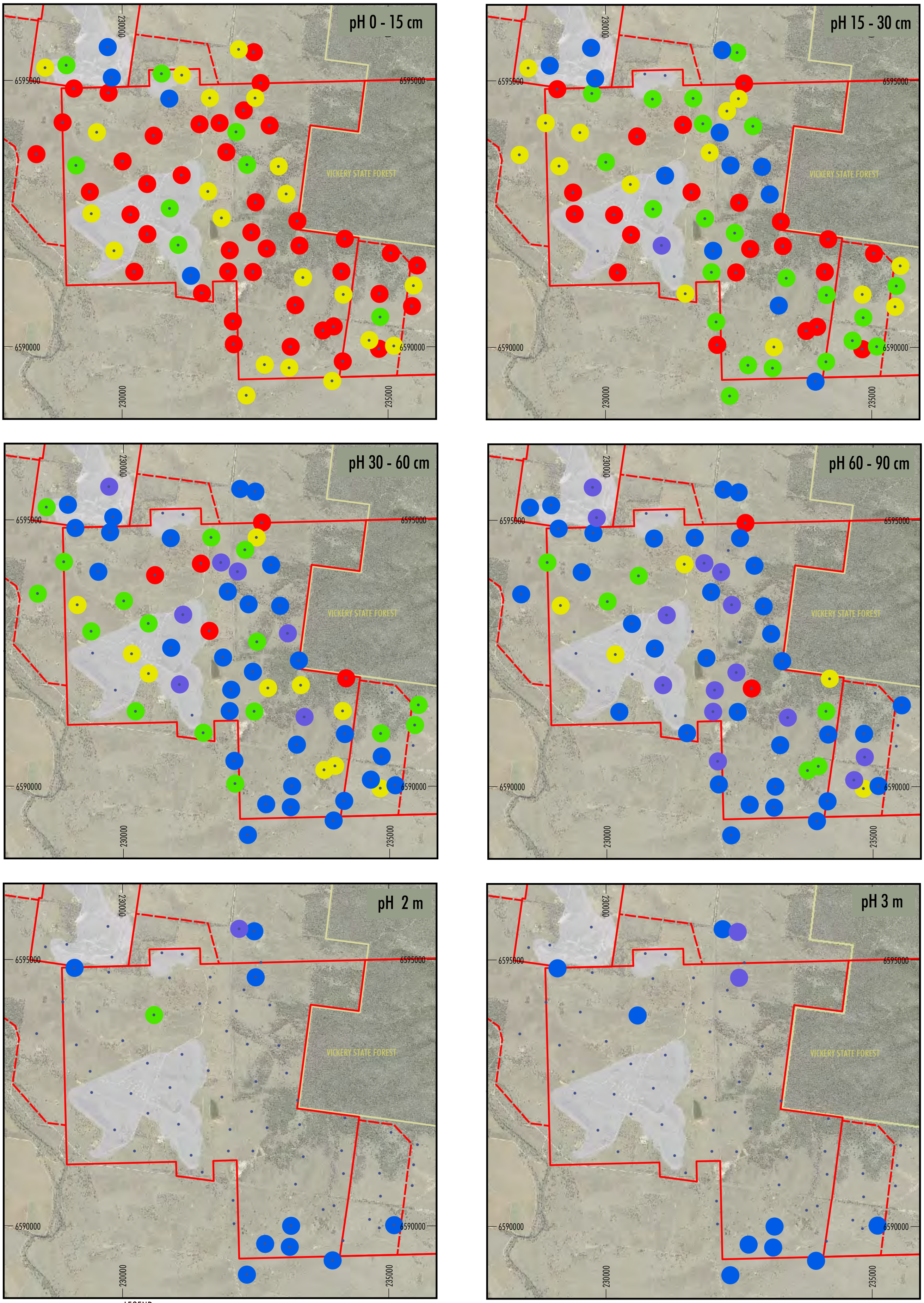
MAP 11 of 14

Salinity

(Electrical Conductivity – ECe)

WHITEHAVEN COAL

WHC-10-03 EIS_App AIA AM_210E



LEGEND

- Tenement Boundary
- Indicative Mining Lease Application Area
- Previously Disturbed Mining Area
- Project Soil Pit

- < 5.5
- 5.6 – 6.5
- 6.6 – 7.5
- 7.6 – 8.5
- > 8.5

0 0.5 1 2 3 4

Kilometres

GRID DATUM MGA 94 ZONE 56

Source: Orthophoto - Department of Land and Property Information, Aerial Photography Flown (July 2011)

SOILmgt

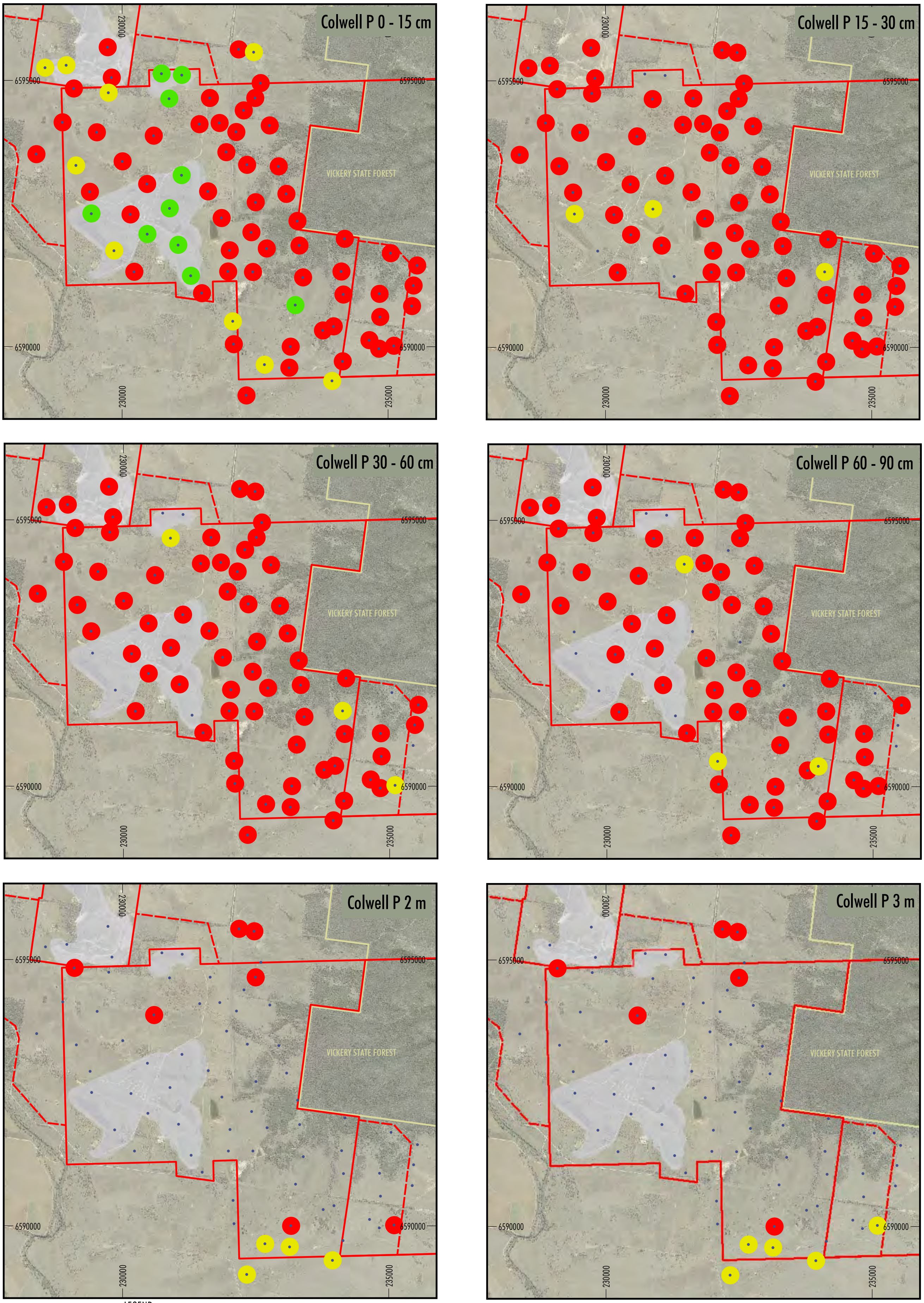
VICKERY COAL PROJECT

MAP 12 of 14

pH ($CaCl_2$)

WHITEHAVEN COAL

WHC-10-03 EIS_App AIA AM_211D



LEGEND

- Tenement Boundary
- Indicative Mining Lease Application Area
- Previously Disturbed Mining Area
- Project Soil Pit

- < 10 mg/kg
- 10 - 30 mg/kg
- > 30 mg/kg

0 0.5 1 2 3 4

Kilometres

GRID DATUM MGA 94 ZONE 56

Source: Orthophoto - Department of Land and Property Information, Aerial Photography Flown (July 2011)

VICKERY COAL PROJECT

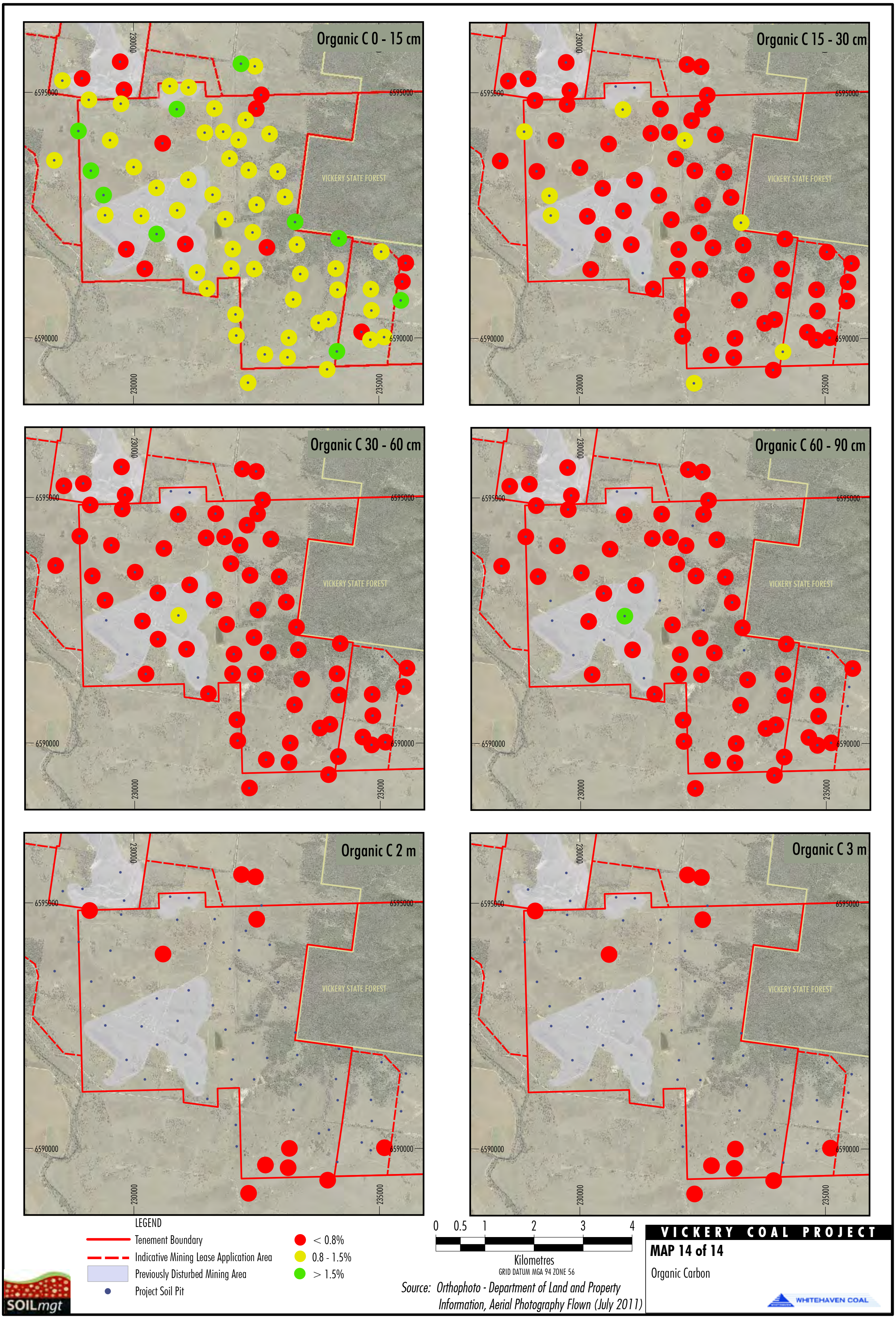
MAP 13 of 14

Phosphorus (Colwell P)

SOILmgt

WHITEHAVEN COAL

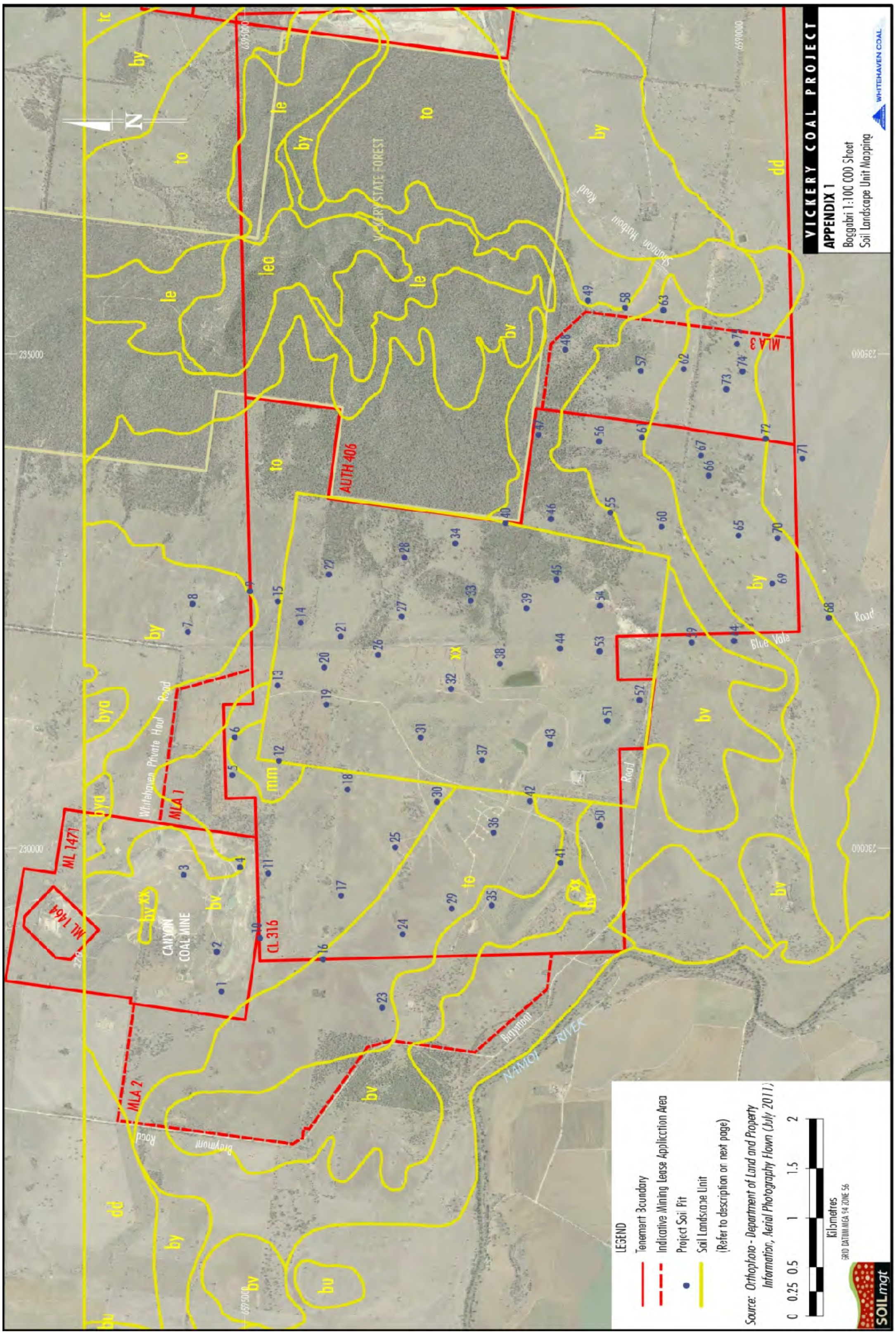
WHC-10-03 EIS_App AIA AM_212D



WHC-10-03 EIS_App AIA AM_213D

Appendix 1 New South Wales Government Soil Landscape Units Mapping

(a) Sub-section of Boggabri 1:100 000 Sheet Soil Landscapes Map provided by Soil Futures Consulting, Gunnedah.



(b) Description of Soil Landscape Units for the Project Site.

Soil Landscape Unit	Position in Landscape	Soil Types (Australian Soil Classification)
Blue Vale (bvy)	Undulating low hills and hills on Permian sandstones and conglomerates (Residual).	Brown Chromosols and Brown Sodosols are dominant.
Brentry (byr)	Drainage plains and fans formed on Quaternary alluvium from Permian quartz sandstones and conglomerates (Transferral).	Footslopes are dominated by Grey Chromosols or by Brown Sodosols. Plain elements of the landscape are dominated by Brown Vertosols and Brown Sodosols.
Driggle Draggle (ddw)	Extensive plains created by ancient alluvial processes which are no longer evident (Stagnant Alluvial).	Soil distribution is complex. Soil types include Grey Chromosols, Brown Sodosols, Grey and Brown Vertosols and Brown Dermosols.
Mount Millbulla (mm)	Steep rises and hills on Jurassic basalts and dolerites of the Garrawilla Volcanics.	Lithic Leptic Tenosols occur on crests and upper slopes which grade into moderately deep red gravelly Red Ferrosols on mid to lower slopes.
Top Rock (tot)	Broad, long (1000-1500 metres) gently inclined footslopes on colluvium derived from Permian sandstones and conglomerates of the Curlewis Hills (Transferral).	Upper slopes are generally dominated by very deep Red Sodosols and some Bleached Red Chromosols; mid to lower footslopes are dominated by imperfectly to poorly drained deep to very deep Brown Sodosols.

(c) Soil Profile Information from the New South Wales Government Soil Profile Attribute Data Environment (SPADE) Database.

SPADE Profile 15

NSW SOIL AND LAND INFORMATION SYSTEM

Soil Essentials Report

Site Location: Site Name Unknown for Profile 15

Map Reference: MGA Grid Reference : Easting 230942, Northing 6595478 BOGGABRI (8936) 1:100,000 sheet

Profile Details: Boggabri Native Vegetation Program Survey, Profile 15, collected by Mark Young on July 02, 2001

Physiography: siltstone/mudstone lithology .

Soil Type:

Soil Description:

Layer 1 00.00 - m: brown sandy clay loam with weak pedality (sub-angular blocky 10 - 20 mm) , field pH is 6.5

Laboratory Test Data:

Upper Bound	Lower Bound	% Clay	USCS	PH	EC	OC	Bray P	P Sorbt	Exch Al	Exch Ca	Exch K	Exch Mg	Exch Na

For information on laboratory test data and units of measure, please see the SPADE Help page

SALIS Soil Essentials Report To contact us email:soils@dnr.nsw.gov.au Thu Jul 12 21:23:05 EST 2012

SPADE Profile 180

NSW SOIL AND LAND INFORMATION SYSTEM

Soil Essentials Report

Site Location:	Gulligal - S End Leard SF
Map Reference:	MGA Grid Reference : Easting 234021, Northing 6592266 BOGGABRI (8936) 1:100,000 sheet
Profile Details:	Soil Landscapes of the Boggabri 1:100 000 Sheet Survey, Profile 180, collected by Robert Banks on May 03, 2000
Physiography:	hillslope in hills on siltstone/mudstone lithology and used for logged native forest . Slope 14 % (measured) , elevation 305 m , aspect north . profile is mod. well drained , erosion hazard is slight , and no salting evident
Soil Type:	Brown Chromosol (ASC) , Yellow Podzolic Soil (GSG)

Soil Description:

Layer 0	
Layer 1 00.00 - 00.10 m A1 Horizon	clay loam with massive structure (earthy) , many (25-100/10x10cm) roots (<1mm) , field pH is 6.5 . Coarse fragments are as parent material , gravel (6-20 mm),coarse gravel (20-60 mm),cobbles (60-200 mm) ; clear (20-50 mm) boundary to...
Layer 2 00.10 - 00.65 m B2 Horizon	clay with strong pedality (prismatic 20 - 50 mm , smooth-faced peds) , few (1-10/10x10cm) roots (<1mm) , field pH is 6.5 ; diffuse (>100 mm) boundary to...
Layer 99	weak highly weathered rock siltstone/mudstone

Laboratory Test Data:

Upper Bound	Lower Bound	% Clay	USCS	PH	EC	OC	Bray P	P Sorbt	Exch Al	Exch Ca	Exch K	Exch Mg	Exch Na

For information on laboratory test data and units of measure, please see the SPADE Help page

SALIS Soil Essentials Report To contact us email:soils@dnr.nsw.gov.au Thu Jul 12 21:37:24 EST 2012

SPADE Profile 226

Soil Essentials Report   Page 1 of 1

NSW SOIL AND LAND INFORMATION SYSTEM

Soil Essentials Report

Site Location:	Gulligal - N Blue Vale Rd
Map Reference:	MGA Grid Reference : Easting 232222, Northing 6588790 BOGGABRI (8936) 1:100,000 sheet
Profile Details:	Soil Landscapes of the Boggabri 1:100 000 Sheet Survey, Profile 226, collected by Robert Banks on July 02, 2002
Physiography:	swamp in plain under swamp complex on alluvium lithology and used for volun./native pasture . Slope 0 % (measured) , elevation 253 m , aspect flat . profile is very poorly drained , erosion hazard is slight , and no salting evident
Soil Type:	Epipedal Grey Vertosol (ASC)

Soil Description:

Layer 1 00.00 - 00.10 m A1 Horizon	clay with strong pedality (polyhedral 2 - 5 mm , smooth-faced peds) , many (25-100/10x10cm) roots (<1mm) , field pH is 7 . Segregations are not evident , not evident ; diffuse (>100 mm) boundary to...
Layer 2 00.10 - 01.10 m B2 Horizon	clay with strong pedality (lenticular 10 - 20 mm , smooth-faced peds) , common (10-25/10x10cm) roots (<1mm) , field pH is 9 . Segregations are calcareous , calcareous ; gradual (50-100 mm) boundary to...
Layer 3 01.10 - 01.40 m B22 Horizon	clay with strong pedality (prismatic 20 - 50 mm , smooth-faced peds) , none roots (<1mm) , field pH is 9 . Segregations are calcareous , calcareous ; gradual (50-100 mm) boundary to...

Laboratory Test Data:

Upper Bound	Lower Bound	% Clay	USCS	PH	EC	OC	Bray P	P Sorbt	Exch Al	Exch Ca	Exch K	Exch Mg	Exch Na
00.00	00.10												
00.10	01.10												
01.10	01.40												

For information on laboratory test data and units of measure, please see the SPADE Help page

SALIS Soil Essentials Report   To contact us email:soils@dnr.nsw.gov.au   Thu Jul 12 21:39:03 EST 2012

http://spade.dnr.nsw.gov.au/SoilEssentials.jsp?p_profile_id=69467   12/07/2012

SPADE Profile 226 (cont.)

NSW SOIL AND LAND INFORMATION SYSTEM

Soil Technical Report

LOCATION: Gulligal - N Blue Vale Rd

SURVEY: Soil Landscapes of the Boggabri 1:100 000 Sheet (1000935)

PROFILE: 226

PROFILE MAP DETAILS:

1:100,000 Mapsheet:	BOGGABRI (8936)	Scale of Mapping:	other
MGA Easting:	232222	MGA Northing:	6588790

SITE DETAILS:

Described by:	Robert Banks	Profile Date:	July 02, 2002
Nature of Exposure:	core sample	Photo Taken:	both site & profile
No of Layers:	3		

SOIL AND MAP CODES:

Geology Map Code:	Qa	Soil Map Code:	dd
Aust. Soil Classification:	Vertosol, Grey, Epipedal, non gravelly, very fine, very fine, giant		
Great Soil Group:		Northcote PPF:	
Soil Taxonomy:		Atlas (Northcote) Code:	
Atlas (A&M) Code:			

TOPOGRAPHY:

Slope:	0%, measured		
Elevation:	253 m	Aspect:	flat

LANDFORM:

Site Morphology:	open depression	Site Process:	253 m
Slope Morphology:		Local Relief:	extremely low (< 9m)
Landform Pattern:	plain	Landform Element:	swamp
Microrelief	crabhole gilgai		
Pos in LF Element:		Plan Curvature:	

LITHOLOGY:

Solum PM:	alluvium	Substrate:	alluvium m
Rock Outcrop:	nil	Outcrop Same As:	
Substrate Strength:			
Weathering & Alteration:	m		
Discontinuities:			
Fragment Amount:			

VEGETATION:

Vegetation Community:	swamp complex
Growth Form(s):	rush,tussock grass,sod grass
Crown Separation Ratio:	
Upper Stratum Height:	0.5 - <1 m

SPADE Profile 226 (cont.)

SITE CONDITION:

Ground Cover %:	00	Site Disturbance:	no effective disturbance
Current Condition (s):	cracked	Expected Dry Condition:	seasonal cracking

LAND USE:

Site:	volun./native pasture	General Area:	volun./native pasture

HYDROLOGY:

Presence of Free Water:	none	Free Water Depth:	
Run-on:	high	Run-off:	low
Permeability:	very slowly permeable	Profile Drainage:	very poorly drained
Free Water pH:		Free Water Salinity:	

EROSION HAZARD: slight

SALINITY: no salting evident

PROFILE ADDENDUM:

SOIL DESCRIPTION:

LAYER 1 A1 horizon
Depth: 00.00 - 00.10

TEXTURE: medium clay

COLOUR:
Moist: dark grey (brownish grey) (10YR 4/1)
Dry:

MOTTLES:

Dominant Mottles:	Type:	biological	Colour: orange	Contrast:	Abundance: 10% - 20%

FIELD CHEMICAL TESTS:

pH:	7 (Raupach)	$AgNO_3$:	no precipitate	HCl:	no effervescence

STRUCTURE:

Grade of Pedality:	strong pedality	Fabric:	smooth-faced peds
Dominant Peds:	2 - 5 mm,polyhedral		
Subdominant Peds:			
Artificial Aggregates:			

ROOTS:

<1 mm size:	many (25-100/10x10cm)	1-2 mm size:		2-5 mm size:		>5 mm size:	

SOIL WATER STATUS: dry

ERODIBILITY TESTS:

Crumb Test:	no change	Bolus		Field	

SPADE Profile 226 (cont.)

		Formation:		Dilatency:			

SAMPLE TAKEN: disturbed

BOUNDARY:
Distinctiveness: diffuse (>100 mm) Shape:

LAYER 2 B2 horizon
Depth: 00.10 - 01.10

TEXTURE: heavy clay

COLOUR:
Moist: dark grey (yellowish grey) (2.5Y 4/1)
Dry:

FIELD CHEMICAL TESTS:

pH:	9 (Raupach)	$AgNO_3$:	no precipitate	HCl:	audible/slight effervescence

STRUCTURE:

Grade of Pedality:	strong pedality	Fabric:	smooth-faced peds
Dominant Peds:	10 - 20 mm,lenticular		
Subdominant Peds:			
Artificial Aggregates:			

ROOTS:

<1 mm size:	common (10-25/10x10cm)	1-2 mm size:		2-5 mm size:		>5 mm size:	

SOIL WATER STATUS: dry

ERODIBILITY TESTS:

Crumb Test:	aggregates slake	Bolus Formation:		Field Dilatency:	

SAMPLE TAKEN: disturbed

BOUNDARY:
Distinctiveness: gradual (50-100 mm) Shape

LAYER 3 B22 horizon
Depth: 01.10 - 01.40

TEXTURE: medium clay

COLOUR:
Moist: greyish brown (dark greyish yellow) (2.5Y 5/2)
Dry:

FIELD CHEMICAL TESTS:

pH:	9 (Raupach)	$AgNO_3$:	conspicuous white precipitate	HCl:	audible/slight effervescence

STRUCTURE:

Grade of	strong	Fabric:	smooth-

SPADE Profile 226 (cont.)

Pedality:	pedality		faced peds			
Dominant Peds:	20 - 50 mm,prismatic					
Subdominant Peds:						
Artificial Aggregates:						

ROOTS:

<1 mm size:	none	1-2 mm size:		2-5 mm size:		>5 mm size:

SOIL WATER STATUS: moderately moist

ERODIBILITY TESTS:

Crumb Test:	aggregates disperse	Bolus Formation:		Field Dilatency:	

SAMPLE TAKEN: disturbed

BOUNDARY:

Distinctiveness:	gradual (50-100 mm)	Shape:	

LAYER 99 horizon

Depth: -

LABORATORY TESTS:

Sample No: 213

Depth: 00.00 - 00.00 m

Test Results:

N504.99 [Oven-dry moisture content]:	7.1
N518.99 [Volume expansion]:	25
N517.99_CL [PSA clay - SDS]:	55
N517.99_SI [PSA silt - SDS]:	29
N517.99_FS [PSA fine sand - SDS]:	10
N517.99_CS [PSA coarse sand - SDS]:	1
N517.99_GR [PSA gravel - SDS]:	5
N514.99 [Dispersion percentage]:	27
N513.98 [Emerson aggregate test SCS method]:	3(2)
N550.01 [USCS - lab]:	OL
N504.02_FC [Field Capacity, SWC pressure plate]:	58.1
N504.02_PWP [Permanent Wilt Point, SWC pressure plate]:	27.4
N515.99 [Wind erodible aggregate percentage]:	3
N505.99 [Water repellence field method]:	1
N3A1 [EC of 1:5 soil/water extract]:	0.13
N4A1 [pH of 1:5 soil/water suspension]:	6.4
N4B1 [pH of 1:5 soil/0.01M CaCl2 extract - direct, no stir]:	5.5
N15F1_CEC [CEC by 0.01M silver-thiourea (AgTU)+, no pret.]:	28.5
N15F1_CA [Exchangeable Ca - 0.01M (AgTU)+, no pretreatment]:	16.5
N15F1_MG [Exchangeable Mg - 0.01M (AgTU)+, no pretreatment]:	10.4
N15F1_NA [Exchangeable Na - 0.01M (AgTU)+, no pretreatment]:	1.7
N15F1_K [Exchangeable K - 0.01M (AgTU)+, no pretreatment]:	1.5
N15F1_AL [Exch. bases (Al+), 0.01M (AgTU)+, no pretreat.]:	0
N9E1 [Fluoride-extractable P (Bray 1-P) - manual colour]:	10
N9I1 [Phosphate sorption index]:	501
N6B2 [Total organic carbon- high-freq. induction,volumetric]:	3.11

Sample No: 214

Depth: 00.10 - 00.10 m

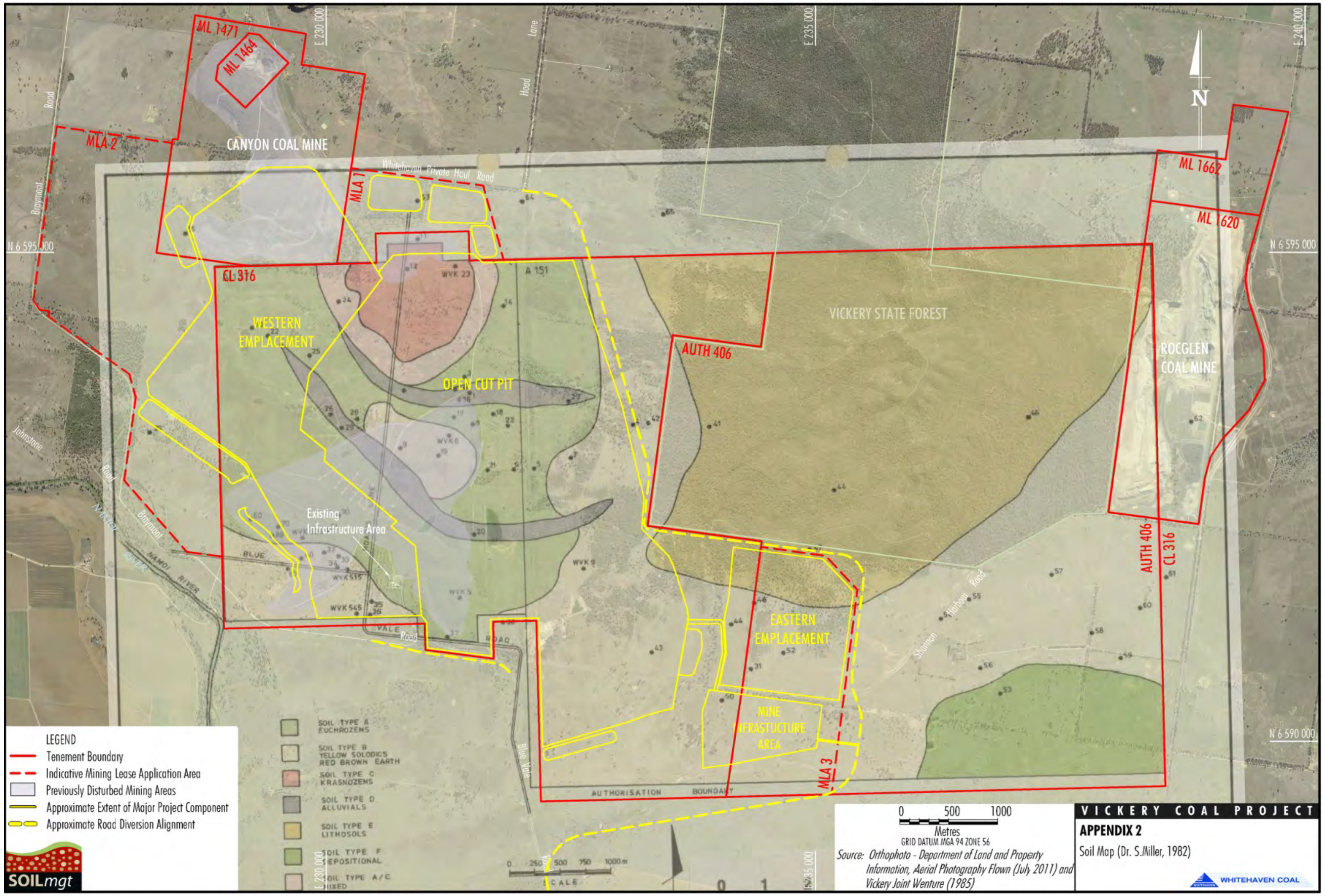
Test Results:

SPADE Profile 226 (cont.)

N504.99 [Oven-dry moisture content]:	6.9
N518.99 [Volume expansion]:	fs
N518.01 [Linear shrinkage]:	19
N517.99_CL [PSA clay - SDS]:	62
N517.99_SI [PSA silt - SDS]:	25
N517.99_FS [PSA fine sand - SDS]:	11
N517.99_CS [PSA coarse sand - SDS]:	2
N517.99_GR [PSA gravel - SDS]:	0
N514.99 [Dispersion percentage]:	38
N513.98 [Emerson aggregate test SCS method]:	2(1)
N550.01 [USCS - lab]:	CH
N504.02_FC [Field Capacity, SWC pressure plate]:	57.2
N504.02_PWP [Permanent Wilt Point, SWC pressure plate]:	22.9
N515.99 [Wind erodible aggregate percentage]:	3
N505.99 [Water repellence field method]:	0
N3A1 [EC of 1:5 soil/water extract]:	0.53
N4A1 [pH of 1:5 soil/water suspension]:	7.8
N4B1 [pH of 1:5 soil/0.01M CaCl2 extract - direct, no stir]:	7.0
N15F1_CEC [CEC by 0.01M silver-thiourea (AgTU)+, no pret.]:	29.5
N15F1_CA [Exchangeable Ca - 0.01M (AgTU)+, no pretreatment]:	15.0
N15F1_MG [Exchangeable Mg - 0.01M (AgTU)+, no pretreatment]:	8.6
N15F1_NA [Exchangeable Na - 0.01M (AgTU)+, no pretreatment]:	4.3
N15F1_K [Exchangeable K - 0.01M (AgTU)+, no pretreatment]:	0.5
N15F1_AL [Exch. bases (Al+), 0.01M (AgTU)+, no pretreat.]:	0
N9E1 [Fluoride-extractable P (Bray 1-P) - manual colour]:	13
N9I1 [Phosphate sorption index]:	274
N9D1 [Lactate-extractable phosphorus - manual colour]:	8
N6B2 [Total organic carbon- high-freq. induction,volumetric]:	0.64
Sample No:	215
Depth:	01.10 - 01.10 m
Test Results:	
N504.99 [Oven-dry moisture content]:	6.9
N518.99 [Volume expansion]:	fs
N518.01 [Linear shrinkage]:	19.5
N517.99_CL [PSA clay - SDS]:	68
N517.99_SI [PSA silt - SDS]:	23
N517.99_FS [PSA fine sand - SDS]:	7
N517.99_CS [PSA coarse sand - SDS]:	1
N517.99_GR [PSA gravel - SDS]:	1
N514.99 [Dispersion percentage]:	38
N513.98 [Emerson aggregate test SCS method]:	2(1)
N550.01 [USCS - lab]:	CH
N504.02_FC [Field Capacity, SWC pressure plate]:	55.7
N504.02_PWP [Permanent Wilt Point, SWC pressure plate]:	23.3
N515.99 [Wind erodible aggregate percentage]:	1
N505.99 [Water repellence field method]:	0
N3A1 [EC of 1:5 soil/water extract]:	1.14
N4A1 [pH of 1:5 soil/water suspension]:	8.4
N4B1 [pH of 1:5 soil/0.01M CaCl2 extract - direct, no stir]:	7.6
N15F1_CEC [CEC by 0.01M silver-thiourea (AgTU)+, no pret.]:	31.2
N15F1_CA [Exchangeable Ca - 0.01M (AgTU)+, no pretreatment]:	14.5
N15F1_MG [Exchangeable Mg - 0.01M (AgTU)+, no pretreatment]:	9.5
N15F1_NA [Exchangeable Na - 0.01M (AgTU)+, no pretreatment]:	5.7
N15F1_K [Exchangeable K - 0.01M (AgTU)+, no pretreatment]:	0.5
N15F1_AL [Exch. bases (Al+), 0.01M (AgTU)+, no pretreat.]:	0
N9E1 [Fluoride-extractable P (Bray 1-P) - manual colour]:	66
N9I1 [Phosphate sorption index]:	201
N9D1 [Lactate-extractable phosphorus - manual colour]:	47
N6B2 [Total organic carbon- high-freq. induction,volumetric]:	0.39

For information on laboratory test data and units of measure, please see the SPADE Help page

Appendix 2 Vickery Soil Map Prepared by Dr Stuart Miller, 1982, showing Project General Arrangement



Appendix 3 Overview Data

Field site #	Map site #	Site description	Land use/vegetation type	Landscape features	Easting, m WGS84	Northing, m WGS84	Australian Soil Classification	Depth to rock (cm)	Depth to permeable gravel/sand (cm)	TAW (0-100 cm), (mm)	Depth to mottled layer (cm)	Other comments
23	1	West of Canyon Mine	Healthy pasture	Flat low-lying area	56228552	6595237	Brown Dermosol	>140		94		Shrinkage cracks 25-70 cm; tree root burnt out 55-70 cm; reddening of soil (5YR5/4)
43	2	Canyon rehab	Sparse pasture	Upper slope	56228952	6595283	Spolic Anthroposol	140		94		Crust 7mm thick; pale fine sand; disp.=1; S'pak 0.3
42	3	Canyon rehab	Vigorous tropical grasses	Plateau on ridge	56229730	6595620	Spolic Anthroposol	>140		109	45	90-120 = 108-120 sample
41	4	Canyon rehab	Sparse pasture	Mid-slope	56229807	6595049	Spolic Anthroposol	>140		95		Upper 25 cm contour bank; ant activity at 1 m
40	5	Vickery - Red Hill rehab	Vigorous tropical grasses	Top of slope	56230741	6595127	Spolic Anthroposol	15		28		
39	6	Vickery - Red Hill rehab	Pasture	Crest of ridge	56231124	6595101	Spolic Anthroposol	18		27		Ant colony 110
28	7	East of Bluevale Road diversion	Pasture	Flat area	56232190	6595577	Stratic Rudosol	>300	8	84		0-15 = 0-8 cm, 30-60 = 30-48 cm for sampling
56	8	Greenwood	Poor pasture; pine regrowth.	Flat area	56232474	6595529	Brown Dermosol	>300		102		
29	9	East of Bluevale Road	Pasture	Flat area	56232600	6594949	Stratic Rudosol	>140	10	35	120	Green ant colony
74	10	Vickery near Canyon boundary	Poor pasture; dispersive surface	Flat area	56229092	6594845	Brown Dermosol	>300		105		Evidence of cattle trampling damage
22	11	Vickery - Canyon boundary	Healthy pasture	Lower slope	56229745	6594764	Red Kandosol	>140		91		Shrinkage cracks 10-20 cm; ant activity
71	12	Vickery - Red Hill	Broad leaved ironbark; thick healthy pasture; disturbed ground nearby	Near crest of hill	56230885	6594657	Red Vertosol	130		75		Parent material = basalt; 30-60 = 40-60 cm sample

Field site #	Map site #	Site description	Land use/vegetation type	Landscape features	Easting, m WGS84	Northing, m WGS84	Australian Soil Classification	Depth to rock (cm)	Depth to permeable gravel/sand (cm)	TAW (0-100 cm), (mm)	Depth to mottled layer (cm)	Other comments
25	13	Vickery (east of Red Hill)	Healthy pasture	Mid-slope	56231647	6594669	Red Ferrosol	>140		102	75	Basalt pebbles
55	15	Greenwood	Vigorous pasture	Flat area; 150m north of small hill	56232499	6594668	Stratic Rudosol	>300	130	76		Water seepage @130 cm, 0.34 dS/m
73	16	Vickery	Healthy pasture	Crest of hill	56228878	6594210	Brown Chromosol	90		85	55	A/B horizon varies from 52-60 cm.
20	17	Vickery (south of old farm sheds)	Healthy pasture	Flat area	56229522	6594026	Red Dermosol	>140		125		
75	18	Vickery	Healthy pasture	Flat area	56230595	6593960	Red Chromosol	>300	240	125	35	65-95 cm, Mn coatings
24	19	Vickery (near Red Hill)	Near broadleaf ironbark	Lower slope	56231455	6594177	Red Ferrosol	>140		118	80	B21 sub-plastic; basalt fragments present; earthworm @ 20 cm
58	20	Vickery East (near Bluevale Road)	Degraded pasture	Lower slope	56231830	6594196	Brown Sodosol	>140		117		0 - 7 = 0 -15 cm sample
54	21	Greenwood (near Bluevale Road)	Poor pasture	Lower slope	56232143	6594030	Red Dermosol	>140		126		0-15 = 0-8 cm sample; 15-30 = 8-20 cm
30	22	East of Bluevale Road (edge of pine)	Pasture - 25% bare patches	Lower slope, gently sloping	56232770	6594149	Brown Dermosol	>140		125	110	B1 - fine cracks, 18-19 cm trace of A2, B21 - fine shrinkage cracks
19	23	Vickery (below Wilga old shed)	Healthy ground cover	Mid-slope	56228388	6593612	Red Dermosol	>140		101		No slaking; shrinkage cracks 30 -100 cm, 25 cm apart
72	24	Vickery	Moderate pasture performance	Mid-slope	56229131	6593401	Red Dermosol	>140		118		
21	25	Vickery (in valley)	Healthy pasture	Flat area	56230010	6593478	Brown Dermosol	>140		100		Cracks 17-140 cm
59	26	Vickery East	Healthy pasture; pine regrowth nearby	Mid slope; northerly aspect	56231956	6593652	Brown Dermosol	80		84		Parent material = conglomerate
31	27	Greenwood	Pasture with 50% ground cover; 10% stone coverage 20 mm	Lower slope	56232347	6593413	Brown Vertosol	>140		105	65	Fine cracks 8 cm apart; 25-65 cm
53	28	Greenwood	Poor pasture; pine regrowth	Mid-slope	56232942	6593385	Brown Vertosol	>140		87		

Field site #	Map site #	Site description	Land use/vegetation type	Landscape features	Easting, m WGS84	Northing, m WGS84	Australian Soil Classification	Depth to rock (cm)	Depth to permeable gravel/sand (cm)	TAW (0-100 cm), (mm)	Depth to mottled layer (cm)	Other comments
18	29	Vickery (below house)	Healthy pasture	Gently sloping mid-slope	56229389	6592905	Red Dermosol	75		93		Volcanic rock pale & dark fragments; shrinkage cracks throughout soil profile
70	30	Vickery	Good pasture cover on disturbed land	Near dam.	56230470	6593056	Spolic Anthroposol	>140		100	25	Bags of soil; 0-10, 10-25, 25-40, 60-90
35	31	Vickery - rehab	Pasture	Upper slope	56231120	6593221	Spolic Anthroposol	>140		44		
26	32	Vickery (east of void)	Pasture	Upper slope gentle	56231614	6592913	Leptic Tenosol	50		45		Andesite pebbles
51	33	Greenwood	Healthy pasture	Lower slope	56232508	6592712	Grey Sodosol	60		70	30	Parent material = conglomerate
32	34	East of Bluevale Road (near forest)	Pasture with 80% cover	Lower slope, gently sloping	56233083	6592869	Brown Vertosol	>140		87		0-15=0.10 cm, 15-30 = 20-30 cm for sampling; shrinkage cracks to 20 cm
36	35	Vickery - rehab	Pasture	Lower slope	56229421	6592500	Spolic Anthroposol	25		24		Coal/chitter layer 25+
17	36	Vickery (in valley)	Excellent pasture cover (90%)	Flat alluvial terrace	56230159	6592483	Red Ferrosol	>140		121	85	Numerous biopores 35-60 cm
34	37	Vickery - rehab	Pasture	Plateau on ridge	56230894	6592596	Spolic Anthroposol	>140		75		Ant activity
60	38	Vickery East	Healthy pasture	Lower slope	56231867	6592416	Red Sodosol	140		125	95	Soil texture unexpected for this parent material (sandstone); likely to be aeolian inputs
68	39	Greenwood	Healthy pasture	Mid-slope	56232428	6592147	Brown Sodosol	>140		94		Trace of A2 7 mm thick
52	40	Greenwood (edge of State Forest)	Ironbark/Pine regrowth	Upper slope	56233291	6592359	Brown Sodosol	105		113		Parent material = shale
37	41	Vickery - rehab	Pasture	Mid slope	56229854	6591803	Spolic Anthroposol	18		24		
69	42	Vickery	Poor quality sown pasture (Rhodes grass *[chloris gayana]*) near box and ironbark trees; 50% stones on surface	Mid-slope	56230477	6592112	Red Dermosol	60		49	35	Parent material = conglomerate

Field site #	Map site #	Site description	Land use/vegetation type	Landscape features	Easting, m WGS84	Northing, m WGS84	Australian Soil Classification	Depth to rock (cm)	Depth to permeable gravel/sand (cm)	TAW (0-100 cm), (mm)	Depth to mottled layer (cm)	Other comments
33	43	Vickery - rehab near sheds	Pasture	Upper slope	56231054	6591910	Spolic Anthroposol	>140		69		Strongly compacted 25-30 cm
27	44	Vickery (west of Bluevale Road)	Degraded grassland (60% cover)	Gentle mid-slope	56232023	6591809	Red Sodosol	120		102		
50	45	Greenwood	Healthy pasture	Mid-slope	56232717	6591844	Grey Sodosol	>140		84		
13	46	Greenwood (near trig station)	Sparse pasture	Top of hill	56233330	6591900	Leptic Tenosol	35		48		
48	47	Greenwood (near State Forest)	Regrowth eucalyptus - whitebox and yellowbox	Upper slope	56234182	6592025	Brown Dermosol	>140		119		
45	48	Greenwood	Weedy pasture	Top of hill	56235044	6591755	Leptic Tenosol	30		31		Ant activity
9	49	Greenwood (near forest).	Pasture (80% groundcover); near pine regrowth	Upper slope	56235542	6591527	Grey Chromosol	120		85	35	
16	50	Vickery (behind backhoe shed)	80% groundcover; wire/plains grass	Lower slope	56230230	6591406	Yellow Sodosol	>140		103		
38	51	Vickery - rehab	Sparse tropical grass; weeds dominant	Upper slope	56231291	6591330	Spolic Anthroposol	15		17		
15	52	Vickery (near entrance)	Pasture	Mid-slope	56231500	6591005	Brown Dermosol	95		98	40	Parent material = sandstone
61	53	Vickery East	Sparse pasture; 30% stones on surface	Mid-slope	56231992	6591409	Brown Dermosol	>140		107		Ant chamber @ 20 cm
14	54	Greenwood (near big dam)	80% wire/plains grass cover; 10% stones cover	Mid-slope	56232455	6591404	Brown Chromosol	100		74		
49	55	Greenwood	Sparse pasture, near pine regrowth; 50% stone cover	Mid-slope	56233396	6591299	Brown Sodosol	60		79		Parent material = shale
11	56	Greenwood (near creek)	Good grass cover (70%); large ironbark nearby	Mid-slope	56234117	6591412	Brown Chromosol	>140		86		Bleached A2 horizon
10	57	Greenwood (near pine regrowth)	Pasture	Mid-slope	56234831	6590991	Grey Sodosol	120		92	14	Shrinkage cracks @ 90 cm; colluvium with possible aeolian inputs

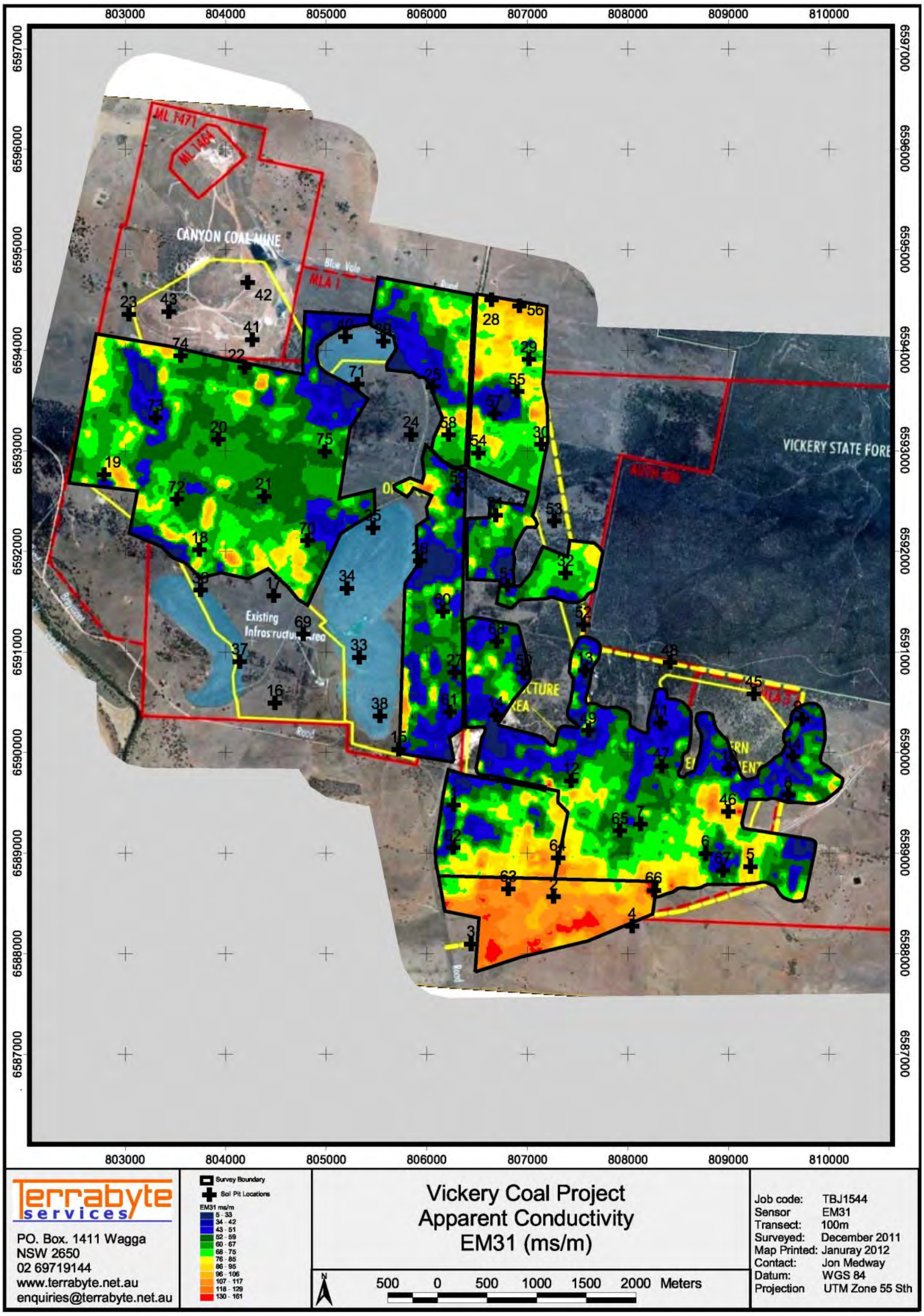
Field site #	Map site #	Site description	Land use/vegetation type	Landscape features	Easting, m WGS84	Northing, m WGS84	Australian Soil Classification	Depth to rock (cm)	Depth to permeable gravel/sand (cm)	TAW (0-100 cm), (mm)	Depth to mottled layer (cm)	Other comments
44	58	East Greenwood	Healthy pasture	Mid-slope	56235471	6591148	Red Sodosol	70		73	45	
1	59	Welkeree	Grazed unimproved pasture; large ironbark/pine nearby	Mid slope, southern aspect	56232082	6590476	Brown Dermosol	>140		105		May originally been cropped (>50 years ago)
12	60	Greenwood (near road).	60% pasture cover, 50% stones	Lower slope	56233252	6590781	Brown Dermosol	130		107		
47	61	Greenwood	Open paddock	Lower slope	56234154	6590979	Brown Dermosol	>140		105		Colluvium
46	62	Greenwood (near Haul Road)	Degraded pasture; stones on surface (70% coverage)	Lower slope	56234847	6590558	Stratic Rudosol	>140		101	25	
8	63	Greenwood (north of haul road)	Pasture; 3% stone cover on surface	Mid-slope	56235444	6590762	Leptic Tenosol	30		37		Ants present
62	64	South of Shannon Harbour Road	Excellent pasture cover	Lower slope	56232099	6590046	Brown Sodosol	>140		109	37	
64	65	South of Shannon Harbour Road	Poor pasture.	Flat area	56233163	6590002	Grey Dermosol	>300		120		Dispersive surface
65	66	South of Shannon Harbour Road	Healthy pasture	Footslope	56233770	6590306	Stratic Rudosol	>140		83		Ant activity; 60-90 = 80-110 cm sample; 90-120 = 110-140; 120-150 = 140-150 cm
7	67	Welkeree	Healthy pasture; 100% ground cover	Lower slope	56233973	6590384	Brown Sososol	>140		73		Bleached A2 horizon
3	68	Welkeree	Pasture and sedges; bimble box trees	Flat area	56232333	6589086	Grey Vertosol	>300		109		Stock trampling damage; 1% gypsum in lowest depth; shrinkage cracks present
63	69	South of Shannon Harbour Road	Poor pasture	Flat area	56232679	6589662	Brown Vertosol	>300		100		Natural gypsum below 90 cm
2	70	Welkeree	Pasture with bare patches	Flat area	56233138	6589607	Brown Vertosol	>300		107		Sodic; cattle trampling; 8% gypsum in B22; occ. surface cracks
4	71	Welkeree	Pasture with scattered sedges and occasional trees	Flat area	56233944	6589355	Brown Vertosol	>300		113		Cattle trampling; 0.5% gypsum >80 cm; infrequent shrinkage cracks

Field site #	Map site #	Site description	Land use/vegetation type	Landscape features	Easting, m WGS84	Northing, m WGS84	Australian Soil Classification	Depth to rock (cm)	Depth to permeable gravel/sand (cm)	TAW (0-100 cm), (mm)	Depth to mottled layer (cm)	Other comments
66	72	Stratford	Healthy pasture	Boundary between footslope and floodplain.	56234142	6589726	Grey Dermosol	>140		105		
6	73	Welkeree	Degraded pasture, bare patches with rounded pebbles, impeded root growth	Lower slope	56234644	6590124	Brown Kandosol	>140		86		Variety of ants present
67	74	Stratford	Healthy pasture	Footslope	56234825	6589962	Yellow Sodosol	>140		89	40	Wet between A & B horizons; upper 20 mm B gleyed
5	75	Welkeree	Degraded pasture with bare patches and cryptograms	Flat area	56235102	6590016	Stratic Rudosol	>300		137	30	Rounded pebbles 60-62 cm(20%); tree root found at 3 m

m = metres
cm = centimetres
mm = millimetres
TAW = Total Available Water
% = percent
dS/m = deciSiemens per metre

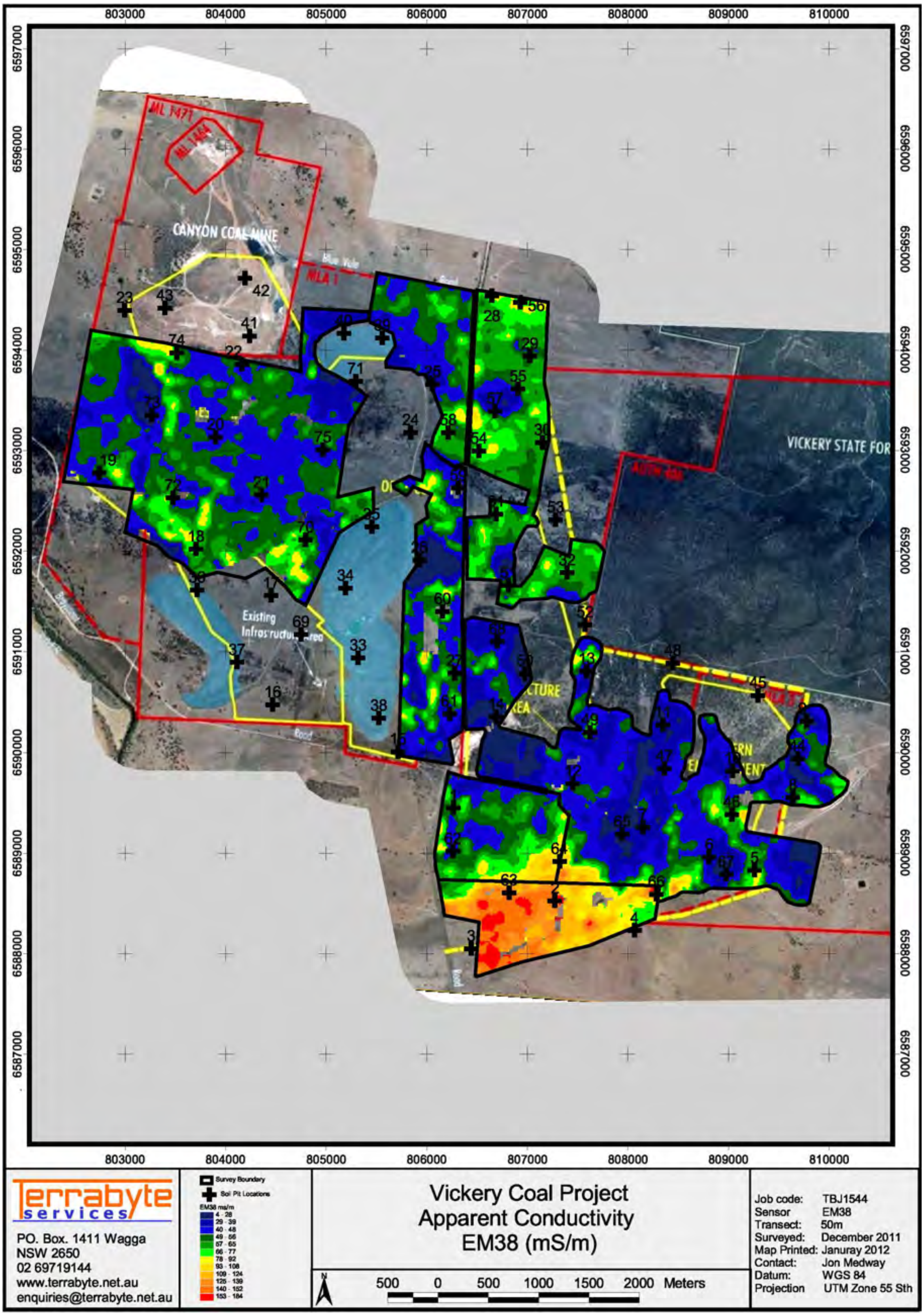
Appendix 4 EM31 and EM38 Maps Supplied by Terrabyte Services, Wagga Wagga

EM31 (0-5 m deep zone of influence)[1]



[1] The pit numbers shown are for the field work. The corresponding site numbers used for the other maps in this report are shown in Appendix 1.

EM38 (0-1.5 m deep zone of influence) [2]



2 The pit numbers shown are for the field work. The corresponding site numbers used for the other maps in this report are shown in Appendix 1.

Appendix 5 Layer Data

Pit	Horizon	Lower Depth (cm)	Texture	pH Water	Moist Soil Colour (Munsell)	Colour	Mottles	SOILpak Compaction Score	Gravel (%)	Dispersion 10 min.	Moisture	Lime %	Lime Type	Root Score
1	A1	18	Light medium clay	6.0	7.5YR3/2	Dark brown		1.6	2	0	Moist			2
1	A2	23	Light clay	6.0	7.5YR4/2	Brown		1.4	20	0	Slight/Moist			2
1	B2	80	Medium clay	8.0	7.5YR4/3	Brown		0.8	1	0	Slight	2	N	2
1	2B	140+	Light clay	8.5	10YR5/3	Brown		0.9	3	1	Slight/Moist			1 (115)
2	A1	20	Light medium clay	8.0	7.5YR4/2	Brown		1.1	1	1	Slight			2
2	2B	40	Light clay	9.0	7.5YR5/4	Brown		0.4	1	1	Slight	2	N	1
2	3B	58	Sandy light clay	9.5	7.5YR5/4	Brown		1.0	2	1	Slight	5	N	1
2	4B	140	Sandy light clay	8.0	10YR6/4	Light yellowish brown		1.2	2	0	Slight	5	D	1 (75)
2	5BC	150+	Gravel						99					
3	A11	10	Light medium clay	9.0	5YR4/4	Reddish brown		1.8	2	2	Moist	2	D	3
3	A12	35	Heavy clay	9.5	5YR4/6	Yellowish red		1.4	1	3	Moist	4	D	4
3	2B	45	Medium heavy clay	10.0	10YR7/3	Very pale brown		1.5	2	3	Moist	8	D	4
3	3B	108	Medium clay	10.0	10YR6/3	Pale brown	Yellow	1.4	15	3	Moist	5	D	2
3	4A	120	Sandy light clay	9.5	5YR5/6	Yellowish red		1.6	10	0	Moist	2	D	2
3	5BC	140+	Sandy light clay	9.0	10YR5/2	Greyish brown		1.4	30	0	Slight/Moist	2	D	2
4	A1	45	Medium clay	10.0	7.5YR4/4	Brown		1.6	2	3	Moist	5	D	3
4	2A	60	Light medium clay	10.0	7.5YR5/6	Strong brown		0.7	4	1	Slight/Moist	3	D	2
4	3BC1	80	Sandy clay loam	10.0	10YR6/3	Pale brown		1.2	20	1	Slight/Moist	1	D	1
4	3BC2	140+	Sandy clay loam	10.0	10YR7/3	Very pale brown		1.0	15	1	Moist	1	D	1
5	A	15	Sandy light clay	7.0	7.5YR3/3	Dark brown		1.4	15	2	Slight/Moist			3
5	BC1	70		9.0	7.5YR5/4	Brown			98	0	Slight	5	D	2
5	BC2	150+	Clayey sand	10.0	10YR7/3	Very pale brown			50	1	Slight/Moist			1
6	A	18	Sandy clay loam	6.5	5YR3/3	Dark reddish brown		1.5	10	2	Slight/Moist			4
6	B-C	120+		9.0	10YR8/2	Very pale brown			99	0	Slight			1
7	A1	8	Silty light clay	7.0	10YR4/2	Dark greyish brown		1.0		3	Wet			2

Pit	Horizon	Lower Depth (cm)	Texture	pH Water	Moist Soil Colour (Munsell)	Colour	Mottles	SOILpak Compaction Score	Gravel (%)	Dispersion 10 min.	Moisture	Lime %	Lime Type	Root Score
7	2B	48	Loamy sand	8.0	7.5YR5/4	Brown		structureless sand	40	1	Moist (25)			3
7	3B	95	Sandy light clay	9.0	7.5YR4/4	Brown		0.8	3	0	Slight			1
7	4B	140+	Light medium clay	10.0	10YR6/3	Pale brown		1.1		0	Slight/Moist	20	P/N	1 (110)
8	A1	7	Silty light clay	6.5	7.5YR4/2	Brown		1.5	2	2	Moist			3
8	2A	30	Light medium clay	7.5	7.5YR4/3	Brown		1.2	5	1	Slight/Moist			2
8	3B	100	Light clay	9.0	7.5YR5/4	Brown		1.2	20	0	Slight/Moist			1 (60)
8	4B	140+	Sandy clay loam	8.5	7.5YR6/4	Light brown		1.3	1	0	Slight/Moist			
9	A11	10	Sandy clay loam	6.0	7.5YR4/3	Brown		1.7	3	2	Moist			
9	A12	35	Clayey sand	6.0	7.5YR4/4	Brown		1.5	60	0	Moist (18)			
9	2B	120	Loamy sand	6.0	7.5YR5/4	Brown			75	1	Slight			
9	3B	140+	Light medium clay	7.0	7.5YR6/4	Light brown	Grey	1.3	2	1	Slight/Moist			
10	A1	10	Sandy light clay	6.5	7.5YR4/3	Brown		0.2		3	Slight/Moist			3
10	2A	40	Medium clay	6.5	7.5YR4/2	Brown		0.7		1	Moist			2
10	3B21	90	Light clay	9.0	7.5YR5/3	Brown		1.2		0	Slight/Moist	1	P/N	1 (60)
10	3B22	140+	Light clay	8.5	7.5YR5/4	Brown		0.6		0	Slight	1	N	0
11	A1	10	Sandy light clay	6.5	5YR3/3	Dark reddish brown		1.7	10	2	Moist			3
11	B21	50	Light medium clay	9.0	5YR4/4	Reddish brown		0.5	1	1	Slight			2
11	B22	70	Light medium clay	9.5	5YR4/6	Yellowish red		0.8	1	0	Slight	7	P	1
11	B23	140+	Light clay	9.5	5YR5/6	Yellowish red		0.9	2	0	Slight/Moist	15	P	1 (100)
12	A1	10	Light clay	7.5	5YR3/2	Dark reddish brown		1.7	20	0	Moist			2
12	B2	42	Medium heavy clay	7.5	5YR3/3	Dark reddish brown		1.7	2	0	Slight/Moist			3
12	BC	65	Light clay	7.5	10YR5/6	Yellowish brown		1.6		1	Slight/Moist			2
12	C1	130							BASALT WITH CALCIUM VEINS					1
12	C2	140+							BASALT					
13	A1	12	Sandy clay loam	7.0	5YR3/2	Dark reddish brown		1.8	15	0	Moist			3
13	B21	50	Light medium clay	7.0	2.5YR4/4	Reddish brown		1.1	1	0	Slight			3

Pit	Horizon	Lower Depth (cm)	Texture	pH Water	Moist Soil Colour (Munsell)	Colour	Mottles	SOILpak Compaction Score	Gravel (%)	Dispersion 10 min.	Moisture	Lime %	Lime Type	Root Score
13	B22	75	Light clay	8.0	5YR5/6	Yellowish red		1.2	2	0	Slight			2
13	C	130+	Light clay	8.0	7.5YR5/6	Strong brown	Yellow	1.4	60	0	Slight/Moist			1 (105)
14	A11	10	Sandy clay loam	6.5	7.5YR4/2	Brown		1.8	10	0	Slight/Moist			4
14	A12	25	Sandy loam	7.0	7.5YR5/3	Brown		1.7	15	1	Moist			4
14	B	65	Heavy clay	7.0	10YR5/4	Yellowish brown	Strong grey	0.8	6	3	Moist			2
14	C	70+												
15	A1	17	Sandy clay loam	6.5	7.5YR4/3	Brown		1.4	2	1	Moist			3
15	2A	35	Sandy loam	7.0	7.5YR5/4	Brown		1.4	10	2	Moist/Wet			4
15	3A	60	Loamy sand	7.0	7.5YR5/3	Brown			40	2	Moist			3
15	4A	130	Clayey sand	7.5	7.5YR6/3	Light brown			50	0	Moist			1
15	5A	140+	SAND/GRAVEL											
16	A11	20	Sandy loam	6.0	7.5YR3/3	Dark brown		1.6	30	0	Dry			3
16	A12	55	Sandy loam	7.0	7.5YR4/4	Brown		1.7	50	2	Slight			3
16	B2	90	Medium clay	8.0	7.5YR5/6	Strong brown	Strong red grey	1.5	2	0	Moist			1
16	C	105+							CONGLO-MERATE					
17	A1	16	Sandy clay loam	6.0	5YR3/3	Dark reddish brown		1.5	1	0	Slight/Moist			3
17	A2	20	Sandy loam	7.0	5YR3/3	Dark reddish brown		1.2	15	1	Slight			3
17	B21	55	Medium clay	8.0	2.5YR4/4	Reddish brown		0.7	1	2	Slight			2.5
17	B22	140+	Light medium clay	10.0	5YR5/6	Yellowish red		0.9	2	1	Slight/Moist	10	NP	1 (110)
18	A1	15	Sandy clay loam	6.0	7.5YR3/3	Dark brown		1.7		1	Slight/Moist			2
18	2B	35	Sandy light clay	6.0	5YR4/6	Yellowish red		1.8		0	Moist			3
18	3B	70	Heavy clay	7.5	5YR4/6	Yellowish red	Grey	1.5		3	Moist			3
18	4B21	95	Light medium clay	8.0	7.5YR5/4	Brown	Grey	1.3		0	Slight/Moist			1
18	4B22	140+	Medium clay	9.0	7.5YR5/4	Brown	Grey	1.3	10	0	Slight/Moist	5	P	1
19	A1	15	Light clay	5.5	5YR4/3	Reddish brown		1.8	1	0	Moist			3
19	B21	52	Light clay	6.0	2.5YR4/6	Red		1.5	2	0	Slight			3

Pit	Horizon	Lower Depth (cm)	Texture	pH Water	Moist Soil Colour (Munsell)	Colour	Mottles	SOILpak Compaction Score	Gravel (%)	Dispersion 10 min.	Moisture	Lime %	Lime Type	Root Score
19	B22	80	Light clay	6.0	5YR5/6	Yellowish red		1.2	1	0	Slight			3
19	B23	140+	Light clay	6.0	5YR5/6	Yellowish red	Grey	1.3	2	1	Slight/Moist			2
20	A1	7	Silty clay loam	6.0	7.5YR3/3	Dark brown		1.5	2	2	Slight			4
20	2A	20	Medium clay	7.5	5YR3/3	Dark reddish brown		1.3	1	1	Slight/Moist			2
20	3B	45	Light medium clay	10.0	5YR4/4	Reddish brown		0.7		0	Slight/Moist	2	N	1
20	4B21	95	Light clay	10.0	7.5YR4/4	Brown		1.1	1	0	Slight	15	P	1 (55)
20	4B22	140+	Light clay	10.0	7.5YR5/4	Brown			3	0	Slight			0
21	A1	8	Silty clay loam	6.0	7.5YR3/3	Dark brown		1.6	3	3	Moist			3
21	2A	20	Medium clay	8.0	5YR4/3	Reddish brown		1.0	1	1	Moist			2
21	2B	75	Medium heavy clay	10.0	5YR4/6	Yellowish red		1.2	1	0	Moist	15	P	1 (50)
21	3B	140+	Light medium clay	10.0	7.5YR5/4	Brown		1.1	1	0	Slight	3	N	0
22	A1	18	Sandy clay loam	6.0	7.5YR3/2	Dark brown		1.8	2	2	Moist (12)			3
22	B1	50	Light medium clay	9.0	7.5YR4/6	Strong brown		1.4	3	0	Slight			3
22	B21	110	Light medium clay	9.0	7.5YR5/4	Brown		1.1	1	0	Slight	15	P	1 (70)
22	B22	150+	Light clay	9.0	7.5YR7/4	Pink	Grey	1.0	10	1	Slight/Moist	2	P	
23	A1	10	Sandy clay loam	6.0	7.5YR3/3	Dark brown		1.7	5	0	Moist			3
23	A3	25	Sandy clay loam	6.5	5YR4/6	Yellowish red		1.3	2	0	Slight			2
23	B1	28	Sandy clay loam	7.0	5YR4/4	Reddish brown		1.2	15	3	Slight			2
23	B21	60	Light clay	7.5	2.5YR5/6	Red		0.9	1	0	Slight			2
23	B22	90	Light medium clay	7.5	7.5YR5/6	Strong brown		0.7	1	0	Slight			1
23	B23	140+	Sandy light clay	10.0	7.5YR5/6	Strong brown		0.7	3	1	Slight/Moist	5	P/D	1 (115)
24	A1	13	Light clay	6.5	2.5YR3/2	Dusky red		1.5	3	0	Moist			3
24	B21	60	Medium heavy clay	6.5	2.5YR3/6	Dark red		1.7	1	0	Moist			2
24	B22	115	Heavy clay	6.5	2.5YR4/6	Red		1.4	2	0	Moist			1 (110)
24	B23	140+	Light clay	8.0	2.5YR4/6	Red		0.7	2	0	Slight	5	N	0
25	A1	8	Sandy clay loam	6.0	7.5YR4/3	Brown		1.6	1	0	Slight/Moist			3

Pit	Horizon	Lower Depth (cm)	Texture	pH Water	Moist Soil Colour (Munsell)	Colour	Mottles	SOILpak Compaction Score	Gravel (%)	Dispersion 10 min.	Moisture	Lime %	Lime Type	Root Score
25	A3	17	Sandy light clay	6.5	7.5YR4/3	Brown		0.5	2	1	Slight			2
25	B21	70	Medium clay	7.5	7.5YR4/4	Brown		0.8	2	1	Slight			2
25	B22	140+	Sandy light clay	9.5	7.5YR4/6	Strong brown		1.0	5	0	Slight/Moist	2	N	1 (90)
26	A1	20	Sandy loam	6.0	7.5YR3/3	Dark brown		1.7	30	1	Slight/Moist			4
26	B21	55	Heavy clay	8.5	7.5YR5/4	Brown		1.2		2	Moist			2
26	B22	80	Light clay	9.5	7.5YR5/4	Brown		0.5	2	1	Slight	3	P	1 (70)
26	C	140+												
27	A1	10	Sandy light clay	7.0	7.5YR4/3	Brown		1.2	3	3	Moist/Wet			3
27	B2	25	Heavy clay	9.0	7.5YR4/4	Brown		1.2	2	2	Moist			3
27	2B2	65	Light medium clay	10.0	7.5YR5/4	Brown		1.0	3	1	Slight	10	P/N	1
27	3B21	110	Sandy light clay	10.0	7.5YR5/4	Brown	Yellow	0.7	12	0	Slight	15	P/N	1
27	3B22	140+	Sandy light clay	10.0	7.5YR5/6	Strong brown		1.1	3	0	Slight/Moist	2	N	0
28	A1	20	Light medium clay	6.5	7.5YR4/3	Brown		0.5	1	2	Slight/Moist			3
28	B2	70	Heavy clay	9.0	7.5YR4/6	Strong brown		0.5		1	Slight/Moist	2	N	1
28	2B	140+	Light clay	8.0	7.5YR7/3	Pink		0.9	10	0	Slight	2	P	1 (110)
29	A1	10	Clay loam	6.0	5YR3/2	Dark reddish brown		1.2	5	1	Slight/Moist			3
29	B21	35	Light medium clay	7.0	5YR3/3	Dark reddish brown		1.1	2	0	Slight			3
29	B22	75	Medium clay	8.0	5YR4/3	Reddish brown		1.0	1	0	Slight			2
29	C	140												1 (115)
30	A11	10	Sandy clay loam	6.0	5YR3/2	Dark reddish brown		1.8	10	0	Slight/Moist			3
30	A12	25	Sandy clay loam	6.5	7.5YR4/3	Brown		1.4	15	0	Slight/Moist			1
30	B2	40	Heavy clay	7.5	10YR5/4	Strong grey	Grey	0.5	2	3	Moist			0.5 (100)
30	2B21	75	Light clay	9.0	5YR5/6	Yellowish red		0.7	5	2	Slight			0
30	2B22	140+	Light medium clay	9.5	10YR5/6	Yellowish brown		0.5	2	0	Slight	2	N	0
31	A1	15	Sandy clay loam	7.5	7.5YR4/4	Brown		1.3	25	0	Moist			3
31	2B	60	Sandy clay loam	8.5	10YR5/4	Yellowish brown		1.2	90	0	Slight	5	D	2

Pit	Horizon	Lower Depth (cm)	Texture	pH Water	Moist Soil Colour (Munsell)	Colour	Mottles	SOILpak Compaction Score	Gravel (%)	Dispersion 10 min.	Moisture	Lime %	Lime Type	Root Score
31	3B	140+	Sandy clay loam	10.0	10YR7/3	Very pale brown		1.3	70	2	Slight/Moist	2	D	1
32	A1	15	Sandy loam	6.5	5YR4/3	Reddish brown		1.7	25	0	Moist			3
32	B1	50	Sandy clay loam	6.5	5YR5/6	Yellowish red		1.5	40	0	Slight			3
32	C	65												1 (65)
33	A1	10	Sandy loam	5.5	7.5YR3/3	Dark brown		1.7	15	0	Moist			4
33	A2	30	Sandy loam	7.5	7.5YR6/4	Light brown		1.2	70	1	Slight			3
33	B2	60	Medium clay	8.5	10YR7/2	Light grey	Strong yellow/red	1.0	2	3	Slight/Moist			1
33	C	80+			ROCK									1 (65)
34	A11	10	Sandy light-medium clay	6.5	5YR3/2	Dark reddish brown		0.8	10	3	Moist			3
34	A12	20	Sandy light-medium clay	7.5	5YR4/3	Reddish brown		0.5	2	0	Slight/Moist			3
34	B21	60	Medium clay	10.0	5YR4/6	Yellowish red		0.9	2	0	Slight	5	P/N	2
34	B22	140+	Medium clay	9.0	5YR6/6	Reddish yellow		1.1	4	0	Slight/Moist	15	P/N	1 (80)
35	A11	10	Sandy loam	6.0	7.5YR4/3	Brown		1.2	20		Slight/Moist			4
35	A12	25	Sandy loam	6.0	7.5YR4/6	Strong brown		1.2	40		Slight			3
35	C	140+	COAL/COARSE MATERIAL											1 (40)
36	A1	12	Sandy clay loam	6.0	7.5YR3/3	Dark brown		1.6	1	0	Slight			2
36	B21	60	Light clay	7.0	2.5YR4/6	Red		1.3	1	0	Slight			2
36	B22	85	Light clay	7.0	7.5YR5/6	Strong brown		1.6	3	0	Slight/Moist			2
36	B23	140+	Light medium clay	7.0	7.5YR5/8	Strong brown	Slight grey & yellow	1.0	10	0	Slight/Moist			1 (110)
37	A11	18	Sandy light clay	8.0	7.5YR4/4	Brown		1.7	2	0	Moist			4
37	A12	28	Sandy clay loam	7.5	7.5YR4/4	Brown		0.2	10	0	Slight			0.5
37	2B	90	Light medium clay	10.0	10YR5/1	Grey		1.3	50	1	Slight			1
37	3B	120	Loamy sand	10.0	10YR7/6	Yellow		1.3	70	0	Slight/Moist			0
37	4B	140+	Loamy sand	10.0	10YR7/2	Light grey			8	0	Slight/Moist			0
38	A1	20	Silty clay loam	6.0	7.5YR2.5/2	Very dark brown		1.7	10	1	Slight/Moist			4
38	B21	60	Heavy clay	8.0	7.5YR4/4	Brown		0.8		2	Moist			3

Pit	Horizon	Lower Depth (cm)	Texture	pH Water	Moist Soil Colour (Munsell)	Colour	Mottles	SOILpak Compaction Score	Gravel (%)	Dispersion 10 min.	Moisture	Lime %	Lime Type	Root Score
38	B22	95	Light medium clay	9.5	7.5YR4/6	Strong brown		1.4		1	Slight/Moist	5	P	2
38	B23	140	Light clay	9.0	7.5YR5/4	Brown	Grey	1.0		0	Slight	2	P	0
38	C	150+	SANDSTONE											
39	A1	15	Sandy clay loam	5.5	7.5YR3/2	Dark brown		1.6	20	2	Slight/Moist			4
39	B1	35	Medium heavy clay	7.5	10YR5/2	Greyish brown		0.8		3	Moist			2
39	B2	120	Medium clay	10.0	7.5YR5/4	Brown		0.6	3	1	Slight	20	P	1 (80)
39	C	125+	Light medium clay	10.0	7.5YR6/4	Light brown		1.2		0	Slight	5	N	0
40	A1	15	Sandy loam	6.0	7.5YR3/2	Dark brown		1.8	15	2	Moist (8)			3
40	B2	70	Medium heavy clay	6.0	10YR5/4	Strong grey		1.2		1	Moist	2	P (50-70)	2
40	BC	105	Medium clay	9.0	10YR7/3	Very pale brown		1.3	20	0	Slight/Moist			1
40	C	115+												
41	A	18	Sandy loam	7.0	7.5YR5/4	Brown		1.5	15		Slight/Moist	5	D	4
41	B/C	140+	Sandy loam	10.0	10YR6/3	Pale brown		1.2	98		Slight/Moist			1
42	A1	10	Sandy loam	5.5	5YR3/2	Dark reddish brown		1.3	40	1	Slight/Moist			2
42	A3	35	Sandy loam	6.0	5YR5/4	Reddish brown		1.0	30	2	Slight			2
42	B2	60	Sandy clay loam	7.5	5YR4/6	Yellowish red	Strong yellow grey	1.1	60	0	Slight/Moist			2
42	C	80+							CONGLO-MERATE					0
43	A1	15	Sandy light clay	7.0	5YR3/3	Dark reddish brown		1.6	3	2	Moist			4
43	B31	30	Sandy light clay	9.5	10YR6/4	Light yellowish brown		0.4	40	1	Slight/Moist			3
43	B32	60	Sandy clay loam	9.0	10YR7/4	Very pale brown		1.3	70	0	Slight	2	D	1
43	B33	140+	Sandy light clay	7.5	10YR5/4	Yellowish brown		1.1	40	0	Moist	4	D	1 (130)
44	A1	10	Sandy loam	6.5	5YR3/3	Dark reddish brown		1.5	30	1	Slight/Moist			2
44	B21	55	Light medium clay	10.0	5YR4/4	Reddish brown		0.7	5	1	Slight	2	P/N	1
44	B22	120	Light clay	10.0	5YR4/3	Reddish brown		1.2	5	3	Slight/Moist	2	P/N	1 (80)
44	C	140+	98% GRAVEL											
45	A11	12	Sandy loam	6.0	7.5YR4/3	Brown		1.6	30	1	Moist			3

Pit	Horizon	Lower Depth (cm)	Texture	pH Water	Moist Soil Colour (Munsell)	Colour	Mottles	SOILpak Compaction Score	Gravel (%)	Dispersion 10 min.	Moisture	Lime %	Lime Type	Root Score
45	A12	30	Sandy loam	6.0	7.5YR5/3	Brown		1.4	10	2	Moist			3
45	B21	70	Silty clay loam	7.0	10YR7/3	Very pale brown		1.3	70	4	Moist			0
45	B22	95	Medium clay	6.0	10YR7/3	Very pale brown		1.2		0	Slight/Moist			0
45	C	120+												
46	A1	12	Sandy loam	5.5	7.5YR3/3	Dark brown		1.6	15					4
46	A3	35	Sandy loam	6.0	7.5YR4/4	Brown			50					1 (65)
46	B1	90	Sandy clay loam	6.0	7.5YR4/4	Brown		1.5	80					3
46	C	92							100					
47	A1	15	Light clay	5.5	7.5YR4/3	Brown		1.5	2	0	Slight			3
47	B21	55	Medium heavy clay	5.5	7.5YR5/6	Strong brown		1.4		1	Moist			3
47	B22	85	Medium clay	6.5	10YR6/6	Brownish yellow		1.2		0	Slight/Moist			1
47	C	140+	Sandy clay loam	5.0	10YR8/2	Very pale brown		0.7		0	Slight			1 (90)
48	A1	10	Sandy loam	6.0	7.5YR4/3	Brown		1.4	20	0	Slight			4
48	B1	30	Sandy loam	5.5	7.5YR5/4	Brown		1.5	30	1	Slight			2 (40)
48	C	50+							98					2 (50)
49	A1	12	Sandy loam	6.0	7.5YR4/3	Brown		1.4	15	1	Slight			2
49	A2	35	Clayey sand	7.0	7.5YR5/3	Brown		0.9	7	0	Dry			2
49	B21	60	Sandy light clay	8.0	7.5YR6/6	Reddish yellow	Strong grey	0.4	5	2	Slight			1
49	B22	120	Sandy light clay	9.0	5YR6/8	Reddish yellow		0.5	15	0	Slight			1 (90)
49	C	130+	GRAVEL											
50	A1	20	Sandy loam	6.0	7.5YR4/4	Brown		1.3	2	0	Slight			2
50	A2	35	Sandy loam	6.5	7.5YR6/4	Light brown		1.1	3	1	Dry			2
50	B21	70	Light clay	8.5	7.5YR6/6	Reddish yellow		0.8	5 (GV, Mn)	2	Slight			1
50	B22	135+	Light clay	9.5	10YR5/6	Yellowish brown		0.9	7 (GV, Mn)	0	Slight/Moist			1 (80)
51	A	15	Light medium clay	8.5	7.5YR3/3	Dark brown		1.7	15		Slight/Moist	1	D	4
51	B/C	80							98					1 (80)

Pit	Horizon	Lower Depth (cm)	Texture	pH Water	Moist Soil Colour (Munsell)	Colour	Mottles	SOILpak Compaction Score	Gravel (%)	Dispersion 10 min.	Moisture	Lime %	Lime Type	Root Score
52	A1	15	Sandy clay loam	5.5	5YR3/2	Dark reddish brown		1.0	10	2	Slight			2
52	B1	40	Light medium clay	7.0	5YR5/8	Yellowish red		0.8	20	1	Dry			2
52	B21	65	Light medium clay	8.0	5YR5/6	Yellowish red	Slight grey	1.2	5	0	Slight			1
52	B22	95	Medium clay	9.0	5YR5/6	Yellowish red	Grey & yellow	1.3	15	2	Slight	1	D	1
52	C	120	SANDSTONE											
53	A1	13	Sandy clay loam	5.5	7.5YR3/3	Dark brown		1.4	15	3	Slight/Moist			2
53	B1	35	Light clay	9.0	7.5YR3/3	Dark brown		1.4	5	1	Slight/Moist			1
53	B21	60	Light medium clay	10.0	7.5YR4/3	Brown		1.1	3	1	Slight/Moist			0.5
53	B22	95	Light clay	10.0	7.5YR4/4	Brown		0.8	0	0	Slight	15	P	0
53	B23	140+	Light clay	9.5	10YR6/6	Brownish yellow		0.9	30 (GV/ Mn)	0	Slight	3	N	0
54	A1	10	Sandy loam	6.0	7.5YR4/3	Brown		1.2	15	0	Slight			4
54	A2	20	Clayey sand	6.0	7.5YR4/4	Brown		1.0	20	1	Dry			3
54	B21	65	Light clay	7.0	7.5YR4/4	Brown		0.7	2	3	Slight			1 (55)
54	B22	100+	Medium clay	10.0	10YR6/4	Light yellowish brown		1.1	60	0	Slight	0.5	D	
55	A1	20	Sandy loam	6.5	7.5YR4/3	Brown		1.3	20	1	Slight/Moist			3
55	B2	60	Heavy clay	9.0	10YR5/4	Strong grey		1.1	2	0	Moist	3	P	1
55	BC	120+	Light clay	9.0	10YR8/2	Very pale brown			80	0	Slight	3	P	1 (45)
56	A1	12	Sandy loam	5.5	10YR4/2	Dark greyish brown		1.6	2	0	Slight			4
56	A2	55	Clayey sand	6.5	10YR5/4	Yellowish brown		0.9	50	1	Dry			3
56	B21	105	Sandy light clay	7.5	10YR5/4	Yellowish brown		1.2	3	0	Slight			1 (115)
56	B22	140+	Sandy clay loam	7.5	7.5YR5/6	Strong brown		0.8	23 (GV, Mn)	1	Slight			
57	A1	8	Sandy loam	6.0	7.5YR4/3	Brown		1.5	3	0	Slight/Moist			3
57	B1	14	Sandy clay loam	6.0	7.5YR3/1	Very dark grey		1.5	2	2	Slight/Moist			3
57	2B2	40	Sandy clay	7.0	10YR4/1	Dark grey	Yellow	0.6	10	2	Slight			1
57	3B2	90	Light medium clay	10.0	10YR7/2	Light grey	Yellow	0.3	7	1	Slight	4	D	1 (70)
57	4B2	120	Medium clay	9.5	2.5Y6/3	Light yellowish brown	Yellow	0.2	0	1	Slight	2	D	

Pit	Horizon	Lower Depth (cm)	Texture	pH Water	Moist Soil Colour (Munsell)	Colour	Mottles	SOILpak Compaction Score	Gravel (%)	Dispersion 10 min.	Moisture	Lime %	Lime Type	Root Score
57	BC	125+	GRAVEL											
58	A11	8	Sandy loam	6.5	7.5YR3/3	Dark brown		1.3	10	0	Slight/Moist			4
58	A12	20	Clayey sand	6.5	7.5YR5/4	Brown		1.5	10	1	Slight/Moist			4
58	B21	45	Heavy clay	7.5	5YR4/6	Yellowish red		1.4	3	3	Moist			1
58	B22	70	Medium clay	9.0	7.5YR5/6	Strong brown	Yellow	1.3	15	1	Slight	0.5	D	1
58	C	120+							100					1 (85)
59	A1	10	Light clay	6.0	7.5YR3/3	Dark brown		1.5	10	0	Slight/Moist	0		2
59	B1	45	Light medium clay	9.0	7.5YR4/4	Brown		0.9	3	2	Slight	0		2
59	B21	115	Light medium clay	9.5	7.5YR4/6	Strong brown		1.1	3	0	Slight	5	P	1 (70)
59	B22`	150+	Medium clay	9.5	10YR6/6	Brownish yellow		1.2	2	0	Slight	1	D	0
60	A1	10	Sandy clay loam	6.0	10YR4/3	Brown		1.4	20	0	Slight/Moist			3
60	B1	50	Sandy light clay	9.0	10YR4/4	Dark yellowish brown		0.8	2	0	Slight	2	D	2
60	B2	130	Sandy light clay	10.0	10YR6/6	Brownish yellow		1.0	2	1	Slight/Moist	15	P	1 (120)
60	C	135+	GRAVEL											
61	A1	15	Silty clay loam	6.0	7.5YR4/3	Brown		1.6	2	3	Slight/Moist			4
61	B2	50	Medium heavy clay	8.0	10YR5/4	Strong grey		1.3	5	0	Moist			3
61	2B	85	Medium clay	9.0	5YR5/6	Yellowish red		0.6	25	1	Slight	5	N	1
61	3B	130+	Light medium clay	9.0	7.5YR6/4	Light brown		0.3	2	1	Slight	3	N	0
62	A1	10	Sandy loam	8.0	7.5YR5/4	Brown		0.5	40	1	Slight			2
62	2A	25	Coarse sand	8.0					5		Moist			4
62	3A	32	Medium heavy clay	9.0	7.5YR5/6	Strong brown	Strong grey	1.3	0	3	Moist			1
62	4B21	60	Medium heavy clay	10.0	7.5YR5/4	Brown	Slight grey	1.3	3	3	Moist	2	N	1
62	4B22	140+	Medium clay	10.0	7.5YR5/4	Brown		1.4	8	1	Slight/Moist	15	P/N	1 (95)
63	A1	10	Sandy clay loam	6.0	7.5YR4/3	Brown		1..5	15	0	Dry			2
63	B1	30	Sandy light clay	6.5	7.5YR3/2	Dark brown		1.2	10	1	Dry			3
63	C	90		6.5	10YR5/4	Yellowish brown			98	3	Slight			1

Pit	Horizon	Lower Depth (cm)	Texture	pH Water	Moist Soil Colour (Munsell)	Colour	Mottles	SOILpak Compaction Score	Gravel (%)	Dispersion 10 min.	Moisture	Lime %	Lime Type	Root Score
63	Hard gravel	92												
64	A11	15	Sandy loam	6.0	7.5YR3/3	Dark brown		1.8	5	2	Moist			3
64	A12	30	Sandy loam	6.5	7.5YR4/3	Brown		1.6	25	1	Moist			3
64	A2	37	Sandy loam	6.5	7.5YR5/3	Brown		1.6	80	2	Wet			2
64	B21	70	Light medium clay	9.0	7.5YR5/6	Strong brown	Grey	1.5	1	3	Slight	4	N	1 (55)
64	B22	140+	Light clay	10.0	10YR6/4	Light yellowish brown		1.1	10	0	Slight	10	P	0
65	A1	10	Silty light clay	6.0	7.5YR4/2	Brown		1.1		3	Moist			3
65	2B	55	Medium heavy clay	8.0	7.5YR4/2	Brown		1.0		2	Moist			2
65	3B21	90	Light medium clay	9.0	7.5YR4/3	Brown		1.3		0	Slight	3	N	0
65	3B22	140+	Light clay	9.0	7.5YR4/4	Brown		1.1		0	Slight	1	N	0
66	A1	15	Fine sandy clay loam	6.0	7.5YR3/2	Dark brown		1.8	2	1	Moist			3
66	2A	80	Loamy sand	6.5	10YR4/3	Brown			15	1	Moist/Wet			3
66	3A	115	Sandy loam	7.5	10YR5/4	Strong grey		0.3	50	0	Slight			0
66	4A	140	Silty clay loam	8.0	10YR5/3	Brown		0.3	5	0	Slight			0
66	5A	150+	Light medium clay	8.5	10YR4/1	Dark grey		0.8		1	Slight			0
67	A1	28	Sandy loam	5.5	7.5YR3/2	Dark brown		1.1		0	Dry			2
67	A2	55	Clayey sand	6.5	10YR5/4	Yellowish brown		1.1	60	3	Dry			3
67	B2	140+	Sandy clay	9.0	10YR5/4	Yellowish brown		0.8	10	0	Slight			1 (85)
68	A1	12	Light clay	6.0	10YR4/1	Dark grey		0.4		3	Slight			3
68	B2	55	Medium clay	7.5	10YR4/1	Dark grey		1.0		2	Slight			2
68	2B21	80	Light clay	8.0	10YR5/3	Brown		0.9		1	Slight	2	N	1 (65)
68	2B22	140+	Light medium clay	8.0	10YR5/2	Greyish brown		1.0		0	Slight/Moist			0
69	A1	8	Silty light clay	6.0	7.5YR4/3	Brown		0.7		4	Moist			3
69	2B	40	Heavy clay	10.0	7.5YR4/3	Brown		1.1		0	Moist			2
69	3B21	90	Light clay	9.5	7.5YR5/4	Brown		0.4		0	Slight	10	N	1 (65)
69	3B22	140+	Light clay	8.0	7.5YR5/4	Brown		0.7		0	Slight			0

Pit	Horizon	Lower Depth (cm)	Texture	pH Water	Moist Soil Colour (Munsell)	Colour	Mottles	SOILpak Compaction Score	Gravel (%)	Dispersion 10 min.	Moisture	Lime %	Lime Type	Root Score
70	A1	8	Light clay	6.0	10YR5/2	Greyish brown		0.3		2	Slight			3
70	B1	45	Medium clay	7.5	10YR3/2	Very dark greyish brown		0.7		1	Slight			2
70	B21	75	Light medium clay	8.0	10YR5/3	Brown		1.0		1	Slight/Moist	2	N	1
70	B22	140+	Light medium clay	8.0	7.5YR5/3	Brown		1.2		0	Slight/Moist			0
71	A1	15	Silty light clay	6.5	10YR5/3	Brown	Slight grey	0.4		1	Dry			2
71	B1	45	Medium clay	9.0	10YR4/3	Brown		0.7		3	Slight	2	N	2
71	B2	75	Medium clay	9.0	10YR4/4	Dark yellowish brown		0.9		1	Slight	5	ND	1
71	2B2	140+	Light medium clay	8.5	7.5YR5/6	Strong brown		1.4		0	Slight/Moist	2	ND	0
72	A1	12	Light medium clay	6.0	7.5YR4/2	Brown		1.8		3	Moist			4
72	2B	60	Heavy clay	10.0	10YR5/2	Greyish brown		1.1	2	0	Moist	5	D	3
72	3B	100	Light medium clay	9.0	10YR5/3	Brown		0.2	3	0	Slight	15	P/N	1 (80)
72	4B	140+	Light clay	9.0	7.5YR5/4	Brown		0.2		0	Slight	3	N	0
73	A1	15	Sandy clay loam	6.5	7.5YR4/3	Brown		0.1	5	0	Dry			1
73	B1	40	Light medium clay	8.5	7.5YR5/4	Brown		0.4	7	1	Dry			1
73	B21	100	Light medium clay	9.0	7.5YR4/6	Strong brown		0.6	10	0	Slight	25	P	0
73	B22	140+	Light clay	9.0	10YR5/4	Yellowish brown		0.9		0	Slight	3	PN	0
74	A11	15	Sandy loam	6.0	7.5YR4/3	Brown		1.7	20	1	Moist			4
74	A12	40	Clayey sand	6.5	7.5YR5/4	Brown		1.7	20	1	Moist			3
74	B2	120+	Light clay	7.0	7.5YR6/6	Reddish yellow	Grey red	1.0	20	0	Slight			1 (80)
75	A1	15	Light clay	6.0	7.5YR4/2	Brown		0.3		1	Dry			1
75	B1	30	Light medium clay	8.0	7.5YR4/3	Brown		0.6		2	Dry			1
75	2B	65	Silty clay loam	7.5	7.5YR5/6	Strong brown	Grey	1.6		0	Slight			1 (40)
75	3B	105	Light clay	8.5	7.5YR4/6	Strong brown		1.1		2	Slight/Moist	8	N	0
75	4B	140+	Sandy light clay	9.0	10YR5/8	Yellowish brown		1.3		0	Slight/Moist	10	N/P	0

cm = centimetre
% = percent

Appendix 6 Layer Data – Soil Structure Details

Pit	Depth (cm)	Pedality			Fabric	Consistence	SOILpak Score
		Grade	Type	Size (mm)			
1	18	M	SB	7	E	2	1.6
1	23	M	PO	5	E	2	1.4
1	80	S	LE	15	RP	6	0.8
1	140+	W	LE	15	RP	4	0.9
2	20	S	PO	12	RP	4	1.1
2	40	M	LE	15	RP	6	0.4
2	58	S	LE	10	RP	4	1
2	140	W	LE	15	RP	3	1.2
2	150+						0
3	10	S	SB	7	RP	2	1.8
3	35	M	SB	10	RP	3	1.4
3	45	M	PO	7	RP	2	1.5
3	108	M	LE	10	RP	3	1.4
3	120	M	PO	5	RP	2	1.6
3	140+	W	LE	7	E	3	1.4
4	45	M	SB	5	E	2	1.6
4	60	M	LE	15	RP	5	0.7
4	80	W	PO	8	E	2	1.2
4	140+	W	LE	10	RP	3	1
5	15	S	PO	7	RP	3	1.4
5	70						0
5	150+						0
6	18	M	PO	8	E	3	1.5
6	120+						0
7	8	W	LE	10	RP	2	1
7	48						structureless sand
7	95	M	PL	12	RP	4	0.8
7	140+	S	LE	10	RP	3	1.1
8	7	M	PO	5	E	2	1.5
8	30	S	PO	10	RP	5	1.2
8	100	M	B	10	RP	4	1.2
8	140+	W	LE	8	RP	2	1.3
9	10	S	SB	5	E	2	1.7
9	35	M	PO	7	E	2	1.5
9	120						structureless sand
9	140+	S	LE	8	RP	3	1.3
10	10	S	B	20	RP	6	0.2
10	40	S	LE	10	RP	5	0.7
10	90	S	LE	8	RP/SP	3	1.2
10	140+	M	LE	10	RP	5	0.6
11	10	M	SB	5	E	1	1.7
11	50	S	AB	20	RP	6	0.5
11	70	S	LE	15	RP	5	0.8
11	140+	S	LE	10	RP	4	0.9
12	10	M	SB	3	RP	2	1.7
12	42	S	SB	7	RP	3	1.7
12	65	M	PO	5	RP	2	1.6
12	130						0

Pit	Depth (cm)	Pedality			Fabric	Consistence	SOILpak Score
		Grade	Type	Size (mm)			
12	140+						0
13	12	S	SB	2	E	2	1.8
13	50	S	PO	10	RP	5	1.1
13	75	S	PO	10	RP	3	1.2
13	130+	M	LE	7	RP	3	1.4
14	10	S	SB	3	E	1	1.8
14	25	S	PO	5	E	1	1.7
14	65	M	B	15	RP	3	0.8
14	70+						0
15	17	W	PO	5	E	2	1.4
15	35	W	PO	10	E	2	1.4
15	60	Single grained					0
15	130	Single grained					0
15	140+	Gravel & sand					0
16	20	M	PO	3	E	2	1.6
16	55	M	PO	3	RP	2	1.7
16	90	W	PO	7	RP	2	1.5
16	105+						0
17	16	M	PO	7	E	3	1.5
17	20	M	PO	10	E	2	1.2
17	55	S	AB	15	RP & SP	5	0.7
17	140+	S	LE	7	RP	4	0.9
18	15	S	SB	5	E	1	1.7
18	35	S	SB	5	RP	2	1.8
18	70	S	PO	12	RP	3	1.5
18	95	M	LE	7	RP	3	1.3
18	140+	M	LE	8	RP	3	1.3
19	15	S	SB	3	E	1	1.8
19	52	M	PO	5	RP	2	1.5
19	80	S	PO	6	RP	4	1.2
19	140+	S	PO	7	RP	3	1.3
20	7	M	PO	8	E	3	1.5
20	20	S	PO	8	RP	4	1.3
20	45	W	LE	15	RP	6	0.7
20	95	M	LE	8	RP	5	1.1
20	140+						0
21	8	S	PO	8	E	2	1.6
21	20	S	Columnar	20	RP	4	1
21	75	M	LE	12	RP	3	1.2
21	140+	M	LE	8	RP	3	1.1
22	18	S	SB	3	E	1	1.8
22	50	S	PO	8	RP	3	1.4
22	110	M	LE	12	RP	4	1.1
22	150+	W	PO	15	RP	4	1
23	10	M	SB	4	E	2	1.7
23	25	W	LE	15	E	3	1.3
23	28	W	PO	5	E	2	1.2
23	60	S	PO	20	RP	5	0.9
23	90	S	B	25	RP & SP	6	0.7
23	140+	W	LE	10	RP	5	0.7
24	13	S	PO	7	RP	2	1.5

Pit	Depth (cm)	Pedality			Fabric	Consistence	SOILpak Score
		Grade	Type	Size (mm)			
24	60	S	PO	8	RP	2	1.7
24	115	S	PO	8	RP	3	1.4
24	140+	M	LE	15	RP	6	0.7
25	8	M	PO	5	E	2	1.6
25	17	S	LE	15	E	4	0.5
25	70	S	LE	10	RP	6	0.8
25	140+	W	LE	15	E	2	1
26	20	M	SB	2	E	1	1.7
26	55	M	PO	10	RP	3	1.2
26	80	M	LE	20	RP	6	0.5
26	140+						0
27	10	W	PO	10	E	2	1.2
27	25	S	PO	10	RP	5	1.2
27	65	W	AB	12	RP	4	1
27	110	M	LE	10	RP	5	0.7
27	140+	M	LE	8	RP	3	1.1
28	20	M	B	20	RP	6	0.5
28	70	M	LE	20	RP	4	0.5
28	140+	W	LE	20	RP	3	0.9
29	10	S	SB	10	RP	3	1.2
29	35	S	PO	15	RP & SP	6	1.1
29	75	S	LE	15	RP & SP	5	1
29	140						0
30	10	S	SB	3	E	1	1.8
30	25	M	PO	5	E	2	1.4
30	40	S	LE	15	RP	5	0.5
30	75	S	LE	7	RP	6	0.7
30	140+	S	LE	15	RP	6	0.5
31	15	M	PO	8	RP	3	1.3
31	60	W	PO	7	E	2	1.2
31	140+	W	PO	5	E	1	1.3
32	15	M	SB	5	E	2	1.7
32	50	M	PO	10	RP	2	1.5
32	65						0
33	10	M	SB	5	E	2	1.7
33	30	W	LE	8	E	3	1.2
33	60	M	LE	10	RP	4	1
33	80+						0
34	10	W	AB	10	E	3	0.8
34	20	S	AB	25	RP	7	0.5
34	60	S	LE	12	RP	4	0.9
34	140+	S	PO	7	RP	4	1.1
35	10	W	PO	3	E	1	1.2
35	25	W	PO	3	E	1	1.2
35	140+						0
36	12	M	SB	7	E	2	1.6
36	60	M	PO	10	RP	3	1.3
36	85	S	PO	7	RP	3	1.6
36	140+	W	LE	15	RP	4	1
37	18	S	SB	5	RP	2	1.7

Pit	Depth (cm)	Pedality			Fabric	Consistence	SOILpak Score
		Grade	Type	Size (mm)			
37	28	W	LE	15	RP	6	0.2
37	90	M	PO	8	RP	2	1.3
37	120	M	PO	8	RP	3	1.3
37	140+	structureless sand					0
38	20	M	SB	5	E	2	1.7
38	60	M	PO	20	RP	4	0.8
38	95	M	PO	10	RP	3	1.4
38	140	W	LE	8	RP	4	1
38	150+						0
39	15	M	PO	7	E	2	1.6
39	35	W	B	12	RP	3	0.8
39	120	W	LE	15	RP	5	0.6
39	125+	M	PO	8	RP	4	1.2
40	15	M	SB	5	E	2	1.8
40	70	M	LE	10	RP	3	1.2
40	105	M	LE	7	RP	3	1.3
40	115+						0
41	18	M	PO	10	E	2	1.5
41	140+	W	PO	5	E	2	1.2
42	10	W	B	8	E	2	1.3
42	35	M	PO	7	E	2	1
42	60	M	LE	8	RP	3	1.1
42	80+						0
43	15	S	SB	5	RP	2	1.6
43	30	W	PO	3	E	4	0.4
43	60	M	PO	8	E	2	1.3
43	140+	M	PO	10	E	3	1.1
44	10	M	SB	4	E	1	1.5
44	55	M	LE	25	RP	7	0.7
44	120	S	PO	8	RP	4	1.2
44	140+						0
45	12	M	PO	2	E	1	1.6
45	30	W	PO	3	E	1	1.4
45	70	W	PO	7	E	2	1.3
45	95	W	LE	8	RP	3	1.2
45	120+						0
46	12	W	PO	7	E	2	1.6
46	35						0
46	90	M	PO	7	E	2	1.5
46	92						0
47	15	M	PO	7	E	2	1.5
47	55	M	PO	8	RP	3	1.4
47	85	M	PO	10	RP	4	1.2
47	140+	W	B	15	RP	6	0.7
48	10	W	PO	3	E	1	1.4
48	30	W	PO	8	E	2	1.5
48	50+						0
49	12	W	PO	4	E	1	1.4
49	35	W	LE	12	E	3	0.9
49	60	W	LE	15	RP	5	0.4
49	120	W	LE	15	RP	4	0.5

Pit	Depth (cm)	Pedality			Fabric	Consistence	SOILpak Score
		Grade	Type	Size (mm)			
49	130+						0
50	20	M	PO	8	E	3	1.3
50	35	W	LE	8	E	2	1.1
50	70	S	LE	12	RP	4	0.8
50	135+	S	LE	10	RP	4	0.9
51	15	S	SB	5	RP	2	1.7
51	80						0
52	15	W	PO	15	E	3	1
52	40	M	PO	8	RP	6	0.8
52	65	M	PO	8	RP	3	1.2
52	95	M	PO	5	RP	2	1.3
52	120						0
53	13	W	PO	7	E	2	1.4
53	35	M	PO	10	RP	3	1.4
53	60	M	LE	10	RP	3	1.1
53	95	M	LE	15	RP	6	0.8
53	140+	W	PO	7	RP	5	0.9
54	10	W	PO	2	E	2	1.2
54	20	M	PO	6	E	3	1
54	65	S	LE	12	RP	6	0.7
54	100+	M	LE	5	RP	4	1.1
55	20	M	PO	8	RP	4	1.3
55	60	M	B	12	RP	4	1.1
55	120+	rock	rock				0
56	12	M	PO	5	E	2	1.6
56	55	W	LE	5	E	3	0.9
56	105	M	PO	8	RP	3	1.2
56	140+	W	LE	10	RP	3	0.8
57	8	W	PO	4	E	2	1.5
57	14	M	PO	6	E	2	1.5
57	40	M	LE	15	RP	6	0.6
57	90	S	LE	25	RP	7	0.3
57	120	W	LE	35	RP	7	0.2
57	125+						0
58	8	W	PO	5	E	2	1.3
58	20	M	PO	5	E	2	1.5
58	45	M	PO	8	RP	3	1.4
58	70	M	PO	12	RP	4	1.3
58	120+						0
59	10	S	SB	7	E	3	1.5
59	45	S	PO	12	RP	6	0.9
59	115	S	PO	15	RP	5	1.1
59	150+	S	PO	10	RP	5	1.2
60	10	M	PO	6	E	2	1.4
60	50	M	LE	10	RP	5	0.8
60	130	S	LE	6	RP	4	1
60	135+						0
61	15	M	PO	4	E	2	1.6
61	50	M	PO	8	RP	3	1.3
61	85	M	LE	15	RP	6	0.6
61	130+	W	LE	10	RP	7	0.3

Pit	Depth (cm)	Pedality			Fabric	Consistence	SOILpak Score
		Grade	Type	Size (mm)			
62	10	W	B	20	E	5	0.5
62	25						0
62	32	M	PO	10	RP	3	1.3
62	60	M	PO	10	RP	3	1.3
62	140+	M	LE	8	RP	3	1.4
63	10	W	PO	3	E	1	1..5
63	30	M	PO	8	E	3	1.2
63	90						0
63	92						0
64	15	S	SB	5	E	1	1.8
64	30	M	PO	5	E	1	1.6
64	37	M	PO	5	E	1	1.6
64	70	M	PO	10	RP	2	1.5
64	140+	W	B	8	RP	3	1.1
65	10	M	B	12	RP	3	1.1
65	55	M	LE	10	RP	3	1
65	90	M	LE	8	RP	2	1.3
65	140+	W	LE	10	RP	2	1.1
66	15	S	SB	5	E	1	1.8
66	80	Structureless					0
66	115	W	LE	15	E	5	0.3
66	140	W	LE	15	E	5	0.3
66	150+	M	LE	10	RP	3	0.8
67	28	M	LE	10	E	3	1.1
67	55	W	PO	3	E	2	1.1
67	140+	M	LE	12	RP	3	0.8
68	12	S	B	30	RP	7	0.4
68	55	S	LE	18	RP	4	1
68	80	M	LE	12	RP	5	0.9
68	140+	S	LE	15	RP	4	1
69	8	M	B	15	RP	3	0.7
69	40	M	LE	15	RP	2	1.1
69	90	W	LE	20	RP	5	0.4
69	140+	W	LE	10	RP	4	0.7
70	8	S	B	40	E	7	0.3
70	45	S	LE	20	RP	7	0.7
70	75	S	LE	12	RP	5	1
70	140+	M	PO	10	E	4	1.2
71	15	M	B	31	E	6	0.4
71	45	S	LE	20	RP & SP	6	0.7
71	75	S	LE	10	RP	5	0.9
71	140+	S	PO	8	RP	4	1.4
72	12	S	SB	4	RP	2	1.8
72	60	M	PO	12	RP	4	1.1
72	100	S	LE	15	RP	6	0.2
72	140+	M	LE	15	RP	6	0.2
73	15	W	P	60	E	8	0.1
73	40	W	LE	25	E	7	0.4
73	100	M	LE	15	RP	8	0.6
73	140+	M	LE	10	RP	4	0.9

Pit	Depth (cm)	Pedality			Fabric	Consistence	SOILpak Score
		Grade	Type	Size (mm)			
74	15	M	PO	3	E	2	1.7
74	40	W	PO	5	S	1	1.7
74	120+	M	LE	10	RP	3	1
75	15	W	B	30	E	6	0.3
75	30	M	LE	15	RP	5	0.6
75	65	S	PO	7	RP	3	1.6
75	105	M	LE	15	RP	4	1.1
75	140+	M	LE	8	RP	3	1.3

cm = centimetres
mm = millimetres

Appendix7 Laboratory Data

Site	Depth (cm)	pH ($CaCl_2$)	EC 1:5 (dS/m)	ECe (dS/m)	Chloride (mg/kg)	Exchangeable cations (meq/100g) Ca	Mg	K	Na	Al	CEC	ESP	ESI	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 (%)
1	0-15	5.6	0.08	0.69	16	8.0	3.2	1.4	0.3	0.0	12.9	1.9	0.04	2.50	12	9	11	3	0.37	1.10	0.79	1.50
1	15-30	5.7	0.04	0.34	11	6.5	2.8	0.7	0.3	0.0	10.4	3.3	0.01	2.32	14	2	6	2	0.13	0.83	0.60	0.78
1	30-60	6.7	0.08	0.60	11	11.0	7.3	0.8	0.8	0.0	19.9	3.9	0.02	1.51	12	1	5	3	0.03	0.79	1.20	0.53
1	60-90	7.9	0.21	1.81	60	12.0	9.9	0.7	1.0	0.0	23.6	4.2	0.05	1.21	0	1	5	11	0.03	0.78	1.90	0.22
1	90-120	7.8	0.16	1.38	55	10.0	9.9	1.0	1.0	0.0	21.9	4.6	0.03	1.01	10	1	5	10	0.03	0.75	1.30	0.15
2	0-15	7.5	0.21	1.81	40	11.0	6.0	0.4	3.0	0.0	20.4	14.7	0.01	1.83	9	7	15	8	0.08	0.66	1.40	0.41
2	15-30	8.1	0.26	2.24	91	11.0	6.7	0.4	3.6	0.0	21.7	16.6	0.02	1.64	7	1	5	9	0.03	0.76	1.88	0.24
2	30-60	8.3	0.36	3.10	91	14.0	8.1	0.5	4.4	0.0	27.0	16.3	0.02	1.73	6	1	6	7	0.05	0.73	2.00	0.15
2	60-90	8.3	0.28	2.41	83	10.0	7.4	0.5	4.8	0.0	22.7	21.1	0.01	1.35	10	2	6	8	0.03	0.49	1.70	0.15
3	0-15	8.1	0.17	1.46	10	21.0	12.0	0.8	0.6	0.0	34.4	1.7	0.10	1.75	2	1	5	2	0.16	0.65	2.20	0.47
3	15-30	8.1	0.21	1.22	10	19.0	9.9	0.6	1.6	0.0	31.1	5.1	0.04	1.92	14	1	5	4	0.10	0.74	2.50	0.62
3	30-60	8.7	0.24	1.80	15	9.5	9.9	0.5	3.0	0.0	22.9	13.1	0.02	0.96	13	1	5	7	2.70	1.00	1.30	0.46
3	60-90	8.7	0.29	2.49	46	8.0	11.0	0.4	3.1	0.0	22.5	13.8	0.02	0.73	15	1	5	30	4.50	1.20	0.77	0.47
3	90-120	8.5	0.35	3.01	13	9.0	14.0	0.5	3.3	0.0	26.8	12.3	0.03	0.64	11	1	5	78	1.10	0.57	1.00	0.17
4	0-15	8.2	0.17	1.28	10	16.0	8.2	0.6	1.1	0.0	25.9	4.2	0.04	1.95	11	2	9	2	0.07	0.39	1.40	0.18
4	15-30	8.3	0.22	1.65	13	14.0	9.1	0.6	2.1	0.0	25.8	8.1	0.03	1.54	11	1	41	5	0.08	0.38	1.40	0.23
4	30-60	8.4	0.33	2.48	10	16.0	12.0	0.6	4.0	0.0	32.6	12.3	0.03	1.33	13	1	5	9	0.04	0.44	3.20	0.15
4	60-90	8.8	0.45	3.87	72	12.0	9.9	0.6	7.8	0.0	30.3	25.7	0.02	1.21	14	1	5	20	0.05	0.23	0.37	0.15
4	90-120	8.7	0.59	5.07	360	10.0	8.2	0.5	7.4	0.0	26.1	28.4	0.02	1.22	14	1	5	47	0.04	0.22	0.39	0.15
5	0-15	6.8	0.12	1.03	10	10.0	4.8	1.5	0.0	0.0	16.3	0.1	1.96	2.08	11	13	53	3	0.77	0.51	0.79	1.40
6	0-15	6.2	0.09	0.77	10	8.5	4.0	1.2	0.0	0.0	13.7	0.3	0.31	2.13	13	18	110	3	0.61	0.83	0.61	1.10
7	0-15	6.3	0.23	1.98	10	10.0	4.9	1.3	0.1	0.0	16.3	0.7	0.31	2.04	11	84	9	6	0.33	0.42	0.94	1.80
7	15-30	8.1	0.08	1.10	10	6.0	1.3	0.4	0.0	0.0	7.8	0.4	0.21	4.62	4	2	5	1	0.03	0.12	0.37	0.23
7	30-60	8.2	0.07	0.60	10	5.5	1.5	0.3	0.1	0.0	7.4	1.2	0.06	3.67	4	1	5	1	0.03	0.09	0.37	0.15

Appendix7 Laboratory Data

Site	Depth (cm)	pH ($CaCl_2$)	EC 1:5 (dS/m)	ECe (dS/m)	Chloride (mg/kg)	Exchangeable cations (meq/100g)						ESP	ESI	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											
1	0-15	5.6	0.08	0.69	16	8.0	3.2	1.4	0.3	0.0	12.9	1.9	0.04	2.50	12	9	11	3	0.37	1.10	0.79	1.50
1	15-30	5.7	0.04	0.34	11	6.5	2.8	0.7	0.3	0.0	10.4	3.3	0.01	2.32	14	2	6	2	0.13	0.83	0.60	0.78
1	30-60	6.7	0.08	0.60	11	11.0	7.3	0.8	0.8	0.0	19.9	3.9	0.02	1.51	12	1	5	3	0.03	0.79	1.20	0.53
1	60-90	7.9	0.21	1.81	60	12.0	9.9	0.7	1.0	0.0	23.6	4.2	0.05	1.21	0	1	5	11	0.03	0.78	1.90	0.22
1	90-120	7.8	0.16	1.38	55	10.0	9.9	1.0	1.0	0.0	21.9	4.6	0.03	1.01	10	1	5	10	0.03	0.75	1.30	0.15
2	0-15	7.5	0.21	1.81	40	11.0	6.0	0.4	3.0	0.0	20.4	14.7	0.01	1.83	9	7	15	8	0.08	0.66	1.40	0.41
2	15-30	8.1	0.26	2.24	91	11.0	6.7	0.4	3.6	0.0	21.7	16.6	0.02	1.64	7	1	5	9	0.03	0.76	1.88	0.24
2	30-60	8.3	0.36	3.10	91	14.0	8.1	0.5	4.4	0.0	27.0	16.3	0.02	1.73	6	1	6	7	0.05	0.73	2.00	0.15
2	60-90	8.3	0.28	2.41	83	10.0	7.4	0.5	4.8	0.0	22.7	21.1	0.01	1.35	10	2	6	8	0.03	0.49	1.70	0.15
3	0-15	8.1	0.17	1.46	10	21.0	12.0	0.8	0.6	0.0	34.4	1.7	0.10	1.75	2	1	5	2	0.16	0.65	2.20	0.47
3	15-30	8.1	0.21	1.22	10	19.0	9.9	0.6	1.6	0.0	31.1	5.1	0.04	1.92	14	1	5	4	0.10	0.74	2.50	0.62
3	30-60	8.7	0.24	1.80	15	9.5	9.9	0.5	3.0	0.0	22.9	13.1	0.02	0.96	13	1	5	7	2.70	1.00	1.30	0.46
3	60-90	8.7	0.29	2.49	46	8.0	11.0	0.4	3.1	0.0	22.5	13.8	0.02	0.73	15	1	5	30	4.50	1.20	0.77	0.47
3	90-120	8.5	0.35	3.01	13	9.0	14.0	0.5	3.3	0.0	26.8	12.3	0.03	0.64	11	1	5	78	1.10	0.57	1.00	0.17
4	0-15	8.2	0.17	1.28	10	16.0	8.2	0.6	1.1	0.0	25.9	4.2	0.04	1.95	11	2	9	2	0.07	0.39	1.40	0.18
4	15-30	8.3	0.22	1.65	13	14.0	9.1	0.6	2.1	0.0	25.8	8.1	0.03	1.54	11	1	41	5	0.08	0.38	1.40	0.23
4	30-60	8.4	0.33	2.48	10	16.0	12.0	0.6	4.0	0.0	32.6	12.3	0.03	1.33	13	1	5	9	0.04	0.44	3.20	0.15
4	60-90	8.8	0.45	3.87	72	12.0	9.9	0.6	7.8	0.0	30.3	25.7	0.02	1.21	14	1	5	20	0.05	0.23	0.37	0.15
4	90-120	8.7	0.59	5.07	360	10.0	8.2	0.5	7.4	0.0	26.1	28.4	0.02	1.22	14	1	5	47	0.04	0.22	0.39	0.15
5	0-15	6.8	0.12	1.03	10	10.0	4.8	1.5	0.0	0.0	16.3	0.1	1.96	2.08	11	13	53	3	0.77	0.51	0.79	1.40
6	0-15	6.2	0.09	0.77	10	8.5	4.0	1.2	0.0	0.0	13.7	0.3	0.31	2.13	13	18	110	3	0.61	0.83	0.61	1.10
7	0-15	6.3	0.23	1.98	10	10.0	4.9	1.3	0.1	0.0	16.3	0.7	0.31	2.04	11	84	9	6	0.33	0.42	0.94	1.80
7	15-30	8.1	0.08	1.10	10	6.0	1.3	0.4	0.0	0.0	7.8	0.4	0.21	4.62	4	2	5	1	0.03	0.12	0.37	0.23
7	30-60	8.2	0.07	0.60	10	5.5	1.5	0.3	0.1	0.0	7.4	1.2	0.06	3.67	4	1	5	1	0.03	0.09	0.37	0.15

						Exchangeable cations (meq/100g)																
Site	Depth (cm)	pH ($CaCl_2$)	EC 1:5 (dS/m)	ECe (dS/m)	Chloride (mg/kg)	Ca	Mg	K	Na	Al	CEC	ESP	ESI	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 (%)
7	60-90	7.8	0.14	1.20	110	3.2	6.8	0.3	3.9	0.0	14.2	27.4	0.01	0.47	13	1	5	1	0.02	0.16	1.20	0.15
7	90-120	9.0	0.89	7.65	730	16.0	11.0	0.5	10.0	0.0	37.5	26.7	0.03	1.45	0	1	5	50	0.02	0.17	2.20	0.15
7	200	8.8	1.05	9.03	910	10.0	12.0	0.5	12.0	0.0	34.5	34.8	0.03	0.83	10	3	5	73	0.02	0.05	1.20	0.15
7	300	8.4	0.67	5.76	680	2.0	7.6	0.3	8.3	0.0	18.2	45.5	0.01	0.26	5	3	5	48	0.02	0.08	0.65	0.15
8	0-15	5.2	0.08	0.69	17	5.0	2.5	1.0	0.3	0.1	8.9	3.6	0.02	2.00	4	20	14	3	0.42	0.47	0.58	1.50
8	15-30	7.4	0.25	2.15	260	10.0	9.9	0.3	4.8	0.0	25.0	19.2	0.01	1.01	13	1	5	3	0.04	0.29	2.00	0.64
8	30-60	8.5	0.99	8.51	990	18.0	12.0	0.5	9.1	0.0	39.6	23.0	0.04	1.50	0	4	5	71	0.03	0.27	4.30	0.19
8	60-90	8.5	1.06	9.12	1100	19.0	12.0	0.6	10.0	0.0	41.6	24.1	0.04	1.58	0	4	5	80	0.02	0.23	3.50	0.15
8	90-120	8.5	1.12	9.63	1100	15.0	13.0	0.7	12.0	0.0	40.7	29.5	0.04	1.15	0	5	5	77	0.02	0.19	2.40	0.15
8	200	8.3	1.14	9.80	1200	6.5	14.0	0.6	18.0	0.0	39.1	46.0	0.02	0.46	0	4	5	91	0.04	0.14	1.30	0.15
8	300	8.9	1.33	11.44	1100	10.0	13.0	0.4	18.0	0.0	41.4	43.4	0.03	0.77	0	5	5	100	0.02	0.12	0.81	0.15
9	0-15	5.0	0.04	0.34	10	2.7	0.9	0.6	0.0	0.1	4.3	0.9	0.04	2.97	10	13	5	1	0.17	0.11	0.23	0.70
9	15-30	4.7	0.01	0.23	10	1.4	0.8	0.3	0.0	0.3	2.8	1.4	0.01	1.71	6	1	5	1	0.04	0.09	0.17	0.29
9	30-60	4.6	.	0.41	10	0.4	1.3	0.3	0.1	0.3	2.3	3.5	.	0.28	6	1	5	1	0.05	0.12	0.20	0.15
9	60-90	5.5	0.01	0.04	10	0.9	1.3	0.3	0.1	0.1	2.6	2.7	0.00	0.69	6	1	5	1	0.03	0.11	0.17	0.15
9	90-120	6.2	0.01	0.14	10	1.2	1.1	0.3	0.1	0.1	2.8	4.0	0.00	1.09	6	1	5	1	0.03	0.11	0.19	0.15
10	0-15	5.4	0.06	0.52	22	6.0	3.6	0.7	0.8	0.1	11.2	7.0	0.01	1.67	12	3	5	1	0.17	0.60	0.62	1.10
10	15-30	5.2	0.13	0.98	91	9.5	5.6	0.4	1.9	0.1	17.5	10.8	0.01	1.70	14	1	5	2	0.04	0.80	0.92	0.57
10	30-60	7.8	0.49	4.21	430	12.0	8.0	0.5	4.0	0.0	24.5	16.4	0.03	1.50	0	1	5	25	0.03	0.55	2.60	0.20
10	60-90	7.8	0.50	4.30	490	10.0	6.9	0.5	3.9	0.0	21.3	18.3	0.03	1.45	0	1	5	27	0.03	0.52	2.10	0.17
10	90-120	7.8	0.60	5.16	690	12.0	8.2	0.6	5.2	0.0	26.0	20.0	0.03	1.46	0	1	5	32	0.05	0.48	2.00	0.19
10	200	7.7	0.41	3.53	370	9.0	6.7	0.4	4.4	0.0	20.5	21.5	0.02	1.34	1	1	6	28	0.06	0.40	1.00	0.15
10	300	8.1	0.47	4.04	370	9.0	6.0	0.4	4.4	0.0	19.8	22.2	0.02	1.50	12	1	5	24	0.04	0.38	0.76	0.15
11	0-15	4.9	0.04	0.34	14	3.3	3.6	0.8	0.3	0.1	8.1	3.7	0.01	0.92	10	5	10	2	0.26	0.76	0.69	0.93
11	15-30	7.2	0.10	0.86	42	8.5	12.0	0.5	2.0	0.0	23.0	8.7	0.01	0.71	13	1	5	3	0.03	0.65	2.20	0.45
11	30-60	8.3	0.49	4.21	330	21.0	13.0	0.3	3.4	0.0	37.7	9.0	0.05	1.62	0	1	5	20	0.04	0.53	4.20	0.32
11	60-90	8.4	0.79	6.79	860	19.0	13.0	0.3	4.8	0.0	37.1	12.9	0.06	1.46	0	1	5	41	0.03	0.48	4.70	0.15

						Exchangeable cations (meq/100g)																
Site	Depth (cm)	pH ($CaCl_2$)	EC 1:5 (dS/m)	ECe (dS/m)	Chloride (mg/kg)	Ca	Mg	K	Na	Al	CEC	ESP	ESI	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 (%)
7	60-90	7.8	0.14	1.20	110	3.2	6.8	0.3	3.9	0.0	14.2	27.4	0.01	0.47	13	1	5	1	0.02	0.16	1.20	0.15
7	90-120	9.0	0.89	7.65	730	16.0	11.0	0.5	10.0	0.0	37.5	26.7	0.03	1.45	0	1	5	50	0.02	0.17	2.20	0.15
7	200	8.8	1.05	9.03	910	10.0	12.0	0.5	12.0	0.0	34.5	34.8	0.03	0.83	10	3	5	73	0.02	0.05	1.20	0.15
7	300	8.4	0.67	5.76	680	2.0	7.6	0.3	8.3	0.0	18.2	45.5	0.01	0.26	5	3	5	48	0.02	0.08	0.65	0.15
8	0-15	5.2	0.08	0.69	17	5.0	2.5	1.0	0.3	0.1	8.9	3.6	0.02	2.00	4	20	14	3	0.42	0.47	0.58	1.50
8	15-30	7.4	0.25	2.15	260	10.0	9.9	0.3	4.8	0.0	25.0	19.2	0.01	1.01	13	1	5	3	0.04	0.29	2.00	0.64
8	30-60	8.5	0.99	8.51	990	18.0	12.0	0.5	9.1	0.0	39.6	23.0	0.04	1.50	0	4	5	71	0.03	0.27	4.30	0.19
8	60-90	8.5	1.06	9.12	1100	19.0	12.0	0.6	10.0	0.0	41.6	24.1	0.04	1.58	0	4	5	80	0.02	0.23	3.50	0.15
8	90-120	8.5	1.12	9.63	1100	15.0	13.0	0.7	12.0	0.0	40.7	29.5	0.04	1.15	0	5	5	77	0.02	0.19	2.40	0.15
8	200	8.3	1.14	9.80	1200	6.5	14.0	0.6	18.0	0.0	39.1	46.0	0.02	0.46	0	4	5	91	0.04	0.14	1.30	0.15
8	300	8.9	1.33	11.44	1100	10.0	13.0	0.4	18.0	0.0	41.4	43.4	0.03	0.77	0	5	5	100	0.02	0.12	0.81	0.15
9	0-15	5.0	0.04	0.34	10	2.7	0.9	0.6	0.0	0.1	4.3	0.9	0.04	2.97	10	13	5	1	0.17	0.11	0.23	0.70
9	15-30	4.7	0.01	0.23	10	1.4	0.8	0.3	0.0	0.3	2.8	1.4	0.01	1.71	6	1	5	1	0.04	0.09	0.17	0.29
9	30-60	4.6	.	0.41	10	0.4	1.3	0.3	0.1	0.3	2.3	3.5	.	0.28	6	1	5	1	0.05	0.12	0.20	0.15
9	60-90	5.5	0.01	0.04	10	0.9	1.3	0.3	0.1	0.1	2.6	2.7	0.00	0.69	6	1	5	1	0.03	0.11	0.17	0.15
9	90-120	6.2	0.01	0.14	10	1.2	1.1	0.3	0.1	0.1	2.8	4.0	0.00	1.09	6	1	5	1	0.03	0.11	0.19	0.15
10	0-15	5.4	0.06	0.52	22	6.0	3.6	0.7	0.8	0.1	11.2	7.0	0.01	1.67	12	3	5	1	0.17	0.60	0.62	1.10
10	15-30	5.2	0.13	0.98	91	9.5	5.6	0.4	1.9	0.1	17.5	10.8	0.01	1.70	14	1	5	2	0.04	0.80	0.92	0.57
10	30-60	7.8	0.49	4.21	430	12.0	8.0	0.5	4.0	0.0	24.5	16.4	0.03	1.50	0	1	5	25	0.03	0.55	2.60	0.20
10	60-90	7.8	0.50	4.30	490	10.0	6.9	0.5	3.9	0.0	21.3	18.3	0.03	1.45	0	1	5	27	0.03	0.52	2.10	0.17
10	90-120	7.8	0.60	5.16	690	12.0	8.2	0.6	5.2	0.0	26.0	20.0	0.03	1.46	0	1	5	32	0.05	0.48	2.00	0.19
10	200	7.7	0.41	3.53	370	9.0	6.7	0.4	4.4	0.0	20.5	21.5	0.02	1.34	1	1	6	28	0.06	0.40	1.00	0.15
10	300	8.1	0.47	4.04	370	9.0	6.0	0.4	4.4	0.0	19.8	22.2	0.02	1.50	12	1	5	24	0.04	0.38	0.76	0.15
11	0-15	4.9	0.04	0.34	14	3.3	3.6	0.8	0.3	0.1	8.1	3.7	0.01	0.92	10	5	10	2	0.26	0.76	0.69	0.93
11	15-30	7.2	0.10	0.86	42	8.5	12.0	0.5	2.0	0.0	23.0	8.7	0.01	0.71	13	1	5	3	0.03	0.65	2.20	0.45
11	30-60	8.3	0.49	4.21	330	21.0	13.0	0.3	3.4	0.0	37.7	9.0	0.05	1.62	0	1	5	20	0.04	0.53	4.20	0.32
11	60-90	8.4	0.79	6.79	860	19.0	13.0	0.3	4.8	0.0	37.1	12.9	0.06	1.46	0	1	5	41	0.03	0.48	4.70	0.15

						Exchangeable cations (meq/100g)																
Site	Depth (cm)	pH ($CaCl_2$)	EC 1:5 (dS/m)	ECe (dS/m)	Chloride (mg/kg)	Ca	Mg	K	Na	Al	CEC	ESP	ESI	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 (%)
12	0-15	7.6	0.16	1.38	10	31.0	8.1	1.1	0.1	0.0	40.3	0.2	0.81	3.83	4	5	120	2	0.45	0.71	0.87	2.30
12	15-30	7.3	0.09	0.68	10	35.0	14.0	0.4	0.1	0.0	49.5	0.2	0.45	2.50	0	1	47	1	0.09	0.89	0.63	1.30
12	30-60	7.6	0.11	0.95	10	37.0	15.0	0.1	0.1	0.0	52.3	0.3	0.41	2.47	1	1	30	1	0.06	0.33	0.30	0.40
12	60-90	8.1	0.11	0.95	10	33.0	9.9	0.1	0.1	0.0	43.2	0.3	0.37	3.33	4	1	5	1	0.05	0.11	0.13	0.24
13	0-15	6.4	0.07	0.60	10	7.0	2.4	1.0	0.0	0.0	10.4	0.1	0.73	2.92	5	13	5	3	0.44	0.34	0.51	1.40
13	15-30	6.7	0.04	0.34	10	7.5	3.1	1.2	0.0	0.0	11.8	0.3	0.16	2.42	9	1	5	2	0.04	0.34	0.97	0.74
13	30-60	7.2	0.05	0.43	10	9.0	4.4	1.4	0.1	0.0	14.9	0.9	0.06	2.05	5	1	5	1	0.02	0.17	2.10	0.46
13	60-90	7.6	0.08	0.69	10	9.0	5.7	1.5	0.3	0.0	16.5	1.9	0.04	1.58	5	1	5	1	0.02	0.16	2.70	0.31
14	0-15	5.5	0.04	0.34	10	4.3	1.1	0.8	0.1	0.0	6.2	1.1	0.04	3.91	10	9	5	1	0.12	0.19	0.29	0.85
14	15-30	6.3	0.02	0.28	10	2.9	0.8	0.5	0.1	0.0	4.3	2.1	0.01	3.72	13	3	5	1	0.03	0.08	0.24	0.28
14	30-60	6.7	0.07	0.41	12	4.7	8.1	1.0	1.0	0.0	14.8	6.8	0.01	0.58	16	1	5	1	0.02	0.21	1.20	0.19
15	0-15	5.7	0.03	0.26	10	4.3	0.8	0.8	0.0	0.0	6.0	0.5	0.06	5.24	5	6	5	1	0.20	0.23	0.32	0.76
15	15-30	6.0	0.02	0.28	10	3.5	0.6	0.6	0.0	0.0	4.6	0.2	0.09	6.25	12	4	5	1	0.06	0.13	0.23	0.32
15	30-60	6.5	0.01	0.23	10	2.4	0.5	0.3	0.0	0.0	3.2	0.3	0.03	5.33	14	1	5	1	0.02	0.05	0.17	0.15
15	60-90	7.7	0.04	0.91	10	6.0	3.8	0.5	0.2	0.0	10.5	1.9	0.02	1.58	12	1	5	2	0.02	0.09	0.49	0.15
15	90-120	6.7	0.04	0.55	10	7.0	6.4	0.6	0.4	0.0	14.4	2.9	0.01	1.09	14	1	5	3	0.02	0.15	0.52	0.15
15	200	8.4	0.20	1.92	10	6.5	7.5	0.8	4.8	0.0	19.6	24.5	0.01	0.87	14	1	5	2	0.02	0.23	1.80	0.15
15	300	8.6	0.21	1.81	10	7.5	7.8	0.7	7.4	0.0	23.4	31.6	0.01	0.96	15	1	5	4	0.02	0.14	1.70	0.15
16	0-15	5.3	0.05	0.69	11	4.7	1.2	1.0	0.0	0.1	7.0	0.1	0.35	3.92	3	9	7	2	0.87	0.29	0.46	1.70
16	15-30	6.3	0.04	0.55	18	5.0	1.2	0.7	0.0	0.0	6.9	0.6	0.07	4.17	10	2	5	3	0.14	0.20	0.48	0.88
16	30-60	6.7	0.03	0.41	10	3.2	0.7	0.5	0.1	0.0	4.5	1.1	0.03	4.38	12	1	5	2	0.05	0.11	0.33	0.25
16	60-90	7.2	0.06	0.45	10	8.5	6.5	1.0	0.5	0.0	16.5	3.1	0.02	1.31	14	1	5	1	0.22	0.30	1.10	0.15
17	0-15	5.6	0.03	0.26	10	5.5	2.4	1.0	0.1	0.0	9.0	0.8	0.04	2.29	11	1	5	1	0.13	0.85	0.85	0.81
17	15-30	6.3	0.04	0.55	10	7.0	6.4	0.9	0.6	0.0	14.9	4.1	0.01	1.09	13	1	5	1	0.03	0.61	1.10	0.48
17	30-60	8.0	0.22	1.65	10	12.0	12.0	0.8	1.7	0.0	26.5	6.4	0.03	1.00	12	1	5	3	0.02	0.50	3.50	0.25
17	60-90	8.3	0.27	2.32	27	14.0	12.0	0.7	2.2	0.0	28.9	7.6	0.04	1.17	11	1	5	11	0.02	0.42	5.40	0.18

Site	Depth (cm)	pH ($CaCl_2$)	EC 1:5 (dS/m)	ECe (dS/m)	Chloride (mg/kg)	Exchangeable cations (meq/100g) Ca	Mg	K	Na	Al	CEC	ESP	ESI	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 (%)
17	90-120	8.4	0.32	2.75	23	18.0	12.0	0.7	2.7	0.0	33.4	8.1	0.04	1.50	10	1	5	28	0.02	0.37	5.40	0.15
18	0-15	4.9	0.03	0.26	10	2.7	0.9	0.7	0.0	0.1	4.4	0.2	0.13	2.97	5	7	6	1	0.19	0.31	0.27	0.70
18	15-30	4.5	0.01	0.09	10	2.5	1.1	0.3	0.1	0.4	4.3	1.2	0.01	2.27	13	1	6	1	0.04	0.33	0.31	0.21
18	30-60	5.0	0.02	0.12	10	6.5	4.8	0.5	0.5	0.2	12.5	3.8	0.01	1.35	15	1	5	3	0.03	0.33	1.20	0.15
18	60-90	6.6	0.04	0.30	10	8.0	6.0	0.7	0.7	0.0	15.5	4.8	0.01	1.33	15	1	5	3	0.02	0.32	3.00	0.15
18	90-120	8.1	0.26	1.95	10	13.0	6.9	0.8	0.9	0.0	21.6	4.2	0.06	1.88	11	1	5	4	0.02	0.28	2.60	0.15
18	200	7.4	0.06	0.45	10	10.0	8.1	0.8	1.4	0.0	20.3	6.9	0.01	1.23	13	1	5	2	0.02	0.17	0.92	0.15
18	300	8.3	0.09	0.77	10	5.5	3.5	0.5	0.7	0.0	10.2	7.3	0.01	1.57	12	1	5	2	0.02	0.10	0.37	0.15
19	0-15	4.7	0.04	0.34	10	3.3	1.7	0.8	0.0	0.1	6.0	0.2	0.24	1.94	2	10	5	2	0.24	0.61	0.46	1.10
19	15-30	4.8	0.01	0.09	10	3.3	2.4	0.5	0.0	0.2	6.4	0.6	0.02	1.38	0	1	5	1	0.03	0.48	0.64	0.47
19	30-60	5.4	0.02	0.17	10	3.0	3.9	0.4	0.2	0.1	7.6	2.2	0.01	0.77	1	1	7	1	0.02	0.34	0.95	0.25
19	60-90	5.7	0.03	0.26	10	3.2	4.9	0.6	0.3	0.0	9.0	3.8	0.01	0.65	0	1	10	5	0.02	0.25	1.50	0.16
20	0-15	5.1	0.06	0.52	15	3.6	2.8	1.2	0.5	0.1	8.2	5.9	0.01	1.29	10	10	8	1	0.39	0.54	0.44	1.40
20	15-30	7.4	0.48	3.60	490	8.0	12.0	0.5	7.4	0.0	27.9	26.6	0.02	0.67	13	2	5	7	0.07	0.56	1.90	0.59
20	30-60	8.6	1.24	10.66	1200	19.0	14.0	0.4	11.0	0.0	44.4	24.8	0.05	1.36	0	2	5	78	0.02	0.42	4.00	0.21
20	60-90	8.7	1.12	9.63	1000	18.0	13.0	0.5	11.0	0.0	42.5	25.9	0.04	1.38	0	2	5	85	0.04	0.32	3.10	0.15
20	90-120	8.8	1.17	10.06	1000	13.0	14.0	0.5	13.0	0.0	40.5	32.1	0.04	0.93	0	2	5	84	0.02	0.25	2.80	0.15
21	0-15	6.9	0.22	1.89	18	7.5	4.0	0.9	0.5	0.0	12.9	3.7	0.06	1.88	11	19	6	3	0.40	0.59	0.62	1.30
21	15-30	7.9	0.25	1.88	34	19.0	11.0	0.7	1.8	0.0	32.5	5.5	0.05	1.73	12	1	5	1	0.06	0.55	1.20	0.82
21	30-60	8.6	0.72	5.40	640	18.0	13.0	0.4	5.7	0.0	37.1	15.4	0.05	1.38	0	1	5	27	0.02	0.32	4.40	0.25
21	60-90	8.7	0.96	7.20	930	16.0	16.0	0.5	7.8	0.0	40.3	19.4	0.05	1.00	0	2	5	68	0.02	0.24	4.90	0.15
22	0-15	5.2	0.07	0.60	10	4.7	2.0	0.9	0.2	0.1	8.0	2.5	0.03	2.35	11	28	6	2	0.30	0.56	0.51	0.89
22	15-30	7.4	0.24	2.06	250	7.5	9.9	0.6	4.1	0.0	22.1	18.6	0.01	0.76	14	1	5	2	0.03	0.48	1.80	0.35
22	30-60	8.2	0.91	7.83	1200	8.5	13.0	0.7	8.3	0.0	30.5	27.2	0.03	0.65	1	1	5	26	0.03	0.65	3.70	0.22
22	60-90	8.5	1.29	11.09	1400	15.0	14.0	0.7	10.0	0.0	39.7	25.2	0.05	1.07	0	3	5	98	0.05	0.44	5.10	0.15
22	90-120	8.6	1.36	11.70	1500	15.0	11.0	0.5	8.7	0.0	35.2	24.7	0.06	1.36	1	1	5	120	0.04	0.22	2.70	0.15

Site	Depth (cm)	pH ($CaCl_2$)	EC 1:5 (dS/m)	ECe (dS/m)	Chloride (mg/kg)	Exchangeable cations (meq/100g) Ca	Mg	K	Na	Al	CEC	ESP	ESI	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 (%)
23	0-15	5.5	0.04	0.34	10	5.5	1.6	1.0	0.0	0.0	8.1	0.4	0.11	3.44	6	5	7	1	0.24	0.59	0.56	1.10
23	15-30	6.0	0.02	0.17	10	4.4	1.5	0.7	0.1	0.0	6.7	0.7	0.03	2.93	9	1	5	1	0.04	0.44	0.54	0.38
23	30-60	7.1	0.05	0.43	10	9.0	7.7	1.1	0.8	0.0	18.6	4.2	0.01	1.17	11	1	5	1	0.03	0.48	2.10	0.17
23	60-90	8.0	0.16	1.38	10	9.0	9.1	0.8	1.4	0.0	20.3	6.9	0.02	0.99	11	1	5	1	0.02	0.43	4.40	0.15
23	90-120	8.3	0.26	2.24	10	20.0	11.0	0.7	2.2	0.0	33.9	6.5	0.04	1.82	11	1	5	5	0.02	0.38	5.10	0.15
24	0-15	6.9	0.19	1.63	10	20.0	4.9	1.3	0.0	0.0	26.2	0.1	1.66	4.08	5	1	12	2	0.32	0.90	0.65	1.90
24	15-30	6.5	0.03	0.23	10	10.0	3.1	0.3	0.1	0.0	13.4	0.4	0.07	3.23	12	1	5	1	0.04	0.73	0.60	0.47
24	30-60	6.4	0.03	0.23	10	12.0	5.2	0.3	0.1	0.0	17.6	0.7	0.04	2.31	13	1	5	1	0.03	0.54	1.10	0.33
24	60-90	6.4	0.03	0.17	10	11.0	5.1	0.2	0.2	0.0	16.5	1.0	0.03	2.16	12	1	5	1	0.03	0.40	1.70	0.23
25	0-15	4.9	0.04	0.34	17	4.2	1.6	0.9	0.1	0.1	6.9	0.9	0.05	2.63	5	4	9	2	0.28	0.56	0.73	1.00
25	15-30	6.6	0.04	0.30	10	10.0	6.0	0.8	0.4	0.0	17.2	2.4	0.02	1.67	12	1	5	1	0.03	0.52	0.97	0.31
25	30-60	7.0	0.05	0.38	12	9.0	5.9	0.6	0.6	0.0	16.1	3.8	0.01	1.53	11	1	5	1	0.02	0.48	1.00	0.33
25	60-90	7.5	0.11	0.95	54	9.5	8.2	0.6	1.2	0.0	19.5	6.2	0.02	1.16	9	1	5	3	0.02	0.50	1.50	0.15
26	0-15	5.3	0.03	0.41	10	4.5	1.4	1.0	0.1	0.1	7.1	1.0	0.03	3.21	10	4	5	1	0.62	0.32	0.33	1.20
26	15-30	6.5	0.06	0.35	14	7.0	6.9	0.8	1.1	0.0	15.8	7.0	0.01	1.01	16	1	5	1	0.03	0.21	0.98	0.44
26	30-60	8.3	0.29	1.68	87	19.0	11.0	0.8	2.4	0.0	33.2	7.2	0.04	1.73	13	1	5	4	0.02	0.25	2.10	0.34
26	60-90	8.5	0.47	4.04	280	20.0	12.0	0.9	3.4	0.0	36.3	9.4	0.05	1.67	10	1	5	19	0.03	0.27	3.20	0.20
27	0-15	6.7	0.13	1.12	16	8.0	5.8	1.4	1.0	0.0	16.2	5.9	0.02	1.38	14	16	5	3	0.24	0.92	1.20	0.83
27	15-30	8.2	0.26	1.51	91	17.0	9.9	1.5	2.3	0.0	30.7	7.5	0.03	1.72	14	1	5	1	0.08	1.00	2.50	0.28
27	30-60	8.5	0.53	4.56	380	18.0	9.9	1.1	4.1	0.0	33.1	12.4	0.04	1.82	0	2	5	24	0.03	0.65	5.10	0.15
27	60-90	8.6	0.63	5.42	410	18.0	12.0	1.2	5.7	0.0	36.9	15.4	0.04	1.50	0	4	5	57	0.04	0.53	6.20	0.15
27	90-120	8.8	0.48	4.13	240	9.0	6.6	0.8	4.4	0.0	20.8	21.2	0.02	1.36	10	2	5	43	0.03	0.42	4.20	0.15
28	0-15	6.5	0.10	0.86	29	10.0	9.1	1.3	1.4	0.0	21.8	6.4	0.02	1.10	13	4	6	2	0.24	0.61	1.30	1.40
28	15-30	8.2	0.25	1.45	85	15.0	12.0	0.9	2.8	0.0	30.7	9.1	0.03	1.25	14	1	5	1	0.04	0.51	3.10	0.59
28	30-60	8.5	0.59	3.42	480	19.0	12.0	0.5	5.7	0.0	37.2	15.3	0.04	1.58	12	1	5	19	0.03	0.36	5.60	0.41
28	60-90	8.5	0.97	8.34	1000	19.0	12.0	0.6	8.3	0.0	39.9	20.8	0.05	1.58	0	1	5	63	0.03	0.42	4.70	0.21

						Exchangeable cations (meq/100g)																
Site	Depth (cm)	pH ($CaCl_2$)	EC 1:5 (dS/m)	ECe (dS/m)	Chloride (mg/kg)	Ca	Mg	K	Na	Al	CEC	ESP	ESI	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 (%)
29	0-15	5.1	0.05	0.43	10	9.0	3.1	0.5	0.1	0.1	12.9	0.9	0.05	2.90	6	6	7	2	0.19	0.80	0.64	1.60
29	15-30	5.5	0.05	0.43	10	17.0	7.2	0.3	0.6	0.0	25.1	2.3	0.02	2.36	8	1	5	1	0.04	0.58	0.90	0.85
29	30-60	7.2	0.08	0.60	10	20.0	9.1	0.3	1.2	0.0	30.6	3.9	0.02	2.20	6	1	5	1	0.03	0.37	1.50	0.60
30	0-15	5.3	0.02	0.17	10	3.8	1.4	0.6	0.0	0.1	6.0	0.5	0.04	2.71	11	2	5	1	0.19	0.46	0.27	0.84
30	15-30	5.6	0.02	0.17	10	2.5	1.0	0.3	0.1	0.0	3.9	2.3	0.01	2.53	13	2	5	1	0.05	0.23	0.21	0.23
30	30-60	6.8	0.06	0.45	27	6.5	6.3	0.5	1.2	0.0	14.5	8.3	0.01	1.03	16	1	5	1	0.03	0.34	0.94	0.21
30	60-90	8.2	0.26	2.24	37	9.5	12.0	0.6	3.2	0.0	25.3	12.6	0.02	0.79	13	1	5	3	0.08	0.37	3.30	0.15
31	0-15	5.0	0.07	0.60	10	6.0	2.3	1.1	0.0	0.1	9.5	0.1	0.67	2.61	5	24	37	2	0.66	0.66	0.57	1.20
31	15-30	8.1	0.10	0.86	10	8.0	6.3	0.4	0.2	0.0	14.8	1.1	0.09	1.27	4	1	5	2	0.15	0.09	0.20	0.15
31	30-60	8.7	0.18	1.55	230	10.0	6.4	0.4	1.6	0.0	18.4	8.7	0.02	1.56	7	1	5	2	0.13	0.09	0.33	0.15
31	60-90	8.6	0.18	1.55	10	6.5	5.0	0.4	1.5	0.0	13.4	11.2	0.02	1.30	7	1	5	4	0.19	0.22	0.38	0.15
32	0-15	5.6	0.05	0.69	10	4.2	1.0	0.8	0.0	0.0	6.0	0.2	0.30	4.24	7	11	8	3	0.30	0.41	0.30	1.30
32	15-30	4.9	0.01	0.09	10	3.6	0.7	0.3	0.0	0.1	4.7	0.2	0.05	5.37	12	1	5	1	0.04	0.34	0.22	0.41
32	30-60	5.0	0.01	0.09	10	3.6	1.4	0.3	0.0	0.2	5.5	0.5	0.02	2.57	12	1	5	1	0.03	0.19	0.19	0.24
33	0-15	4.5	0.03	0.41	10	2.2	0.7	0.5	0.0	0.1	3.6	0.3	0.11	3.01	10	5	7	1	0.36	0.16	0.12	1.10
33	15-30	4.6	0.01	0.14	10	1.3	0.7	0.4	0.0	0.1	2.5	1.2	0.01	2.00	12	1	5	1	0.03	0.07	0.06	0.21
33	30-60	6.8	0.05	0.38	10	6.0	4.0	0.9	0.4	0.0	11.2	3.2	0.02	1.50	14	1	5	4	0.02	0.15	0.64	0.20
34	0-15	6.0	0.16	1.38	36	6.5	6.9	1.1	1.0	0.0	15.5	6.5	0.02	0.94	11	38	6	5	0.75	0.89	1.20	1.40
34	15-30	8.4	0.67	5.03	560	21.0	16.0	0.5	5.7	0.0	43.2	13.2	0.05	1.31	0	1	5	10	0.06	0.66	2.90	0.45
34	30-60	8.6	1.20	9.00	1300	19.0	15.0	0.4	8.3	0.0	42.7	19.5	0.06	1.27	0	1	5	69	0.04	0.51	4.20	0.25
34	60-90	8.5	1.63	12.23	2000	17.0	14.0	0.4	10.0	0.0	41.4	24.2	0.07	1.21	0	1	5	140	0.05	0.40	2.70	0.15
35	0-15	5.6	0.10	1.38	35	4.0	2.1	1.1	0.0	0.0	7.2	0.4	0.24	1.90	4	19	54	8	0.90	0.30	0.47	1.00
35	15-30	5.4	0.10	1.38	10	3.5	2.1	0.4	0.1	0.1	6.1	0.8	0.12	1.67	11	2	17	52	0.35	0.29	0.43	0.81
36	0-15	5.1	0.03	0.26	10	3.4	1.0	0.8	0.0	0.1	5.3	0.6	0.05	3.43	6	4	8	2	0.28	0.59	0.39	0.80
36	15-30	5.5	0.01	0.09	10	3.9	1.5	0.5	0.0	0.0	5.9	0.3	0.03	2.60	7	1	5	1	0.03	0.56	0.40	0.33
36	30-60	6.0	0.02	0.18	10	4.6	2.6	0.5	0.1	0.0	7.7	0.6	0.03	1.77	7	1	6	1	0.03	0.34	0.60	0.18

Site	Depth (cm)	pH ($CaCl_2$)	EC 1:5 (dS/m)	ECe (dS/m)	Chloride (mg/kg)	Exchangeable cations (meq/100g) Ca	Mg	K	Na	Al	CEC	ESP	ESI	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 (%)
36	60-90	5.9	0.03	0.26	10	6.0	4.3	0.6	0.3	0.0	11.2	2.4	0.01	1.40	7	1	6	2	0.05	0.27	1.40	0.15
37	0-15	7.3	0.15	1.29	10	12.0	3.6	1.4	0.1	0.0	17.1	0.4	0.37	3.33	4	18	140	4	0.69	0.33	0.83	0.93
37	15-30	6.8	0.06	0.52	10	6.0	3.7	0.6	0.1	0.0	10.4	1.1	0.06	1.62	10	2	15	2	0.38	0.49	0.60	0.45
37	30-60	8.5	0.15	1.29	10	7.5	8.0	0.3	0.7	0.0	16.6	4.5	0.03	0.94	11	1	5	5	0.85	0.77	0.25	1.20
37	60-90	8.5	0.22	1.89	18	6.5	6.8	0.3	1.4	0.0	15.0	9.3	0.02	0.96	14	1	5	23	0.78	0.61	0.25	2.20
37	90-120	8.5	0.27	6.13	74	8.5	4.4	0.4	1.4	0.0	14.7	9.5	0.03	1.93	1	1	20	81	0.86	0.09	0.15	0.15
38	0-15	5.8	0.05	0.43	10	7.0	3.1	1.0	0.2	0.0	11.3	1.6	0.03	2.26	12	3	6	1	0.48	0.67	0.56	1.40
38	15-30	7.4	0.12	0.78	63	6.5	9.9	0.5	2.7	0.0	19.6	13.8	0.01	0.66	16	1	5	1	0.03	0.43	1.60	0.47
38	30-60	8.1	0.29	2.49	220	7.5	12.0	0.4	4.1	0.0	24.0	17.1	0.02	0.63	15	1	5	2	0.02	0.31	2.60	0.34
38	60-90	8.5	0.80	6.88	770	9.5	13.0	0.5	7.0	0.0	30.0	23.3	0.03	0.73	0	1	5	26	0.02	0.24	4.30	0.18
38	90-120	8.7	0.83	7.14	690	13.0	15.0	0.6	8.3	0.0	36.9	22.5	0.04	0.87	0	1	5	42	0.02	0.24	3.70	0.15
39	0-15	5.1	0.04	0.34	10	3.9	1.6	1.2	0.1	0.1	6.9	1.4	0.03	2.44	8	6	8	1	0.40	0.50	0.40	1.10
39	15-30	6.8	0.06	0.45	10	7.5	6.5	0.6	1.6	0.0	16.2	9.9	0.01	1.15	16	1	5	1	0.04	0.29	1.10	0.33
39	30-60	8.5	0.26	1.95	25	11.0	8.2	0.4	2.9	0.0	22.5	12.9	0.02	1.34	16	1	5	2	0.02	0.24	2.00	0.20
39	60-90	8.8	0.43	3.23	77	15.0	12.0	0.4	6.1	0.0	33.5	18.2	0.02	1.25	13	1	5	15	0.02	0.30	2.00	0.15
40	0-15	5.1	0.05	0.69	10	5.0	1.5	0.5	0.0	0.1	7.1	0.6	0.09	3.33	4	6	7	2	0.78	0.30	0.31	2.00
40	15-30	4.1	0.08	0.60	63	4.0	7.8	0.5	1.0	1.9	15.2	6.6	0.01	0.51	15	1	5	1	0.06	0.88	0.54	0.81
40	30-60	8.3	0.34	2.55	230	20.0	12.0	0.8	2.2	0.0	35.1	6.3	0.05	1.67	0	1	5	1	0.02	0.63	1.40	0.39
40	60-90	8.4	0.37	2.78	250	20.0	12.0	1.1	2.9	0.0	36.0	8.1	0.05	1.67	10	1	5	2	0.06	0.73	1.00	0.20
41	0-15	6.0	0.07	0.97	13	5.0	1.9	0.9	0.1	0.0	7.9	0.8	0.09	2.63	6	7	19	2	0.21	0.27	0.56	0.76
42	0-15	4.6	0.03	0.41	10	2.8	1.2	0.7	0.0	0.3	5.1	0.8	0.04	2.33	4	5	34	2	0.22	0.29	0.35	1.90
42	15-30	4.9	0.01	0.14	16	1.9	1.1	0.3	0.0	0.1	3.4	0.9	0.01	1.73	12	1	5	2	0.02	0.14	0.16	0.34
42	30-60	6.3	0.04	0.34	18	4.3	4.5	0.6	0.2	0.0	9.6	2.1	0.02	0.96	13	1	5	2	0.04	0.18	0.48	0.19
43	0-15	7.4	0.13	1.12	22	10.0	5.4	0.8	0.3	0.0	16.5	1.7	0.08	1.85	4	3	46	2	0.25	0.69	0.90	0.58
43	15-30	8.9	0.20	1.72	10	12.0	5.4	0.3	2.0	0.0	19.7	10.2	0.02	2.22	12	1	5	3	0.51	0.45	0.52	0.19
43	30-60	9.0	0.25	2.15	35	8.0	4.5	0.3	2.7	0.0	15.6	17.4	0.01	1.78	13	1	5	10	0.74	0.27	0.29	0.30

Site	Depth (cm)	pH ($CaCl_2$)	EC 1:5 (dS/m)	ECe (dS/m)	Chloride (mg/kg)	Exchangeable cations (meq/100g)						ESP	ESI	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											
43	60-90	8.9	0.28	2.41	110	10.0	5.0	0.4	2.9	0.0	18.3	15.9	0.02	2.00	12	1	5	17	0.66	0.25	0.23	0.19
43	90-120	8.8	0.37	3.18	260	8.5	5.9	0.3	3.3	0.0	18.0	18.3	0.02	1.44	12	1	5	39	0.63	0.22	0.27	0.15
44	0-15	5.5	0.08	1.10	10	4.1	3.3	0.9	0.3	0.0	8.6	3.4	0.02	1.24	4	22	8	1	0.36	0.36	0.55	1.20
44	15-30	8.1	0.23	1.98	41	15.0	9.1	0.5	2.1	0.0	26.7	7.9	0.03	1.65	12	1	5	1	0.05	0.44	2.20	0.59
44	30-60	8.5	0.41	3.53	240	18.0	9.9	0.3	3.9	0.0	32.1	12.2	0.03	1.82	1	1	5	5	0.02	0.32	4.30	0.24
44	60-90	8.6	0.59	5.07	440	15.0	12.0	0.4	5.7	0.0	33.1	17.2	0.03	1.25	1	1	5	16	0.02	0.31	4.40	0.15
45	0-15	4.8	0.03	0.41	10	2.5	0.9	0.7	0.0	0.1	4.3	0.7	0.04	2.75	10	6	7	1	0.23	0.20	0.18	0.78
45	15-30	5.1	0.02	0.28	10	2.4	1.0	0.5	0.0	0.1	4.0	0.8	0.03	2.42	12	3	5	1	0.03	0.11	0.14	0.40
45	30-60	6.1	0.02	0.17	10	2.4	2.3	0.4	0.1	0.0	5.2	1.3	0.01	1.04	14	2	5	1	0.02	0.08	0.10	0.15
45	60-90	5.5	0.07	0.53	10	5.5	11.0	0.9	1.4	0.0	18.8	7.4	0.01	0.50	15	1	5	2	0.10	0.33	0.37	0.15
46	0-15	5.4	0.08	1.10	29	4.4	1.5	1.3	0.0	0.1	7.3	0.3	0.29	2.93	11	11	9	5	1.20	0.29	0.37	1.50
46	15-30	5.4	0.03	0.41	12	5.5	1.2	1.0	0.0	0.1	7.8	0.1	0.23	4.58	12	2	5	3	0.19	0.22	0.32	0.71
46	30-60	6.2	0.03	0.26	10	6.5	1.2	0.7	0.0	0.0	8.5	0.4	0.08	5.42	12	1	5	2	0.04	0.08	0.28	0.28
47	0-15	5.1	0.03	0.26	10	6.5	2.9	0.6	0.1	0.1	10.1	0.6	0.05	2.24	10	3	5	1	1.00	1.60	0.35	1.60
47	15-30	5.1	0.05	0.38	24	9.5	5.8	0.7	0.3	0.1	16.4	1.8	0.03	1.64	12	1	5	1	0.16	2.50	0.26	0.64
47	30-60	5.3	0.08	0.60	68	10.0	7.3	0.6	0.6	0.1	18.6	3.3	0.02	1.37	12	1	5	1	0.25	1.60	0.26	0.41
47	60-90	5.9	0.08	0.60	59	9.5	7.3	0.4	0.8	0.0	18.0	4.6	0.02	1.30	11	1	5	1	0.31	0.55	0.21	0.15
47	90-120	4.4	0.07	0.60	62	8.5	6.3	0.3	0.8	0.7	16.6	4.7	0.01	1.35	11	1	11	1	0.23	0.51	0.07	0.15
48	0-15	4.5	0.04	0.55	10	2.8	0.7	0.7	0.0	0.2	4.4	0.2	0.18	4.06	11	8	9	2	0.54	0.20	0.28	1.20
48	15-30	4.8	0.03	0.41	10	3.0	0.9	0.3	0.0	0.2	4.4	0.2	0.13	3.30	13	4	5	2	0.06	0.08	0.18	0.49
49	0-15	5.1	0.03	0.41	10	3.5	0.9	0.9	0.0	0.1	5.5	0.2	0.16	3.85	12	3	5	1	0.16	0.25	0.26	0.78
49	15-30	6.0	0.02	0.45	10	3.0	0.7	0.5	0.0	0.0	4.2	0.2	0.08	4.23	14	1	5	1	0.02	0.11	0.17	0.15
49	30-60	7.2	0.04	0.34	10	8.0	5.2	0.7	0.3	0.0	14.2	1.9	0.02	1.54	13	1	5	1	0.02	0.20	0.51	0.15
49	60-90	7.7	0.08	0.69	43	4.5	4.4	0.6	0.4	0.0	9.9	4.2	0.02	1.02	11	3	5	1	0.02	0.11	0.54	0.15
50	0-15	4.7	0.03	0.41	11	1.7	0.6	0.7	0.0	0.1	3.1	0.3	0.09	2.74	12	3	5	2	0.13	0.27	0.33	0.56
50	15-30	5.1	0.02	0.28	10	1.5	0.5	0.2	0.1	0.1	2.4	5.3	0.00	3.00	12	1	5	1	0.03	0.11	0.25	0.18

Site	Depth (cm)	pH ($CaCl_2$)	EC 1:5 (dS/m)	ECe (dS/m)	Chloride (mg/kg)	Exchangeable cations (meq/100g)						ESP	ESI	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											
50	30-60	7.0	0.18	1.55	150	2.9	5.8	0.3	3.0	0.0	12.0	25.1	0.01	0.50	15	1	5	6	0.02	0.31	1.40	0.20
50	60-90	7.7	0.46	3.96	500	2.3	6.8	0.4	5.2	0.0	14.7	35.4	0.01	0.34	10	1	5	31	0.02	0.29	1.90	0.15
51	0-15	7.7	0.18	1.55	10	16.0	5.6	1.0	0.1	0.0	22.7	0.4	0.41	2.86	1	24	31	5	1.10	0.40	0.86	1.10
52	0-15	5.2	0.04	0.34	11	6.0	2.2	1.3	0.0	0.1	9.6	0.4	0.10	2.73	10	4	5	2	0.37	0.68	0.59	1.40
52	15-30	6.5	0.04	0.34	10	10.0	7.0	1.6	0.2	0.0	18.8	1.1	0.04	1.43	14	1	5	1	0.03	0.41	1.40	0.31
52	30-60	7.2	0.07	0.60	10	10.0	9.1	1.4	0.3	0.0	20.8	1.6	0.04	1.10	8	1	5	2	0.02	0.34	1.60	0.31
52	60-90	8.0	0.18	1.55	19	12.0	11.0	1.2	0.8	0.0	25.0	3.1	0.06	1.09	3	1	5	4	0.02	0.29	3.70	0.15
53	0-15	5.3	0.04	0.34	10	4.2	3.0	1.1	0.6	0.1	9.0	6.8	0.01	1.40	12	5	5	1	0.26	0.60	0.49	0.88
53	15-30	7.4	0.16	1.38	130	8.5	11.0	1.4	4.0	0.0	24.9	16.1	0.01	0.77	11	1	5	1	0.03	0.52	1.20	0.37
53	30-60	8.2	0.60	5.16	590	6.5	14.0	1.2	7.0	0.0	28.7	24.4	0.02	0.46	0	1	5	10	0.02	0.48	2.10	0.23
53	60-90	8.7	0.88	7.57	840	15.0	15.0	1.0	8.3	0.0	39.3	21.1	0.04	1.00	0	2	5	28	0.02	0.40	3.60	0.15
53	90-120	8.7	1.03	8.86	1100	8.5	16.0	0.9	11.0	0.0	36.4	30.2	0.03	0.53	0	2	5	38	0.03	0.34	2.40	0.15
54	0-15	4.8	0.04	0.55	14	3.0	1.1	0.8	0.0	0.1	5.0	0.2	0.20	2.73	11	4	5	3	0.22	0.16	0.24	1.00
54	15-30	4.9	0.02	0.45	10	2.5	0.8	0.4	0.0	0.1	3.8	0.3	0.08	3.29	13	1	5	2	0.04	0.08	0.14	0.34
54	30-60	6.7	0.07	0.60	18	6.0	8.2	0.9	0.7	0.0	15.9	4.7	0.02	0.73	13	1	5	2	0.02	0.23	1.30	0.26
54	60-90	8.4	0.24	1.80	110	14.0	12.0	1.0	1.8	0.0	28.8	6.3	0.04	1.17	11	1	5	6	0.04	0.19	1.20	0.15
55	0-15	6.0	0.06	0.83	20	7.0	6.7	1.0	0.7	0.0	15.4	4.8	0.01	1.04	12	1	5	1	0.34	0.71	0.62	1.10
55	15-30	7.3	0.19	1.10	160	8.5	13.0	0.9	2.6	0.0	25.1	10.4	0.02	0.65	12	1	5	1	0.07	0.60	1.40	0.60
55	30-60	8.6	0.63	3.65	490	18.0	15.0	0.5	4.8	0.0	38.3	12.5	0.05	1.20	0	1	5	15	0.03	0.38	2.00	0.23
55	60-90	8.9	0.61	5.25	520	16.0	14.0	0.4	5.2	0.0	35.6	14.6	0.04	1.14	0	2	5	23	0.07	0.30	0.98	0.15
56	0-15	5.3	0.04	0.55	11	4.5	2.9	0.7	0.2	0.1	8.4	2.5	0.02	1.55	10	4	6	2	0.28	0.63	0.46	1.00
56	15-30	5.2	0.02	0.28	10	3.0	0.6	0.5	0.0	0.0	4.1	0.2	0.08	5.17	13	1	20	1	0.08	0.16	0.14	0.35
56	30-60	5.9	0.01	0.14	10	2.3	0.8	0.3	0.0	0.0	3.4	0.9	0.01	3.03	13	1	12	1	0.02	0.08	0.11	0.15
56	60-90	6.7	0.03	0.26	10	7.0	4.2	0.7	0.1	0.0	12.0	1.2	0.02	1.67	8	1	5	2	0.02	0.17	0.75	0.15
57	0-15	5.0	0.04	0.55	10	4.4	1.5	0.8	0.0	0.1	6.9	0.6	0.07	2.93	12	7	7	2	0.40	0.58	0.30	0.98
57	15-30	6.1	0.04	0.55	10	8.5	5.3	0.9	0.8	0.0	15.4	5.0	0.01	1.60	13	1	5	1	0.05	0.39	0.64	0.49

Site	Depth (cm)	pH ($CaCl_2$)	EC 1:5 (dS/m)	ECe (dS/m)	Chloride (mg/kg)	Exchangeable cations (meq/100g) Ca	Mg	K	Na	Al	CEC	ESP	ESI	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 (%)
57	30-60	7.4	0.11	0.95	71	7.0	8.1	0.6	1.7	0.0	17.4	9.8	0.01	0.86	13	1	5	3	0.02	0.37	0.77	0.28
57	60-90	8.2	0.48	4.13	480	5.5	9.1	0.5	3.7	0.0	18.8	19.7	0.02	0.60	12	1	5	19	0.02	0.25	0.99	0.15
57	90-120	8.3	0.67	5.76	570	6.0	13.0	0.5	6.1	0.0	25.6	23.8	0.03	0.46	11	1	5	51	0.02	0.24	1.20	0.15
58	0-15	5.6	0.04	0.55	10	3.1	1.0	0.8	0.1	0.0	4.9	1.2	0.03	3.13	6	5	5	1	0.16	0.34	0.34	0.64
58	15-30	6.7	0.07	1.59	17	6.5	7.6	1.7	1.0	0.0	16.8	6.0	0.01	0.86	16	1	5	1	0.03	0.41	0.97	0.27
58	30-60	7.5	0.12	0.70	33	5.5	11.0	1.9	1.7	0.0	20.1	8.5	0.01	0.50	15	1	5	3	0.02	0.38	2.00	0.18
59	0-15	5.1	0.05	0.43	11	4.5	3.5	1.7	0.3	0.1	10.1	2.9	0.02	1.29	12	10	10	1	0.49	0.84	0.62	1.20
59	15-30	7.3	0.12	1.03	85	7.5	9.9	1.2	2.3	0.0	20.9	11.0	0.01	0.76	12	1	5	2	0.03	0.75	1.70	0.33
59	30-60	8.5	0.69	5.93	640	13.0	13.0	1.0	4.8	0.0	31.8	15.1	0.05	1.00	2	1	5	14	0.03	0.59	4.50	0.22
59	60-90	8.6	0.94	8.08	730	15.0	14.0	1.0	6.5	0.0	36.5	17.8	0.05	1.07	0	3	11	36	0.05	0.42	4.70	0.15
59	90-120	8.6	0.98	8.42	940	10.0	13.0	0.9	7.4	0.0	31.3	23.6	0.04	0.77	0	5	5	46	0.03	0.38	3.70	0.15
60	0-15	4.9	0.05	0.43	10	3.4	0.8	1.0	0.0	0.1	5.3	0.2	0.26	4.20	11	11	37	2	0.50	0.29	0.22	0.85
60	15-30	7.8	0.15	1.29	10	24.0	5.3	0.8	0.2	0.0	30.3	0.5	0.28	4.53	0	1	5	2	0.06	0.54	0.89	0.56
60	30-60	8.2	0.16	1.38	10	18.0	9.1	0.7	0.8	0.0	28.6	2.9	0.06	1.98	1	1	5	2	0.02	0.40	2.20	0.24
60	60-90	8.4	0.24	2.06	10	19.0	13.0	0.7	2.0	0.0	34.7	5.8	0.04	1.46	8	1	5	3	0.02	0.42	3.60	0.16
61	0-15	5.8	0.07	0.60	10	6.0	1.9	1.2	0.1	0.0	9.2	0.7	0.11	3.16	5	15	6	2	0.32	0.54	0.45	0.94
61	15-30	7.3	0.11	0.83	10	12.0	3.5	1.2	0.1	0.0	16.8	0.5	0.21	3.43	11	1	5	1	0.06	0.46	0.70	0.50
61	30-60	8.2	0.14	1.05	10	17.0	6.4	0.9	0.5	0.0	24.8	1.9	0.07	2.66	4	1	5	1	0.02	0.56	1.50	0.18
61	60-90	8.4	0.24	1.80	10	17.0	9.9	1.2	2.2	0.0	30.3	7.3	0.03	1.72	14	1	5	2	0.02	0.38	3.70	0.15
61	90-120	8.5	0.28	2.41	32	11.0	9.9	1.1	2.9	0.0	24.9	11.6	0.02	1.11	13	1	5	8	0.03	0.41	3.40	0.15
62	0-15	7.5	0.11	1.52	10	10.0	3.0	0.8	0.2	0.0	14.0	1.4	0.08	3.33	5	2	5	2	0.30	0.51	0.87	1.20
62	15-30	7.3	0.04	0.91	10	3.8	2.0	0.3	0.4	0.0	6.5	6.1	0.01	1.90	14	1	5	1	0.05	0.33	0.41	0.18
62	30-60	8.5	0.32	2.40	33	10.0	12.0	0.6	5.7	0.0	28.3	20.1	0.02	0.83	16	1	5	2	0.02	0.89	2.90	0.15
62	60-90	9.0	0.65	4.88	300	15.0	9.9	0.6	8.3	0.0	33.8	24.6	0.03	1.52	13	1	5	16	0.03	0.52	3.70	0.15
63	0-15	5.0	0.15	1.29	45	4.3	1.6	1.9	0.1	0.1	8.0	1.4	0.11	2.69	10	41	6	5	1.40	0.35	0.56	1.90
63	15-30	5.7	0.04	0.34	10	4.3	2.1	0.9	0.1	0.0	7.4	1.4	0.03	2.05	11	2	5	2	0.11	0.23	0.42	0.54

Site	Depth (cm)	pH ($CaCl_2$)	EC 1:5 (dS/m)	ECe (dS/m)	Chloride (mg/kg)	Exchangeable cations (meq/100g) Ca	Mg	K	Na	Al	CEC	ESP	ESI	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 (%)
64	0-15	5.2	0.04	0.55	10	3.9	1.5	0.7	0.2	0.1	6.5	3.6	0.01	2.60	11	7	7	1	0.27	0.37	0.42	0.90
64	15-30	5.5	0.04	0.55	17	2.7	1.2	0.5	0.4	0.0	4.8	8.0	0.01	2.25	13	3	6	1	0.08	0.22	0.31	0.37
64	30-60	7.2	0.50	4.30	550	5.0	12.0	0.7	7.4	0.0	25.1	29.5	0.02	0.42	14	1	5	10	0.02	0.40	1.10	0.19
64	60-90	8.5	0.80	6.88	660	11.0	11.0	0.7	7.8	0.0	30.5	25.6	0.03	1.00	10	1	5	41	0.03	0.27	1.80	0.15
65	0-15	5.2	0.10	0.86	31	5.5	5.0	1.2	1.0	0.1	12.8	7.8	0.01	1.10	14	8	5	5	0.32	0.70	0.67	1.30
65	15-30	6.3	0.28	2.10	220	10.0	9.1	0.5	3.8	0.0	23.4	16.3	0.02	1.10	14	1	5	13	0.07	0.78	1.20	0.79
65	30-60	8.1	1.06	9.12	1000	16.0	12.0	0.5	7.4	0.0	35.9	20.6	0.05	1.33	11	1	5	160	0.06	0.89	1.80	0.34
65	60-90	8.1	1.07	9.20	810	11.0	9.1	0.4	7.0	0.0	27.5	25.5	0.04	1.21	0	1	6	260	0.05	0.69	1.30	0.16
65	90-120	7.7	0.96	8.26	3700	8.0	9.1	0.6	7.8	0.0	25.5	30.6	0.03	0.88	0	1	8	180	0.03	0.85	1.40	0.16
65	200	7.6	0.92	7.91	710	7.0	9.9	0.6	8.3	0.0	25.8	32.2	0.03	0.71	0	1	5	170	0.06	0.67	0.72	0.15
65	300	7.6	0.97	8.34	800	7.0	9.9	0.5	8.7	0.0	26.1	33.3	0.03	0.71	0	1	6	200	0.09	0.48	0.54	0.15
66	0-15	5.4	0.03	0.26	10	8.0	2.3	0.8	0.1	0.1	11.3	0.5	0.06	3.48	13	2	5	1	0.25	0.59	0.41	0.86
66	15-30	5.5	0.03	0.68	10	7.5	2.7	0.8	0.1	0.0	11.0	0.6	0.05	2.78	14	1	5	1	0.07	0.51	0.43	0.56
66	30-60	6.1	0.02	0.45	10	5.5	2.6	0.5	0.2	0.0	8.7	2.2	0.01	2.12	14	1	5	1	0.09	0.25	0.32	0.25
66	60-90	6.7	0.18	4.09	230	4.2	2.6	0.4	2.0	0.0	9.2	21.8	0.01	1.62	12	1	5	1	0.03	0.26	0.34	0.15
66	90-120	7.3	0.32	4.42	400	5.5	4.0	0.5	3.6	0.0	13.6	26.5	0.01	1.38	11	1	5	3	0.03	0.20	0.47	0.15
67	0-15	4.8	0.05	0.69	10	4.0	1.2	0.9	0.0	0.1	6.2	0.6	0.08	3.33	10	11	9	2	0.57	0.37	0.42	1.10
67	15-30	5.2	0.02	0.45	10	3.1	0.7	0.5	0.0	0.1	4.4	0.5	0.04	4.31	12	2	9	1	0.07	0.15	0.29	0.31
67	30-60	5.9	0.02	0.45	10	2.4	0.8	0.3	0.1	0.0	3.6	1.4	0.01	3.00	13	1	6	1	0.02	0.08	0.22	0.15
67	60-90	7.4	0.06	1.36	19	3.8	5.5	0.3	1.8	0.0	11.4	15.8	0.00	0.69	11	1	19	2	0.02	0.15	0.48	0.15
68	0-15	6.0	0.11	0.95	54	14.0	9.1	0.9	2.3	0.0	26.3	8.7	0.01	1.54	13	3	7	3	0.16	1.40	1.20	1.10
68	15-30	7.0	0.35	2.63	290	18.0	11.0	0.6	4.8	0.0	34.4	14.0	0.03	1.64	11	2	5	7	0.07	1.10	1.70	0.82
68	30-60	7.7	0.87	6.53	780	19.0	13.0	0.6	8.7	0.0	41.3	21.1	0.04	1.46	11	1	5	110	0.05	1.10	2.80	0.56
68	60-90	7.7	2.60	22.36	930	26.0	12.0	0.6	9.6	0.0	48.2	19.9	0.13	2.17	0	1	5	1100	0.06	1.10	2.00	0.22
68	200	8.1	2.52	21.67	840	29.0	7.7	0.4	7.8	0.0	44.9	17.4	0.15	3.77	1	1	16	1200	0.09	0.43	0.86	0.15
68	300	8.3	1.47	12.64	730	21.0	8.1	0.4	8.3	0.0	37.8	22.0	0.07	2.59	1	1	13	400	0.08	0.36	0.79	0.15
69	0-15	5.7	0.13	1.12	40	6.5	6.4	0.9	1.5	0.0	15.3	9.8	0.01	1.02	15	17	12	10	0.32	0.62	0.72	1.40

Site	Depth (cm)	pH ($CaCl_2$)	EC 1:5 (dS/m)	ECe (dS/m)	Chloride (mg/kg)	Exchangeable cations (meq/100g)						ESP	ESI	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											
69	15-30	7.0	0.37	2.15	340	12.0	12.0	0.5	5.2	0.0	29.7	17.5	0.02	1.00	13	1	5	12	0.09	0.54	1.70	0.79
69	30-60	8.1	1.62	13.93	1800	19.0	13.0	0.6	9.1	0.0	41.6	21.8	0.07	1.46	0	1	5	230	0.06	0.98	3.10	0.26
69	60-90	8.0	2.32	19.95	1400	24.0	12.0	0.6	10.0	0.0	46.5	21.5	0.11	2.00	0	1	6	900	0.06	0.90	3.50	0.15
69	90-120	7.9	3.26	28.04	1300	35.0	12.0	0.6	10.0	0.0	57.6	17.4	0.19	2.92	0	1	9	1900	0.09	0.73	2.90	0.15
69	200	8.2	1.11	9.55	840	9.5	9.9	0.6	9.1	0.0	29.1	31.3	0.04	0.96	0	2	11	250	0.09	0.53	1.10	0.15
69	300	8.4	0.90	7.74	730	14.0	8.2	0.5	8.7	0.0	31.4	27.7	0.03	1.71	1	2	12	170	0.07	0.31	0.80	0.15
70	0-15	5.8	0.11	0.95	50	9.0	6.6	0.8	1.6	0.0	18.0	8.9	0.01	1.36	12	4	5	3	0.23	0.92	1.00	1.10
70	15-30	7.0	0.39	2.93	360	12.0	8.2	0.3	4.4	0.0	24.9	17.6	0.02	1.46	11	1	5	19	0.03	0.69	1.10	0.72
70	30-60	7.6	1.27	9.53	1800	11.0	11.0	0.4	8.3	0.0	30.7	27.0	0.05	1.00	1	1	5	240	0.03	0.78	1.80	0.29
70	60-90	7.8	1.89	16.25	1000	16.0	11.0	0.5	8.7	0.0	36.1	24.1	0.08	1.45	0	1	5	720	0.04	0.59	1.40	0.15
70	200	8.0	0.81	6.97	680	8.0	7.2	0.4	7.8	0.0	23.4	33.3	0.02	1.11	2	2	11	140	0.07	0.35	0.85	0.15
70	300	7.8	0.61	5.25	530	6.0	6.5	0.3	8.3	0.0	21.1	39.3	0.02	0.92	11	1	15	120	0.07	0.23	0.59	0.15
71	0-15	6.4	0.12	1.14	25	13.0	9.1	0.9	1.4	0.0	24.4	5.7	0.02	1.43	10	5	13	5	0.57	1.90	1.50	1.10
71	15-30	7.9	0.25	1.88	46	17.0	12.0	0.6	3.2	0.0	32.8	9.8	0.03	1.42	13	1	5	2	0.19	1.60	2.00	0.71
71	30-60	8.3	0.65	4.88	470	22.0	12.0	0.5	6.1	0.0	40.6	15.0	0.04	1.83	1	1	5	39	0.11	1.30	4.80	0.42
71	60-90	8.3	1.24	9.30	1100	15.0	11.0	0.5	9.1	0.0	35.6	25.6	0.05	1.36	0	1	6	250	0.07	0.79	4.90	0.24
71	200	8.1	0.93	0.80	780	10.0	8.2	0.4	9.1	0.0	27.7	32.8	0.03	1.22	1	1	16	190	0.11	0.43	1.20	0.15
71	300	8.4	1.17	10.06	960	14.0	9.1	0.5	9.6	0.0	33.2	28.9	0.04	1.54	1	1	22	200	0.10	0.58	1.00	0.15
72	0-15	5.2	0.06	0.52	10	8.5	4.2	1.1	0.4	0.1	14.3	2.8	0.02	2.02	4	8	9	2	1.10	0.89	0.75	1.80
72	15-30	6.9	0.10	0.58	12	14.0	6.3	0.8	1.0	0.0	22.1	4.5	0.02	2.22	14	1	5	1	0.14	0.58	1.10	0.83
72	30-60	8.4	0.28	1.62	150	17.0	7.4	0.5	2.6	0.0	27.5	9.5	0.03	2.30	11	1	5	3	0.04	0.43	1.70	0.38
72	60-90	8.4	0.46	3.96	300	15.0	9.9	0.6	4.4	0.0	29.9	14.7	0.03	1.52	1	1	5	9	0.04	0.53	0.04	0.22
72	90-120	8.4	0.43	3.70	270	10.0	9.1	0.4	5.2	0.0	24.7	21.0	0.02	1.10	10	2	5	13	0.03	0.46	2.50	0.15
73	0-15	6.1	0.07	0.60	15	7.5	4.3	0.8	0.8	0.0	13.4	5.8	0.01	1.74	10	9	6	2	0.26	0.78	0.81	0.71
73	15-30	7.5	0.25	2.15	170	8.5	6.7	0.4	3.9	0.0	19.5	20.0	0.01	1.27	10	2	5	2	0.03	0.51	1.10	0.15
73	30-60	8.4	0.85	7.31	180	15.0	9.1	0.5	7.8	0.0	32.4	24.1	0.04	1.65	1	2	5	29	0.04	0.60	2.80	0.15
73	60-90	8.6	0.98	8.43	910	18.0	9.9	0.5	10.0	0.0	38.4	26.0	0.04	1.82	1	6	5	59	0.04	0.58	3.80	0.15

Site	Depth (cm)	pH ($CaCl_2$)	EC 1:5 (dS/m)	ECe (dS/m)	Chloride (mg/kg)	Exchangeable cations (meq/100g)						ESP	ESI	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											
74	0-15	5.0	0.04	0.55	10	3.1	1.1	0.9	0.0	0.1	5.2	0.8	0.05	2.82	11	9	5	2	0.27	0.26	1.50	1.00
74	15-30	5.4	0.02	0.45	10	2.6	0.9	0.5	0.0	0.1	4.2	1.0	0.02	2.86	13	3	5	1	0.04	0.15	0.34	0.35
74	30-60	6.4	0.05	0.69	24	4.0	4.0	0.3	1.0	0.0	9.3	10.8	0.00	1.00	15	1	5	1	0.02	0.23	0.43	0.16
74	60-90	6.3	0.32	2.75	340	7.0	9.1	0.5	3.8	0.0	20.4	18.6	0.02	0.77	12	1	5	8	0.06	0.40	0.63	0.17
75	0-15	6.0	0.11	0.95	28	7.0	4.0	1.1	0.7	0.0	12.8	5.5	0.02	1.75	10	19	9	4	0.48	0.84	0.71	1.50
75	15-30	7.1	0.10	0.86	37	10.0	6.4	0.6	2.3	0.0	19.3	11.9	0.01	1.56	13	1	5	1	0.05	0.65	0.92	0.47
75	30-60	7.6	0.27	2.32	140	9.5	7.1	0.5	4.0	0.0	21.1	19.0	0.01	1.34	8	12	13	24	0.22	0.80	1.60	0.30
75	60-90	8.3	0.57	4.90	190	15.0	9.9	0.8	6.5	0.0	32.2	20.2	0.03	1.52	5	34	6	48	0.05	0.91	2.60	0.15
75	200	8.5	0.42	3.61	210	7.0	8.2	0.6	7.8	0.0	23.6	33.1	0.01	0.85	11	2	7	32	0.05	0.54	1.10	0.15
75	300	8.1	0.46	3.96	340	6.0	7.7	0.5	9.6	0.0	23.8	40.3	0.01	0.78	13	1	12	65	0.08	0.50	0.72	0.15

cm = centimetres

$CaCl_2$ = calcium chloride

dS/- = deciSiemens per metre

mg/kb = milligrams per kilogram

Ca = calcium

Mg = magnesium

K = potassium

Na = sodium

Al = aluminium

Ca/Mg = calcium/magnesium

DTPA = diethylene triamine penta acetate

C = carbon

org. = organic

Cu = copper

Zn = zinc

EC_e: 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.

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 number 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; $EC_{1:5}$ (dS/m) divided by ESP; it is a measure of soil stability in water; aim for values greater than 0.05.

Appendix 8 SCS Laboratory; Calibration Data

NSW | Soil Conservation Service

Experienced people protecting your resources

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Orange NSW 2800

16 February 2012 SCO12/024R1

Dear David McKenzie

Analysis of twelve soil samples – SCPL

The Soil Conservation Service has analysed twelve soil samples (Soil test report SCO12/024R1). These samples were analysed for: particle size analysis (clay, silt, fine sand, coarse sand and gravel); dispersion percentage (D%); Emerson aggregate test (EAT); organic carbon (OC); and particle size analysis-mechanical dispersion (clay, silt, fine sand, coarse sand and gravel). The soil erodibility factor (K factor) has been determined (as described by Rosewell 1993) using the particle size analysis-mechanical dispersion and the organic carbon. That is, apart from the SCPL Pit 63 30-60cm and SCPL Pit 63 60-90cm samples (Lab No 7 and 8) which flocculated during testing, and therefore, the K factor was determined using the particle size analysis. The surface soil structure was assumed to be medium granular and the profile permeability was assumed to be slow to moderate.

Lab No	Sample Id	K factor	Rating
1	SCPL Pit 49 0-15cm	0.023	Moderate
2	SCPL Pit 49 15-30cm	0.022	Moderate
3	SCPL Pit 49 30-60cm	0.034	Moderate
4	SCPL Pit 49 60-90cm	0.054	High
5	SCPL Pit 63 0-15cm	0.050	High
6	SCPL Pit 63 15-30cm	0.040	Moderate
7	SCPL Pit 63 30-60cm	0.012	Low
8	SCPL Pit 63 60-90cm	0.015	Low
9	SCPL Pit 72 0-15cm	0.032	Moderate
10	SCPL Pit 72 15-30cm	0.028	Moderate
11	SCPL Pit 72 30-60cm	0.024	Moderate
12	SCPL Pit 72 60-90cm	0.035	Moderate

This interpretation was based on the soil samples being representative, and literature guidelines.

SR Young
(Laboratory Manager)

References

Rosewell CJ (1993) Soiloss – A program to assist in the selection of management practices to reduce erosion. Department of Conservation and Land Management.

NSW Soil Conservation Service

Experienced people protecting your resources

David McKenzie
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Lab No	Sample Id	K factor	Rating
1	SCPL Pit 49 0-15cm	0.023	Moderate
2	SCPL Pit 49 15-30cm	0.022	Moderate
3	SCPL Pit 49 30-60cm	0.034	Moderate
4	SCPL Pit 49 60-90cm	0.054	High
5	SCPL Pit 63 0-15cm	0.050	High
6	SCPL Pit 63 15-30cm	0.040	Moderate
7	SCPL Pit 63 30-60cm	0.012	Low
8	SCPL Pit 63 60-90cm	0.015	Low
9	SCPL Pit 72 0-15cm	0.032	Moderate
10	SCPL Pit 72 15-30cm	0.028	Moderate
11	SCPL Pit 72 30-60cm	0.024	Moderate
12	SCPL Pit 72 60-90cm	0.035	Moderate

SOIL CONSERVATION SERVICE
Scone Research Service Centre

Report No: SCO12/024R1
Client Reference: David McKenzie
McKenzie Soil Management Pty Ltd
PO Box 2171
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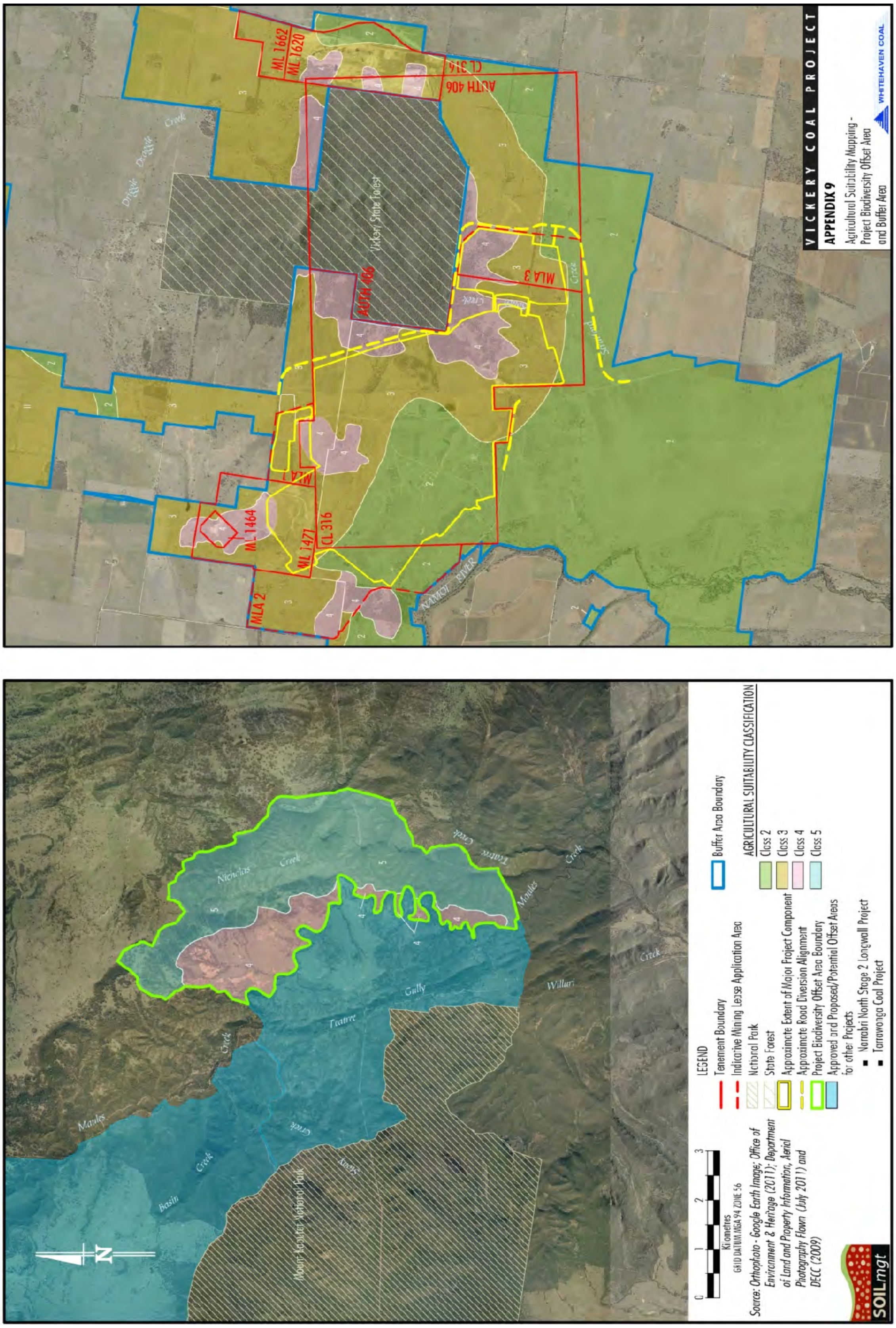
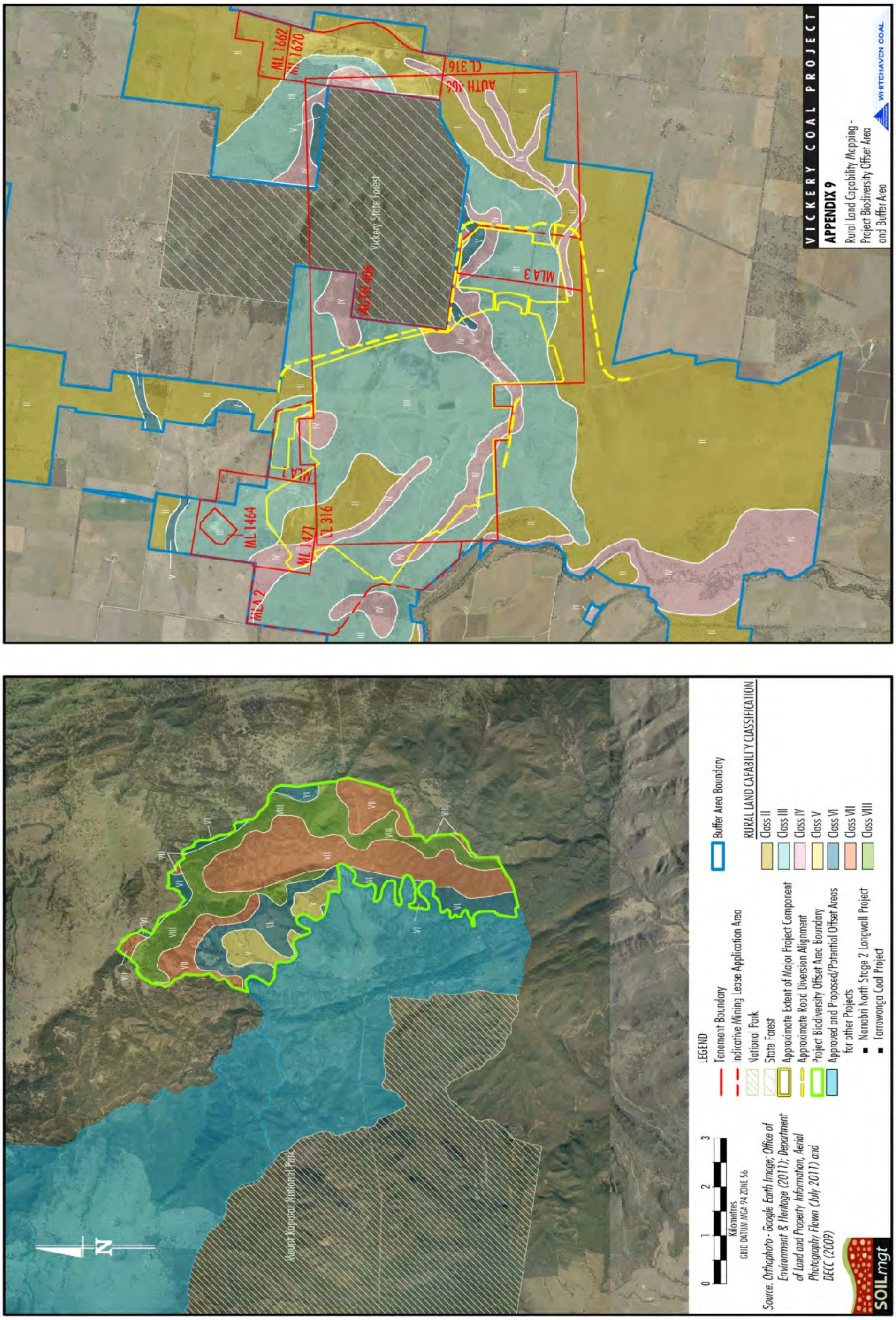
Lab No	Method	P7B/2 Particle Size Analysis (%)					P8A/2	P9B/2	C6A/2	P7C/2 Particle Size Analysis – mech dis (%)				
	Sample Id	clay	silt	f sand	c sand	gravel	D%	EAT	OC (%)	clay	silt	f sand	c sand	gravel
1	SCPL Pit 49 0-15cm	27	7	22	19	25	64	2(1)	1.15	22	12	21	20	25
2	SCPL Pit 49 15-30cm	55	11	19	13	2	70	2(1)	0.46	47	17	20	14	2
3	SCPL Pit 49 30-60cm	53	13	23	10	1	58	3(1)	0.31	38	29	22	10	1
4	SCPL Pit 49 60-90cm	32	25	41	2	<1	63	2(1)	0.06	23	31	37	9	<1
5	SCPL Pit 63 0-15cm	35	22	35	8	<1	63	2(1)	1.58	19	36	36	9	<1
6	SCPL Pit 63 15-30cm	54	29	15	2	<1	76	2(1)	0.70	35	40	18	7	<1
7	SCPL Pit 63 30-60cm	72	11	14	3	<1	35	2(1)	0.30	f	f	f	5	<1
8	SCPL Pit 63 60-90cm	66	16	14	4	0	0	2(1)	0.15	f	f	f	5	0
9	SCPL Pit 72 0-15cm	37	16	26	11	10	31	8	1.57	26	26	25	13	10
10	SCPL Pit 72 15-30cm	45	10	25	17	3	28	3(1)	0.48	37	21	22	17	3
11	SCPL Pit 72 30-60cm	63	4	14	9	10	24	3(1)	0.34	42	25	14	9	10
12	SCPL Pit 72 60-90cm	68	6	16	9	1	26	3(1)	0.24	39	36	15	9	1

f = flocculated

END OF TEST REPORT

Appendix 9 New South Wales Office of Environment and Heritage Regional Rural Land Capability Mapping and Regional Agricultural Suitability Mapping


VICKERY COAL PROJECT
APPENDIX 9
Agricultural Suitability Mapping - Project Biodiversity Offset Area and Buffer Area
WHITEHAVEN COAL
LEGEND
Tenement Boundary
Indicative Mining Lease Application Area
National Park
State Forest
Approximate Extent of Major Project Component
Approximate Road Diversion Alignment
Project Biodiversity Offset Area Boundary
Approved and Proposed/Potential Offset Areas for other Projects
Narrabri North Stage 2 Longwall Project
Tarrawonga Coal Project
Buffer Area Boundary
AGRICULTURAL SUITABILITY CLASSIFICATION
Class 2
Class 3
Class 4
Class 5
Kilometres
GRID DATUM MGA 94 ZONE 56
Source: Orthophoto - Google Earth Image; Office of Environment & Heritage (2011); Department of Land and Property Information; Aerial Photography Flown (July 2011) and DECC (2009)
SOILmgt
ML 1662
ML 1620
CL 316
AUTH 406
Vickery State Forest
MLA 3
ML 1464
ML 1471
MLA 2
NAMOI RIVER
Nicholas Creek
Teatree Gully
Maules Creek
Basin Creek
Willuri
Mount Kaputar National Park


VICKERY COAL PROJECT
APPENDIX 9
Rural Land Capability Mapping - Project Biodiversity Offset Area and Buffer Area
WHITEHAVEN COAL
LEGEND
Tenement Boundary
Indicative Mining Lease Application Area
National Park
State Forest
Approximate Extent of Major Project Component
Approximate Road Diversion Alignment
Project Biodiversity Offset Area Boundary
Approved and Proposed/Potential Offset Areas for other Projects
Narrabri North Stage 2 Longwall Project
Tarrawonga Coal Project
Buffer Area Boundary
RURAL LAND CAPABILITY CLASSIFICATION
Class II
Class III
Class IV
Class V
Class VI
Class VII
Class VIII
Kilometres
Source: Orthophoto - Google Earth Image; Office of Environment & Heritage (2011); Department of Land and Property Information, Aerial Photography Flown (July 2011) and DECC (2009)
Vickery State Forest
Mount Kaputar National Park
ML 1662
ML 1620
AUTH 406
CL 316
MLA 3
MLA 1
ML 1464
ML 1471
MLA 2
SOILmgt

Appendix 10 Agricultural Suitability Matrix

The soil factors with the worst ratings determine the overall Agricultural Suitability ranking (Hulme *et al.* 2002).

All of the 75 sampling sites had at least one type of nutrient limitation.

Example Pit	Agricultural Suitability Factors*										
	Slope/ erosion hazard	Water holding capacity		Compaction (SOILpak score)	Dispersive topsoil	Dispersive subsoil	Acidic topsoil	Acidic subsoil	Salinity	**Overall Rating**	Additional Notes
		Depth to gravel/sand	Depth to hard rock								
13	3	2	2	2	2	2	2	2	2	3	Limited space to accommodate modern broad-acre farming equipment.
17	2	2	2	3	2	2	2	2	3	3	Limited space to accommodate modern broad-acre farming equipment.
21	2	2	2	2	2	4	2	2	4	4	
24	2	2	2	2	2	2	2	2	2	2	Limited space to accommodate modern broad-acre farming equipment.
35	4	2	4	2	2	2	2	3	2	4	
39	3	2	2	3	2	4	3	2	4	4	
47	4	2	2	2	2	2	3	4	2	4	
71	2	2	2	4	3	4	2	2	4	4	

* The listed Agricultural Suitability factors (Section 4.4) are sub-sets of the following soil fertility categories:

1. PHYSICAL FERTILITY: Erosion hazard, water holding capacity, waterlogging caused by compaction and/or dispersion.
2. CHEMICAL FERTILITY: pH imbalance (acidity), salinity, nutrients.
3. BIOLOGICAL FERTILITY: Affected by all of the above plus organic matter content.

REFERENCES

Hulme T, Grosskopf T, Hindle J (2002)
Agricultural Land Classification. Agfact AC 25 (NSW Agriculture: Orange).

Appendix 11 Assessment against Biophysical Strategic Agricultural Land Criteria

Biophysical Strategic Agricultural Land Criteria

The *New England North West Strategic Regional Land Use Plan* (SRLUP) New South Wales (NSW) Office of Environment and Heritage (OEH) (2012a) includes the following criteria for biophysical strategic agricultural land (Biophysical Strategic Agricultural Land [BSAL]):

- *land that falls under soil fertility classes 'high' or 'moderately high' under the Draft Inherent General Fertility of NSW (OEH, 2012b); and*
- *land capability classes I, II or III under the Land and Soil Capability Mapping of NSW (OEH, 2012c); and*
- *reliable water of suitable quality, characterised by having rainfall of 350 mm or more per annum (9 out of 10 years); or properties within 150 m of a regulated river, or unregulated rivers where there are flows for at least 95% of the time (i.e. the 95th percentile flow of each month of the year is greater than zero) or 5th order and higher rivers; or groundwater aquifers (excluding miscellaneous alluvial aquifers, also known as small storage aquifers) which have a yield rate greater than 5 litres per second (L/s) and total dissolved solids of less than 1,500 milligrams per litre (mg/L).*

OR

- *land that falls under soil fertility classes 'moderate' under the Draft Inherent General Fertility of NSW (OEH, 2012b); and*
- *land capability classes I or II under the Land and Soil Capability Mapping of NSW (OEH, 2012c); and*
- *reliable water of suitable quality, characterised by having rainfall of 350 mm or more per annum (9 out of 10 years); or properties within 150m of a regulated river, or unregulated rivers where there are flows for at least 95% of the time (i.e. the 95th percentile flow of each month of the year is greater than zero) or 5th order and higher rivers; or groundwater aquifers (excluding miscellaneous alluvial aquifers, also known as small storage aquifers) which have a yield rate greater than 5 L/s and total dissolved solids of less than 1,500 mg/L.*

Map 6 from the SRLUP shows the BSAL mapped within the New England North West. Map 6 shows that no BSAL has been mapped in the Project mining area.

Notwithstanding, an assessment against the above criteria has been conducted.

Draft Inherent General Fertility of NSW

A summary of the inherent general fertility of the soils observed on the Project site is provided in Table 1. This summary has been interpreted by correlating the Australian Soil Classification soil types (Isbell, 2002) (Section 4.3) to the superseded Great Soil Group classes (Stace *et al.* 1968). The Great Soil Group classes have been used to develop the 'Draft Inherent General Fertility of NSW' scheme (OEH, 2012b) used in the identification of BSAL.

No sites within the Project disturbance area are considered to have a 'High General Fertility' classification (e.g. Black Earth or Chernozem). Sites that are considered to potentially have 'Moderately High General Fertility' or 'Moderate General Fertility' classification are further assessed in Table 2.

Land and Soil Capability Mapping of NSW

Details of the 'Land and Soil Capability Mapping of NSW' scheme (OEH, 2012b) used in the identification of BSAL were released in October 2012 (OEH, 2012d). The mapping is based on an unpublished mapping method and rule set developed by Murphy *et al.* (unpublished, 2007).

To assess the Project against the BSAL criteria, the Land and Soil Capability criteria (OEH, 2012d) has been used as a guide. This assessment is presented in Table 2.

Rainfall

The 'Decile 1' annual rainfall for Gunnedah is 377millimetres (mm), i.e. greater than 350 mm. The mean annual total is 622 mm.

Table 1. Vickery Project Site's Inherent General Fertility (according to the draft Inherent General Soil Fertility of NSW criteria [OEH, 2012b]).

Pit	Australian Soil Classification	Great Soil Group	Is it '<u>High</u>' <u>Fertility</u> class[1]? (i.e. Black Earth or Chernozem)	Is it '<u>Moderately High</u>' Fertility class[1]?	Is it '<u>Moderate</u>' Fertility class[1]?
1	Brown Dermosol	Alluvial – medium texture	No	Potentially	Potentially
2	Spolic Anthroposol	n/a	No	No	No
3	Spolic Anthroposol	n/a	No	No	No
4	Spolic Anthroposol	n/a	No	No	No
5	Spolic Anthroposol	n/a	No	No	No
6	Spolic Anthroposol	n/a	No	No	No
7	Stratic Rudosol	Alluvial – light texture	No	No	No
8	Brown Dermosol	Brown Podzolic	No	No	Potentially
9	Stratic Rudosol	Alluvial – light texture	No	No	No
10	Brown Dermosol	Alluvial – medium texture	No	Potentially	Potentially
11	Red Kandosol	Red Earth	No	Potentially	Potentially
12	Red Vertosol	Grey, Brown, Red Clays	No	No	No
13	Red Ferrosol	Kraznozem	No	Potentially	Potentially
14	Brown Sodosol	Soloth	No	No	No
15	Stratic Rudosol	Alluvial – light texture	No	No	No
16	Brown Chromosol	Brown Podzolic	No	No	Potentially
17	Red Dermosol	Red Podzolic	No	Potentially	Potentially
18	Red Chromosol	Alluvial – medium texture	No	Potentially	Potentially
19	Red Ferrosol	Kraznozem	No	Potentially	Potentially
20	Brown Sodosol	Solodic Soils	No	No	No
21	Red Dermosol	Red Podzolic	No	Potentially	Potentially
22	Brown Dermosol	Brown Podzolic	No	No	Potentially
23	Red Dermosol	Red Podzolic	No	Potentially	Potentially
24	Red Dermosol	Alluvial – medium texture	No	Potentially	Potentially
25	Brown Dermosol	Brown Podzolic	No	No	Potentially
26	Brown Sodosol	Solodic Soils	No	No	No
27	Brown Vertosol	Grey, Brown, Red Clays	No	No	Potentially
28	Brown Vertosol	Grey, Brown, Red Clays	No	No	Potentially
29	Red Dermosol	Red Podzolic	No	Potentially	Potentially
30	Spolic Anthroposol	n/a	No	No	No
31	Spolic Anthroposol	n/a	No	No	No
32	Leptic Tenosol	Lithosol	No	No	No
33	Grey Sodosol	Soloth	No	No	No
34	Brown Vertosol	Grey, Brown, Red Clays	No	No	Potentially
35	Spolic Anthroposol	n/a	No	No	No
36	Red Ferrosol	Kraznozem	No	Potentially	Potentially
37	Spolic Anthroposol	n/a	No	No	No
38	Red Sodosol	Solodic Soils	No	No	No
39	Brown Sodosol	Solodic Soils	No	No	No
40	Brown Sodosol	Solodic Soils	No	No	No
41	Spolic Anthroposol	n/a	No	No	No
42	Red Dermosol	Red Podzolic	No	Potentially	Potentially
43	Spolic Anthroposol	n/a	No	No	No
44	Red Sodosol	Solodic Soils	No	No	No
45	Grey Sodosol	Soloth	No	No	No
46	Leptic Tenosol	Lithosol	No	No	No
47	Brown Dermosol	Brown Podzolic	No	No	Potentially
48	Leptic Tenosol	Lithosol	No	No	No
49	Grey Chromosol	Gleyed Podzolic	No	No	No
50	Yellow Sodosol	Soloth	No	No	No
51	Spolic Anthroposol	n/a	No	No	No
52	Brown Dermosol	Brown Podzolic	No	No	Potentially
53	Brown Dermosol	Brown Podzolic	No	No	Potentially
54	Brown Chromosol	Red-Brown Earth	No	No	Potentially
55	Brown Sodosol	Solodic Soils	No	No	No
56	Brown Chromosol	Brown Podzolic	No	No	Potentially
57	Grey Sodosol	Solodic Soils	No	No	No
58	Red Sodosol	Solodic Soils	No	No	No
59	Brown Dermosol	Brown Podzolic	No	No	Potentially
60	Brown Dermosol	Brown Podzolic	No	No	Potentially

Table 1. Vickery Project Site's Inherent General Fertility (*continued*).

Pit	Australian Soil Classification	Great Soil Group	Is it '<u>High</u>' <u>Fertility</u> class[1]? (i.e. Black Earth or Chernozem)	Is it '<u>Moderately High</u>' Fertility class[1]?	Is it '<u>Moderate</u>' Fertility class[1]?
61	Brown Dermosol	Brown Podzolic	No	No	Potentially
62	Stratic Rudosol	Alluvial – light texture	No	No	No
63	Leptic Tenosol	Lithosol	No	No	No
64	Brown Sodosol	Solodic	No	No	No
65	Grey Dermosol	Gleyed Podzolic	No	No	No
66	Stratic Rudosol	Alluvial – light texture	No	No	No
67	Brown Sodosol	Soloth	No	No	No
68	Grey Vertosol	Grey, Brown, Red Clays	No	No	Potentially
69	Brown Vertosol	Grey, Brown, Red Clays	No	No	Potentially
70	Brown Vertosol	Grey, Brown, Red Clays	No	No	Potentially
71	Brown Vertosol	Grey, Brown, Red Clays	No	No	Potentially
72	Grey Dermosol	Gleyed Podzolic	No	No	No
73	Brown Kandosol	Calcareous Red Earth	No	No	No
74	Yellow Sodosol	Soloth	No	No	No
75	Stratic Rudosol	Alluvial – medium texture	No	Potentially	Potentially

[1] In accordance with Draft Inherent General Fertility of NSW (OEH, 2012b)

Thirty-three of the 75 pits may have a 'Moderately High General Fertility' or a 'Moderate General Fertility' classification. The key soil factors for each of these 33 sites were considered in more detail (Table 2).

Table 2. Assessment against Land and Soil Capability.

Pit	Slope Class (2=<3%, 3=3-10%, 4=>10%)	Soil constraints relevant to LSC classification	Is it '<u>High'</u> <u>Fertility</u> class[1]?	Is it '<u>Moderately High'</u> Fertility class[1]?	Is it '<u>Moderate'</u> Fertility class[1]?	Land and Soil Capability (LSC) classification[2]
1	2		No	Potentially	Potentially	Class 2
8	2	Saline subsoil (ECe >5 dS/m)	No	No	Potentially	Class 5
10	2	Saline subsoil (ECe >5 dS/m)	No	Potentially	Potentially	Class 5
11	2	Saline subsoil (ECe >5 dS/m)	No	Potentially	Potentially	Class 5
13	3		No	Potentially	Potentially	Class 3
16	2	Bedrock within 100cm of soil surface	No	No	Potentially	Class 3
17	2		No	Potentially	Potentially	Class 2
18	2	Topsoil acidic (pH $CaCl_2$ <4.7), low buffering capacity (CEC <5 meq/100g)	No	Potentially	Potentially	Class 5
19	3		No	Potentially	Potentially	Class 3
21	2	Saline subsoil (ECe >5 dS/m)	No	Potentially	Potentially	Class 5
22	3	Saline subsoil (ECe >5 dS/m)	No	No	Potentially	Class 5
23	2		No	Potentially	Potentially	Class 2
24	2		No	Potentially	Potentially	Class 2
25	2		No	No	Potentially	Class 2
27	3	Saline subsoil (ECe >5 dS/m)	No	No	Potentially	Class 5
28	3	Saline subsoil (ECe >5 dS/m)	No	No	Potentially	Class 5
29	3		No	Potentially	Potentially	Class 3
34	3	Saline subsoil (ECe >5 dS/m)	No	No	Potentially	Class 5
36	2	(Rehabilitated area)	No	Potentially	Potentially	
42	3	Topsoil acidic (pH CaCl2 <4.7), low buffering capacity (CEC <5 meq/100g)	No	Potentially	Potentially	Class 5
47	4	Subsoil acidic (pH CaCl2 <4.7)	No	No	Potentially	Class 4
52	3	Bedrock within 100 cm of soil surface	No	No	Potentially	Class 3
53	3	Saline subsoil (ECe >5 dS/m)	No	No	Potentially	Class 5
54	4		No	No	Potentially	Class 4
56	2		No	No	Potentially	Class 2
59	3	Saline subsoil (ECe >5 dS/m)	No	No	Potentially	Class 5
60	3		No	No	Potentially	Class 3
61	2		No	No	Potentially	Class 2
68	2	Saline subsoil (ECe >5 dS/m)	No	No	Potentially	Class 5
69	3	Saline subsoil (ECe >5 dS/m)	No	No	Potentially	Class 5
70	2	Saline subsoil (ECe >5 dS/m)	No	No	Potentially	Class 5
71	2	Saline subsoil (ECe >5 dS/m)	No	No	Potentially	Class 5
75	2	Strongly sodic subsoil	No	Potentially	Potentially	Class 7

[1] In accordance with Draft Inherent General Fertility of NSW (OEH, 2012b).

[2] In accordance with Land and Soil Capability (OEH, 2012c and 2012d).

% = percent
dS/m = deciSiemens per metre
LSC = Land and Soil Capability
CaCl2 = calcium chloride
ECe = Electrical Conductivity
meq/100g = milliequivalents per 1000 grams
cm = centimetre

Conclusion

Seven of the 75 pits within the Project site could be considered to meet the BSAL criteria as described in the SRLUP (pits 1, 17, 23, 24, 25, 56 and 61). Five of the seven pits with high quality soils are located on colluvium derived from basic volcanic parent material on the slopes of Red Hill and to the southwest of this feature (pits 1, 17, 23, 24 and 25). There is also a small area of colluvium in 'Drainage Line Variant a' (represented by Pits 56 and 61) that could be considered to have BSAL status.

Note that thresholds specific to the Project site have been introduced in the column in Table 2 labelled 'Soil constraints relevant to LSC classification'. In Section 4.3 of OEH (2012d), it is noted that '*When an initial LSC determination does not match known or indicative conditions of the landscape or soils, expert knowledge is used to record a modified LSC class that overrides the original assessment*.' The following assumptions have been introduced to provide a sensible outcome:

- The presence of saline subsoil (EC_e >5 dS/m) gives an LSC Class 5 because it restricts the ability of landholders to grow sufficient biomass to protect the soil from soil degradation processes.
- The presence of strongly sodic subsoil (ESP>20) gives an LSC Class 7 because it restricts the ability of landholders to grow sufficient biomass to protect the soil from soil degradation processes.
- The presence of serious acidity (pH $CaCl_2$ <4.7) gives an LSC Class 5 because it restricts the ability of landholders to grow sufficient biomass to protect the soil from soil degradation processes.

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Appendix 12 Soil Characteristics at the Vickery Coal Project Site, in Relation to descriptions of 'Natural grasslands on basalt and fine-textured alluvial plains of northern New South Wales and southern Queensland'

Introduction

Published soil features associated with the 'Natural grasslands on basalt and fine-textured alluvial plains of northern New South Wales and southern Queensland' threatened ecological community are as follows, with highlighting added to emphasise key points in each of the three references:

1. Threatened Species Scientific Committee (2008) *Commonwealth Listing Advice on Natural grasslands on basalt and fine-textured alluvial plains of northern New South Wales and southern Queensland*.

- p. 2: *"The distribution of the ecological community is **strongly reliant on soil type** as it is associated with fine textured, often cracking clays derived from either basalt or quaternary alluvium. The clay minerals in these soils are generally expanding i.e. upon wetting, water is absorbed into the clay particles causing them to expand. On drying, the water is released and the clay particles shrink. The expansion and contraction means that **these soils are cracking or self-mulching**. The high water-holding capacity of the clay soil inhibits deep penetration during most rainfall events. The development of **deep cracks** as the soils dry, and the tearing up of tap roots during the soil contraction and expansion cycle are possible reasons why trees and large woody shrubs are typically lacking in these grasslands…".*
- p. 4: *"**Deep cracking black soils** are a key habitat characteristic for some of the more grassland dependent fauna, particularly reptiles such as Anomalopus mackayi (*Five-clawed Worm-skink*), Tympanocryptis pinguicolla (*Grassland Earless Dragon*) and numerous other lizards and snakes (Hobson 2002). Within the ecological community deep soil cracks in these grasslands are habitat for small mammals such as Planigale tenuirostris (*Narrow-nosed Planigale*), P. ingrami (*Long-tailed Planigale*), P. maculata (*Common Planigale*) and Rattus tunneyi (*Pale Field-rat*)…".*

2. NSW Office of Environment & Heritage (2011) *Identification Guidelines for Endangered Ecological Communities: Native Vegetation on Cracking Clay Soils of the Liverpool Plains.*

- p. 4: *"Is the site on flat, **heavy cracking clay soils (black earths)**?"*

3. New South Wales Scientific Committee (2011) *Final Determination: Native Vegetation on Cracking Clay Soils of the Liverpool Plains.*

- *"The community occurs on cracking clay soils (vertosols - **including soils referred to as Black Earth**) and is within the Liverpool Plains Catchment".*

The key criteria from these documents may be summarised as follows:

1. The soil is classified as 'Black Earth';
2. The surface is self-mulching; and
3. The soil requires a capacity to shrink that is great enough to provide cracks with the capacity to be used by reptiles and small mammals.

Definitions of Vertosols ("cracking clays") and shrink-swell capacity used by soil scientists in Australia

Since introduction of the Isbell (2002) classification scheme, cracking clays have been called 'Grey, Brown, Red and Black Vertosols'. Previously they were referred to as 'Grey, Brown and Red Clays' and 'Black Earths' under the Stace *et al.* (1968) scheme. The terms 'Black Vertosol' and 'Black Earth' are synonymous.

Vertosols are shrink-swell soils with a clay-field texture containing 35 percent or more clay (i.e. hand texture of 'light clay' or heavier) throughout the solum, although they may have very thin (0.03 m) crusty surface horizons (McKenzie *et al.* 2004). Cracks occur at some time in most years, and the soils have slickensides or lenticular peds, or both, occurring at some depth in the solum.

The A horizon (topsoil) in cracking clays may be structured or massive (The National Committee on Soil and Terrain 2009). The structural 'A horizon' is the granular, subangular blocky, angular blocky or polyhedral surface horizon where ped faces are not accommodated and have irregular coarse voids between them. This is exemplified in soils with a self-mulching surface.

Isbell (2002) has noted that field indicators of shrink-swell behaviour do not work well when the soil is moist. Attempts have been made to develop laboratory methods to refine the classification process. A research technique, referred to as the modified Coefficient of Linear Extensibility method, can be used to determine shrinkage behaviour of soil. A linear shrinkage threshold of about 8% or greater will help differentiate soils with vertic properties from others. A more convenient approach is to use soil cation exchange capacity (CEC) as a surrogate measure of shrink-swell behaviour – this approach has been used as part of the 'Cotton SOILpak' system (McKenzie 1998). In this study, a minimum CEC value of 15 milliequivalents of hydrogen 100 grams (meq/100g) is required through the solum for classification as a Vertosol. This value is derived from an examination of the laboratory data for 'Grey, Brown and Red Clays' presented by Stace *et al.* (1968). The high-CEC 'Black Earths' (Black Vertosols) have a much greater shrink-swell capacity than moderate-CEC 'Grey, Brown and Red Clays' (Grey, Brown and Red Vertosols).

It is important to note that shrinkage cracks can be observed in soil with CEC less than about 15 meq/100g, but their frequency and width are inadequate for the soil to be referred to as a genuine "cracking clay".

Soil properties at the Vickery Development Site

Table 1 presents information about soil profiles at the Vickery site with potential to be classified as "cracking clays". Although eight of the 75 profiles (see photographs in Attachment A) are classified as Brown, Grey or Red Vertosols (Pits 2, 3, 4, 31, 32, 53, 63, 71), only one of them (Pit 71; a Red Vertosol) has a self-mulching surface. Of the non-self-mulching Vertosols, only one (Pit 3) has a CEC profile similar to the examples shown in Table 2. Pit 71 is located near the top of Red Hill; further testing is required to determine its shrink-swell potential. None of the soil profiles had all of the morphological features of the Black Vertosol / Black Earth shown in Attachment A.

Addressing of the key criteria

1. The soil is classified as 'Black Earth'

The Vertosols at Vickery do not have the required combination of dark colouration and shrink-swell potential to allow classification as Black Vertosol / Black Earth (Table 1).

2. The surface is self-mulching

Only one soil pit, Pit 71, has a self-mulching surface but the soil there is Red Vertosol, not Black Vertosol, and it is located outside of the relevant grassland vegetation community (Attachment A).

3. ***The soil requires a capacity to shrink that is great enough to provide cracks with the capacity to be used by reptiles and small mammals***

Cracks large enough to provide favourable habitat for small reptiles and mammals were not observed on the soil surface or in any of the soil pits at Vickery.

Conclusion

None of the 75 soil profiles examined at the Vickery Coal Project Site can be described as Black Earths (Black Vertosols) with self-mulching surfaces. The soil conditions at Vickery do not match the descriptions/criteria specified in the relevant Commonwealth and NSW State reference material for the threatened ecological community under consideration.

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Threatened Species Scientific Committee (2008*) Commonwealth Listing Advice on Natural grasslands on basalt and fine-textured alluvial plains of northern New South Wales and southern Queensland. Advice to the Minister for the Environment, Heritage and the Arts.*

Table 1. Soil profiles at the Vickery study site that had features with potential to allow classification as Vertosols ("cracking clays")

Vickery Landscape	Vickery Pit Number (Field #; see Appendix 1)	Australian Soil Classification*	Texture Equal to or Greater than 'Light Clay' to a Depth of at Least 90 cm	Evidence of Field Shrinkage	Field Water Content	CEC Values to a Depth of 90 cm = Greater than 15 meq/100g	CEC Values to a Depth of 90 cm = Greater than 25 meq/100g	Self-mulching Surface (SOILpak Score in Brackets)	Lenticular Aggregates and/or Slickensides 0-90 cm
Southern Plain	1	Brown Dermosol	Yes	Yes	Not moist	No (15-90 cm only)	No (30-90 cm only)	Yes (1.5)	No
	2	Brown Vertosol	Yes	Yes	Not moist	Yes	No (30-90 cm only)	No (0.3)	Yes
	3	Grey Vertosol	Yes	Yes	Not moist	Yes	Yes – up to 48 meq/100g)	No (0.4) (ESP 0-15 cm =8.7)	Yes
	4	Brown Vertosol	Yes	Yes	Not moist	Yes	No (15-90cm only)	No (0.4)	Yes
	63	Brown Vertosol	Yes	No	Moist 0-40 cm	Yes	No 15-90 cm only)	No (0.7)	Yes
	64	Grey Dermosol	Yes	No	Moist 0-55 cm	No (15-90 cm only)	No (30-90 cm only)	No (1.1)	Yes
	66	Grey Dermosol	Yes	No	Moist 0-60 cm	No (15-90 cm only)	No (30-90 cm only)	Yes (1.8)	Yes
North-eastern Plain	56	Brown Dermosol	Yes	No	Moist 0-30 cm	No (15-90 cm only)	No (30-90 cm only)	Yes (1.5)	No
Hillside near Forest (sedimentary rock)	31	Brown Vertosol	Yes	Yes	Moist 0-25 cm	Yes	No (15-90 cm only)	No (1.2)	Yes
	32	Brown Vertosol	Yes	Yes	Moist 0-10 cm	Yes	No (15-90 cm only)	No (0.8)	Yes
	48	Brown Dermosol	Yes	No	Moist 0-55 cm	No (15-90 cm only)	No	Yes (1.5)	No
	53	Brown Vertosol	Yes	No	Sl. moist 0-70 cm	Yes	No (15-90 cm only)	No (0.5)	Yes
Western Slopes (basaltic influence)	22	Red Kandosol	Yes	Yes	Moist 0-10 cm	No (15-90 cm only)	No (30-90 cm only)	Yes (1.7)	Yes
	23	Brown Dermosol	Yes	Yes	Moist 0-18 cm	No (30-90 cm only)	No	Yes (1.6)	Yes
	24	Red Ferrosol	Yes	No	Moist 0-15 cm	No	No	Yes (1.8)	No
	71	Red Vertosol	Yes	No	Sl. moist 0-65 cm	Yes	Yes – up to 52 meq/100g)	Yes (1.7)	No
	72	Red Dermosol	Yes	No	Moist 0-115 cm	Yes (except 15-30 cm)	No (0-15 cm only)	Yes (1.5)	No
	74	Brown Dermosol	Yes	No	Sl. moist 0-90 cm	No (15-90 cm only)	No	No (0.2)	No

cm = centimetre

ESP = exchangeable sodium potential

*Isbell RF (2002) The Australian Soil Classification, Revised edition (CSIRO Publishing: Collingwood).

Table 2. Examples of "cracking clays" (Vertosols) with self-mulching surfaces from other parts of Australia showing typical CEC profiles

Examples from 'Australian Soils and Landscapes'*	CEC Values to a Depth of 90 cm = Greater than 15 meq/100g	CEC Values to a Depth of 90 cm = Greater than 25 meq/100g	Self-mulching Surface
Red Vertosol, p. 370	Yes	Yes (up to 43 meq/100g)	Yes
Grey Vertosol, p. 374	Yes	Yes (up to 46 meq/100g)	Yes
Grey Vertosol, p. 378	Yes	Yes (up to 38 meq/100g)	Yes
Black Vertosol, p. 384	Yes	Yes (up to 64 meq/100g)	Yes
Black Vertosol, p. 386	Yes	Yes (up to 83 meq/100g)	Yes

Please Note: Black Vertosols are also referred to as 'Black Earths'*

* McKenzie N, Jacquier D, Isbell R, Brown K (2004) Australian Soils and Landscapes: An Illustrated Compendium (CSIRO Publishing: Collingwood).

Attachment A. Photographs of Brown, Red and Grey Vertosols at the Vickery Development Site (a, b, c), in relation to a published example of a Black Vertosol (d).

a. Pit 2. Brown Vertosol

b. Pit 71. Red Vertosol

c. Pit 3. Grey Vertosol

d. Example of a Black Vertosol (McKenzie *et al*. 2004)

ATTACHMENT B

ECONOMIC REVIEW OF POTENTIAL AGRICULTURAL IMPACTS
(Gillespie Economics, 2012a)

Vickery Coal Project

Economic Review of Potential Agricultural Impacts

Prepared for

Whitehaven Coal Limited

By

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October 2012

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1 INTRODUCTION

Whitehaven Coal Limited (Whitehaven) is seeking Development Consent under Part 4 of the New South Wales (NSW) *Environmental Planning and Assessment Act, 1979* (EP&A Act) to develop an open cut coal mine and associated infrastructure (herein referred to as the Vickery Coal Project [the Project]). The Project is located within the Gunnedah Basin, in the NSW Gunnedah Coalfield, with the planned open cut situated approximately 25 kilometres (km) north of Gunnedah.

The Project includes the production of up to 4.5 million tonnes per annum (Mtpa) of run-of-mine (ROM) coal for a period of approximately 30 years.

A detailed description of the Project is provided in Section 2 in the Main Report of the Environmental Impact Statement. This report assesses the potential economic implications of the impacts of the Project on agricultural (including land and water) resources and forms a component of the Agricultural Impact Statement for the Project (Resource Strategies, 2012).

2 AGRICULTURAL AND MINING INDUSTRIES IN NEW SOUTH WALES

2.1 LAND USE

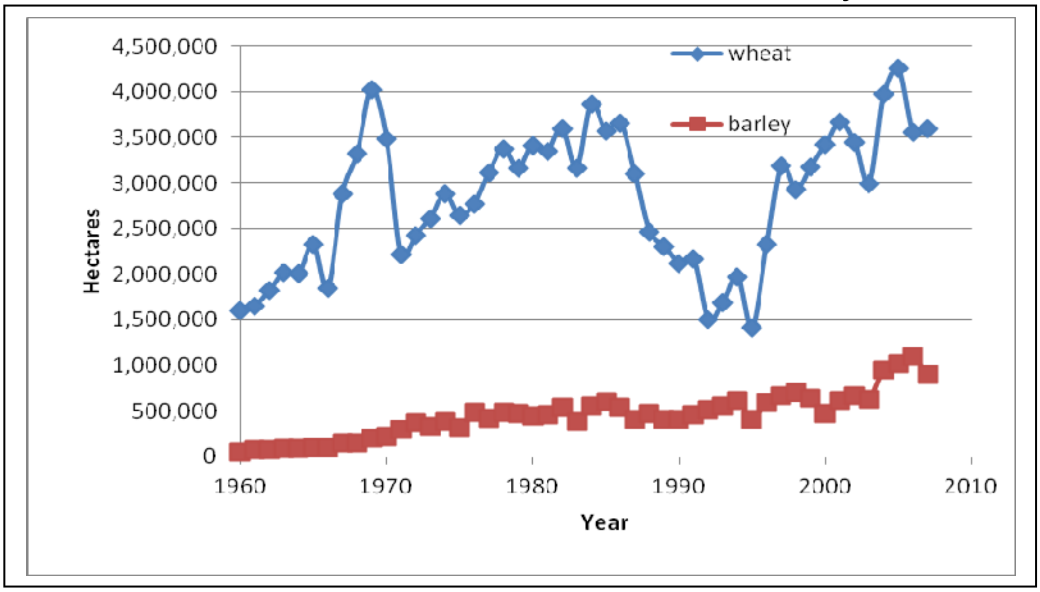
Agricultural lands are important to NSW and cover approximately 81 percent (%) of the State (i.e. 65 million [M] hectares [ha]) (Australian Natural Resources Atlas [ANRA], 2009a). While the total agricultural land area in NSW has declined marginally since 1960 (Table 1), the area of land under major food crop production (i.e. wheat and barley[1]) has actually increased (Figure 1).

Table 1
NSW Agricultural Land Area

	1960	1980	1997
Area of Agricultural Land (M ha)	69.95	65.01	60.90

Source: ANRA (2009b).

Figure 1
NSW Land Area Allocated to Wheat and Barley



Source: ABS (2009).

[1] Wheat and barley are the two largest food crops produced in Australia.

Dryland and irrigated cropping land covers an area of approximately 84,878 square kilometers (km^2) in NSW. Mining (and waste disposal) covers an area of approximately 630 km^2, 0.74% of the area of cropping lands (Table 2).

Table 2
NSW Land Uses

Land use	Area (km^2)	Percentage of NSW
Nature conservation	61,058	7.6%
Other protected areas	2,478	0.3%
Minimal use	59,178	7.4%
Grazing native vegetation	309,428	38.6%
Production forestry	25,242	3.2%
Plantation forestry	4,200	0.5%
Grazing modified pastures	222,164	27.7%
Dryland cropping	74,692	9.3%
Dryland horticulture	390	0.0%
Irrigated pastures	3,160	0.4%
Irrigated cropping	10,186	1.3%
Irrigated horticulture	1,073	0.1%
Land in transition	951	0.1%
Intensive animal and plant production	243	0.0%
Intensive uses (mainly urban)	10,218	1.3%
Rural residential	4,387	0.5%
Mining and waste	630	0.1%
Water	11,352	1.4%
Total	**801,030**	**100.0%**

Source: Bureau of Regional Science (2009).

The NSW agricultural industry directly provides employment for 76,261 people or 2.7% of total employment in NSW (Australian Bureau of Statistics [ABS], 2006)[2]. Payment to agriculture, forestry and fishing employees in 2010-11 was $1,539M and value-added was $7,062M. Gross operating surplus and gross mixed income from agriculture, forestry and fishing was $6,908M (ABS, 2011a).

Mining land use is a small fraction of the area of NSW (i.e. less than 0.1% of the total NSW land area) (Bureau of Regional Science 2009) and directly employs 19,026 or 0.7% of total employment in NSW (ABS, 2006). Payment to mining employees in 2010-11 was $2,466M and value-added was $10,633M. Gross operating surplus and gross mixed income from mining was $10,035M (ABS, 2011a).

In this comparison, mining is a more significant sector than agriculture in terms of payments to employees, value-added and gross operating surplus and gross mixed income. However, agriculture does employ more people, albeit while using a much larger area of NSW to achieve this employment.

Nevertheless, no policy implication should be drawn from the relative magnitudes of existing sectors. What is relevant in a policy context is whether moving from one land use to another is more economically efficient or not. That is, do the benefits to the community from changing land uses exceed the costs to the community. This is discussed in more detail in Section 4.

[2] This is based on the ABS sector of Agriculture, forestry and fishing.

2.2 ECONOMIC GROWTH IN REGIONAL AREAS

Agricultural lands have historically supported the economies of regional areas. However, regional economies are facing a number of trends including:

- loss of significant industries such as abattoirs and timber mills from many rural areas;
- increased mechanisation of agriculture and aggregation of properties, resulting in loss of employment opportunities in this industry;
- preference of Australians for coastal living, particularly for retirement; and
- preference of many of today's fastest growing industries for locating in large cities (Collits, 2001).

The result is that there has been declining population growth in 47 out of 96 rural statistical local areas (SLAs) that are located in non-coastal statistical subdivisions in NSW (excluding Hunter Statistical Division) (ABS, 2011b). There has also been a decline in the population of smaller towns even in regions that have been growing.

Trends in agriculture are leading to improved productivity, but reduced economic stimulus in regional areas, as demand for inputs such as labour decline. In general, the prosperity of rural areas that are reliant on agriculture has also been in decline.

It is increased or new spending in regions that contributes to economic stimulus and growth. One potential source of new spending is mining projects that utilise the resource endowments of a region. Studies (Gillespie Economics, 2003, 2007) have shown that mining projects provide significant new economic stimulus to regional and rural economies through direct expenditures on inputs to production as well as the expenditure of employees. This latter stimulus is enhanced by the high wages paid in the mining sector.

Mining projects can also broaden the economic base of regions, thereby insulating the economy from external shocks such as droughts and downturns in agricultural commodity prices (Collits, 2001).

3 AGRICULTURAL AND MINING INDUSTRIES IN THE NARRABRI AND GUNNEDAH REGION

3.1 Agriculture

The Gunnedah and Narrabri region (i.e. the Gunnedah and Narrabri local government areas [LGAs]) have a combined land area of approximately 1.8M ha, of which 68% is agricultural land (Table 3). Of this agricultural land, 5.6% is irrigated with annual irrigation volumes of approximately 323,000 megalitres (ML) (Table 3). The total value of agricultural production in this region in 2006 is estimated at $386M (ABS, 2010a, 2010b) (Table 3).

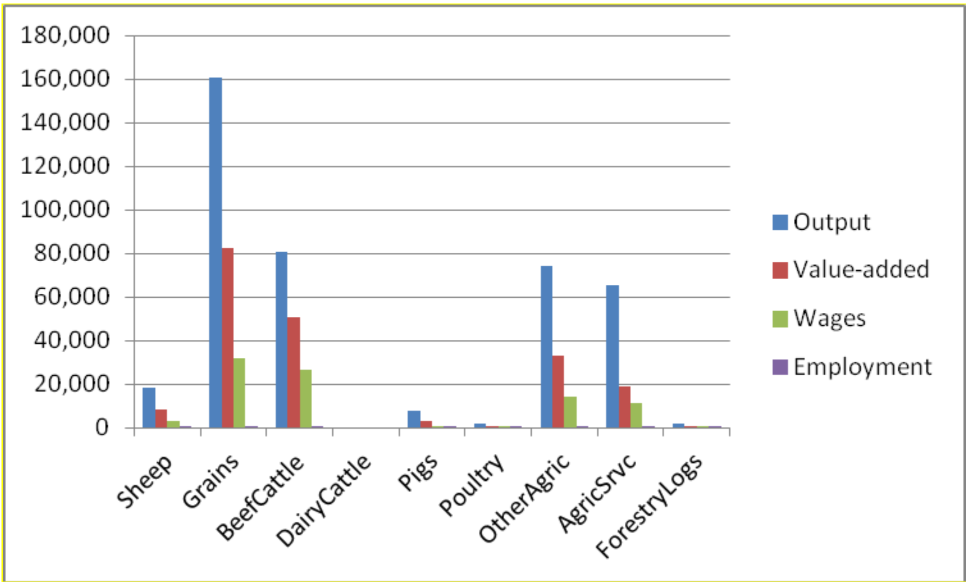
Table 3
Existing Agricultural Land Use and Value of Production
in Gunnedah and Narrabri – 2006

	Units	Gunnedah LGA	Narrabri LGA	Total
Area				
Land Area	ha '000	499	1,303	1,802
Area of Agricultural Land	ha '000	434	791	1,225
Cereals for grain	ha '000	123	157	280
Vegetables for human consumption	ha '000	0	0.1	0.1
Orchard trees (including nuts)	ha '000	0.06	0.1	0.16
All fruit (excluding grapes)	ha '000	0.06	0.1	0.16
Non-cereal broadacre crops	ha '000	25	71	96
Total Number				
Sheep and lambs	No.	67,195	180,265	247,460
Milk cattle (excluding house cows)	No.	0	299	299
Meat cattle	No.	85,293	105,351	190,644
Pigs	No.	6,940	17,897	24,837
Irrigation				
Area Irrigated	ha '000	18	51	69
Irrigation Volume Applied	ML	62,907	260,266	323,173
Other Agricultural Uses	ML	2,068	4,355	6,423
Total Water Use	ML	64,974	264,621	329,595
Area Irrigated as Proportion of Agricultural Land	%	4.1	6.4	5.6
Value				
Gross Value of Crops	$M	95	215	310
Gross Value of Livestock Slaughtering	$M	29	41	71
Gross Value of Livestock Products	$M	1	4	5
Total Gross Value of Agricultural Production	***$M***	***126***	***261***	***386***

Source: ABS (2010a, 2010b).
Note: Totals may have minor discrepancies due to rounding.
ML = megalitres.

The input-output table developed for the Narrabri and Gunnedah LGAs (Gillespie Economics, 2012) provides an indication of the direct relative significance of the different agricultural sectors, affirming grains, beef cattle and other agriculture (which includes cotton) as the main agricultural sectors (Figure 2).

Figure 2
Agricultural Sectors in Gunnedah and Narrabri LGAs



Source: Gillespie Economics (2012).

Total employment in the agricultural industry in the Gunnedah and Narrabri LGAs is 2,252 (ABS, 2010c). Table 4 provides a more detailed employment by industry breakdown which indicates that the main agricultural employment is in beef farming (specialised), grain-sheep or grain-beef cattle farming, other grain growing and cotton growing.

3.2 Mining

Extractive industries in Gunnedah and Narrabri are less than 1% of the land area (Edge Land Planning, 2007, 2009). Despite being a small fraction of the footprint of agriculture, the saleable coal output level in 2008/09 is estimated to have a value of around $480M[3] (Table 5) which is greater than the value of agricultural production in the Gunnedah and Narrabri LGAs (Table 3).

[3] Assuming a market price of $100 per tonne. The average value of steaming and coking coal at that time was considerably greater than $100 per tonne.

Table 4
Employment by Agricultural Sectors in Gunnedah and Narrabri LGAs

Industry	Employment
Agriculture, not further defined	72
Vegetable Growing (Outdoors)	5
Grape Growing	3
Citrus Fruit Growing	3
Olive Growing	8
Sheep, Beef Cattle and Grain Farming	14
Sheep Farming (Specialised)	74
Beef Cattle Farming (Specialised)	457
Beef Cattle Feedlots (Specialised)	4
Sheep-Beef Cattle Farming	101
Grain-Sheep or Grain-Beef Cattle Farming	381
Other Grain Growing	428
Cotton Growing	388
Other Crop Growing	8
Poultry Farming	3
Poultry Farming (Eggs)	4
Pig Farming	30
Beekeeping	7
Other Livestock Farming	4
Forestry and Logging	3
Forestry	3
Hunting and Trapping	3
Agriculture, Forestry and Fishing Support Services, not further defined	3
Forestry Support Services	5
Cotton Ginning	118
Shearing Services	3
Other Agriculture and Fishing Support Services	101
Agriculture, Forestry and Fishing, not further defined	19
Total	**2,252**

Source: ABS (2010c).

Table 5
Coal Mining Production, Gross Value and Direct Employment in Gunnedah and Narrabri LGAs

Coal Mining	Units	Total
Coal Saleable Production (2008/2009)	Mt	4.8
Gross Value of Coal Production	$M	480
Direct Mining Employment	No.	356

Source: NSW Department of Primary Industries (NSW DPI) (2010).
Mt = million tonnes.

4 ECONOMIC FRAMEWORKS FOR THE ASSESSMENT OF PROPOSALS THAT IMPACT AGRICULTURAL LAND AND WATER

4.1 Economic Efficiency

From an economic perspective, it is desirable to use scarce resources, such as capital, labour, land and water, to maximise economic welfare or community fulfilment. This is referred to as economic efficiency and refers to a situation where production costs are as low as possible (technical or productive efficiency), and consumers want the combination of goods and services that is being produced (allocative efficiency).

Economic efficiency can be achieved for market goods, where there are no externalities, through competitive markets. In this situation, the price mechanism (interaction of supply and demand) functions to allocate resources in a manner that maximises the net benefits to society as a whole.

Agricultural land and water (where property rights have been established) are market goods. The market will allocate these resources to their most productive use for society. The exception is where a change in land use or water use may result in market failure through the occurence of externalities. In these circumstances, markets will not allocate resources to maximise economic welfare. Government intervention may therefore be required to determine how resources should be allocated.

In these situations, any Government intervention should be guided by a consideration of the costs and benefits of the intervention. The method that economists use to do this is benefit cost analysis (BCA). The essence of BCA is:

- the estimation of the extent to which a community is made better off by a resource reallocation;
- the estimation of the extent to which the community is made worse off by a resource reallocation; and
- a comparison of these two figures.

If the benefits of the intervention are greater than the costs of the intervention then it provides net benefits to the community and results in an improvement in economic efficiency.

In a simple BCA framework, the potential costs and benefits of a mining project that impacts agricultural land and water are identified in Table 6.

Table 6
Potential Costs and Benefits of a Mining Proposal that Impacts Agricultural Land

	Costs	Benefits
Net Production Benefits	Opportunity costs of land and capital	Value of mineral resource
	Capital and operating costs (including impact mitigation and rehabilitation)	Residual value of land and capital
Net Externalities	Residual environmental impacts of mining after impact mitigitation	Any avoided environmental impacts of agriculture
		Any non use employment benefits of mining[1]

[1] Indications of the potential quantum of these benefits have been estimated using choice modelling in Gillespie Economics (2008, 2009a, 2009b).

Where the proposal uses agricultural land and water there is an opportunity cost to society of using these resources for mining instead of agriculture. The magnitude of this opportunity cost is reflected in the market value of land and water.

The market value of the land reflects, among other things, the discounted future net income that can be earned from the property, and income reflects how much the community values the outputs from the land. Where agriculture production becomes increasingly scarce, this will be reflected in the value of agricultural products and the value of agricultural land. However, the long-term trend for agricultural commodity prices has been a decline in real value rather than an increase in value, reflecting that with growth in productivity, supply has strengthened more rapidly than demand (ABARES, 2011). Between 1961 and 2008, world population grew by 117% while food production grew by 179% (ABARES, 2011). While commodity price increases have risen over the last few years this is partly a response to government subsidies and mandates regarding the production of biofuels (ABARES, 2011). In the future, growth in global food consumption is expected to slow. Strong productivity growth and the utilisation of hitherto unused cropping should ensure the continuing adequacy of food supplies (ABARES, 2011). Consequently, substantial real increases in food prices are not anticipated.

Similiarly, the market value of agricultural water entitlements reflects, among other things, its value as an input to production (i.e. its marginal value product). Where water becomes increasingly scarce or the value of output that is produced from water becomes increasingly valuable, the value of water as an input to production increases.

The utlimate outcome of any BCA of a project is an empirical issue. But estimating the value of the opportunity cost of agricultural land and water is an integral component of the analysis.

4.2 Regional Economic Impact Assessment

Regional economic impact assessment (using input-output analysis) may provide additional information as an adjunct to economic efficiency analysis. Input-output analysis can be used to estimate the change in economic activity in a region from land and water resources being used for mining instead of agriculture. These changes in economic activity are defined in terms of a number of specific indicators of economic activity, such as:

- gross regional output – the gross value of business turnover;
- value-added – the difference between the gross value of business turnover and the costs of the inputs of raw materials, components and services bought in to produce the gross regional output;
- household income – the wages paid to employees including imputed wages for self employed and business owners; and
- employment – the number of people employed (including full-time and part-time).

It is important not to confuse the results of regional economic impact assessment, which focuses on indicators of economic activity in a specific region, with the results of BCA which is concerned with the net benefits to Australia from a project.

5 PROJECT IMPACTS ON AGRICULTURAL RESOURCES

5.1 OPPORTUNITY COST OF AGRICULTURE AND WATER RESOURCES

NSW DPI has developed gross margin budgets to provide a guide to the relative profitability of particular agricultural enterprises (NSW DPI, 2012a). These budgets identify the revenue and variable costs that could be expected for a particular enterprise in a particular region. The revenue stipulated in these budgets is referred to here as 'gross value'.

The variable costs identified in the budgets are those that are directly attributable to an enterprise and which vary in proportion to the size of an enterprise, however do not include fixed or overhead costs which have to be met regardless of enterprise size (DPI, 2012a). The 'gross margin' of the relevant enterprise is the gross value minus these variable costs.

NSW DPI gross margin budgets have been used in conjunction with information gathered during consultation with local farmers to estimate the opportunity cost of agriculture and water resources that would be potentially impacted by the Project.

Land Resources

The Project (including the biodiversity offset areas) would result in the temporary disturbance and the long-term loss of some agricultural lands. A summary of the agricultural lands at the Project and the biodividersity offest area is provided below.

<u>*Disturbance Footprint*</u>

The Project disturbance area is predominantly Agricultural Suitability Class 3 and Class 4, with a small area of Agricultural Suitability Class 2 land (Table 7).

Table 7
Agricultural Suitabililty Class of the Project Distrubance Area

Agricultural Suitability Class	Area (ha)
Class 1	0
Class 2	124
Class 3	598
Class 4	1520
Class 5	0
Total	2,242

Source: McKenzie Soil Management (2012).

It is estimated that approximately 2,242 ha of agricultural land would be progressively disturbed by the development of the Project. 780 ha of disturbed land is proposed to be rehabilitated to agricultural land (mostly Agricultural Suitability Class 3 and Class 4) (Resource Strategies, 2012).

The agricultural land within the Project mining area is currently used for beef cattle grazing on unimproved pasture. NSW DPI (2012b) identify inland weaner production on native pasture as generating $125.55 of gross value per ha per year and a gross margin of $96.05 per ha per year.

Conservatively assuming that agricultural production from the entire footprint (2,242 ha) ceases at the commencement of the Project, and that post-mining, agricultural production is lost in perpetuity from 1,462 ha (i.e. 780 ha of the 2,242 ha disturbance footprint is rehabilitated to agricultural land) the gross value of production foregone is estimated at $281,000 per annum during the mine life and $184,000 per annum post-mining. The present value of foregone agricultural output, in perpetuity, (at 7% discount rate) is estimated at $3.8M.

The gross margin of production foregone is estimated at $215,000 per annum during the mine life and $140,000 per annum post-mining. The present value of foregone agricultural gross margin, in perpetuity, (at 7% discount rate) is estimated at $2.9M.

Biodiversity Offset Area

The biodiversity offset area proposed for the Project totals 1,667 ha comprising 1,231 ha of Agricultural Suitability Class 5 land and 436 ha of Agricultural Suitability Class 4 land. Approximately 250 ha of this land is currently cleared (i.e. comprised of grassland). For this analysis, it is conservatively assumed that the Class 4 biodiversity offset land could otherwise be used for beef grazing with the same gross margin budget as reported above (NSW DPI, 2012a). Assuming that agricultural production from the biodiversity offset area ceases at the commencement of the Project for perpetuity the gross value of production foregone is estimated at $55,000 per annum ($775,000 present value at 7% discount rate) and the gross margin of agricultural production foregone is $42,000 ($593,000 present value at 7% discount rate).

Total Land Resources

In total, the foregone gross value and gross margin of agricultural production from agricultural land resources required for the Project is estimated at $4.59M and $3.51M present value (using a 7% discount rate), respectively.

Water Resources

As well as using the agricultural lands, the Project would divert surface and groundwater resources of approximately 2,035 ML per year during the mine life, and 530 ML per year following mine closure, that could potentially be used for agricultural production (Evans & Peck, 2012 and Heritage Computing, 2012). For the purposes of this assessment, this water has been assumed to be otherwise used for irrigated cotton production.

The NSW DPI (2012c) farm budget for irrigated cotton suggests a requirement of 7 ML per ha of irrigated cotton. The surface and groundwater diverted by the Project could therefore otherwise contribute to an estimated 291 ha of irrigated cotton per year during the life of the mine, and 75 ha of irrigated cotton following mine closure. This irrigated cotton would have a gross value of $1.78M per annum during the mine life and $459,000 per annum following mine closure ($22.9M present value at 7% discount rate) and gross margin of $890,000 per annum during the mine life and $229,000 per annum following mine closure ($11.4M present value at 7% discount rate).

In the absence of this water being available for irrigated cotton production it is assumed that the land would be used for dryland cotton (NSW DPI 2012d) with a gross value of $695,000 per annum during the mine life and $179,000 per annum following mine closure ($8.9M present value at 7% discount rate) and gross margin of $300,000 per annum during the mine life and $77,000 per annum following mine closure ($3.9M present value at 7% discount rate).

The net impact on agricultural production would therefore be gross value of $1.08M per annum ($13.9M present value at 7% discount rate) and gross margin of $590,000 per annum ($7.6M present value at 7% discount rate). The annual impact would decrease significantly following mine closure as a substantial volume of water used by the Project would become available for agricultural use.

Total Land and Water Resources

Table 8 summarises the potential impact of the Project on agriculture in terms of annual revenue (i.e. gross value) and gross margin and present value of revenue (i.e. gross value) and gross margin. The total impact of the Project on agriculture is estimated at a gross value of $1.4 M per annum ($18.5M present value at 7% discount rate) and gross margin of $0.8 M per annum ($11.1M present value at 7% discount rate).

Table 8
Summary of Land and Water Resources Impacts

	Gross Value		**Gross Margin**	
	Annual	**Present Value (7% discount rate)**	**Annual**	**Present Value (7% discount rate)**
Land Resources				
Disturbance footprint	$0.3M	$3.8M	$0.2M	$2.9M
Offsets	$0.1M	$0.8M	$0.0M	$0.6M
Sub-total	$0.3M	**$4.6M**	$0.3M	**$3.5M**
Water Resources				
Irrigated cotton	$1.8M	$22.9M	$0.9M	$11.4M
Dryland cotton	$0.7M	$8.9M	$0.3M	$3.9M
Net cotton	**$1.1M**	**$13.9M**	**$0.6M**	**$7.6M**
Total	**$1.4M**	**$18.5M**	**$0.8M**	**$11.1M**

Note: Totals may have minor discrepancies due to rounding.

5.2 ECONOMIC EFFICIENCY OF REALLOCATION OF AGRICULTURAL RESOURCES TO THE PROJECT

The present value of the net production benefit of the Project has been estimated and is detailed in the Socio-Economic Assessment for the Project (Gillespie Economics, 2012) (Appendix K of the EIS).

This value can be compared to the present value of net production benefits from future use of agricultural land and water that would be used by the Project which is estimated at $11.1M (Table 9).

Table 9
Net Production Benefits of Agricultural Resources Potentially Affected by the Project

	Agricultural Production
Annual Net Production Benefits	$0.8M
Net Production Benefits[1]	$11.1M

Source: Gillespie Economics (2012).
[1] Discounting is at 7%.

The Project is estimated to provide a considerable net production benefit that is far in excess of the net production benefit of continued use of land and water resources for agriculture.

5.3 REGIONAL IMPACTS

The regional impacts of the level of annual agricultural production forgone as a result of the Project (Section 5.1) were estimated from the sectors in the regional input-output table (Gillespie Economics, 2012) within which production is located i.e. the *beef sector and the cotton sector.* Table 10, Table 11 and Table 12 summarise the estimated direct and indirect regional impacts of the Project (with the assumptions in Section 5.1 above) on annual agricultural production.

Table 10
Regional Economic Impacts of Agricultural Land Required for the Project Disturbance Area

	Direct Effect	Indirect Effect			TOTAL EFFECT
		Production Induced	Consumption Induced	Total Indirect Effect	
Output ($'000)	**281**	**61**	**55**	**115**	**396**
Type 11A Ratio	*1.00*	*0.22*	*0.19*	*0.41*	*1.41*
Value Added ($'000)	**176**	**24**	**26**	**50**	**226**
Type 11A Ratio	*1.00*	*0.14*	*0.15*	*0.29*	*1.29*
Income ($'000)	**92**	**14**	**17**	**31**	**123**
Type 11A Ratio	*1.00*	*0.15*	*0.19*	*0.34*	*1.34*
Employment (No.)	**2**	**0**	**0**	**1**	**2**
Type 11A Ratio	*1.00*	*0.12*	*0.16*	*0.28*	*1.28*

Note: Totals may have minor discrepancies due to rounding.

Table 11
Regional Economic Impacts of Agricultural Land Required for the Biodiversity Offset

	Direct Effect	Indirect Effect			TOTAL EFFECT
		Production Induced	Consumption Induced	Total Indirect Effect	
Output ($'000)	**55**	**12**	**11**	**23**	**78**
Type 11A Ratio	*1.00*	*0.22*	*0.19*	*0.41*	*1.41*
Value Added ($'000)	**34**	**5**	**5**	**10**	**44**
Type 11A Ratio	*1.00*	*0.14*	*0.15*	*0.29*	*1.29*
Income ($'000)	**18**	**3**	**3**	**6**	**24**
Type 11A Ratio	*1.00*	*0.15*	*0.19*	*0.34*	*1.34*
Employment (No.)	**0**	**0**	**0**	**0**	**0**
Type 11A Ratio	*1.00*	*0.12*	*0.16*	*0.28*	*1.28*

Note: Totals may have minor discrepancies due to rounding.

Table 12
Regional Economic Impacts of Water Required for the Project

	Direct Effect	Indirect Effect			TOTAL EFFECT
		Production Induced	Consumption Induced	Total Indirect Effect	
Output ($'000)	**1,082**	**347**	**145**	**492**	**1,574**
Type 11A Ratio	*1.00*	*0.32*	*0.13*	*0.46*	*1.46*
Value Added ($'000)	**485**	**132**	**70**	**202**	**687**
Type 11A Ratio	*1.00*	*0.27*	*0.14*	*0.42*	*1.42*
Income ($'000)	**207**	**73**	**46**	**119**	**326**
Type 11A Ratio	*1.00*	*0.35*	*0.22*	*0.58*	*1.58*
Employment (No.)	**6**	**1**	**1**	**2**	**8**
Type 11A Ratio	*1.00*	*0.22*	*0.15*	*0.37*	*1.37*

Note: Totals may have minor discrepancies due to rounding.

Table 13 provides a summary of the annual regional production and economic impacts associated with the Project (with the conservative assumptions in Section 5.1) on annual agricultural production that would be forgone as a result of the Project (Section 5.1).

Table 13
Annual Regional Production/Economic Impacts of the Foregone Agriculture

	Agriculture Land Disturbed by Project	Agricultural Land Biodiversity Offsets	Water	TOTAL
Direct Effect				
Direct Output ($000)	281	55	1,082	1,418
Direct Value Added ($000)	176	34	485	696
Direct Income ($000)	92	18	207	317
Direct Employment (No.)	2	0	6	8
Total Effect				
Direct and Indirect Output ($000)	396	78	1,574	2,048
Direct and Indirect Value Added ($000)	226	44	687	958
Direct and Indirect Income ($000)	123	24	326	472
Direct and Indirect Employment (No.)	2	0	8	11

Note: Totals may have minor discrepancies due to rounding.

Conservatively, the annual agricultural direct output from the agricultural resources that would potentially be impacted by the Project is estimated to be $1.4M (Table 12).

The Project is estimated to provide considerable stimulus to the regional economy that is far in excess of the regional economic impacts associated with the maximum level of annual agricultural production that would be forgone as a result of the Project (Gillespie Economics, 2012).

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