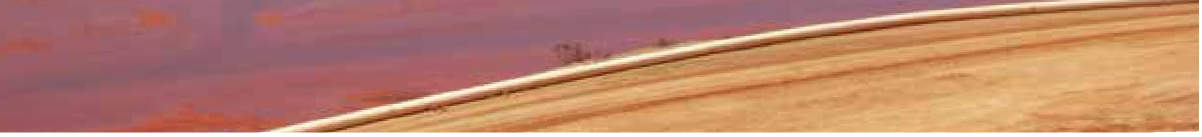
APPENDIX 19

Soil Assessment




Soil Assessment
Mangoola Coal Continued Operations Project

Prepared for Mangoola Coal Operations Pty Limited
May 2019




EMM
creating opportunities

Soil Assessment

Mangoola Coal Continued Operations Project

Prepared for Mangoola Coal Operations Pty Limited
May 2019

EMM Brisbane
Level 10, 87 Wickham Terrace
Spring Hill QLD 4000

T 07 3648 1200
E info@emmconsulting.com.au

www.emmconsulting.com.au

Soil Assessment

Mangoola Coal Continued Operations Project

Report Number

B17193 Soil Assessment

Client

Mangoola Coal Operations Pty Limited

Date

8 May 2019

Version

v2

Document Control

Version	Date	Prepared by	Reviewed by
V01	June 2018	K Drapala	T Rohde
V02	May 2019		C Richards

Executive Summary

EMM Consulting Pty Limited (EMM) was engaged by Mangoola Coal Operations Pty Limited (Mangoola) to complete a Soil Assessment for the Mangoola Coal Continued Operations Project (MCCO Additional Project Area). The purpose of the assessment was to fulfil the following aims:

1. Soil Survey – Undertake a soil survey to identify soil types within the MCCO Additional Project Area;
2. Biophysical Strategic Agricultural Land (BSAL) Assessment – In accordance with the *Interim Protocol for site verification and mapping of BSAL* (NSW Government 2013);
3. Land and Soil Capability (LSC) Assessment – In accordance with the *Land and soil capability assessment scheme – second approximation* (OEH 2012);
4. Soil Balance – Assess the soil material available for stripping and suitable for re-use as a topdressing growth media, and calculate the depth of application possible on the post mining landform; and
5. Impact Assessment – Determine the impact or change in the pre and post mining landforms, soil and land capability, BSAL and general soil mitigation measures to be applied, to reduce the impacts.

The proposed mining activities of the MCCO Additional Project Area will restrict impacts on the land and soil resources to the MCCO Additional Project Area disturbance footprint. The MCCO Additional Project Area was surveyed by EMM in August 2017. Soil profiles were assessed in the field and samples taken from 14 of the 55 sites examined and sent to ALS Global for analytical tests. The main soil type identified in the MCCO Additional Disturbance Area was Grey Sodosol (82%), followed by Red-Orthic Tenosol (11%), both of which generally occur on gently undulating slopes of low rolling hills on sandstone surface geology. These soil types are typical of the region, and are extensively cleared and used mainly for grazing improved pastures. Three other soil types: Brown Dermosols (6%), Grey Kurosols (1%) and Brown Chromosols (isolated sites) were identified in the MCCO Additional Project Area. The Dermosol soil type occurs adjacent to Big Flat Creek. The Kurosol will not be disturbed by the project and the Chromosol is located in small singular locations within the MCCO Additional Project Area.

The MCCO Additional Project Area was assessed through the Site Verification Application (SVA) process and is verified Non-BSAL. The assessment was undertaken in accordance with the Interim Protocol (NSW Government 2013). Subsequently, a Site Verification Certificate was issued by Department of Planning and Environment (DPE) on 10 December 2018 confirming the land as verified Non-BSAL.

The soil resources have been assessed for suitability in post mining landforms, resulting in a total volume of material available being 1,365,000 m^3. The soil balance was undertaken and resulted in a possible soil depth across the rehabilitated landform of between 0.25 m and 0.28 m, which should provide an adequate soil profile for the establishment and growth of native vegetation, whilst providing for some resilience to dry conditions.

The Land and Soil Capability Assessment was undertaken in accordance with the *LSC Assessment Scheme – second approximation* (OEH 2012). This assessment found the majority of the site was considered LSC Class 5, with limited areas of Classes 3, 4 and 7. The proposed post-mining LSC classes include Class 6 for the rehabilitated land (494 ha) and Class 8 for the final void (82 ha). Approximately 7 ha that is disturbed for the realignment of Wybong Post Office Road will remain as permanent road infrastructure. All other areas within the MCCO Additional Disturbance Area will either remain or be rehabilitated back to pre-mining LSC Class.

The proposed final land use within the MCCO Additional Project Area is consistent with that of the approved Mangoola Coal Mine. That is, for the majority of the site to have native vegetation established on the final landform. The soil profile may allow for potential grazing activities if the proposed final land use changes, however native vegetation is the preferred land use.

Table of Contents

Appendices

Tables

Figures

Photographs

1 Introduction

EMM Consulting Pty Limited (EMM) has been engaged by Umwelt (Australia) Pty Limited (Umwelt) on behalf of Mangoola Coal Operations Pty Limited (Mangoola) to complete a Soil Assessment for the Mangoola Coal Continued Operations Project (MCCO Project). The purpose of the assessment is to form part of an Environmental Impact Statement (EIS) being prepared by Umwelt Environmental and Social Consultants (Umwelt) to support an application for development consent under Division 4.1 and 4.7 of Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) for the MCCO Project.

1.1 Project Overview

Mangoola Coal Mine is an open cut coal mine located approximately 20 kilometres (km) west of Muswellbrook and 10 km north of Denman in the Upper Hunter Valley of NSW (refer Figure 1.1). Mangoola has operated the Mangoola Coal Mine in accordance with Project Approval (PA) 06_0014 since mining commenced at the site in September 2010.

The MCCO Project will allow for the continuation of mining at Mangoola Coal Mine into a new mining area to the immediate north of the existing operations. The MCCO Project will extend the life of the existing operation providing for ongoing employment opportunities for the Mangoola workforce. The MCCO Project Area includes the existing approved Project Area for Mangoola Coal Mine and the MCCO Additional Project Area as shown on Figure 1.1.

The MCCO Project generally comprises:

- open cut mining peaking at up to the same rate as that currently approved (13.5 Million tonnes per annum (Mtpa) of run of mine (ROM) coal) using truck and excavator mining methods;
- continued operations within the existing Mangoola Coal Mine;
- mining operations in a new mining area located north of the existing Mangoola Coal Mine, Wybong Road, south of Ridgelands Road and east of the 500 kilovolt (kV) Electricity Transmission Line (ETL);
- construction of a haul road overpass over Big Flat Creek and Wybong Road to provide access from the existing mine to the proposed Additional Mining Area;
- establishment of an out-of-pit overburden emplacement area;
- distribution of overburden between the proposed Additional Mining Area and the existing mine in order to optimise the final landform design of the integrated operation;
- realignment of a portion of Wybong Post Office Road;
- the use of all existing or approved infrastructure and equipment for the Mangoola Coal Mine with some minor additions to the existing mobile equipment fleet;
- construction of a water management system to manage sediment laden water runoff, divert clean water catchment, provide flood protection from Big Flat Creek and provide for reticulation of mine water. The water management system will be connected to that of the existing mine;
- continued ability to discharge excess water in accordance with the Hunter River Salinity Trading Scheme (HRSTS);

- establishment of a final landform in line with current design standards at Mangoola Coal Mine including use of natural landform design principles consistent with the existing site;
- rehabilitation of the proposed Additional Mining Area using the same revegetation techniques as at the existing mine;
- a likely construction workforce of approximately 145 persons. No change to the existing approved operational workforce; and
- continued use of the mine access for the existing operational mine and access to/from Wybong Road, Wybong Post Office Road and Ridgelands Road to the MCCO Project Area for construction, emergency services, ongoing operational environmental monitoring and property maintenance.

Figure 1.2 illustrates the key features of the MCCO Project.

1.2 Secretary's Environmental Assessment Requirements (SEARs)

The NSW Department of Planning and Environment issued SEARs for the MCCO Additional Project Area on 15 February 2019 (replacing a previous version of the SEARs issued on 22 August 2017). A summary of the SEARs relevant to this report, and the section in which they are addressed, is provided in Table 1.1 below.

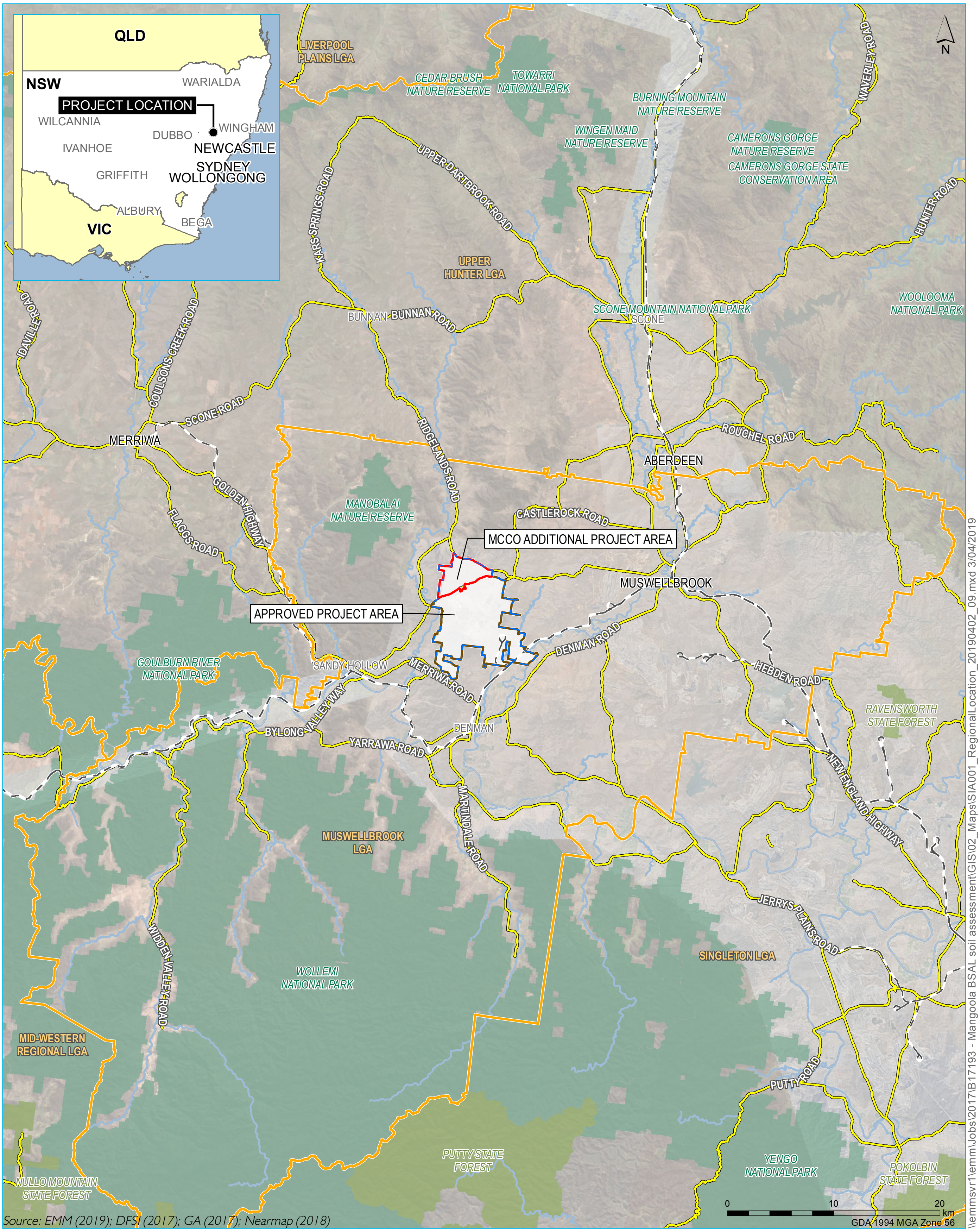
Table 1.1 Summary of the SEARs relevant to this report

SEARs for SSD 8642	Addressed in section	Status
The EIS must address the following key issues:		
Land Resources, including:		
• an assessment of the likely impacts of the development on the soils and land capability of the site and surrounds, paying particular attention to any strategic agricultural land;	Soils: Section 7.2 LSC: Section 7.5	Fully addressed in this report
• an assessment of the agricultural impacts of the development;	Section 5.2	Partially addressed in this report. Further detail in Agricultural Impact Statement

1.3 Project area

There are no proposed changes to the Approved Project Area at the existing and approved Mangoola Coal Mine as part of the MCCO Project with these areas being entirely within existing mining leases held by Mangoola. As such, this soil assessment is only related to the land within the MCCO Additional Project Area (see Figure 1.2).

The MCCO Additional Project Area, is 1,062 hectares (ha) and is shown on Figure 1.2. The area over which the granted Site Verification Certificate applies comprises the MCCO Additional Project Area plus a 100 metre (m) buffer; and is therefore 1,243 ha. The soil survey results for the EIS are reported on the 1,062 ha for the MCCO Additional Project Area only (ie without the 100 m buffer included for the Biophysical Strategic Agricultural Land (BSAL) Assessment).



KEY

- MCCO project area
- Approved project area
- MCCO additional project area
- Local Government Area (LGA) boundary
- Rail line
- Main road
- Watercourse/drainage line
- NPWS reserve
- State forest

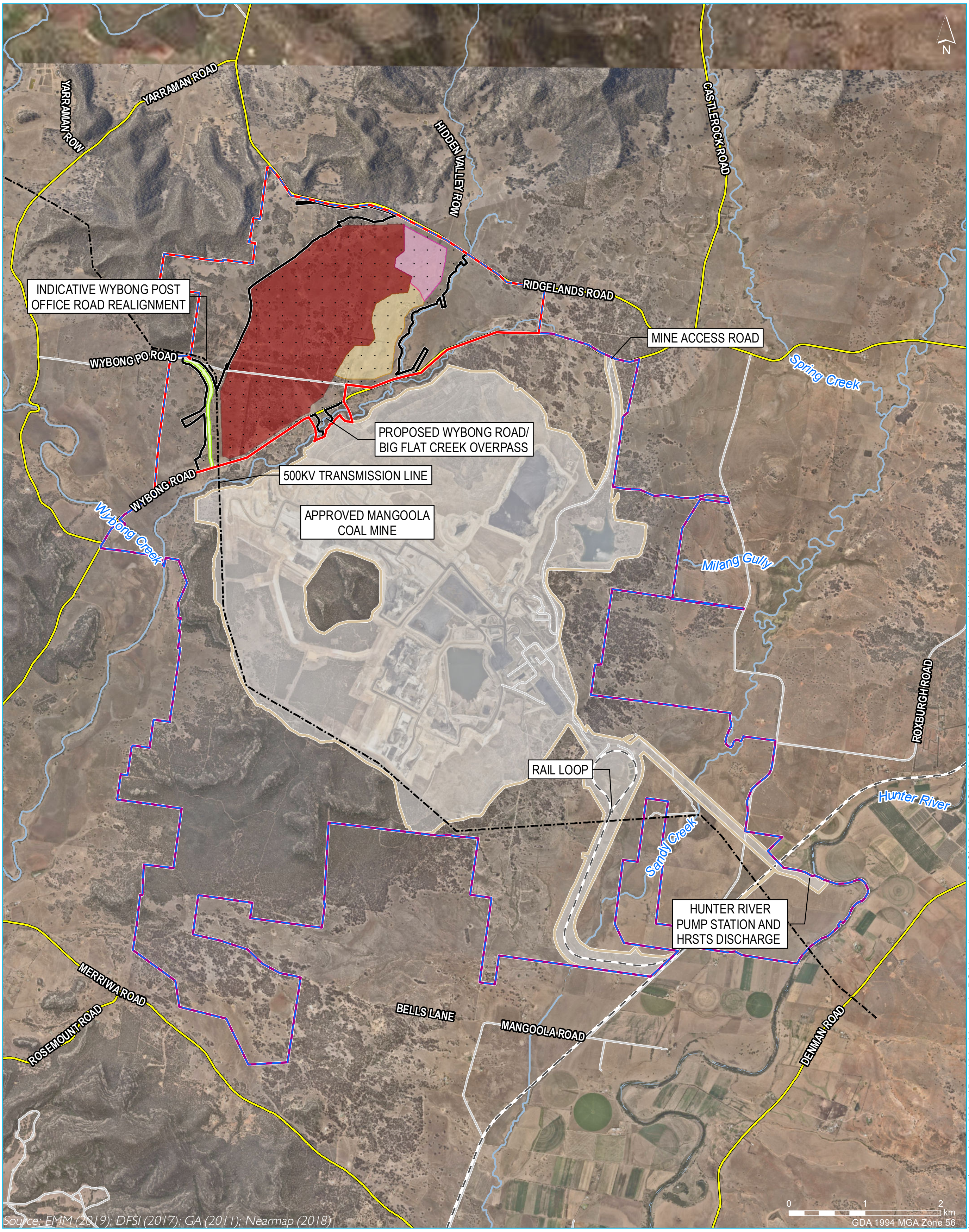
Regional locality plan

Mangoola Coal Continued Operations Project

Soil assessment

Figure 1.1

EMM creating opportunities



\\emmsvr1\emm\Jobs\2017\B17193 - Mangoola BSAL soil assessment\GIS\02_Maps\SIA002_MCCOP_20190423_12.mxd 23/04/2019

KEY

- MCCO project area
- Approved project area
- MCCO additional project area
- MCCO additional disturbance area
- Approved Mangoola Coal Mine disturbance area
- Proposed additional mining area
- Proposed topsoil stockpile area
- Proposed emplacement area
- Indicative Wybong Post Office Road realignment
- 500kV transmission line
- Main road
- Local road
- Rail line
- Watercourse/drainage line

Proposed Mangoola Coal Continued Operations project

Mangoola Coal Continued Operations Project

Soil assessment

Figure 1.2

EMM creating opportunities

2 Soil assessment methodology

2.1 Overview of assessment process

The soil assessment comprised the following steps:

- a desktop review of existing information (incorporated into Section 3);
- a soil survey to characterise soil types, including field assessment and laboratory analysis (Section 4);
- an assessment of BSAL in accordance with the *Interim protocol for site verification and mapping of biophysical strategic agricultural land* (NSW Government 2013), using results from the soil survey (Section 5);
- an assessment of Land and Soil Capability (LSC) in accordance with *The land and soil capability assessment scheme – second approximation* (OEH 2012) using results from the soil survey (Section 6); and
- an assessment of potential impacts on soil resources (Section 7) and proposed management and mitigation methods (Section 8).

2.2 Desktop survey

Existing information on soils and soil environments was sourced from the following regional mapping published by government departments:

- *Soil Landscapes of the Singleton 1:250,000 sheet* (Kovac and Lawrie 1991);
- *Australian soil classification (ASC) soil type map of NSW* (OEH 2017a);
- *Great soil group soil type mapping of NSW* (OEH 2017b);
- *Hydrological soil group mapping* (OEH 2017c);
- *Inherent soil fertility mapping* (OEH 2017d);
- *Strategic regional land use plan Upper Hunter* (DPI 2012) strategic agricultural land map;
- *Land and soil capability classes mapping* (OEH 2017e); and
- *NSW soil and land information system* (SALIS) (OEH 2017f), accessed through eSPADE (OEH 2017g).

The relevant information has been summarised and presented in Section 3

2.3 Field survey

2.3.1 Survey guidelines

The soil survey has been conducted in accordance with the following guidelines:

- *Guidelines for surveying soil and land resources* (McKenzie et al 2008);
- *Australian soil and land survey handbook* (NCST 2009);

- *The Australian soil classification* (Isbell 2016);
- *Soil data entry handbook* (DLWC 2001); and
- *Interim protocol for site verification and mapping of biophysical strategic agricultural land* (NSW Government 2013) (Interim protocol).

The soil survey has taken particular note of the requirements of the Interim Protocol. The soil survey therefore required investigation using two types of inspection sites:

- check sites - low intensity investigation, high repetition, randomised locations and a limited description; and
- detailed sites - high intensity investigation, moderate repetition, randomised and/or targeted locations and a detailed description, selected sampling for laboratory analysis.

2.3.2 Review of available mapping

The soil survey sites were initially planned based on the proposed disturbance areas, a review of Australian Soil Resource Information System (ASRIS) regional soil maps, geology maps and topographic maps. Regional *Soil data contained in the NSW Soil and land information system* (SALIS) (OEH 2017f), was accessed through eSPADE (OEH 2017g) and reviewed as part of the desktop assessment.

2.3.3 Survey sampling density

To determine the density of soil sampling required for both the BSAL assessment and the EIS soil survey, the Interim Protocol recommends risks to agricultural resources and enterprises be evaluated using guidance in Appendix 3 of the Interim Protocol. Risks can be classified as low, medium or high. The Interim Protocol stipulates that sampling densities should be one site per 25 to 400 ha (1:25,000 to 1:100,000) for low risk activities and one site per 5 to 25 ha (1:25,000) for high risk activities (Gallant et al. 2008).

The MCCO Project involves development and operation of mine infrastructure and an open cut pit on land which was shown as unlikely to be BSAL, based on the NSW Government's BSAL trigger map, an extract of which is shown in Figure 2.1. With the exception of small sections of public road corridors, Mangoola owns all land within the proposed MCCO Additional Project Area. Direct surface disturbance will largely involve the open cut pit, stockpile areas, water management and infrastructure areas.

The development and operation of the MCCO Project will have long term impacts (≥20 years) on the MCCO Additional Project Area. However, some stockpile and infrastructure areas will only have a temporary impact. Post-mining, mine infrastructure will be decommissioned and the area rehabilitated to a state where it can support land uses similar to the current land uses.

Based on the above, a risk assessment was undertaken for the MCCO Additional Project Area using the risk ranking matrix in the Interim Protocol. The results are presented in Table 2.1. It is noted that, based on the consequence descriptors in Appendix 3 of the Interim Protocol, the preliminary risk assessments are for an unmitigated scenario, which is not realistic. In practice, mitigation and management measures will be developed and implemented to avoid and minimise impacts.

Table 2.1 Preliminary agricultural risk assessment (unmitigated scenario)

Aspect	Probability[1]	Consequences[1]	Rating[1]	Comments
MCCO project area	A - almost certain	1 - severe	A1 - high	**Applicable consequence descriptor from risk assessment matrix in Appendix 3 of Interim Protocol:** Permanent and irreversible impacts. **EMM comments:** This risk rating applies only to the mining area where a final void will remain. Areas of infrastructure and overburden emplacement areas will be decommissioned and rehabilitated to a state of similar land capability to their current state, allowing for a lower risk ranking. The high-risk ranking has been applied conservatively across the MCCO Additional Project Area.

Note: 1. Based on the probability and consequence descriptors in Appendix 3 of the Interim Protocol and an unmitigated scenario, which is not realistic. In practice, mitigation and management measures will be implemented to avoid and minimise impacts to agriculture.

Accordingly, and as per the requirements of the Interim Protocol, a soil survey density target of at least one site per 5 to 25 ha was adopted for BSAL verification purposes. This survey density was extended for areas greater than 10% within the MCCO Additional Project Area, and therefore is applied to the soil survey undertaken for the EIS.

A total of 55 sites were surveyed within the MCCO Additional Project Area and an average survey density of about one site per 22 ha was achieved (refer to Figure 2.1) which meets the target adopted (as per the Interim Protocol). All sites were described in detail using the SALIS detailed soil data card and keyed out to the ASC Great Group level. A total of 14 sites were chosen for laboratory analysis and classified further to the ASC Family level. This is in accordance with the Interim Protocol. Due to small areas of coverage (8 ha), the Kurosol soil type had only two representative sites sampled and subjected to laboratory analysis. The two sites which were Chromosols have not been mapped separately, instead, this soil type is considered a sub-dominant soil type within the Sodosol soil type.

2.3.4 Site selection

Initial positioning of the soil survey sites was based on stratified random sampling across the MCCO Additional Project Area, though designed to provide a relatively even distribution of detailed and check sites. In accordance with the requirements of stratified random sampling, a greater frequency of sampling was proposed for soil types that cover a greater proportion of the MCCO Additional Project Area. Also, topographic maps were reviewed to ensure surveying was representative of the different landform types in the MCCO Additional Project Area.

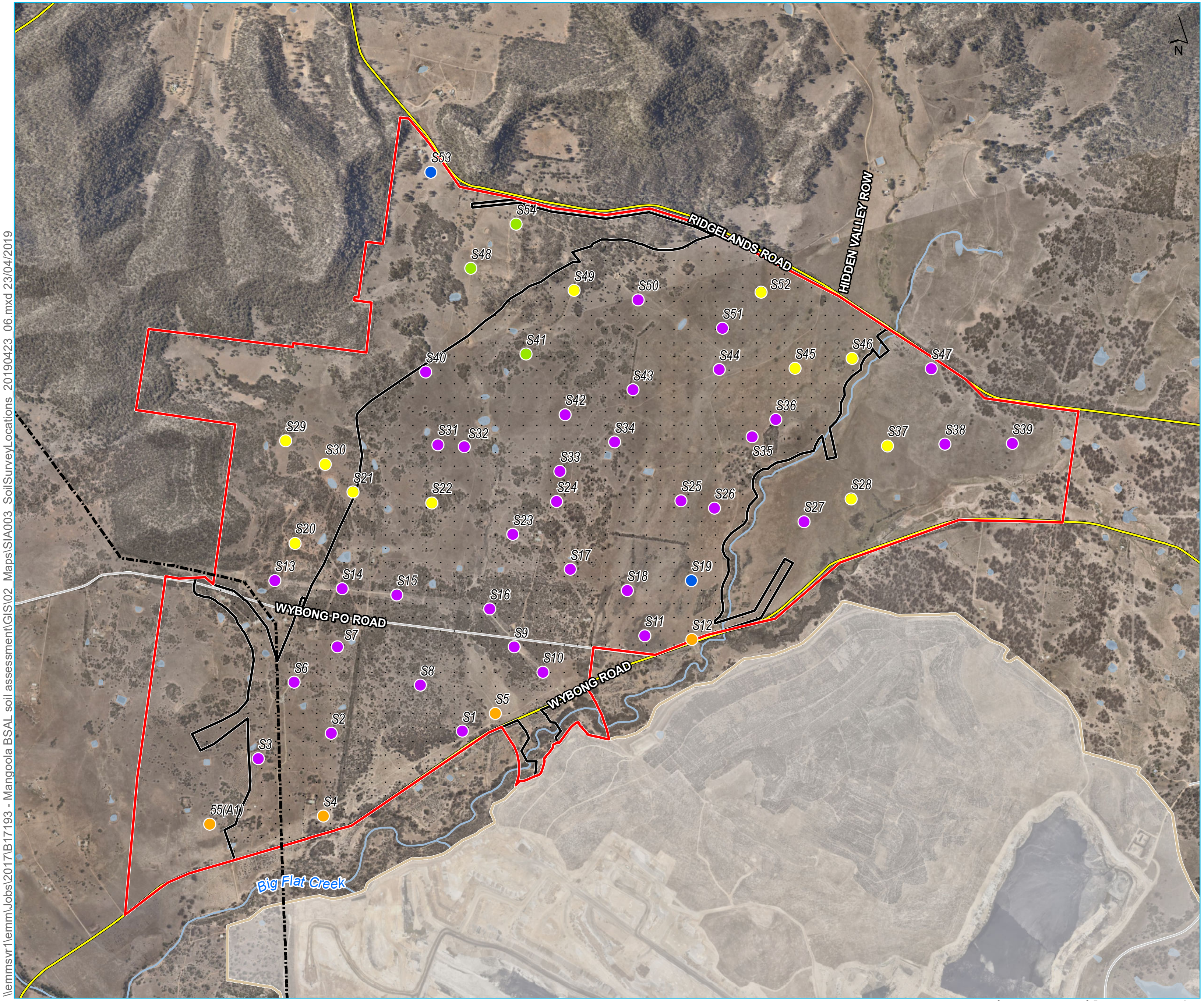
The exact locations of the sites were finalised with consideration to land access constraints and site factors, particularly achieving good sample coverage, past disturbance, vegetation cover and proposed disturbance locations. The sites are shown in Figure 2.1.

Guidance in the Interim Protocol and the National Committee on Soil and Terrain's *Australian Soil and Land Survey Field Handbook* (NCST 2009) (the Handbook) was generally followed for the site assessments. The Interim Protocol suggests that each soil type identified should be examined in detail and samples analysed from at least three sites from each of the soil types. The Handbook suggests:

- 10-30% of sites should be described in detail;
- 1-5% of the sites described in detail should be subject to soil analysis; and
- remaining sites should be used as check sites.

In this way, a total of 55 soil survey sites were assessed using the test pitting technique, all of which were recorded using the SALIS detailed soil data card (of which 14 were subjected to laboratory analysis). This meant that all relevant guidance in the Handbook was achieved or exceeded, with 100% of the sites described in detail and 25% of these subject to analysis.

For the purpose of BSAL verification, a site was defined as occurring within a 10 to 20 m radius of the point of observation of the soil profile. Soil profile data were recorded in the field on SALIS data cards. Photographic records of detailed sites and their soil profiles were taken in the field using a digital camera and are presented in Appendix A.



\\emmsvr1\emm\Jobs\2017\B17193 - Mangoola BSAL soil assessment\GIS\02_Maps\SIA003_SoilSurveyLocations_20190423_06.mxd 23/04/2019

Source: EMM (2019); DFSI (2017); Nearmap (2018)

KEY
- MCCO additional project area
- MCCO additional disturbance area
- Approved Mangoola Coal Mine disturbance area
- 500kV transmission line
- Main road
- Local road
- Watercourse
- Waterbody

Soil test pit
- Chromosol
- Dermosol
- Kurosol
- Sodosol
- Tenosol

Soil survey locations

Mangoola Coal Continued Operations Project
Soil assessment
Figure 2.1

EMM
creating opportunities

2.3.5 Timing of surveys

The soil survey was undertaken over 8 days from 21 to 28 August 2017.

2.3.6 Field Assessment & Sampling method

Soil sampling was carried out with the use of a small excavator to dig test pits to a depth of 1.5 m below ground level (bgl). The test pits were backfilled immediately upon completion of the soil description and sampling.

A field assessment was undertaken, which measured the following parameters:

- Field texture;
- Field pH;
- Horizon layer identification, depth and boundary;
- Structure grade within each layer;
- Pedology (shape, size, fabric);
- Drainage and permeability;
- Presence of fragments and segregations;
- Field colour;
- Presence of mottles (abundance, colours and contrasts);
- Field moisture; and
- Rooting depth.

Soil profiles were chosen as representative for each soil type and were also sampled and subjected to laboratory analysis. Samples were collected using labelled glass jars or zip lock bags with site reference and sample depth indicated. Sample depths varied according to horizon identification ensuring samples avoided layer boundaries and were no more than 25 cm apart. Samples were sent to ALS Global, which has National Association of Testing Authorities (NATA) accreditation for the tests. All analytical results are presented in Appendix C.

Soil profiles were described to sub order level with those profiles sampled and tested described further to family level using the Australian Soil Classification.

2.4 Soil analysis

Laboratory analysis for the survey was undertaken based on the requirements of the following NSW Government guidelines:

- *Interim protocol for site verification and mapping of biophysical strategic agricultural land* (NSW Government 2013);
- *The land and soil capability assessment scheme: second approximation* (OEH 2012); and
- *Agricultural Impact Statement technical notes: A companion to the Agricultural Impact Statement guideline* (NSW Department of Primary Industries 2014).

In the majority of cases, the analysis undertaken meets or exceeds the requirements of these three guidelines. The Kurosol soil type had two representative sites sampled and lab tested. The other soil types had at least three sites tested as representative sites. There were two sites which were classified as Chromosols, however these sites were not mapped separately, instead grouped in with the Sodosol soil unit. The assessment of the remaining sites generally conforms with the nationally accepted standards laid out in the *Australian soil and land survey handbook* (NCST 2009). A NATA-accredited laboratory (ALS Global) was used to ensure that laboratory analysis was undertaken using scientifically correct methods. Table 2.2 lists the laboratory testing program undertaken on the soil samples.

Two levels of analysis were undertaken relevant to the importance of each site. In ascending importance:

- soil pit check sites were analysed in the field for texture, pH and electrical conductivity (EC) only using accepted methods described in the *Australian Soil and Land Survey Field Handbook* (NCST 2009); and
- soil pit detailed sites were sampled with representative sites receiving full laboratory analysis.

A summary of the number of samples analysed from each soil type present in the MCCO Additional Project Area is presented in Table 2.3. The laboratory accreditation is included in Appendix B and full laboratory results, including the naming of analytical method and sampling depths, are included in Appendix C.

Table 2.2 Laboratory analysis

Physical analysis	Chemical analysis
dispersion; and soil texture, other specified significant soil characteristics where these occurred.	organic carbon; pH (water and $CaCl_2$); total and available nitrogen (N); available phosphorus (P); exchangeable potassium (K); cation exchange capacity (CEC); exchangeable sodium (Na); exchangeable calcium (Ca); exchangeable magnesium (Mg); exchangeable aluminium (Al); soluble cations; chloride (Cl); metals (copper (Cu), iron (Fe), zinc (Zn), manganese (Mn), Al, molybdenum (Mo)); and EC.

Table 2.3 Samples analysed from each soil type

Soil types	Number of sites subjected to laboratory analysis	Site numbers	Number of depths analysed
Tenosol	3	20, 21, 37	15
Dermosol	3	55(A1), 5, 12	15
Sodosol	5	10, 23, 43, 41, 47	25
Kurosol	2	48, 54	10
Chromosol	2	53, 19	10

2.5 Land access and mapping approach

Sufficient land was able to be accessed within the MCCO Additional Project Area to satisfy on-site soil sampling density requirements specified in the Interim Protocol. The survey focused on the proposed MCCO Additional Disturbance Area. Access to the western border area was restricted however, this area will not be disturbed.

A manual mapping method has been employed based on the site-specific survey properties and landscape characteristics, including vegetation, topography, aerial imagery and existing soil and geological mapping.

The assessment and soil mapping used soil type map units instead of soil landscape units. Soil landscape units are more appropriate for situations where there is more variability in soil types. They are typically used in areas where there may be a single dominant soil type but two or three common sub-dominants. For the MCCO Additional Project Area, soil map units were chosen due to the relatively low variability observed. The soil map units are referred to as 'soil types' in this report for simplicity.

3 Biophysical environment

3.1 Climate

Local long-term climatic data for the site was obtained from the Bureau of Meteorology (BoM) weather station at Scone Soil Conservation Service (station no. 61089) (BoM 2017) and used to characterise the local climate in the proximity of the MCCO Project.

Mean temperatures range from 31.4°C in the summer months to 3.4°C during winter. The mean annual rainfall is 625 millimetres (mm). Rainfall peaks during the months of spring and summer and declines during winter. Figure 3.1 shows the mean rainfall and maximum and minimum temperatures recorded in Scone (27 km north-west).

Humidity levels exhibit variability over the day and seasonal fluctuations. Mean 9am humidity levels range from 62% in October to 86% in June at Scone. Mean 3pm humidity levels vary from 41% in January to 58% in June.

The most common winds on an annual basis are from the east-south-east, south-east and west to north-west directions. Wind speeds during the warmer months have a greater spread between the 9am and 3pm conditions compared to the colder months. At Scone, mean 9am wind speeds range from 7.0 kilometres per hour (km/h) in May and July to 12.7 km/h in October and November while mean 3pm wind speeds range from 16.0 km/h in June to 20.6 km/h in November.

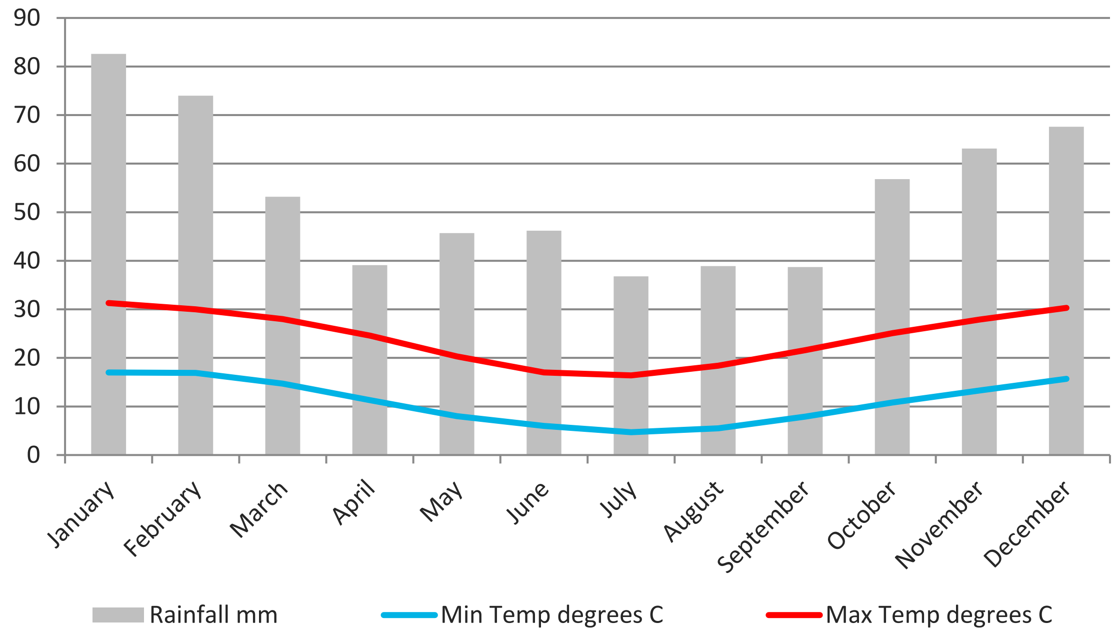


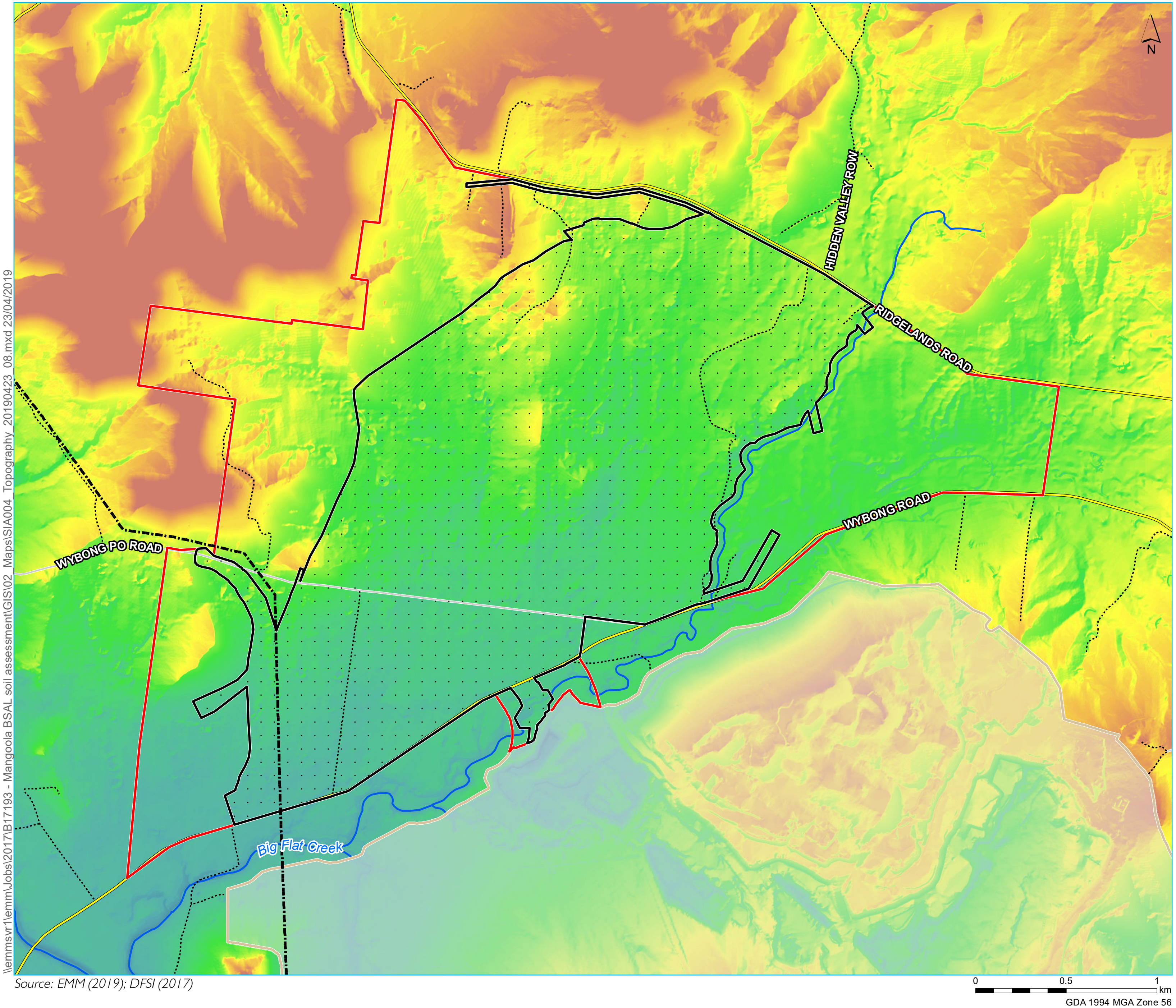
Figure 3.1 Mean rainfall and temperature in Scone (station no. 61089) 1952 to 2017

3.2 Topography

The topography of the MCCO Additional Project Area is characterised by lower slopes, giving way to undulating hills and rocky outcrops to the north and west. Lower topographic areas are associated with drainage lines feeding Big Flat Creek. The main topographical feature in the surrounding landscape is the series of undulating wooded hills which occur outside and to the north of the MCCO Project Additional Project Area. These hills rise to a maximum height of approximately 360 m above Australian Height Datum (AHD) and are elevated approximately 200 m above the surrounding area (Figure 3.2).

3.2.1 Slope and elevation mapping

A review of slope and elevation maps was undertaken to differentiate between potential landscapes in the MCCO Additional Project Area. A digital elevation model (DEM) was developed to detail the slope categories across the MCCO Additional Project Area for the BSAL assessment. The DEM was split into two categories; slopes greater than (>) and less than (<) 10%. The slope map in Figure 3.3 shows that the majority of the MCCO Project Area has slopes of 10% or less. However, there are steeper slopes associated with the hills to the north and west. This slope data has been taken into account in BSAL verification (refer to Section 5 and Appendix E). The soil descriptions in Section 4 reference the different landforms where each of the identified soil types typically occur.



Source: EMM (2019); DFSI (2017)

\\emmsvr1\emm\Jobs\2017\B17193 - Mangoola BSAL soil assessment\GIS\02_Maps\SIA004_Topography_20190423_08.mxd 23/04/2019

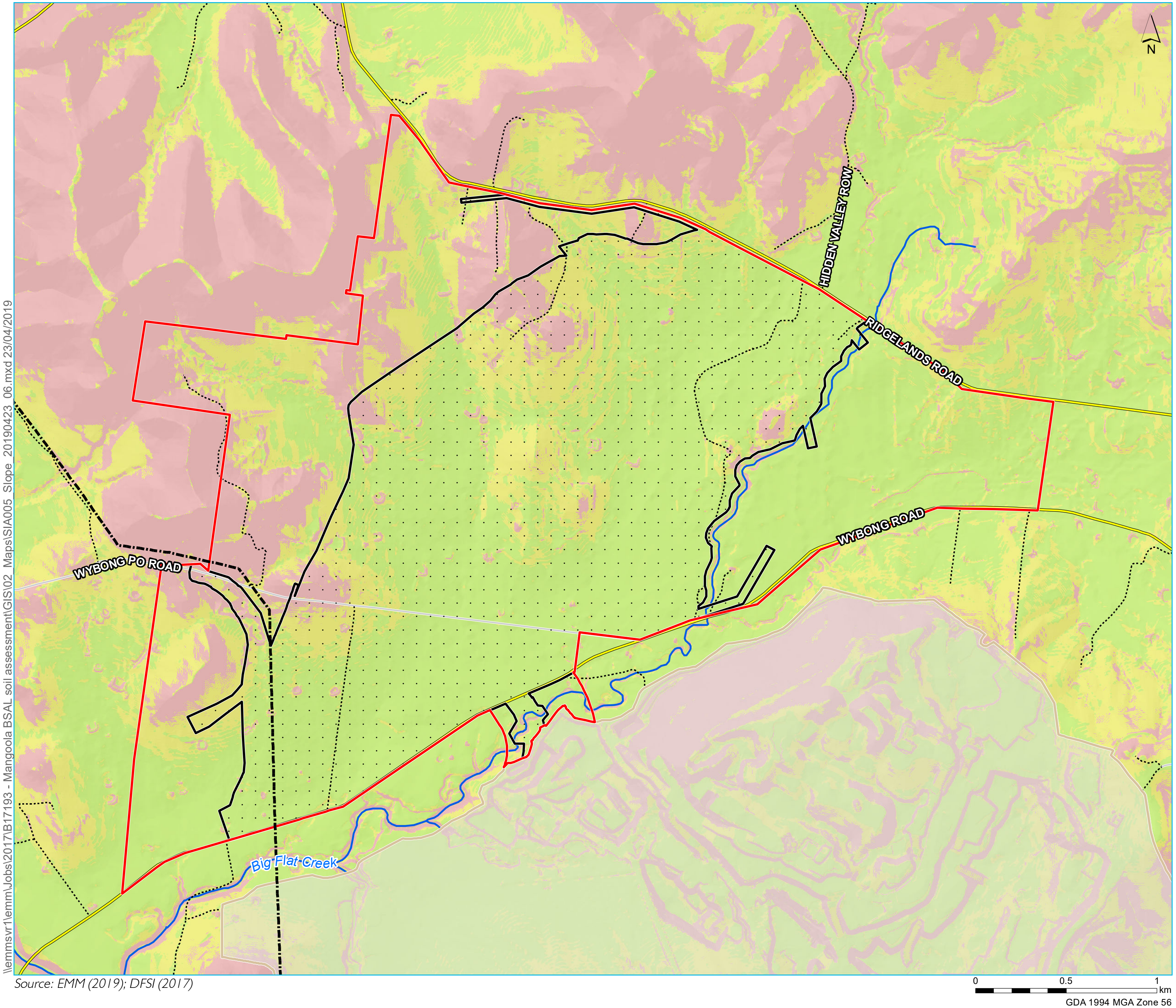
Topography and landform

Mangoola Coal Continued Operations Project

Soil assessment

Figure 3.2

EMM creating opportunities



\\emmsvr1\emm\Jobs\2017\B17193 - Mangoola BSAL soil assessment\GIS\02_Maps\SIA005_Slope_20190423_06.mxd 23/04/2019

Source: EMM (2019); DFSI (2017)

KEY
- MCCO additional project area
- MCCO additional disturbance area
- Approved Mangoola Coal Mine disturbance area
- 500kV transmission line
- Main road
- Local road
- Vehicular track
- Watercourse

Slope (percent rise)
- 0 - 5%
- 5 - 10%
- > 10%

Slope in the MCCO project area

Mangoola Coal Continued Operations Project
Soil assessment
Figure 3.3

EMM
creating opportunities

3.3 Surface and groundwater hydrology

The MCCO Additional Project Area is in the Big Flat Creek catchment, part of the wider catchment of the Hunter. It is traversed by several drainage lines, all of which ultimately discharge to the Hunter River, about 7 km to the south-west.

Two first order ephemeral tributaries in the upper reaches of the Big Flat Creek catchment flow south through the MCCO Additional Project Area. Big Flat Creek is also an ephemeral creek and flows in a generally east-west direction to the south of the MCCO Additional Project Area near Wybong Road (Figure 3.2) and flows into Wybong Creek and Goulburn River before entering the Hunter River.

The main groundwater flow systems that have been identified include:

- The colluvial-alluvial deposits where porosities and hydraulic conductivities while generally low, are more favourable for groundwater storage than the underlying hard rocks. Alluvium is absent in the upper reaches of Big Flat Creek while along Wybong Creek, the alluvium is extensive and assumed to be highly connected to the creek;

- Parts of the overlying weathered zone or regolith. These rainfall recharged systems are localised and perched but may also be fed from deeper strata via occasional faults or fracture zones; and

- Coal seams with groundwater storage held in coal cleats and joints. The Great Northern and Fassifern seams subcrop in the area where mining has been conducted to-date while deeper seams down to the Montrose seam subcrop further to the east. In some areas where the coal seams are capped by conglomerates, groundwaters exhibit sub-artesian conditions.

Agriculturally available groundwater resources within the Big Flat Creek catchment are limited due to poor water qualities and salinities approaching sea water in some areas, in addition to the very low yields associated with the aquifers.

A detailed assessment of the surrounding water resources is provided in the Groundwater and Surface Water Assessment Reports which have been prepared as part of the MCCO EIS.

3.3.1 Water supply

The MCCO Additional Project Area has a reliable water supply, defined in the Interim Protocol as rainfall of 350 mm or more per annum in 9 out of 10 years. Weather records from the nearby locations of Doyles Creek (61130) and Scone Airport AWS (061363) (BoM 2017) indicate that for the past 97 years (1920-2017) rainfall has been in the range of 320-1224 mm per annum with a mean of 647 mm at Doyles Creek and for 26 years (1991-2017), rainfall has been in the range of 362-902 mm per annum, with a mean of 625 mm at Scone Airport (BoM 2017).

The MCCO Additional Project Area is within the "North Coast Fractured and Porous Rock Groundwater Sources 2016" with the Permian coal measures (porous and fractured rock) categorised as “less productive” (DPI-Water 2012). groundwater, not meeting the highly productive groundwater classification.

The MCCO Additional Project Area is also within the area covered by the "Water Sharing Plan for the Wybong Creek Water Source 2003", which was repealed and replaced by the "Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009". An analysis of the requirements for reliable surface water was undertaken by EMM and found the MCCO Additional Project Area was likely to be classified as ‘not reliable surface water’.

3.4 Ecology

A large part of the MCCO Additional Project Area has been previously cleared for grazing and contains exotic grassland. Native vegetation is mostly restricted to the north and western boundary of the MCCO Additional Project Area with some scattered native vegetation areas within the south-west. A detailed assessment of the sites' ecology is provided in the Biodiversity Assessment Report which has been prepared as part of the MCCO EIS.

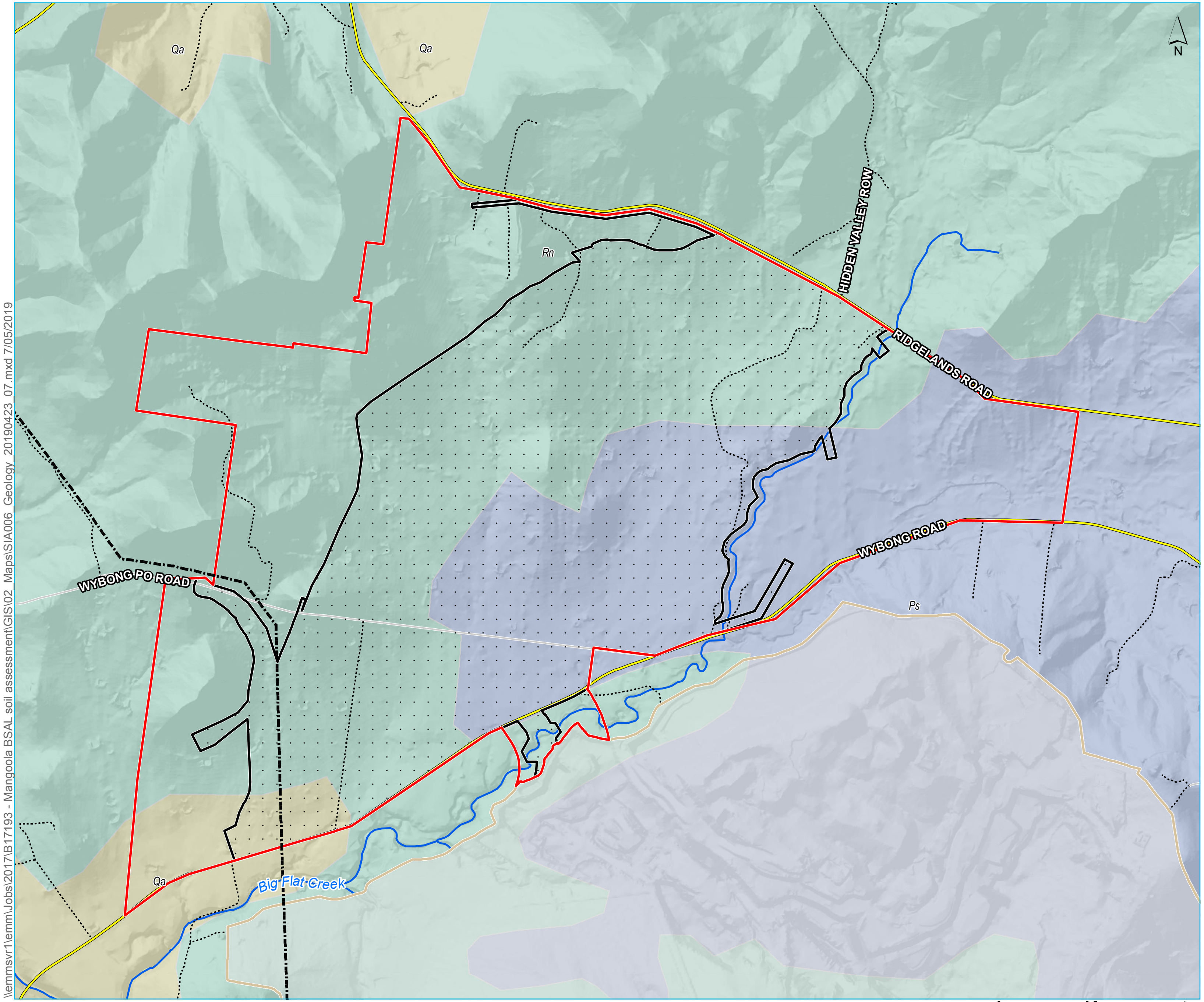
3.5 Geology

A review of geological mapping was completed to differentiate between potential landscapes in the MCCO Additional Project Area. The Singleton 1:250,000 Geological Sheet (SI 56-1) extract in Figure 3.4 shows the Triassic age Narrabeen group sandstone dominates the north west of the MCCO Project Area with the Permian age Singleton coal measures in the south-east and a small area of Quaternary alluvium in the south-west.

During the soil surveys, observations of surface geology were made. Geology is an important determinant of soil type. Table 3.1 summarises soil types most commonly identified in association with each of the observed geological formations.

Table 3.1 Soil and geology relationships within the MCCO Additional Project Area

Mapped geology (Singleton 1:250,000 Geological Sheet)	Surface geology	Common soil types likely to be found
RN: Mesozoic - Triassic, Narrabeen Group	Sandstone, interbedded sandstone and siltstone, claystone	Tenosols/Rudosols
Psl: Palaeozoic - late Permian, Singleton coal measures	Coal seams, claystone (tuffaceous), siltstone, sandstone, conglomerate	Sodosols
Qa: Cainozoic - Quaternary, Silt, sand, gravel	Tertiary alluvial terrace deposits	Sodosols



KEY

- MCCO additional project area
- MCCO additional disturbance area
- Approved Mangoola Coal Mine disturbance area
- 500kV transmission line
- Main road
- Local road
- Vehicular track
- Watercourse

Geology (Singleton, 250k)

Quaternary

- Qa - *Gravel, sand, silt, clay*

Triassic

- Rn -Narrabeen Group - *Sandstone, conglomerate, red and green claystone, shale*

Permian

- Ps - Singleton Coal Measures - *Sandstone, shale, mudstone, conglomerate and coal seams*

Source: EMM (2019); DFSI (2017); DRE (1969)

0 0.5 1 km

GDA 1994 MGA Zone 56

\\emmsvr1\emm\Jobs\2017\B17193 - Mangoola BSAL soil assessment\GIS\02_Maps\SIA006_Geology_20190423_07.mxd 7/05/2019

Surface geology of the MCCO additional project area

Mangoola Coal Continued Operations Project

Soil assessment

Figure 3.4

EMM

creating opportunities

3.6 Regional soil mapping

A desktop assessment was undertaken using existing information on soils and soil environments for the study area, from sources listed in Section 2.2.

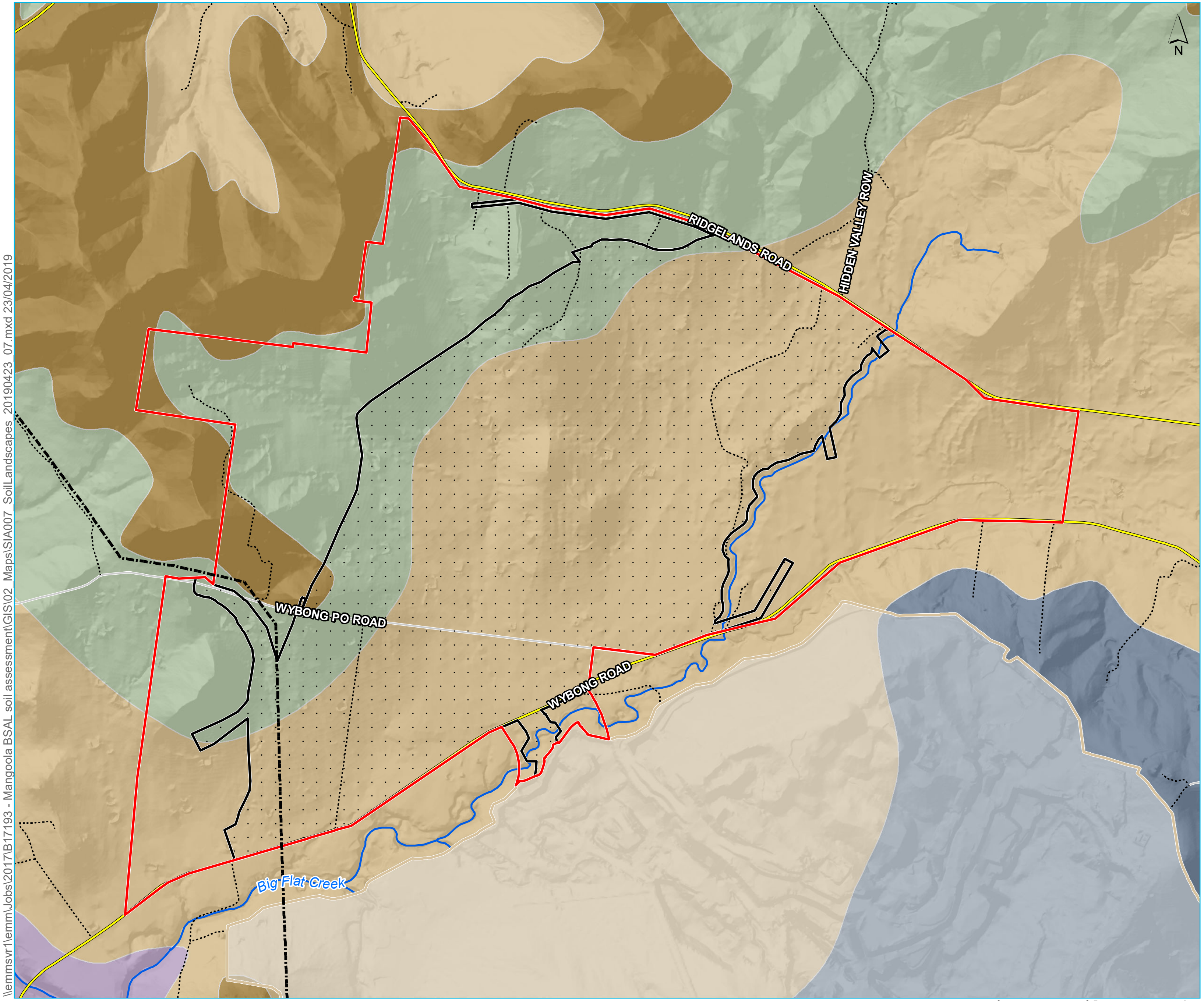
3.6.1 Soil landscape mapping

Soil landscape mapping for the Singleton area was done by Kovac and Lawrie (1991) at a scale of 1:250,000. Three soil landscape units (the Sandy Hollow, Wappinguy and Lees Pinch soil landscapes) are associated with the MCCO Additional Project Area (Figure 3.5):

- **Sandy Hollow:** This landscape is the dominant soil landscape in the project area and is typically located on rolling to steep hills. The main soils associated with this unit are Yellow and Brown Solodic Soils. Yellow and Brown Earths can be found on footslopes and on better drained slopes Yellow Podzolic Soil and Earthy Sands occur (Kovac and Lawrie 1991). Minor sheet and rill erosion occurs on slopes and moderate gully erosion can occur within drainage lines in this landscape;

- **Wappinguy:** This is the second dominant landscape in the project area and is associated with undulating low hills. The soil types are sourced from a variety of parent materials creating a varied soil landscape where Black Earths, Glayed Soloths and Prairie Soils occur along drainage lines; Solodic Soils, Brown Clays and Red Earths occur on slopes and Earthy Sands occur on sandstone outcrops (Kovac and Lawrie 1991). The landscape is prone to minor to moderate gully erosion and moderate sheet and rill erosion on cleared areas; and

- **Lees Pinch:** The Lees Pinch soil landscape is associated with outcropping steep hills and covers a small part of the project area. Soils are generally shallow Solodic Soils or Siliceous Sands and minor to moderate sheet and rill erosion can occur with mass colluvium movement on steep slopes (Kovac and Lawrie 1991).



KEY

- MCCO additional project area
- MCCO additional disturbance area
- Approved Mangoola Coal Mine disturbance area
- 500kV transmission line
- Main road
- Local road
- Vehicular track
- Watercourse

Soil landscape (Singleton, 250k)

- Castle Rock
- Lees Pinch
- Merriwa
- Sandy Hollow
- Wappinguy

Source: EMM (2019); DFSI (2017); DECC (2012)

0 0.5 1 km
GDA 1994 MGA Zone 56

Soil landscapes

Mangoola Coal Continued Operations Project
Soil assessment
Figure 3.5

EMM
creating opportunities

\\emmsvr1\emm\Jobs\2017\B17193 - Mangoola BSAL soil assessment\GIS\02_Maps\SIA007_SoilLandscapes_20190423_07.mxd 23/04/2019

3.6.2 Australian Soil Classification

The ASC scheme (Isbell 2016) is a multi-category scheme with soil classes defined on the basis of diagnostic horizons and their arrangement in vertical sequence as seen in an exposed soil profile. The soil units of the MCCO Additional Project Area can be classed within the current Australian Soil Classification (Isbell 2016).

The Australian soil resource information system (ASRIS) mapping indicated that two soil types were present in the MCCO Additional Project Area, Tenosols associated with the hills and ridges and Sodosols dominant on the flats. eSPADE soil mapping identified similar soil types in similar locations with three soil types identified, Rudosol/Tenosol associated with the hills and ridges and Sodosols dominant on the flats. The agricultural potential of the mapped soils was also referenced. Soils across 96.5% of the MCCO Additional Project Area were classified as having very low agricultural potential. The regional scale map is shown in Figure 3.6 and Table 3.2 summarises the soil types and coverage within the MCCO Additional Project Area, along with their respective agricultural potentials.

Table 3.2 Summary of regional ASC soil mapping: MCCO Additional Project Area

Soil type	Description	Agricultural potential[1]	Area (ha)
Sodosols	Strong texture contrast with sodic B horizon but they are not highly acidic (pH > 5.5).	Low to moderate with low to moderate chemical fertility and water-holding capacity.	1,027
Rudosols and Tenosols	Weakly structured throughout the profile with the exception of the A horizon. Often shallow ie. bedrock is located near surface within the Rudosols.	Very low with low chemical fertility, poor structure and low water-holding capacity.	35

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

3.6.3 Great Soil Groups

Great soil groups (GSG) is a soil classification system developed by Stace et al (1968) based on the description of soil properties such as colour, texture, structure, drainage, lime, iron, organic matter and salt accumulation, as well as on theories of soil formation. Historic soil mapping identified from NSW government mapping (OEH 2017b) for the project area comprise Solodic Soils and Earthy Sands.

Table 3.3 Regional soil mapping - GSG distribution (%) in the MCCO Additional Project Area

GSG	ASC equivalent	Soil landscape	%
Earthy sands	Rudosol/Tenosols	Lees Pinch	3
Solodic soils	Sodosols	Sandy Hollow, Wappinguy	97

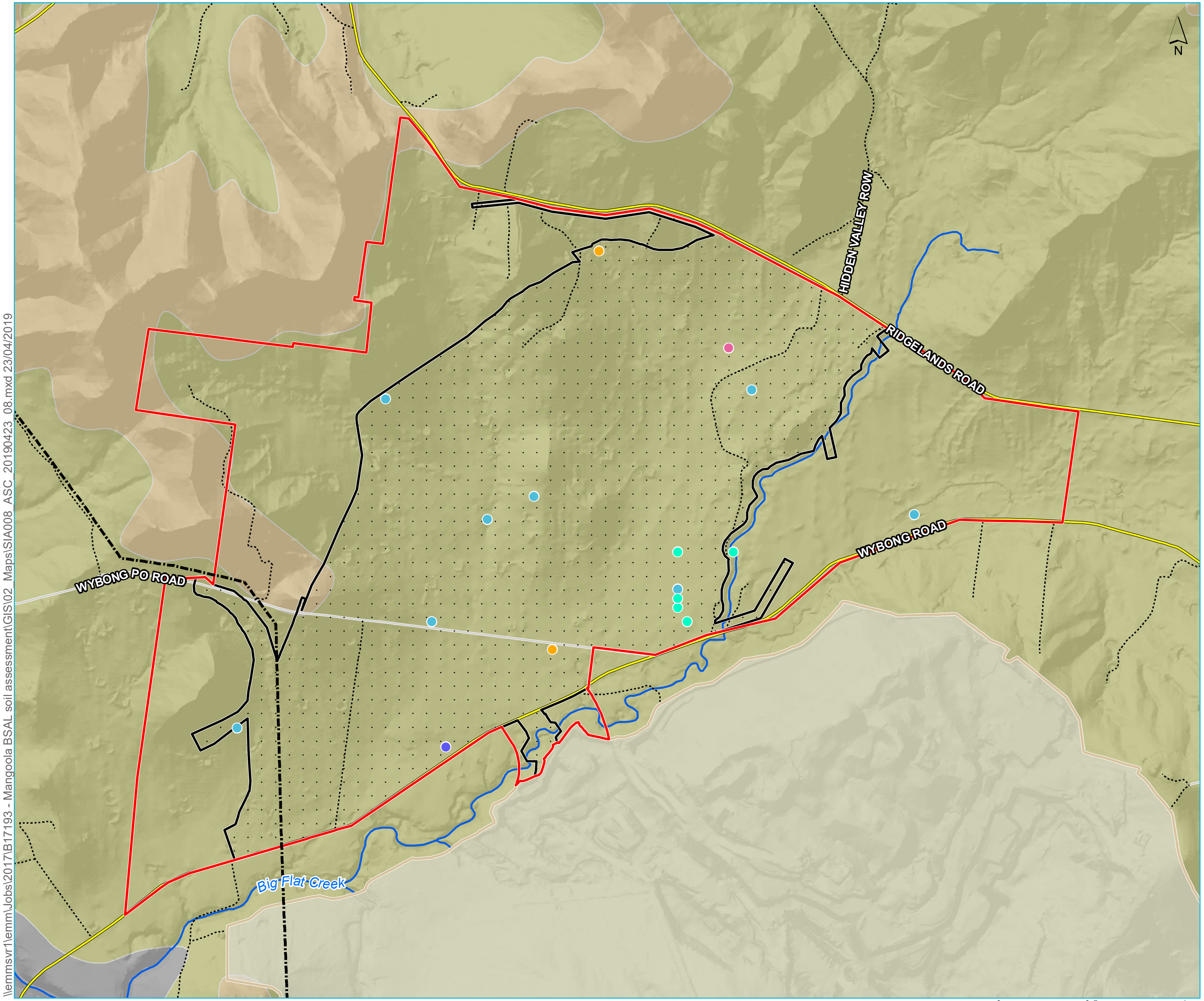
3.6.4 eSPADE soil profiles

The eSPADE soil profile data base search identifies information on soil profiles surveyed in the area and submitted to the SALIS database (OEH 2017e). Thirty profiles occur within the project area. Table 3.4 details the historic eSPADE soil profiles within the MCCO Additional Project Area. Very few of these sites have a complete survey record.

Table 3.4 eSPADE historic soil profiles within the MCCO Additional Project Area

ASC[1]	GSG	Surface pH	Surface texture	ID	Easting	Northing
Sodosol	Solodic Soil	6	Silty loam	34	282280	6429189
	Solodic Soil	5.5	Fine sandy loam	41	281330	6427564
	Soloth (Solod)	5.5	Sandy loam	42	280680	6427714
	Solodic Soil	5.5	Sandy loam	44	280980	6428264
	Soloth (Solod)	6	Sandy loam	45	281230	6428389
	Soloth (Solod)	6	Sandy loam	46	280430	6428914
	Solodized Solonetz	6	Silt clay loam	58	280755	6427039
	Soloth (Solod)	5.8	Sandy loam	59	279630	6427139
	Yellow Podzolic Soil	5.8	Loamy sand	74	282305	6428089
	Soloth (Solod)	6	Loamy sand	1	282005	6428089
	Solodic Soil	8.5	Sandy loam	3	282005	6427889
	Solodic Soil	6	Loamy sand	4	282005	6427789
	Soloth (Solod)	-	Loamy sand	5	282005	6427839
	Solodic Soil	5.5	Fine Sandy Loam	24	281580	6429714
	Solodized Solonetz	6	Sandy Loam	28	283280	6428289
Rudosol / Tenosol	Siliceous Sand	6	Loamy sand	40	282055	6427714
	Siliceous Sand	6	Sandy Loam	32	282405	6428964
	Alluvial Soil	6	Loamy sand	6	282105	6427839
	Unclassified	6	Loam	43	280780	6428139
	Unclassified	5.5	Silty loam	49	281230	6427164
	Unclassified	5.5	Sandy Clay Loam	75	282305	6429289
	Unclassified	6	Loamy sand	2	282005	6427989
	Unclassified	6	Coarse Sandy Loam	27	282680	6428589
	Unclassified	7	Coarse Loamy Sand	22	281980	6429864
	Unclassified	6	Coarse Loamy Sand	23	281980	6426989
	Unclassified	7	Coarse Sandy Loam	29	283205	6428564
	Unclassified	6.5	Light Sandy Clay Loam	30	283230	6429014
	Unclassified	6	Sandy Loam	31	282280	6428114
	Unclassified	4.7	Sandy Loam	33	242355	6428564
	Unclassified	6	Sandy loam	39	282705	642839

Notes: 1 ASC equivalent



KEY

- MCCO additional project area
- MCCO additional disturbance area
- Approved Mangoola Coal Mine disturbance area
- 500kV transmission line
- Main road
- Local road
- Vehicular track
- Watercourse

Soil type

- Fine sandy loam
- Loamy sand
- Sandy loam
- Silt clay loam
- Silty loam

Dominant Australian Soil Classification (ASC) - order

- Rudosols and Tenosols
- Sodosols
- Vertosols

\\emmsvr1\emm\Jobs\2017\B17193 - Mangoola BSAL soil assessment\GIS\02_Maps\SIA008_ASC_20190423_08.mxd 23/04/2019

Source: EMM (2019); eSPADE (2019); DFSI (2017); OEH (2012)

Regional soil mapping - Australian Soil Classification

Mangoola Coal Continued Operations Project
Soil assessment
Figure 3.6

EMM
creating opportunities

3.6.5 Hydrologic soil group

The hydrologic soil groups (OEH 2016c) present in the MCCO Additional Project Area comprise predominately group D – Very slow infiltration, with small areas of Group A along the ridgeline. These are defined as follows:

- **Group A:** soils having high infiltration rates, even when thoroughly wetted and consisting chiefly of deep, well to excessively-drained sands or gravels. These soils have a high rate of water transmission; and

- **Group D:** soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

3.6.6 Inherent soil fertility

The inherent fertility based on GSG mapping of the MCCO Additional Project Area identifies soils ranging from Low (1) through to Moderately High (4) soil fertility. The inherent fertility is based on GSG data (Kovac and Lowrie 1991), from which a fertility value was derived using a lookup table modified from Charman (1978). This classification is used to support the BSAL assessment.

A majority of the MCCO Additional Project Area (96.5%) was mapped as moderately low fertility land associated with the Sodosols and the remaining area was mapped as low inherent fertility. Figure 3.7 shows the inherent soil fertility mapping for the study area.

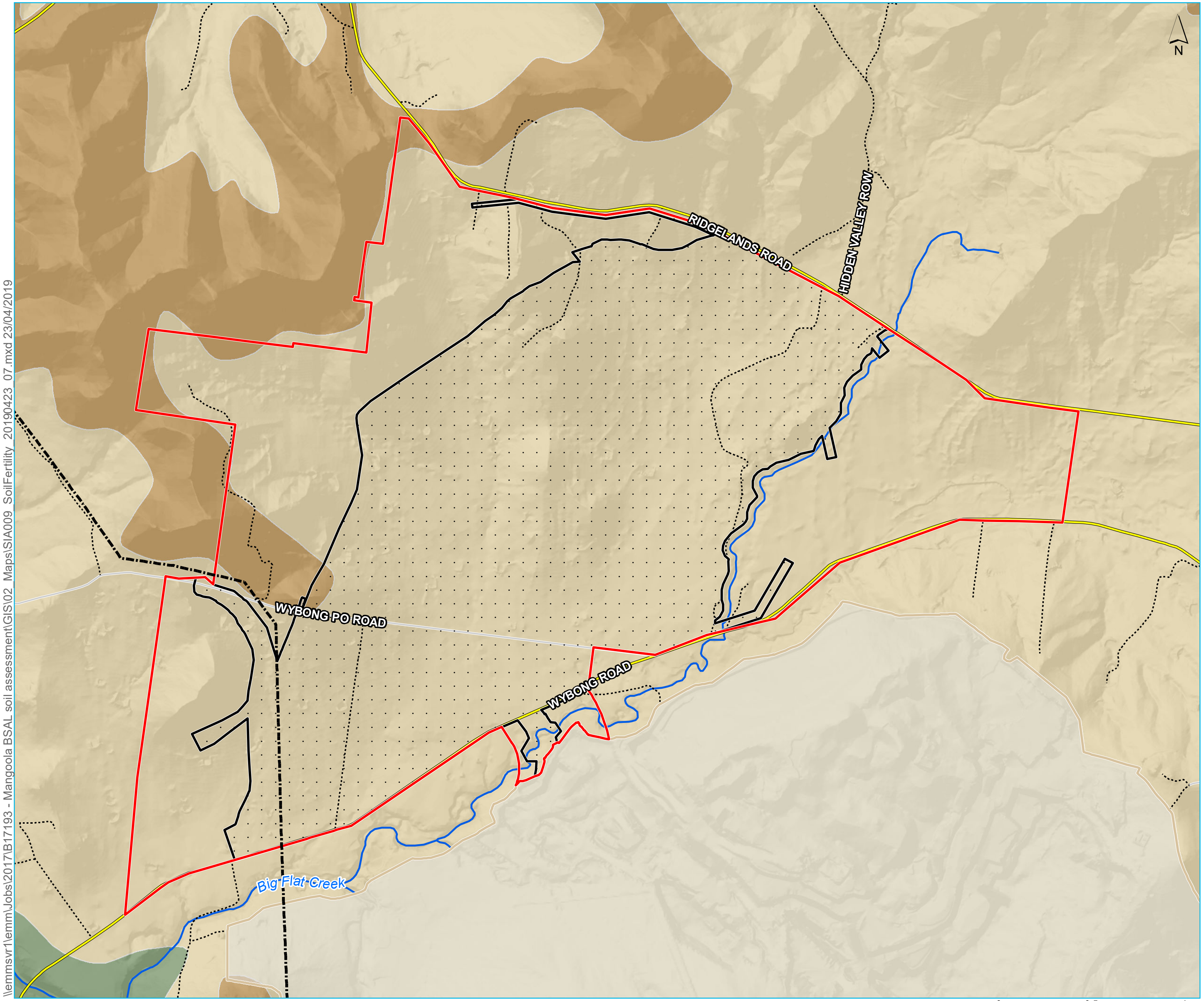
The fertility rankings are defined by OEH (2016d) as:

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

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

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

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



KEY

- MCCO additional project area
- MCCO additional disturbance area
- Approved Mangoola Coal Mine disturbance area
- 500kV transmission line
- Main road
- Local road
- Vehicular track
- Watercourse/drainage line

Estimated soil fertility

- Low
- Moderately low
- High

Source: EMM (2019); DFSI (2017); OEH (2013)

\\emmsvr1\emm\Jobs\2017\B17193 - Mangoola BSAL soil assessment\GIS\02_Maps\SIA009_SoilFertility_20190423_07.mxd 23/04/2019

Inherent soil fertility

Mangoola Coal Continued Operations Project
Soil assessment
Figure 3.7

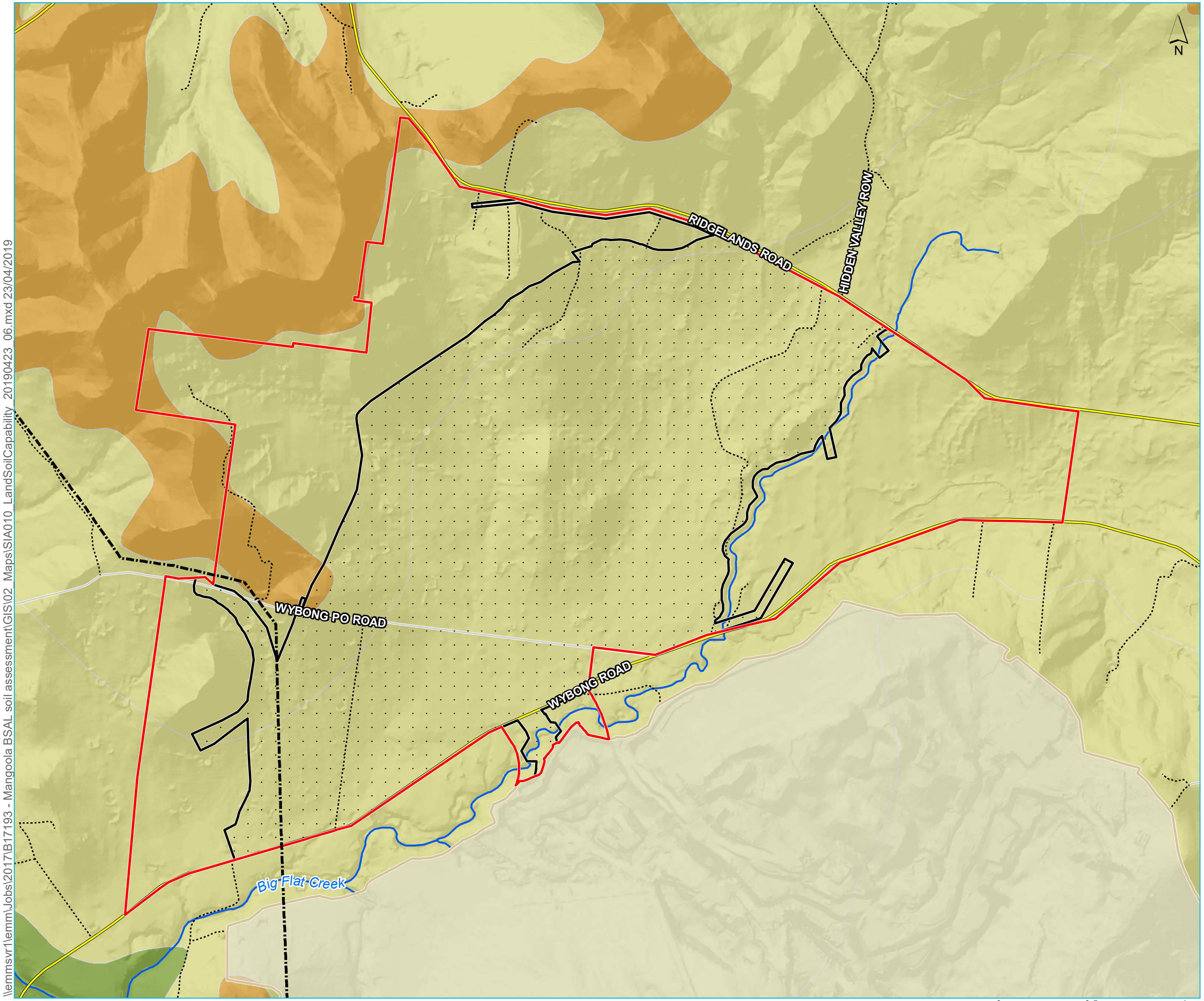
3.6.7 Land and soil capability classes

OEH has done LSC assessment and mapping for most of NSW at a very broad scale. The LSC classes distinguish between the inherent physical capacity of the land to sustain a range of land uses and management practices in the long term without degradation to soil, land, air and water resources.

Most of the MCCO Additional Project Area is currently mapped as Class 5 to Class 7 meaning that there are high to severe limitations to cropping. Agricultural land uses will be restricted to grazing, forestry, and nature conservation. Class 5 to 7 land is unlikely to meet the criteria for BSAL. There are few land management practices available to overcome these limitations. The relevant LSC classes for the MCCO Additional Project Area are detailed in Table 3.5. Figure 3.8 shows the current land and soil capability mapping. A full LSC assessment has been undertaken for the MCCO Additional Project Area based on the soil survey and the results are presented in Appendix D and summarised in Section 6.

Table 3.5 Relevant land and soil capability classes

LSC class	Soil landscape	Description	Area (Ha)	%
5	Wappinguy, Sandy Hollow	**Moderate-low capability land:** High limitations for high-impact land uses. Will largely restrict land use to grazing, some horticulture (orchards), forestry and nature conservation. The limitations need to be carefully managed to prevent long-term degradation.	**1027**	**97**
7	Lees Pinch	**Very low capability land:** Severe limitations that restrict most land uses and generally cannot be overcome. Generally suitable only for selective forestry and nature conservation.	**35**	**3**



KEY
- MCCO additional project area
- MCCO additional disturbance area
- Approved Mangoola Coal Mine disturbance area
- 500kV transmission line
- Main road
- Local road
- Vehicular track
- Watercourse

Land and soil capability
- LSC Class 2
- LSC Class 5
- LSC Class 7

Source: EMM (2019); DFSI (2017); OEH (2013)

0 0.5 1 km
GDA 1994 MGA Zone 56

\\emmsvr1\emm\Jobs\2017\B17193 - Mangoola BSAL soil assessment\GIS\02 Maps\SIA010 LandSoilCapability 20190423 06.mxd 23/04/2019

Land and soil capability

Mangoola Coal Continued Operations Project
Soil assessment
Figure 3.8

EMM
creating opportunities

3.6.8 Acid sulphate soil planning map

There are no acid sulphate soils (ASS) in the MCCO Additional Project Area, as per the *Guidelines for the Use of Acid Sulfate Soil Risk Maps* (DLWC 1998). They are generally only found in coastal areas. The risk of finding ASS is considered negligible.

3.6.9 BSAL

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

The Strategic Agricultural Land Map prepared by OEH and presented in the Interim Protocol, indicates that there is no BSAL in the MCCO Additional Project Area. These maps are trigger maps only, and site verification is required in accordance with the Interim Protocol to confirm whether or not land is actually BSAL. The MCCO Additional Project Area has been assessed for BSAL which determined that no BSAL occurs within the MCCO Additional Project Area. The full report is presented as Appendix E, with the summary of the results presented in Section 5.

3.7 Regional land use and land capability

3.7.1 Regional setting

Mangoola Coal Mine is located in the Hunter Coalfield in the upper Hunter Valley. The Hunter Coalfield is the largest coal producing area in NSW, containing 60 coal seams across three coal measures, the Greta, Wittingham and Newcastle Coal Measures. In places the coal seams are shallow, making them easily accessible to multi-seam open cut mining operations. The *Upper Hunter Strategic Regional Land Use Plan* (DPI 2012) identifies that further development of the coal industry in the Hunter Valley is likely to be focussed on existing mining operations to maximise utilisation of existing infrastructure used for the extraction, processing and transportation of coal for energy and industrial purposes.

The upper Hunter Valley also has a strong association with the rural sector and has traditionally included a mix of grazing and cropping land uses. The Upper Hunter region agricultural profile (DPI 2013) identifies the estimated value of agricultural products (excluding horses) to be $461 Million, attributed to 2,438 farms over 1, 081,841 ha. The estimated value of agricultural products (excluding horses) for the Muswellbrook local government area was $74 Million from314 farms over 103,599 ha.

The region is a well-established grape growing area. The thoroughbred industry is established to the south-east and north-east of the MCCO Additional Project Area, near Jerrys Plains and Scone, respectively. Another dominant land use within the upper Hunter Valley is timbered land contained within national parks, state forests, reserves and on private land. Wollemi National Park is further south of Mangoola Coal Mine, Goulburn River National Park to the west, Manobolai Reserve to the north-west.

3.7.2 Local setting

Mangoola Coal Mine is on land zoned primarily for environmental management and partially zoned primary production under the Muswellbrook Local Environmental Plan 2009. Broadly, surrounding land uses include grazing, vineyards, intensive cultivation, rural residential, mining, quarrying and industrial. There is also land owned by Mangoola which is reserved for biodiversity and sustainable agriculture offsets, required under Condition 42, Schedule 3 of PA 06_0014. These areas include sustainable agriculture, habitat enhancement and conservation offset areas which reflect the key land use priorities and objectives for these areas as identified in *Mangoola Coal's Biodiversity and Offset Management Plan*.

The distribution of agricultural uses surrounding Mangoola Coal Mine and the MCCO Additional Project Area is mainly determined by the local landscape character and soil type. More intensive agriculture and vineyards are primarily on alluvial soils in corridors along the floodplain of the Hunter River, to the south and east. The undulating hill slopes immediately surrounding the MCCO Additional Project Area are generally used for grazing on unimproved pastures. The nearest conservation area is Manobalai nature reserves approximately 5 km to the north-west.

There are no existing mining or industrial operations located in the immediate vicinity of Mangoola Coal Mine, with the closest existing mining operations being located over 8.5 km away. These include Mount Pleasant Coal Mine, Bengalla Coal Mine and Mt Arthur Coal Mine to the north-east, east and south-east, respectively. Other adjacent exploration leases include Ridgelands Coal to the north and West Muswellbrook to the east.

4 Soil descriptions

4.1 Summary of units

The soil survey mapped four major soil types within the MCCO Additional Project Area, Tenosols, Dermosols, Sodosols and Kurosols (refer to Table 4.1). Two Chromosol sites were identified however not mapped due to the singular locations and areas being under 20 ha. Laboratory analysis further identified the soil to Subgroup level as Mesotrophic Mesonatric Grey Sodosols, Basic Arenic Red-Orthic Tenosols, Magnesic-Natric Grey Kurosols, Sodic Eutrophic Brown Dermosols and Mottled Mesotrophic Brown Chromosols.

The MCCO Additional Project Area is situated on the edge of the Permian Singleton Coal Measures mapping with much of the surface geology being formed by the Triassic Narrabeen group (as determined both from regional geological mapping and from detailed geological investigations undertaken with the MCCO Additional Project Area). The detailed soil survey undertaken within the MCCO Additional Project Area found that the soils have mostly been derived from the Triassic Narrabeen group. The Sodosol and Tenosol soils found in the MCCO Additional Project Area generally support the soil landscape mapping done by Kovac and Lawrie (1991) Soil Landscapes of the Singleton 1:250,000 sheet (with some localised boundary readjustments).

There are no clearly Permian derived soils within the MCCO Additional Project Area. Permian derived soils may be located further to the east of the MCCO Additional Project Area, where the Castle Rock, Roxburgh and Brays Hill soil landscapes are located.

Detailed soil descriptions are provided in Sections 4.2 to 4.6. Figure 4.1 presents the spatial distribution of the soil types within the MCCO Additional Project Area.

Table 4.1 Soil types in the MCCO Additional Project Area

ASC[1] order (Soil type)	Total area mapped within project area	
	(ha)	(%)
Sodosol	707	67
Tenosol	260	24
Kurosol	29	3
Dermosol	66	6
Chromosol	0	0
TOTAL	1062	100.00

Note: 1. Australian Soil Classification

4.1.1 Sodosols

This order incorporates soils that show strong texture contrast with highly sodic B horizons, especially in the upper 0.2 m of the B horizon. They are not highly acidic with pH generally above 5.5. Sodosols are generally found in poorly drained areas and have very low agricultural potential with high sodicity leading to high erodibility, poor structure and low permeability. These soils have low to moderate chemical fertility and can be associated with soil salinity. This soil has been described as a Mesotrophic Mesonatric Grey Sodosol.

4.1.2 Tenosols

This soil order incorporates soils with generally weak pedologic organisation apart from the A horizons, encompassing a diverse range of soils. Tenosols generally have poor water retention, almost universal low fertility. They are mainly used for grazing based on native pastures and in better watered areas may support forestry. The Tenosol described in the MCCO Additional Project Area is classified as a Basic Arenic Red-Orthic Tenosol.

4.1.3 Dermosols

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

4.1.4 Kurosol

Kurosols have a strong texture contrast between the A and B horizons with a strongly acid B horizon that may or may not be sodic. The surface of Kurosol soils is also often acidic. Kurosols form from parent materials that are highly siliceous. These soils generally have very low agricultural potential with high acidity (pH <5.5) and low chemical fertility limiting plant growth. Kurosols are often sodic. The Kurosol described in the area is a Mottled Magnesic-Natric Grey Kurosol.

4.1.5 Chromosol

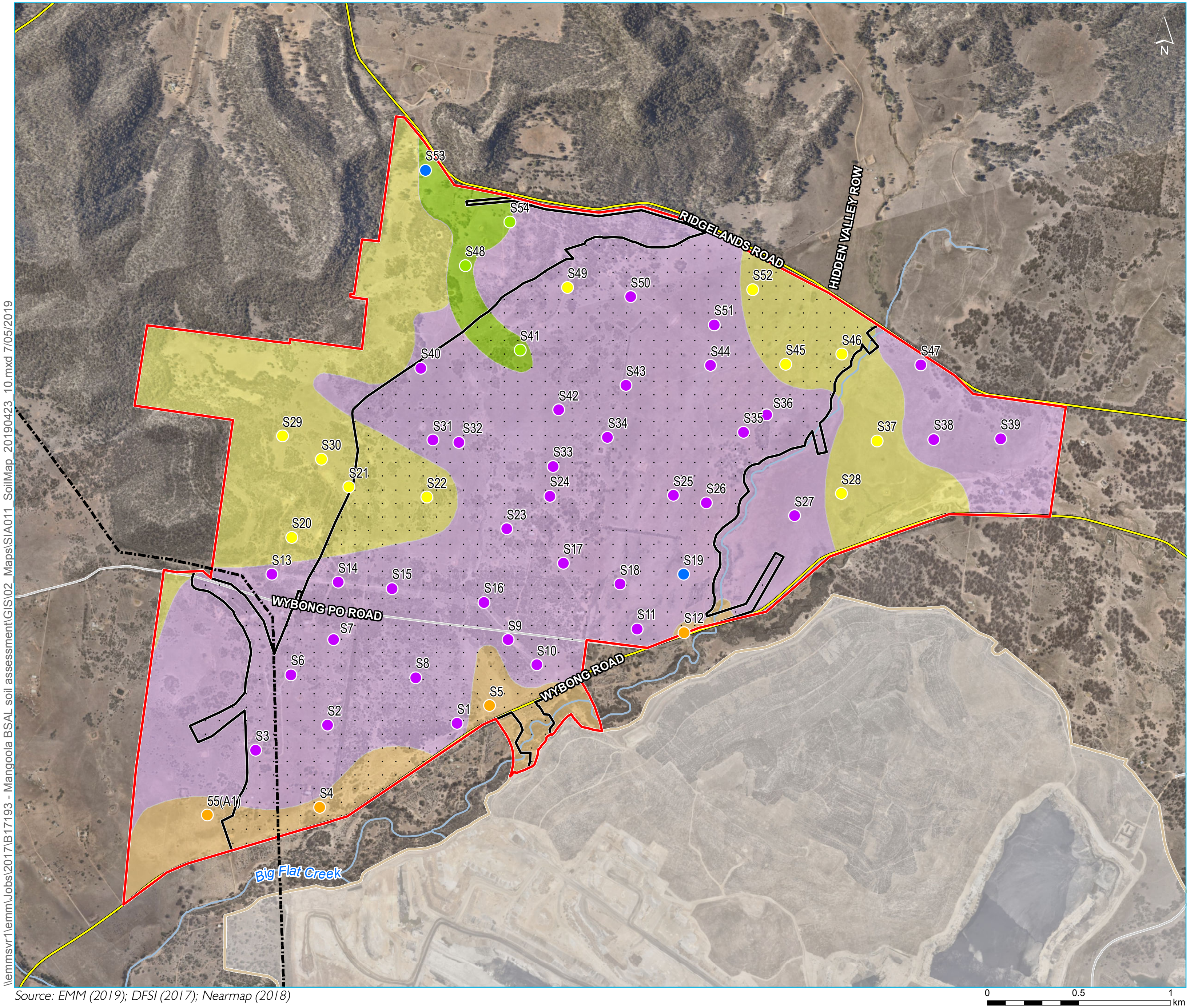
Chromosols also have strong texture contrast between the A and B horizons. The upper part of the B horizon is not strongly acid and not sodic. These soils have moderate agricultural potential with moderate chemical fertility and moderate to high water-holding capacity. They can be susceptible to soil acidification and soil structure decline. The Chromosol soils of the project area have been classified as Mottled Mesotrophic Brown Chromosols.

4.1.6 Soil and geology

Geology tends to be an important determinant of soil characteristics, coupled with surface influence such as alluvial movement. Table 4.2 summarises the soil types commonly identified in association with the geological formations in the MCCO Additional Project Area.

Table 4.2 Soil and geology relationships within the project area

Mapped geology (Singleton 1:250,000 Geological Sheet)	Surveyed soil types associated with geology
RN: Mesozoic - Triassic, Narrabeen Group,	Sodosol Tenosol
Ps: Palaeozoic - late Permian, Singleton coal measures	Sodosol Dermosol
Qa: Cainozoic - Quaternary, Silt, sand, gravel	Kurosol Dermosol



Source: EMM (2019); DFSI (2017); Nearmap (2018)

\\emmsvr1\emm\Jobs\2017\B17193 - Mangoola BSAL soil assessment\GIS\02_Maps\SIA011_SoilMap_20190423_10.mxd 7/05/2019

Soil type distribution within the MCCO additional project area

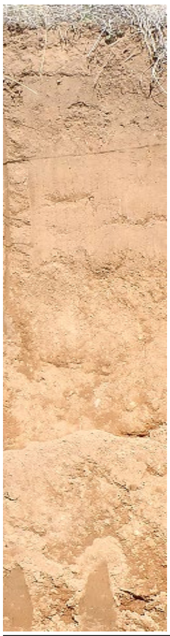
Mangoola Coal Continued Operations Project
BSAL assessment
Figure 4.1

EMM
creating opportunities

4.2 Red-Orthic Tenosol

Orthic Tenosols are characterised by a weakly developed B horizon, usually in terms of colour, texture or structure or a combination of these. These soils typically contain loamy sand to sandy loam in the A horizon and loamy sand textures throughout the B profile. The soil surface is without coarse fragments and of firm condition when dry. The identified basic arenic red-orthic Tenosols have coarse fragments distributed within the profile. There can be up to 2-10% small sized gravel distributed within the B horizon. The subsoils typically have no segregations or mottles. A soil profile description for a typical Arenic Red-Orthic Tenosol is provided in Table 4.3 and a general landscape is shown in Photograph 4.1.

Table 4.3 Red-Orthic Tenosol typical soil profile summary[1]

ASC[3]	Horizon name and average depth (m)	Colour, mottles and bleach	Moisture, laboratory pH (median)[2] and drainage	Texture and structure	Coarse fragments, segregations and roots
	A1 0.0-0.19	Greyish brown, 7.5YR4/3 and no mottles or bleaching.	Dry, pH 5.7 and rapidly drained.	Sandy loam, weak pedality, sub-angular blocky structure.	No surface rock, few coarse fragments, no segregations and many roots.
	A2 0.19-0.40	Reddish brown 5YR4/4 and no mottles or bleaching.	Moderately moist, pH 5.2 and rapidly drained.	Sandy loam, weak pedality, crumb structure.	Few coarse fragments, no segregations and few roots.
	B21 0.40-1.2 (some variation across sites)	Light red 2.5YR6/6 and no mottles or bleaching.	Moderately moist, pH 5.9 and rapidly drained.	Loamy sand, weak pedality, crumb structure.	Few coarse fragments, no segregations.

Notes: 1. Description in accordance with the Australian Soil and Land Survey Field Handbook (NCST 2009)
2. pH are laboratory results and the median values are presented
3. Based on profile no. 29. Some profiles will vary

Photograph 4.1 Basic Arenic Red-Orthic Tenosol (site 29)

The Arenic Red-Orthic Tenosol soil unit occurred on slopes and crests of undulating hills on sandstone and conglomerate surface geology and along the slopes of Big Flat Creek. It is expected that some Rudosol soils will occur on crests and upper slopes of hills to the very west of the MCCO Additional Project Area. This general mix of Tenosol and Rudosol soil is in agreement with the existing mapping. Land associated with this soil has been extensively cleared for grazing, however scattered pockets of vegetation remain. The steep hillslopes have remained vegetated.

The Basic Arenic Red-Orthic Tenosols are not strongly acid with pH generally above 5.5. The profile tends to be slightly gravelly with very weak to no pedality and a sandy texture. Arenic Tenosols tend to have low water holding capacity and the sandy textures tend to have very low inherent fertility (Peverill et al 2005). The macronutrients (P, N, K) and the micronutrients (Ca, Mg, Na, Cu) are mostly low, which could restrict agriculture although fertiliser could amend these concentrations. The cation exchange capacity (CEC) is also very low, which also may present some fertility issues. While the soil profile extended beyond 1 m, the soils contained a sandy texture and low recorded fertility.

All soil chemistry results are given in Table 4.4. The soil chemistry constituent values highlighted in the 'soil sufficiency' column are agricultural industry benchmarks (Baker and Eldershaw 1993; Department of the Environment and Resource Management (DERM) 2011; Peverill, Sparrow and Reuter 1999) and have been referenced in interpreting the laboratory results. The outcomes are presented in the comments column and are in reference to the median values with increasing depth. A summary of the agricultural potential of the Basic Arenic Red-Orthic Tenosol is given in Table 4.5.

Table 4.4 Red-Orthic Tenosol soil chemistry result medians (and ranges of 3 sites)

Constituents	Unit	Soil sufficiency[1]	A1[2] 0-0.12	A2[2] 0.12-0.4	B21[2] 0.4-1.2	Comments on median values (in increasing depth)
pH_{water}	pH units	6.0-7.5	5.8 (5.6-6.2)	6.2 (6.2-6.2)	6.7 (6.1-7.6)	mild acidity (top of A horizon) to neutral (B horizon)
EC – saturated extract (EC_{se})	deciSiemins per metre (dS/m)	<1.9	0.18 (0.25-0.09)	0.09 (0.06-0.11)	0.18 (0.06-0.39)	Very low soil salinity
Chloride (Cl^-)	Milligrams per kilogram (mg/kg)	<800	<10	<10	10 (<10-20)	Not restrictive
Macronutrients						
Nitrite + Nitrate as N (Sol.)	mg/kg	>15	0.85 (0.4-1.4)	0.5 (0.4-0.6)	0.2 (0.1-0.5)	Deficient throughout profile
Total N	mg/kg	>1500	502 (360-740)	165 (160-170)	117 (80-220)	Deficient
P (Colwell)	mg/kg	>10	2.5 (2.5-2.5)	2.5 (2.5-2.5)	2.5 (3-7)	Deficient
K (Acid Extract)	mg/kg	>117	366 (251-474)	329 (296-362)	288 (225-413)	Sufficient
K (Total)	mg/kg	>150	7.5 (5-10)	7.5 (5-10)	6.1 (5-10)	Deficient
Micronutrients						
Cu	mg/kg	>0.3	<1	<1	<1	Low (inconclusive)
Zn	mg/kg	>0.5 (pH<7) >0.8 (pH>7)	0.8 (0.5-1.43)	<1	<1	Moderate in A horizon, Low (inconclusive)
Mn	mg/kg	>2	19.0 (5.2-25.6)	8.4 (8.1-8.7)	4.7 (0.5-20.8)	High (A horizon) to moderate (B horizon)
Exchangeable cations						
CEC	Milli-equivalents per 100 grams (meq/ 100 g)	12-25	2.7 (2.5-3)	1.9 (1.8-2.1)	2.6 (1.3-5.2)	Very low
Ca	meq/ 100 g	>5	1.4 (0.5-1.8)	1.2 (1-1.4)	0.7 (0.1-1.3)	Very low
Mg	meq/ 100 g	>1	0.95 (0.7-1.6)	0.4 (0.4-0.4)	1.5 (0.5-4.1)	Low (A horizon) to moderate (B horizon)
Na	meq/ 100 g	<0.7	<0.1	<0.1	0.3 (0.1-0.5)	Very low
K	meq/ 100 g	>0.3	0.3 (0.2-0.5)	0.25 (0.2-0.3)	0.3 (0.1-0.5)	Low
ESP	%	<6	1.1 (0.-2.8)	0.7 (0.5-0.9)	4.4 (0.1-16.2)	Non-sodic

Table 4.4 Red-Orthic Tenosol soil chemistry result medians (and ranges of 3 sites)

Constituents	Unit	Soil sufficiency[1]	A1[2] 0-0.12	A2[2] 0.12-0.4	B21[2] 0.4-1.2	Comments on median values (in increasing depth)
Ca:Mg ratio		>2	1.85 (0.3-2.6)	3 (2.5-3.5)	1.0 (0.05-2.6)	Stable A horizon. Unstable B horizon
Organic Carbon (OC)	%	>1.2	0.82 (0.6-0.9)	<0.5	<0.5	Low (A1 horizon) to very low (A2 and B horizons)

Notes: 1. Plant sufficiency sources: Baker and Eldershaw (1993), DERM (2011) and Peverill, Sparrow and Reuter (1999).
2. Values in brackets are the ranges measured.

Table 4.5 Red-Orthic Tenosol agricultural use summary

Elements	Comments
pH_{water}	Acidic at the surface, progressing to neutral with depth. Would restrict some agriculture.
EC	Very low salinity levels that would not restrict agriculture.
Cl	Acceptable chloride levels that would not restrict agriculture.
Fertility	
Macronutrients	Mostly low levels of macronutrients, which present fertility issues. Would restrict agriculture.
Micronutrients	Low to moderate levels of micronutrients. Would restrict some agriculture.
CEC	Very low CEC, which may present some fertility issues.
Fertility ranking	**Relative Fertility of ASC Classes (NSW Government 2013):** Moderately low - Tenosol (order), Orthic (suborder), any (soil <1200mm and solum is light sandy textured (sandy to sandy loams) (Great group). **EMM applied Relative Fertility of ASC Classes (lab and field data applied to Murphy et al. 2007):** Moderately low (Group 2) - While the soils are deep the texture is sandy and the tested fertility is very low. **Explanation (Murphy et al. 2007):** Low fertilities that generally only support plants suited to grazing. Generally deficient in nitrogen, phosphorus and many other elements.
ESP	Low ESP at surface, some sodicity at depth, which may not restrict agriculture.
Ca:Mg ratio	A mostly stable Ca:Mg ratio in the topsoil but decreasing with depth to levels that suggest soil instability.
OC	Indicative of good structural condition and structural stability in the A1 horizon. Low levels below this horizon.
Major limitations to agriculture	Macronutrients (eg nitrate, total N, P, K extract) Micronutrients (eg Ca, Mg, Na)

4.3 Brown Dermosol

Brown Dermosols are moderately to well-developed depending on the landform element with which they are associated, and do not have strong texture contrast. The parent materials of Dermosols range from siliceous, intermediate to mafic in composition with siliceous and intermediate in the local area. The identified Sodic Eutrophic Brown Dermosols surface soils are of moderately high fertility, moderately permeable and poorly drained. The Dermosols have saline, sodic B horizons and very slightly acidic A horizons. The soil surface is mostly without coarse fragments and of firm condition. Eutrophic Brown Dermosols generally have few coarse fragments distributed in the lower A and upper B horizons. Subsoils commonly have red and orange mottling with no segregations. Sod and tussock marsh vegetation were observed in some locations. A soil profile description for a typical Sodic Eutrophic Brown Dermosols is provided in Table 4.6.

Table 4.6 Brown Dermosol typical soil profile summary

ASC	Horizon name and average depth (m)	Colour, mottles and bleach	Moisture, laboratory pH (median) and drainage	Texture and structure	Coarse fragments, segregations and roots
	A1 0.0-0.09	Greyish brown, 7.5YR4/3 and no mottles or bleaching.	Dry, pH 5.9 and imperfectly drained.	Sandy clay loam, strong pedality, sub-angular blocky structure.	No surface rock, few coarse fragments, no segregations and many roots.
	B21 0.09-0.60	Reddish brown 2.5YR4/4 and no mottles or bleaching	Moderately moist, pH 7.2 and poorly drained.	Medium clay, moderate pedality, sub-angular blocky structure.	Few coarse fragments, no segregations and few roots.
	B22 0.60-1.2	Dark brown 7.5YR3/3 and no mottles or bleaching	Moderately moist, pH 6.8 and poorly drained.	Medium clay, moderate pedality, sub-angular blocky structure.	Few coarse fragments, no segregations

Notes: 1. Description in accordance with the Australian Soil and Land Survey Field Handbook (NCST 2009).
2. pH are laboratory results and the median values are presented.
3. Based on profile no. 12. Some profiles will vary.

Sodic Eutrophic Grey Dermosols occur on gently inclined rolling low hills associated with the localised back plain or meander of Big Flat Creek. Within the MCCO Additional Project Area, land use on this soil type is primarily for grazing (north of Wybong Road) with riparian zones adjacent to Big Flat Creek south of Wybong Road remaining vegetated (Photograph 4.2).

Photograph 4.2 Sodic Eutrophic Brown Dermosol (site 12)

Eutrophic Brown Dermosols are of moderately high fertility based on the Interim Protocol. The Sodic Eutrophic Brown Dermosols of Site 12 are low to moderate fertility, moderately permeable, poorly drained and have saline and sodic subsoils with slightly acidic A horizons.

Soil chemistry results are given in Table 4.7, the soil chemistry constituent values highlighted in the 'soil sufficiency' column are agricultural industry benchmarks (Baker and Eldershaw 1993; Department of the Environment and Resource Management (DERM) 2011; Peverill, Sparrow and Reuter 1999) and have been referenced in interpreting the laboratory results. The outcomes are presented in the comments column and are in reference to the median values with increasing depth. A summary of the agricultural potential of Sodic Eutrophic Brown Dermosols is given in Table 4.8.

Table 4.7 Brown Dermosol soil chemistry result medians (and ranges of 3 sites)

Constituents	Unit	Soil sufficiency[1]	A1[2] 0-0.09	B21[2] 0.09-0.6	B22[2] 0.6-1.2	Comments on median values (in increasing depth)
pH_{water}	pH units	6.0-7.5	5.9 (5.8-6)	6.4 (4.7-8.5)	5.8 (4.5-8.5)	Generally neutral to alkaline.
EC_{se}	dS/m	<1.9	0.3 (0.1-0.7)	3.5 (0.06-10.0)	3.3 (0.09-9.8)	Low soil salinity (A horizon), saline B horizon, except site 12
Cl	mg/kg	<800	43 (10-110)	618 (5-1540)	596 (5-1780)	Median is not restrictive. Site 5 and A1(55) exceed in lower B horizon.
Macronutrients						
Nitrite + Nitrate as N (Sol.)	mg/kg	>15	0.35 (0.05-0.6)	0.12 (0.05-0.4)	0.23 (0.05-0.6)	Deficient throughout profile.
Total N	mg/kg	>1500	1696 (1,160-2,030)	354 (120-780)	243 (120-360)	Sufficient (A horizon) deficient in upper B horizon.
P (Colwell)	mg/kg	>10	4.8 (2.5-6)	<5	<5	Very low
K (Acid Extract)	mg/kg	>117	473 (467-481)	350 (270-404)	402 (295-539)	Sufficient
K (Total)	mg/kg	>150	15 (5-20)	7.2 (5-20)	6.6 (5-10)	Deficient
Micronutrients						
Cu	mg/kg	>0.3	0.5 (0.5-0.5)	0.72 (5-20)	0.79 (0.5-1.37)	Low (inconclusive) A horizon, moderate B horizon.
Zn	mg/kg	>0.5 (pH<7) >0.8 (pH>7)	2.3 (0.5-3.45)	0.5 (0.5-0.5)	0.5 (0.5-0.5)	Moderate A horizon, Low (inconclusive) B horizon.
Mn	mg/kg	>2	79.7 (24.3-119)	17 (133-54.2)	4.7 (0.5-10.1)	Moderate (A horizon) to very low (B horizon).
Exchangeable cations						
CEC	meq/ 100g	12-25	8.1 (6.-9.8)	9.5 (0.4-18.3)	11.7 (9.8-13.3)	Low (A horizon, upper B horizon) moderate B horizon
Ca	meq/ 100g	>5	3.5 (3.4-3.7)	2.0 (0.3-4.4)	2.4 (1.3-3.2)	Low throughout profile
Mg	meq/ 100g	>1	3.4 (1.8-5)	5.6 (0.1-11.4)	6.9 (5-8.4)	Moderate throughout profile
Na	meq/ 100g	<0.7	0.25 (0.05-0.5)	1.49 (0.05-3.1)	1.8 (0.6-3.2)	Low in A horizon to very high (B horizon)
K	meq/ 100g	>0.3	0.86 (0.8-0.9)	0.36 (0.1-0.7)	0.36 (0.3-0.4)	High (A horizon) to mod (B horizons).

Table 4.7 Brown Dermosol soil chemistry result medians (and ranges of 3 sites)

Constituents	Unit	Soil sufficiency[1]	A1[2] 0-0.09	B21[2] 0.09-0.6	B22[2] 0.6-1.2	Comments on median values (in increasing depth)
ESP	%	<6	3 (0.7-5.4)	13.4 (0.1-30.3)	15.2 (5.1-24.2)	Sodic B horizon
Ca:Mg ratio		>2	1.2 (0.7-2)	0.4 (0.1-1.3)	0.3 (0.1-0.6)	Unstable soil profile
OC	%	>1.2	1.8 (1.4-2)	0.35 (0.25-0.9)	0.25 (0.25-0.25)	Mod (A horizon) to v low (B horizons).

Notes: 1. Plant sufficiency sources: Baker and Eldershaw (1993), DERM (2011) and Peverill, Sparrow and Reuter (1999)
2. Values in brackets are the ranges measured

Table 4.8 Brown Dermosol agricultural use summary

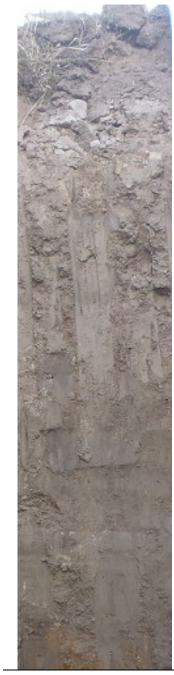
Elements	Comments
pH_{water}	Mildly acidic throughout the profile. Would restrict some agriculture.
EC	Saline B horizon that may restrict some agriculture.
Cl	Acceptable chloride levels that would not restrict agriculture.
Fertility	
Macronutrients	Deficient in some macronutrients, which present fertility issues. Would restrict agriculture.
Micronutrients	Low to moderate levels of micronutrients. Would restrict some agriculture.
CEC	Very low CEC, which may present some fertility issues.
Fertility ranking	**Relative Fertility of ASC Classes (NSW Government 2013):** Moderately high - Dermosol (order), Brown(sub-order), Eutrophic (Great group) **EMM applied Relative Fertility of ASC Classes (lab and field data applied to Murphy et al. 2007):** Moderately low (Group 2) - Classified due to sodic subsoil and low fertility **Explanation (Murphy et al. 2007):** Low fertilities that generally only support plants suited to grazing. Generally deficient in soluble N, P and many other elements. Highly sodic subsoils.
ESP	Moderate ESP at surface, High sodicity in B horizon from 0.1 m. Would restrict agriculture.
Ca:Mg ratio	Low Ca:Mg ratio in the topsoil and decreasing with depth to levels that suggest high soil instability.
OC	Indicative of good structural condition in the A1 horizon. Low levels below this horizon.
Major limitations to agriculture	Macronutrients (eg nitrate and nitrite, P, total K) Micronutrients (eg Ca, Na, Cu)

4.4 Grey Sodosol

Grey Sodosols show strong texture contrast with sandy clay loams over light to medium clays. These soils are generally not highly acidic with pH above 5.5 and have highly sodic B horizons. The Sodosols are associated with surface geology which is siliceous to intermediate in composition. The surface is generally hard setting. The identified Mesotrophic Mesonatric Grey Sodosols have very low agricultural potential with high sodicity. This can lead to high erodibility, poor structure and low permeability. A soil profile description for a typical Mesotrophic Mesonatric Grey Sodosols is provided in Table 4.9.

The Grey Sodosol is the most common soil type across the MCCO Additional Project Area, occurring on all slopes and crests of low rolling hills in the lower west, centre and far east of the project area (Photograph 4.3). Land characterised by this soil type has been extensively cleared associated with historical grazing activities.

Table 4.9 Grey Sodosol typical soil profile summary

ASC:	Horizon name and average depth (m)	Colour, mottles and bleach	Moisture, laboratory pH (median) and drainage	Texture and structure	Coarse fragments, segregations and roots
	A1 0.0-0.10	Brown, 7.5YR4/3 and no mottles or bleaching.	Dry, pH 6.0 and imperfectly drained.	Sandy clay loam, strong pedality, sub-angular blocky structure.	No surface rock, no coarse fragments, no segregations and many roots.
	A2 0.10-0.20	Light gray 10YR7/2 dry, no mottles, bleaching	Dry, pH 6.7 and imperfectly drained	Sandy loam, massive, sandy structure,	Abundant fine gravel fragments, no segregations.
	B21 0.20-0.85	Dark brown 7.5YR3/3 and no mottles or bleaching	Moderately moist, pH 7.9 and poorly drained.	Light medium clay, strong pedality, sub-angular blocky structure.	Few coarse fragments, no segregations and few roots.
	B22 0.85-1.20	Dark brown 7.5YR3/3 and no mottles or bleaching	Moderately moist, pH 8.0 and imperfectly drained.	Light medium clay, strong pedality, sub-angular blocky structure.	Few coarse fragments, no segregations

Notes: 1 Description in accordance with the Australian Soil and Land Survey Field Handbook (NCST 2009).
2. pH are laboratory results and the median values are presented
3. Based on profile no 10. Some profiles will vary

Photograph 4.3 Mesotrophic Mesonatric Grey Sodosol (site 10)

The pH of the surface is slightly acidic progressing to neutral with depth. The macronutrients (N, P, K) and the micronutrients (Cu, Ca, Mg) are mostly low which could restrict agriculture, although fertiliser could amend these concentrations. The CEC is also very low, which also may present some fertility issues. Salinity and Cl concentrations become restrictive in the B horizon from 0.2 m. Salt tolerant species (ie *junkus acutus*) have been identified on this soil type, particularly around sites 11 and 18. High sodicity and small Ca to Mg ratios indicate an unstable subsoil prone to dispersion.

All soil chemistry results are given in Table 4.10. The soil chemistry constituent values highlighted in the 'soil sufficiency' column are agricultural industry benchmarks (Baker and Eldershaw 1993; Department of the Environment and Resource Management (DERM) 2011; Peverill, Sparrow and Reuter 1999) and have been referenced in interpreting the laboratory results. The outcomes are presented in the comments column and are in reference to the median values with increasing depth. A summary of the agricultural potential of Mesotrophic Mesonatric Grey Sodosols in presented in Table 4.11.

Table 4.10 Grey Sodosol soil chemistry result medians (and ranges of 5 sites)

Constituents	Unit	Soil sufficiency[1]	A1[2] 0-0.10	A2[2] 0.10-0.2	B21[2] 0.2-0.85	B22 0.85-1.2	Comments on median values (in increasing depth)
pH_{water}	pH units	6.0-7.5	5.55 (5.4-5.7)	6.3 (6.0-6.6)	7.0 (5.4-9.1)	7.7 (5.9-8.9)	Mild acidity (top of A horizon) to mildly alkaline (B horizon).
EC_{se}	dS/m	<1.9	0.24 (0.1-0.38)	0.22 (0.09-0.36)	1.56 (0.08-6.52)	3.69 (3.04-4.50)	Subsoil salinity
Cl	mg/kg	<800	13.7 (<10-30)	11 (<10-20)	357 (<10-1640)	692 (400-1140)	Restrictive subsoil
Macronutrients							
Nitrite + Nitrate as N (Sol.)	mg/kg	>15	0.26 (005-0.5)	0.48 (0.2-1.1)	0.22 (0.05-0.6)	0.15 (0.05-0.3)	Extremely low throughout profile.
Total N	mg/kg	>1500	1412 (570-2110)	400 (140-930)	224 (120-310)	282 (70-420)	Deficient.
P (Colwell)	mg/kg	>10	4.3 (<5-10)	<5	3.5 (<5-7)	<5	Very low.
K (Acid Extract)	mg/kg	>117	461 (369-566)	212 (100-315)	214 (100-365)	256 (100-363)	Sufficient.
K (Total)	mg/kg	>150	11.25 (5-20)	<10	<10	<10	Deficient throughout profile
Micronutrients							
Cu	mg/kg	>0.3	<0.5	<0.5	<0.5	<0.5	Low (inconclusive).
Zn	mg/kg	>0.5 (pH<7) >0.8 (pH>7)	1.4 (0.5-1.96)	<0.5	<0.5	<0.5	Sufficient (A horizon), low (inconclusive) B horizon.
Mn	mg/kg	>2	24.3 (17.6-33.8)	2.6 (0.5-9.33)	<1	<1	High (A horizon) to very low (B horizon).
Exchangeable cations							
CEC	meq/ 100g	12-25	6.3 (3.6-9.3)	4.6 (1.9-7.9)	8.5 (1.8-13.9)	8.5 (7.3-11.5)	Very low.
Ca	meq/ 100g	>5	3.4 (2.1-4.4)	1.8 (0.9-3.2)	0.5 (0.1-0.9)	1.65 (0.5-2.4)	Low (A horizon) to moderate (B horizon).
Mg	meq/ 100g	>1	1.95 (0.8-3.5)	2.1 (0.5-4)	5.4 (0.9-8.4)	5.0 (4.0-7.1)	Moderate (A horizons) to high (B horizon).
Na	meq/ 100g	<0.7	0.15 (0.05-0.4)	0.36 (0.05-0.8)	1.95 (0.3-3.4)	1.65 (1.2-2.2)	Very low.
K	meq/ 100g	>0.3	0.7 (0.4-0.9)	0.28 (0.2-0.5)	0.29 (0.05-0.7)	0.15 (0.1-0.2)	Moderate (A1 horizon) to low (A2 and B horizons).

Table 4.10 Grey Sodosol soil chemistry result medians (and ranges of 5 sites)

Constituents	Unit	Soil sufficiency[1]	A1[2] 0-0.10	A2[2] 0.10-0.2	B21[2] 0.2-0.85	B22 0.85-1.2	Comments on median values (in increasing depth)
ESP	%	<6	2.1 (0.8-3.9)	7.7 (3.5-14.1)	23.7 (14-33.5)	19.4 (15.2-27.3)	Sodic (A2 and B horizon).
Ca:Mg ratio		>2	2.15 (1.2-3.4)	1.26 (0.6-2.2)	0.18 (0.05-0.8)	0.32 (0.1-0.5)	Stable A horizon. Unstable B horizon.
OC	%	>1.2	2.25 (1.4-2.8)	0.59 (0.25-1.1)	0.3 (0.25-0.6)	0.25 (0.25-0.25)	Moderate (A1 horizon) to very low (A2 and B horizons).

Notes: 1. Plant sufficiency sources: Baker and Eldershaw (1993), DERM (2011) and Peverill, Sparrow and Reuter (1999)
2. Values in brackets are the ranges measured

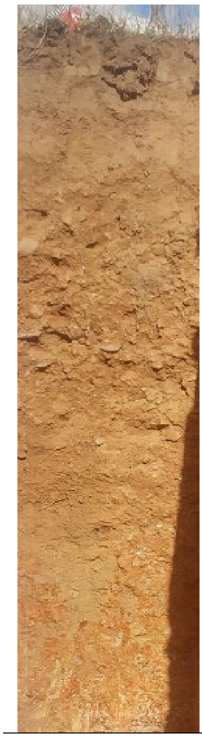
Table 4.11 Sodosol agricultural use summary

Elements	Comments
pH_{water}	Slightly acidic at the surface, progressing to neutral with depth, which does not impede agriculture.
EC	Moderate subsoil salinity that would restrict some agriculture.
Cl	Acceptable chloride levels that would not restrict agriculture.
Fertility	
Macronutrients	Mostly low levels of macronutrients, which present fertility issues. Would restrict agriculture.
Micronutrients	Low to moderate levels of micronutrients. Would restrict some agriculture.
CEC	Very low CEC, which may present some fertility issues.
Fertility ranking	**Relative Fertility of ASC Classes (NSW Government 2013):** Moderately low - Sodosol (order), Grey (suborder), any (Great group) **EMM applied Relative Fertility of ASC Classes (lab and field data applied to Murphy et al. 2007):** Moderately low - Group 2 **Explanation (Murphy et al. 2007):** Low fertilities that generally only support plants suited to grazing. Generally deficient in phosphorus, P and many other elements.
ESP	Low ESP at surface, sodicity from 0.1 m which would restrict agriculture.
Ca:Mg ratio	A mostly stable Ca:Mg ratio in the topsoil, but decreasing with depth to levels that suggest soil instability.
OC	Indicative of good structural condition and structural stability in the A1 horizon. Low levels below this horizon.
Major limitations to agriculture	Macronutrients (eg nitrate, total N, P, K) Micronutrients (eg Ca, Mg, Na) Sodicity (ESP > 6 in the subsoil)

4.5 Grey Kurosol

A very small percentage of the MCCO Additional Project Area is covered by Grey Kurosols. These soils have a strong texture contrast with a strongly acid B horizon that may or may not be sodic. They appear to be a transition soil associated with gentle to moderate slopes and influenced by their location in the landscape and the quaternary depositional geology (Photograph 4.4). The Magnesic-Natric Grey Kurosols identified on site have very low agricultural potential with high acidity (pH <5.5) and low chemical fertility. Moisture loving vegetation profiles were observed in areas of open depressions. A soil profile description for a Magnesic-Natric Grey Kurosols found on site is provided in Table 4.12.

Table 4.12 Grey Kurosol typical soil profile summary

ASC:	Horizon name and average depth (m)	Colour, mottles and bleach	Moisture, laboratory pH (median) and drainage	Texture and structure	Coarse fragments, segregations and roots
	A1 0.0-0.10	Brown, 7.5YR4/3 and no mottles or bleaching.	Dry, pH 6.0 and poorly drained.	Sandy clay loam, moderate pedality, sub-angular blocky structure.	No surface rock, no coarse fragments, no segregations and many roots.
	A2 0.10-0.90	Dull brown 7.5YR5/3 and no mottles or bleaching	Dry, pH 6.2 and poorly drained.	Sandy loam, single grained, sandy fabric.	Many coarse fragments, no segregations and few roots.
	B21 0.90-1.20	Dark brown 7.5YR3/3, Many orange and grey mottles.	Moderately moist, pH 5.2 and poorly drained.	Medium clay, moderate pedality, sub-angular blocky structure.	Few coarse fragments, no segregations

Notes: 1. Description in accordance with the Australian Soil and Land Survey Field Handbook (NCST 2009)
2. pH are laboratory results and the median values are presented
3. Based on profile no 48. Some profiles vary

Photograph 4.4 Mottled Magnesic-Natric Grey Kurosols (site 48)

The Grey Kurosol is acidic in the upper B horizon and mildly acidic throughout the horizon. The surface is generally hard set with no surface fragments but fine gravel dispersed through the A horizon. The soil type has been cleared for grazing in the MCCO Additional Project Area. The macronutrients (P, K) and the micronutrients (Cu, Ca, Mg) are mostly low which could restrict agriculture, although fertiliser could amend these concentrations. The CEC is also very low, which also may present some fertility issues.

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

Table 4.13 Grey Kurosol soil chemistry result medians (and ranges of 2 sites)

Constituents	Unit	Soil sufficiency[1]	A1[2] 0-0.10	A2[2] 0.10-0.9	B21[2] 0.9-1.2	Comments on median values (in increasing depth)
pH_{water}	pH units	6.0-7.5	5.6 (5.5-5.8)	6.1 (5.9-6.6)	5.1 (4.9-5.5)	Mild acidity (top of A horizon) to acidity (B horizon).
EC_{se}	dS/m	<1.9	0.19 (0.1-0.25)	0.72 (0.03-4.07)	0.19 (0.08-0.31)	Very low soil salinity.
Cl	mg/kg	<800	6.6 (<5-10)	<5	12.5 (<5-20)	Not restrictive.
Macronutrients						
Nitrite + Nitrate as N (Sol.)	mg/kg	>15	5.4 (2.2-10.7)	0.5 (0.1-1)	0.3 (0.2-0.5)	Very low throughout profile.
Total N	mg/kg	>1500	1236 (1,000-1,510)	255 (150-380)	215 (140-310)	Deficient.
P (Colwell)	mg/kg	>10	<5	<5	<5	Very low.
K (Acid Extract)	mg/kg	>117	408 (291-495)	145 (100-235)	220 (100-350)	Sufficient in profile.
K (Total)	mg/kg	>150	11.6 (5-20)	<5	<5	Very low
Micronutrients						
Cu	mg/kg	>0.3	<5	<5	<5	Low (inconclusive).
Zn	mg/kg	>0.5 (pH<7) >0.8 (pH>7)	3.2 (1.0-7.3)	<5	<5	Sufficient (A horizon), low (inconclusive) in B.
Mn	mg/kg	>2	45.3 (26.4-58.5)	3.11 (0.5-6.6)	<5	High (A horizon) to low (B horizon).
Exchangeable cations						
CEC	meq/ 100g	12-25	5.06 (4.3-5.8)	2.81 (2.2-3.4)	9.4 (5.6-13)	Very low.
Ca	meq/ 100g	>5	3.3 (2.9-4.1)	1.58 (0.7-2.2)	0.16 (0.05-0.3)	Low (A horizon) to very low (B horizon).
Mg	meq/ 100g	>1	1.06 (0.8-1.3)	0.9 (0.6-1.6)	4.7 (2.7-6.6)	Moderate (A1 and B horizons).
Na	meq/ 100g	<0.7	0.5 (<0.5-0.5)	0.05 (0.05-0.1)	0.98 (0.05-2.01)	Very low.
K	meq/ 100g	>0.3	0.5 (0.3-0.8)	0.12 (0.05-0.2)	0.28 (0.05-0.5)	Mod (A1 horizon) to very low (A2 and B horizon).
ESP	%	<6	0.73 (0.4-1.3)	2.25 (0.7-5.4)	12.9 (2.4-24.3)	Sodic subsoil (transition soil sample).

Table 4.13 Grey Kurosol soil chemistry result medians (and ranges of 2 sites)

Constituents	Unit	Soil sufficiency[1]	A1[2] 0-0.10	A2[2] 0.10-0.9	B21[2] 0.9-1.2	Comments on median values (in increasing depth)
Ca:Mg ratio		>2	3.1 (2.7-3.6)	1.9 (0.4-3.3)	<0.1	Stable A horizon. Unstable B horizon.
OC	%	>1.2	2.3 (1.3-2.9)	0.7 (0.6-0.8)	<0.5	Moderate (A1 horizon) to very low (B horizon).

Notes: 1. Plant sufficiency sources: Baker and Eldershaw (1993), DERM (2011) and Peverill, Sparrow and Reuter (1999).
2. Values in brackets are the ranges measured.

Table 4.14 Grey Kurosol agricultural use summary

Elements	Comments
pH_{water}	Acidic at the surface, progressing to neutral with depth. Would restrict some agriculture.
EC	Very low salinity levels that would not restrict agriculture.
Cl	Acceptable chloride levels that would not restrict agriculture.
Fertility	
Macronutrients	Mostly very low levels of macronutrients, which present fertility issues. Would restrict agriculture.
Micronutrients	Low to moderate levels of micronutrients. Would restrict some agriculture.
CEC	Very low CEC, which may present some fertility issues.
Fertility ranking	**Relative Fertility of ASC Classes (NSW Government 2013):** Moderately low - Kurosol (order), any (suborder), Magnesic-Natric (Great group) **EMM applied Relative Fertility of ASC Classes (lab and field data applied to Murphy et al. 2007):** Moderately low (Group 2) **Explanation (Murphy et al. 2007):** Low fertilities that generally only support plants suited to grazing. Generally deficient in phosphorus, P and many other elements.
ESP	Low ESP at surface, some sodicity at depth, which may not restrict agriculture.
Ca:Mg ratio	A mostly stable Ca:Mg ratio in the topsoil, but decreasing with depth to levels that suggest soil instability.
OC	Indicative of good structural condition and structural stability in the A1 horizon. Low levels below this horizon.
Major limitations to agriculture	Macronutrients (eg nitrate, total N, potassium, K) Micronutrients (eg Ca, Mg, Na)

4.6 Brown Chromosol

Two surveyed soil profiles have been classified as Mottled Mesotrophic Brown Chromosols (sites 19 and 53). These are soils with a strong texture contrast between the A and B horizons and where the upper part of the B horizon is neither sodic or acidic. The Chromosols on site may be a boundary, or transition soil type. The sites occur on gently undulating hills (Photograph 4.5). Chromosols have moderate agricultural potential with moderate chemical fertility and water-holding capacity. They can be susceptible to soil acidification and soil structure decline. A soil profile description for a typical Mottled Mesotrophic Brown Chromosol is shown in Table 4.15.

Table 4.15 Brown Chromosol typical soil profile summary

ASC:	Horizon name and average depth (m)	Colour, mottles and bleach	Moisture, laboratory pH (median) and drainage	Texture and structure	Coarse fragments, segregations and roots
	A1 0.0-0.10	Brown, 7.5YR4/3 and no mottles or bleaching.	Dry, pH 5.8 and moderately drained.	Sandy clay loam, moderate pedality, sub-angular blocky structure.	No surface rock, no coarse fragments, no segregations and many roots.
	A2 0.10-0.50	Dull brown 10YR4/2 and no mottles	Dry, pH 6.0 and imperfectly drained.	Sandy loam, weak pedality, sandy fabric.	Common coarse fragments, no segregations and few roots.
	B21 0.50-1.20	Dull brown 7.5YR3/3	Moderately moist, pH 7.0 and poorly drained.	Light clay, moderate pedality, sub-angular blocky structure.	Common coarse fragments, no segregations

Notes: 1. Description in accordance with the Australian Soil and Land Survey Field Handbook (NCST 2009).
2. pH are laboratory results and the median values are presented
3. based on profile no. 54. Some profiles will vary

Photograph 4.5 Mottled Mesotrophic Brown Chromosol (site 19)

The Brown Chromosol surface is soft with no surface fragments, but fine gravel dispersed through the lower A horizon and B horizon. The soil type has been cleared for grazing in the MCCO Additional Project Area. The soil chemistry results show levels contributing to very poor actual soil fertility. The macronutrients (P and K) and the micronutrients (Cu, Ca and Mg) are very low which could restrict agriculture, although fertiliser could amend these concentrations. The CEC is also very low, which also may present some fertility issues.

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

Table 4.16 Brown Chromosol soil chemistry result medians (and ranges of 2 sites)

Constituents	Unit	Soil sufficiency[1]	A1[2] 0-0.10	A2[2] 0.10-0.5	B21[2] 0.5-1.2	Comments on median values (in increasing depth)
pH_{water}	pH units	6.0-7.5	6.0 (5.5-6.6)	6.5 (6.5-6.6)	7.4 (7.1-7.8)	Neutral profile.
EC_{se}	dS/m	<1.9	0.30 (025-0.35)	0.08 (0.05-0.11)	0.25 (0.13-0.31)	Very low soil salinity.
Cl	mg/kg	<800	<10	<10	20 (<10-50)	Not restrictive.
Macronutrients						
Nitrite + Nitrate as N (Sol.)	mg/kg	>15	7.5 (4.3-10.7)	0.8 (0.4-1.8)	0.3 (0.3-0.4)	Very low throughout profile.
Total N	mg/kg	>1500	1065 (1,000-1,130)	176 (110-260)	136 (130-150)	Deficient.
P (Colwell)	mg/kg	>10	<5	<5	<5	Very low.
K (Acid Extract)	mg/kg	>117	423 (408-439)	236 (235-237)	300 (300-300)	Sufficient in profile.
K (Total)	mg/kg	>150	25 (20-30)	<10	<10	Very low
Micronutrients						
Cu	mg/kg	>0.3	<0.5	<0.5	<0.5	Low (inconclusive).
Zn	mg/kg	>0.5 (pH<7) >0.8 (pH>7)	1.25 (1.0-1.4)	<1	<1	Sufficient (A horizon), low (inconclusive) in B.
Mn	mg/kg	>2	42 (33-51)	9.6 (3.6-19)	3.5 (1.4-5.6)	High (A horizon) to moderate (B horizon).
Exchangeable cations						
CEC	meq/ 100g	12-25	4.2 (4.2-4.3)	2.5 (2-2.9)	2.2 (1.1-3.8)	Very low.
Ca	meq/ 100g	>5	2.6 (2.4-2.9)	1.6 (1.4-2)	1.0 (0.6-1.8)	Low (A horizon) to very low (B horizon).
Mg	meq/ 100g	>1	0.9 (0.8-1)	0.5 (0.2-0.8)	1.0 (0.5-1.7)	Low (A1 and B horizons).
Na	meq/ 100g	<0.7	<0.1	<0.1	0.1 <0.1-0.1)	Very low.
K	meq/ 100g	>0.3	0.5 (0.4-0.7)	0.2 (0.1-0.3)	0.1 (0.1-0.1)	Mod (A1 horizon) to very low (A2 and B horizon).
ESP	%	<6	0.27 (0.05-0.5)	1.1 (0.5-1.8)	1.3 (<1-3.7) (	Low in profile.

Table 4.16 Brown Chromosol soil chemistry result medians (and ranges of 2 sites)

Constituents	Unit	Soil sufficiency[1]	A1[2] 0-0.10	A2[2] 0.10-0.5	B21[2] 0.5-1.2	Comments on median values (in increasing depth)
Ca:Mg ratio		>2	3 (2.4-3.6)	4.0 (2.1-7.0)	0.9 (0.7-1)	Stable A horizon. Unstable B horizon.
OC	%	>1.2	1.6 (1.3-1.9)	<1	<1	Moderate (A1 horizon) to very low (B horizon).

Notes: 1. Plant sufficiency sources: Baker and Eldershaw (1993), DERM (2011) and Peverill, Sparrow and Reuter (1999).
2. Values in brackets are the ranges measured.

Table 4.17 Brown Chromosol agricultural use summary

Elements	Comments
pH_{water}	Neutral throughout profile. Would not restrict agriculture.
EC	Very low salinity levels that would not restrict agriculture.
Cl	Acceptable chloride levels that would not restrict agriculture.
Fertility	
Macronutrients	Mostly very low levels of macronutrients, which present fertility issues. Would restrict agriculture.
Micronutrients	Low to moderate levels of micronutrients. Would restrict some agriculture.
CEC	Very low CEC, which may present some fertility issues.
Fertility ranking	**Relative Fertility of ASC Classes (NSW Government 2013):** Moderately High - Chromosol (order), any (suborder), Mesotrophic (Great group) **EMM applied Relative Fertility of ASC Classes (lab and field data applied to Murphy et al. 2007):** Moderately low (Group 2) **Explanation (Murphy et al. 2007):** Low fertilities that generally only support plants suited to grazing. Generally deficient in phosphorus, P and many other elements.
ESP	Low ESP, which may not restrict agriculture.
Ca:Mg ratio	A mostly stable Ca:Mg ratio in the topsoil, but decreasing with depth to levels that suggest soil instability.
OC	Indicative of good structural condition and structural stability in the A1 horizon. Low levels below this horizon.
Major limitations to agriculture	Macronutrients (eg nitrate, total N, P, K) Micronutrients (eg Ca, Mg, Na)

4.7 Comparison with soil mapping by others

The ASRIS and eSPADE soil mapping in the MCCO Additional Project Area are very similar and have been grouped together for this comparison. There are some broad similarities between the existing ASRIS and eSPADE soil mapping, and the field-based soil survey results from this assessment, in terms of soil orders present and general patterns of distribution. The comparison results are summarised below.

Southern border of the MCCO Additional Project Area:

- ASRIS and eSPADE mapping: dominated by Sodosols; and
- EMM soil survey: Sodosols, with Dermosols adjacent to Big Flat Creek.

Western and north-western part of the MCCO Additional Project Area:

- ASRIS and eSPADE mapping: dominated by Tenosols/Rudosols and Sodosols; and
- EMM soil survey: dominated by a larger expanse of Tenosols. It is expected that Rudosols may occur on the steeper slopes on the very western edge of the MCCO Additional Project Area. A small area of Kurosols occurs in the north-west.

Eastern and central parts of the MCCO Additional Project Area:

- ASRIS and eSPADE mapping: dominated by Sodosols only; and
- EMM soil survey: dominated by Sodosols with an expanse of Tenosols towards the eastern side of the MCCO Additional Project Area.

The ASRIS or eSPADE mapping did not identify any Kurosols or Dermosols within the MCCO Additional Project Area. Field investigations found the Sodosols and Tenosols to be the dominant soil types, in agreement with the existing soil mapping, with the Kurosol and Dermosol occurring in smaller areas. The ASRIS and eSPADE data was not used further in this assessment. The assessments and soil mapping within this report have been based on results of field surveys and laboratory analyses from the current study, which were conducted in accordance with the Interim Protocol. In particular, the field and laboratory investigations for this study provided information which confirmed the presence or absence of various soil orders, including the following:

- Kurosols: small area of Kurosol identified in the north-west. These soils were texture contrast, all with acidic B horizons and one sample also confirmed as having a sodic B horizon; and
- Dermosols: small areas of Dermosols were identified adjacent to Big Flat Creek on the southern border of the MCCO Additional Project Area. Some of these sites had sodic B horizons. The structure of these soils varied between sites, however they did not have a strong texture contrast.

5 Biophysical strategic agricultural land assessment

5.1 Biophysical strategic agricultural land assessment results

A detailed BSAL assessment of the MCCO Additional Project Area was undertaken in accordance with the Interim Protocol. The BSAL assessment determined that no BSAL occurs within the MCCO Additional Project Area. Subsequently, a Site Verification Certificate was issued by DPE on 10 December 2018 confirming the absence of BSAL.

Details of the BSAL assessment are presented in Appendix E.

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

5.1.1 Exclusion criteria

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

5.1.2 Slope

A slope assessment for the MCCO Additional Project Area was conducted using a digital elevation model and site observations were made using a hand-held clinometer. Areas with slopes greater than 10% were identified as BSAL exclusion areas.

5.1.3 Rock outcrop

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

5.1.4 Surface rockiness

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

5.1.5 Gilgai

Gilgai microrelief is a natural soil feature of mounds and depressions commonly associated with cracking clays or Vertosols. The review of NSW regional soils mapping indicated that gilgai microrelief was unlikely to be present within the MCCO Additional Project Area and this was supported by the field observations.

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

5.1.6 Soil fertility

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

The BSAL assessment proceeded using the criteria of the interim protocol. In addition to this actual soil fertility has been assessed for the site soils using chemical analysis and agricultural industry 'soil sufficiency' benchmarks sourced from Baker and Eldershaw (1993); Department of the Environment and Resource Management (DERM) (2011), and Peverill, Sparrow and Reuter (1999).

5.1.7 Effective rooting depth

Effective rooting depth refers to the depth of soil in which roots can function effectively. That is, above any physical or chemical barrier.

Physical and chemical barriers were identified in the field and recorded on SALIS data cards, and/or by laboratory analysis. In the context of BSAL, the depth of soil material from the surface to a physical barrier such as bedrock, weathered rock, hard pans or continuous gravel layers was noted during field surveys. Chemical barriers were identified based on laboratory analysis of soil profile samples, being where limiting values of soil pH, chloride content, electrical conductivity, exchangeable sodium percentage and/or the calcium to magnesium ratio (Ca:Mg) exist.

Survey sites with a physical or chemical barrier to rooting depth at less than 750 mm were identified as BSAL exclusion areas.

5.1.8 Drainage

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

5.1.9 Soil pH

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

5.1.10 Soil salinity

Soil salinity was measured in the laboratory. Sites where soil salinity in the uppermost 600 mm of the soil profile had any of the following properties were identified as BSAL exclusion areas:

- electrical conductivity of greater than 4 deciSiemens per metre (dS/m); or
- the presence of chlorides at 800 milligrams per kilogram (mg/kg) or more, with gypsum present.

5.2 Results of BSAL assessment

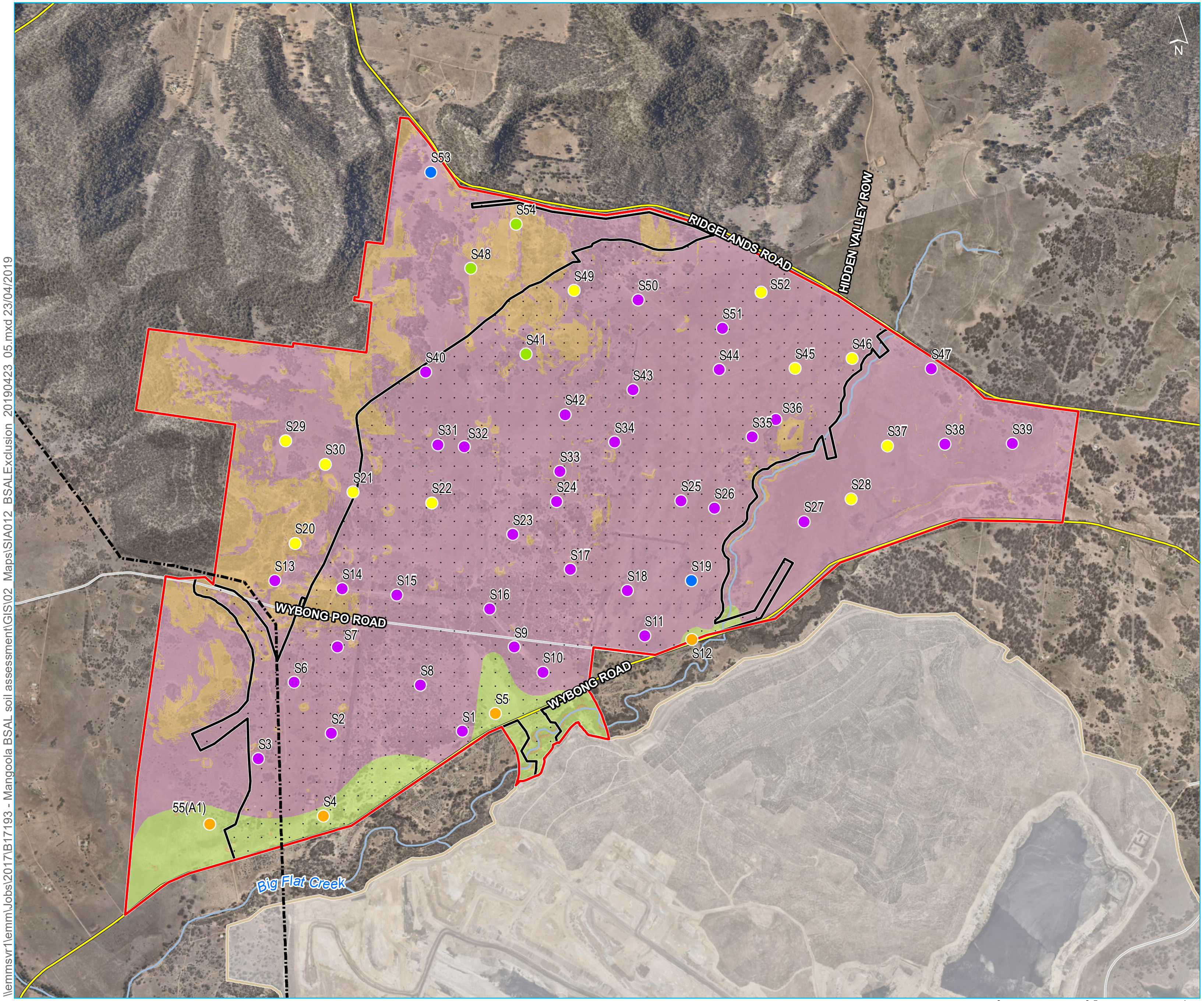
Detailed survey sites in the MCCO Additional Project Area which were subject to soil analysis (Table 2.3) have been classified according to their soil type under the ASC, to family level. These survey sites were assessed against each of the BSAL criteria specified in the Interim Protocol, to determine whether or not the criterion is satisfied. These analysed survey sites represent the soil types within the MCCO Additional Project Area plus 100 m buffer and it is assumed that the results will apply across all other survey sites not laboratory analysed. The results are summarised in Table 5.1, using the following code:

- yes (Y) highlighted in green, for a decisive 'yes' to meeting the subject criterion for BSAL;
- no (N) highlighted in orange, where a site fails the BSAL verification criteria but assessment against subsequent criteria is required to determine whether the site is BSAL or not (applies to criteria 5 to 7b); and
- no (N) highlighted in red, for a decisive 'no' to meeting the subject criterion, meaning the site is excluded as BSAL on this basis alone.

The results in Table 5.1 show that there is no BSAL in the MCCO Additional Project Area or wider assessment area (inclusive of 100 m buffer). Most areas and/or soils fail the BSAL tests on multiple criteria. The principal exclusion criteria across the assessment area are shown in Figure 5.1 and are summarised as follows:

- physical and chemical soil characteristics for BSAL exclusion areas:
  - Sodic Eutrophic Brown Dermosols were excluded because of generally poor drainage. Chemical tests also showed the soils have very low actual fertility;
  - Mesotrophic Mesonatric Grey Sodosols were excluded because of low soil fertility and chemical barriers;
  - Mottled Magnesic-Natric Grey Kurosols were excluded because of low soil fertility and drainage; and
  - Mottled Mesotrophic Brown Chromosols where excluded due to their area although chemical tests showed the soils also have very low actual fertility.
- steep slope BSAL exclusion areas (slopes greater than 10%) occur in much of the western part of the MCCO Additional Project Area associated with an elevated ridge (as shown on Figure 5.1). Some central hills also contain slopes greater than 10%.

Most soils also do not meet other BSAL criteria. For example, many of the soils have high salinity (ECe greater than 4 dS/m and/or chloride greater than or equal to 800 mg/kg) and chemical barriers to plant rooting such as sodicity (exchangeable sodium percentage greater than or equal to 15%).



Source: EMM (2019); DFSI (2017); Nearmap (2018)

\\emmsvr1\emm\Jobs\2017\B17193 - Mangoola BSAL soil assessment\GIS\02_Maps\SIA012_BSALExclusion_20190423_05.mxd 23/04/2019

BSAL exclusion map

Mangoola Coal Continued Operations Project
Soil assessment
Figure 5.1

EMM
creating opportunities

Table 5.1 BSAL verification assessment by soil survey site

Site no.[1]	ASC soil type (to Great Group)	BSAL verification criteria: Water	1	2	3	4	5	6	7a	7b	8	9	10	11	12	Area	Is the site BSAL?
		Access to reliable water supply?	Slope ≤ 10%?	< 30% rock outcrop?	≤ 20% of area has unattached rock fragments > 60 mm diameter?	≤ 50% of the area has gilgais > 500 mm deep?	Slope < 5 %?	Nil rock outcrops?	Moderate soil fertility?	Moderately high or high soil fertility?	Effective rooting depth to physical barrier is ≥750 mm?	Soil drainage is better than poor?	pH 5-8.9 if measured in water or 4.5-8.1 if measured in calcium …	Salinity is ≤ 4 dS/m or chlorides < 800 mg/kg when gypsum is …	Effective rooting depth to a chemical barrier is ≥750 mm?	Is the contiguous area ≥20 ha?	
20	Basic Arenic Red-Orthic Tenosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	No
21	Basic Arenic Red-Orthic Tenosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	No
37	Basic Arenic Red-Orthic Tenosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	No
A1	Sodic Eutrophic Brown Dermosol	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	N	N	Y	No
5	Sodic Eutrophic Brown Dermosol	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	N	N	Y	No
12	Mottled-Sodic Eutrophic Brown Dermosol	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Y	No
10	Mesotrophic Hypernatric Grey Sodosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	N	N	N	Y	No
23	Mesotrophic Mottled-Hypernatric Grey Sodosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y	Y	Y	Y	No
43	Mesotrophic Mottled-Mesonatric Grey Sodosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y	Y	Y	Y	No
47	Mesotrophic Mesonatric Grey Sodosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	N	N	Y	No
41	Mottled Magnesic-Natric Grey Kurosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y	Y	Y	Y	No
48	Mottled Magnesic-Natric Grey Kurosol	Y	Y	Y	Y	Y	N	Y	N	N	Y	N	Y	Y	Y	Y	No
19	Mottled Mesotrophic Brown Chromosol	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	N	No
53	Mottled Mesotrophic Brown Chromosol	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y	Y	N	No

Note: 1. Refer to Figure 3.1 for the locations of survey sites.

Y = Criteria met, N = Criteria not met but inconsequential, N = Criteria not met and not BSAL

6 Land and soil capability assessment

6.1 Land and soil capability assessment system

The LSC classes of the MCCO Additional Project Area were assessed in accordance with the requirements of the *Land and soil capability assessment scheme* (OEH 2012). The LSC class definitions are presented in Table 6.1. The assessment used the information collected during the soil survey and supplemented with information gathered during the desktop assessment. Appendix D presents the detailed LSC assessment with a summary presented in the sections below.

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

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

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

6.2 Land and soil capability assessment and results

Data for the assessment was sourced from field survey observations, desktop analysis and soil laboratory analysis. The results for each site that was assessed are presented in Table 6.2. Appendix D presents the detailed LSC assessment. The MCCO Additional Project Area is in the Eastern Land Division for the purposes of the LSC assessment.

Table 6.2 Summary of LSC classes across the project area

SMUs	Water Erosion LSC class	Wind Erosion LSC class	Soil structural decline LSC class	Soil acidification LSC class	Salinity LSC class	Water-logging LSC class	Shallow soils and rockiness LSC class	Mass movement LSC class	SMULSC class
Dermosol									
A1	3	1	4	3	3	2	1	1	4
4	2	1	3	3	3	2	1	1	3
5	3	1	4	3	3	5	1	1	5
12	2	1	3	3	3	5	1	1	5
Kurosol									
41	3	3	3	4	5	5	1	1	5
48	3	3	3	3	5	5	1	1	5
54	4	3	3	4	5	2	1	1	5
Tenosol									
37	3	3	3	4	3	1	1	1	4
20	3	3	3	4	3	1	1	1	4
21	3	2	3	4	3	1	1	1	4
22	3	3	3	3	3	1	1	1	3
28	3	3	3	4	3	1	1	1	4
29	3	2	3	3	3	1	1	1	3
30	3	2	3	3	3	1	1	1	3
45	2	4	3	4	3	1	1	1	4
46	3	3	3	4	3	1	1	1	4
49	3	4	3	4	3	1	1	1	4
52	3	3	3	3	3	1	1	1	3
Sodosol									
1	2	3	3	4	3	5	1	1	5
2	3	3	3	4	3	5	1	1	5
3	3	3	3	4	3	5	1	1	5
6	3	3	3	4	3	4	1	1	4
7	3	3	3	4	3	5	1	1	5

Table 6.2 Summary of LSC classes across the project area

SMUs	Water Erosion LSC class	Wind Erosion LSC class	Soil structural decline LSC class	Soil acidification LSC class	Salinity LSC class	Water-logging LSC class	Shallow soils and rockiness LSC class	Mass movement LSC class	SMULSC class
8	3	3	3	4	3	5	1	1	5
9	3	1	3	3	3	5	1	1	5
10	3	1	3	3	3	4	1	1	4
11	2	3	3	3	3	5	1	1	5
13	4	3	3	3	3	5	1	1	5
14	3	1	3	3	3	5	1	1	5
15	3	1	3	3	3	5	1	1	5
16	3	1	3	3	3	5	1	1	5
17	3	3	3	4	3	5	1	1	5
18	2	1	3	3	3	1	1	1	3
23	3	1	3	3	3	5	1	1	5
24	3	3	3	4	3	4	1	1	4
25	3	3	3	3	3	5	1	1	5
26	3	3	3	3	3	2	1	1	3
27	3	1	3	3	3	5	1	1	5
31	3	3	3	3	3	5	1	1	5
32	3	1	3	3	3	5	1	1	5
33	4	1	3	3	3	5	1	1	5
34	3	1	3	3	3	5	1	1	5
35	3	1	3	4	3	2	1	1	4
36	2	1	3	3	3	5	1	1	5
38	3	1	3	3	3	3	1	1	3
39	2	3	3	4	3	3	1	1	4
40	3	1	3	3	3	5	1	1	5
42	3	1	3	3	3	5	1	1	5
43	3	3	3	4	3	5	1	1	5
44	3	3	3	4	3	5	1	1	5
47	3	1	3	3	3	4	1	1	4
50	3	1	3	3	3	5	1	1	5
51	3	1	3	3	3	5	1	1	5

Table 6.2 Summary of LSC classes across the project area

SMUs	Water Erosion LSC class	Wind Erosion LSC class	Soil structural decline LSC class	Soil acidification LSC class	Salinity LSC class	Water-logging LSC class	Shallow soils and rockiness LSC class	Mass movement LSC class	SMULSC class
Chromosol									
19	3	3	3	3	3	2	1	1	3
53	3	3	3	4	5	5	1	1	5

6.2.1 Land and soil capability assessment conclusions

i Relationship between soil type and LSC classes

The Sodosols have generally been classified as Class 5 based on the ESP chemical barrier in the B horizon and significant mottling in the subsoil. This means the soils are generally suited to either grazing, forestry or nature conservation. Some sites within the Sodosol soil type are LSC class 4 and 3 which means potentially capable of higher intensity agriculture, but from a property perspective would not be feasible for such small areas to be used in this way. Within the MCCO Additional Project Area a large part of these soils have been cleared for grazing. The Kurosols have also been classified as Class 5 based on poor drainage and surface acidity.

The Tenosols have been classified as Class 3 and 4. However the areas are split into two sections within the MCCO Additional Project Area, and surrounded by the LSC Class 5 sodosols, which makes the feasibility of higher intensity agriculture, uncertain. So, whilst the results of the LSC assessment means these soils are potentially capable of cropping with restricted cultivation, pasture cropping and grazing, significant inputs would be required to make higher intensity agriculture feasible. Slope would also form a restriction on some agriculture.

The Dermosol ranged in LSC classification from Class 3 to Class 5, drainage and soil structure decline within these soils adjacent to Big Flat Creek. The two sites that were classified as Class 3 and 4 and would be capable of some cropping and grazing, however the areas are too small and isolated to make such ventures feasible at the property scale.

Figure 6.1 shows the LSC classes and notes the small total area (6.05 ha) of LSC Class 3 land, which is not considered feasible for higher intensity agriculture. The two points S29 and S30 that have been mapped as LSC Class 3 lie outside the disturbance area, and should remain undisturbed during mining.

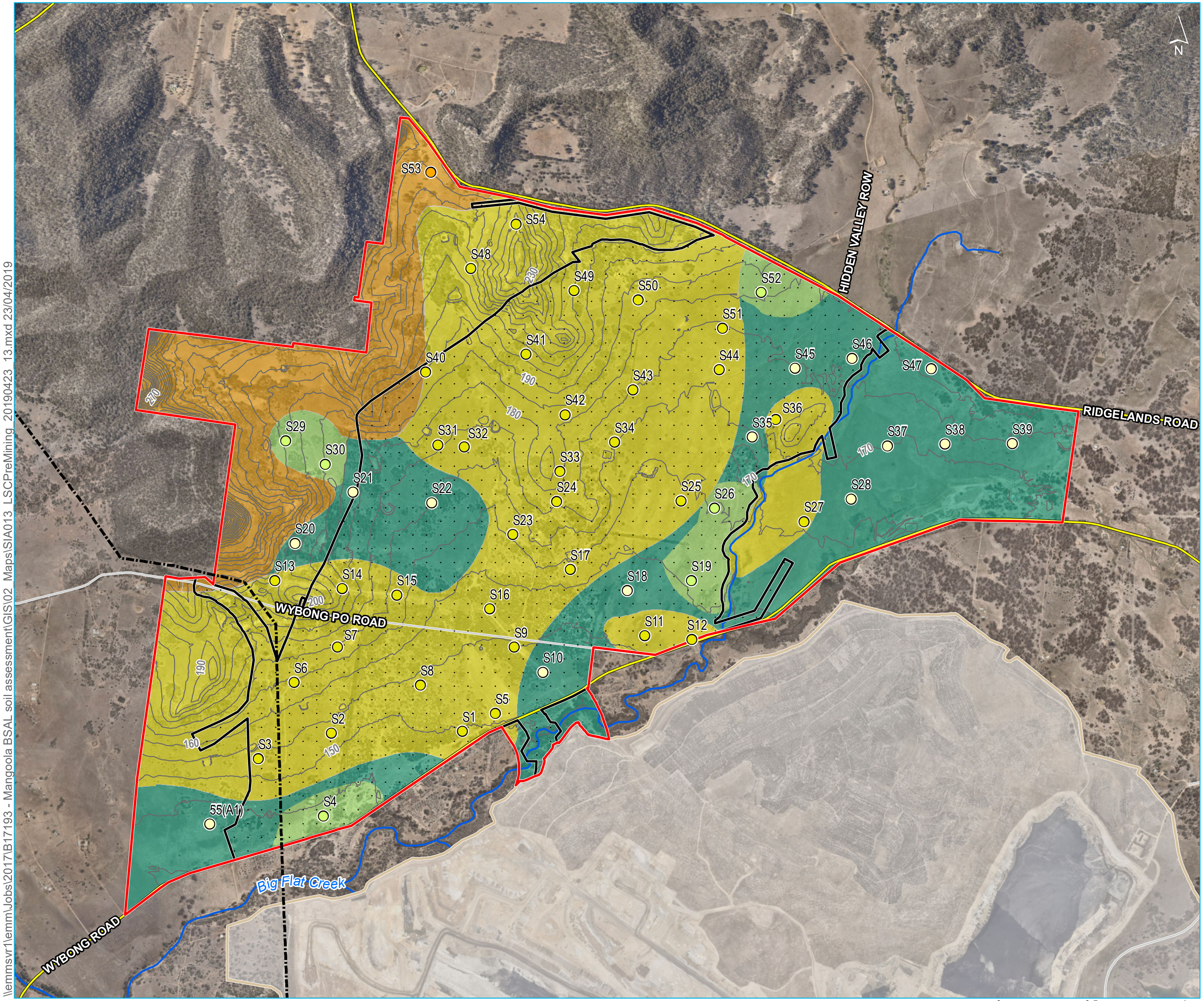
The regional scale mapping in the north west edge of the MCCO Additional Project Area, of LSC Class 7 has been maintained for mapping purposes and included in Figure 6.1. Note there were no field inspection sites located within this area, and therefore the mapping of LSC Class 7 is considered unverified on a property scale, and only the regional mapping is presented. The slopes and the expected shallow soils within this area are considered viable justifications for the regional mapping.

ii Distribution of LSC classes

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

Table 6.3 Land and soil capability class

Class	Capability	Soil type in the project area	Approx. Disturbance Area Hectares (ha)	MCCO Additional Project Area (ha)
Land capable of a wide variety of land uses (cropping, grazing, horticulture, forestry, nature conservation)				
1	Extremely high	None	0	0
2	Very high	None	0	0
3	High	Sodosol, Tenosol, Dermosol	41	54
Land capable of a variety of land uses (cropping with restricted cultivation, pasture cropping, grazing, some horticulture, forestry, nature conservation)				
4	Moderate	Sodosol, Tenosol, Dermosol	144	313
5	Moderate–low	Sodosol, Dermosol, Kurosol	421	560
Land capable for a limited set of land uses (grazing, forestry and nature conservation)				
6	Low	None	0	0
Land generally incapable of agricultural land use (selective forestry and nature conservation)				
7	Very low	Sodosol, Tenosol	9	135
8	Extremely low	None	0	0
		Total Area	**615**	**1,062**



Source: EMM (2019); DFSI (2017); Nearmap (2018)

\\emmsvr1\emm\Jobs\2017\B17193 - Mangoola BSAL soil assessment\GIS\02_Maps\SIA013_LSCPreMining_20190423_13.mxd 23/04/2019

Land and soil capability class - pre-mining

Mangoola Coal Continued Operations Project
Soil assessment
Figure 6.1

EMM creating opportunities

7 Impact assessment

7.1 Soil stripping assessment

A soil stripping assessment and soil balance is outlined in this section to provide information on the soil resources available within the MCCO Additional Disturbance Area, and suitable for use in rehabilitation. This section aims to illustrate the status of soil volumes and the potential best possible outcomes for establishing soil profiles suitable for the target post mining land use.

7.1.1 Soil stripping assessment methodology

Determination of suitable soil to conserve for later use in site remediation has been conducted with consideration given to several publications including:

- Procedure for the selection of material for use in topdressing of disturbed areas (Elliott and Reynolds 2007);
- The Land and Soil Capability Assessment Scheme (OEH 2012);
- Technical guidelines for the environmental management of exploration and mining in QLD – Growth media Management (DME 1995);
- Mangoola Coal Mining Operations Plan (Jan2016-Dec2019); and
- Soil Survey and Land Resource Assessment – Anvil Hill (GSSE 2006).

The approach combined an assessment based on a range of physical and chemical parameters, with consideration for site and soil limitations, and previous rehabilitation methods undertaken on the Mangoola Coal Mine. This provides a practical assessment of soils that will enhance rehabilitation efforts without causing exposure to high risk erosion and sedimentation issues or restricting the success of revegetation programs. It should be noted that the soils onsite will be used, despite some parameters being outside the 'desirable' criteria, however the in-situ soils available currently provide an adequate growth medium and therefore will be considered where possible, unless significant issues are predicted with the exposure, handling, storage and respreading processes, that will degrade the material, or cause other environmental concerns.

Whilst there is variation in the depths of horizons within the same soil type, the depth of recommended stripping has taken a general average in order to calculate the available soil volumes. It is recommended that further on site investigations be undertaken during stripping to assess the suitability of material to ensure the maximum volumes of suitable material are salvaged.

7.1.2 Soil stripping assessment results

Table 7.1 lists the recommended stripping depths for each soil type within the MCCO Additional Disturbance Area. The total volume of material available for stripping and reuse as a topdressing is 1,365,000 m^3.

Table 7.1 Depths of topsoil and subsoil available for stripping

Soil Type	Stripping depth suitable for re-use as: Topsoil (m) topdressing	Subsoil (m) intermediate layer	Total (m)	Approx. Disturbance area (ha) for each soil type to be stripped and rehabilitated	Soil Volume suitable for re-use as: Topsoil (m^3) topdressing	Subsoil (m^3) intermediate layer	Total (m^3)
Sodosol	0.10	0.00	0.10	479	479000	0	479000
Tenosol	1.20	0.00	1.20	66	792000	0	792000
Kurosol	0.90	0.00	0.90	7	63000	0	63000
Dermosol	0.10	0.00	0.10	31	31000	0	31000
Chomosol *	0.50	0.70	1.20	0	0	0	0
Total				**583**	**1365000**	**0**	**1365000**

Note: * Chromosol soil type is not mapped as a stand-alone soil unit and is grouped in with Sodosols

7.2 Soil balance

7.2.1 Volume of soil required for rehabilitation

The current practice at Mangoola Coal mine is to place approximately 0.10 m of topdressing material directly onto reshaped overburden. The rehabilitation target for the majority of the MCCO Additional Project Area is to establish native vegetation for offset purposes. Whilst the current practice of approximately 0.10 m soil cover, appears to provide adequate growth media for this purpose, it is recommended to create a soil profile as deep as the available suitable resources allow. The benefits associated with increased water holding capacity, cation exchange capacity and better structured growth media, when compared to overburden, will be realised with a higher resilience of vegetation from dry periods and therefore warrant the use of the available materials in rehabilitation.

The soil balance for the MCCO Additional Project Area has been calculated with the assumption that all in-situ material suitable for reuse in rehabilitation is salvaged and used on the post mining landform. This assumption therefore results in the following depths able to be achieved post mining, as shown below in Table 7.2.

Table 7.2 Soil balance showing possible depth of soil cover on post mining landform

Stripping Volume suitable for re-use as: Topsoil (m^3) (topdressing)	Subsoil (m^3) (Intermediate layer)	Total (m^3)	Rehabilitation area (ha)	Soil depths recommended for rehabilitation: Topsoil (m) (topdressing)	Subsoil (m) (Intermediate layer)	Total depth
1,365,000		**1,365,000**	**494**	**0.28**	**0**	**0.28**

The available volumes of suitable soil material will be able to be spread at approximately 0.28 m depth across the final landform (excluding the 82 ha final void). Even allowing for a 10% handling loss, this volume still remains above the minimum 0.25 m depth soil profile required for LSC Class 6 land.

7.3 General risks to soil resources

7.3.1 Loss of soil resource

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

7.3.2 Soil degradation

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

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

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

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

7.3.3 Soil erosion and sediment transport

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

7.3.4 Soil contamination

In the surface infrastructure and transport areas there is a risk that land could be contaminated from hydrocarbon spills, storage of fuel and chemicals, refuelling activities, sewage, etc. Also, the storage of drift spoil during mining which could result in leachate of minerals from the overburden.

Soil will likely not be impacted by these potential sources of contamination as it will have been stripped beforehand. Small areas of soil contamination could occur from hydrocarbon spills during soil stripping and construction activities (eg burst hydraulic hose); although the likelihood of occurrence is considered to be very low.

7.4 Land subject to potential impacts

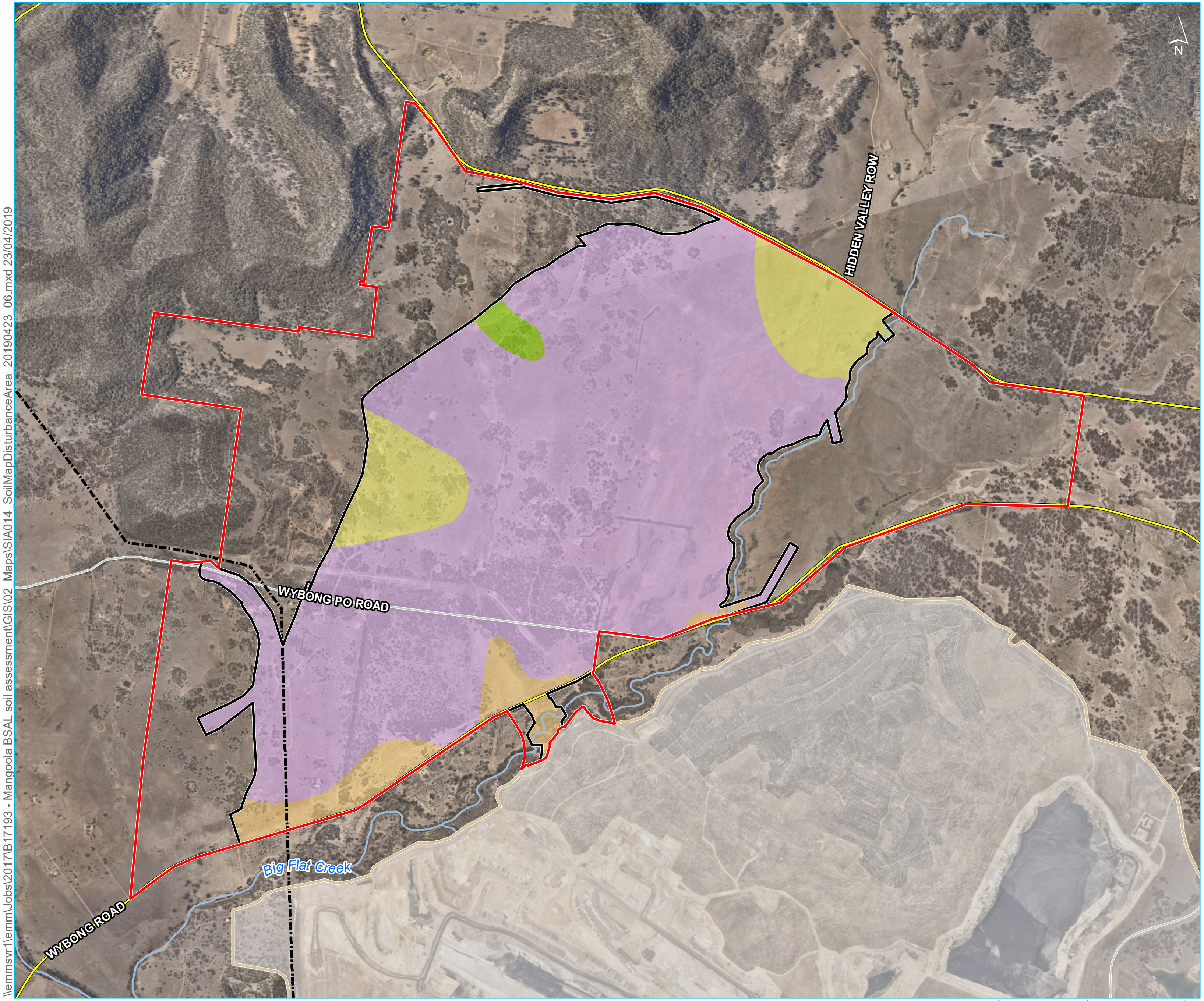
The potential impacts on soil are associated with loss of land due to construction and operation of mine infrastructure (eg void and surface facilities), and activities during rehabilitation and closure. The assessment focuses on the disturbance footprint. Activities during the life of the mine may impact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

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

Due to the open cut coal extraction method to be employed, landforms will be altered and impacts to soil resources will vary across the MCCO Additional Project Area. During operation of the MCCO Project impacts will be localised to the areas of infrastructure, access and extraction as it progresses.

During decommissioning works, in-situ and rehabilitated soils may be disturbed temporarily while infrastructure is dismantled, and access and internal roads and other supporting infrastructure are removed. Landforms will be rehabilitated using available soil stockpiles.

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



KEY

- MCCO additional project area
- MCCO additional disturbance area
- Approved Mangoola Coal Mine disturbance area
- 500kV transmission line
- Main road
- Local road
- Watercourse

Soil type

- Dermosol
- Kurosol
- Sodosol
- Tenosol

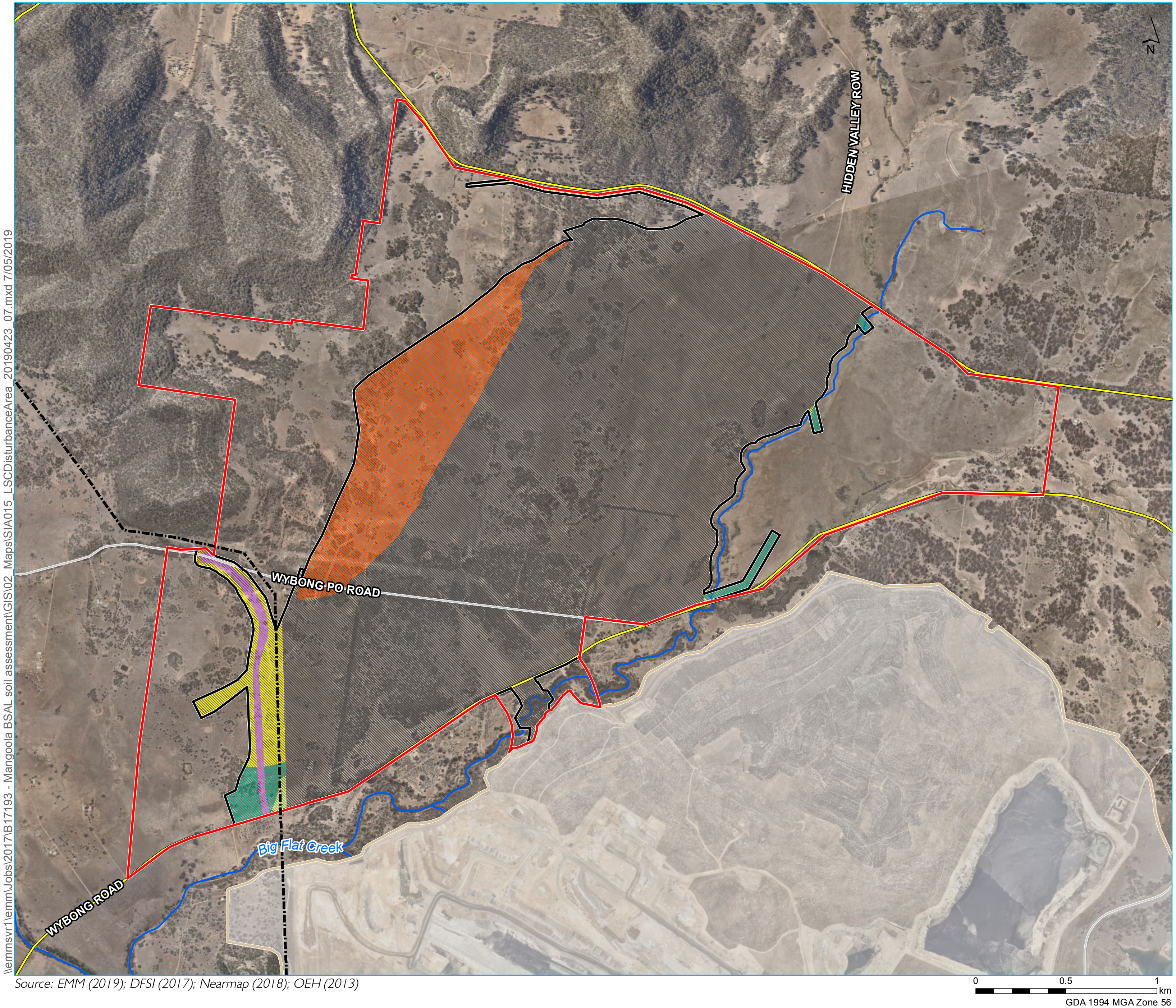
Source: EMM (2019); DFSI (2017); Nearmap (2018)

\\emmsvr1\emm\Jobs\2017\B17193 - Mangoola BSAL soil assessment\GIS\02_Maps\SIA014_SoilMapDisturbanceArea_20190423_06.mxd 23/04/2019

Soil types within the project disturbance footprint

Mangoola Coal Continued Operations Project
Soil assessment
Figure 7.1

EMM
creating opportunities



Source: EMM (2019); DFSI (2017); Nearmap (2018); OEH (2013)

\\emmsvr1\emm\Jobs\2017\B17193 - Mangoola BSAL soil assessment\GIS\02_Maps\SIA015_LSCDisturbanceArea_20190423_07.mxd 7/05/2019

Land and soil capability class - post-mining

Mangoola Coal Continued Operations Project
Soil assessment
Figure 7.2

EMM creating opportunities

7.5 Post mine land use and land capability

The overriding goal for the project's rehabilitation plan is to return disturbed land to a condition that is stable, non-polluting and supports the proposed post mining land use. The dominant post mining land use is for the establishment of native vegetation.

The available soil material suitable for use in rehabilitation is adequate to establish a 0.25 to 0.28 m depth of soil on overburden. This depth will satisfy LSC Class 6 soil depth requirement and therefore it is anticipated the post mining landform will be dominated by LSC Class 6 land (494.22 ha) and Class 8 land (81.91 ha) within the void. Whilst there is no proposal to use this rehabilitated land for agriculture, the potential for some grazing will remain.

Table 7.3 shows the required depths of soil to achieve the various LSC classes, and is taken from the LSC assessment scheme second approximation (OEH 2012).

Table 7.3 Shallow soils and rockiness LSC class assessment table[1] (OEH 2012)

Rocky outcrop (% coverage)	Soil depth (m)	LSC class
<30 (localised)	>1	2
	0.75 -<1	3
	0.5 - <0.75	4
	0.25 - <0.5	6
	0 - <0.25	7
	n/a	8

Notes: 1.only relevant portion of table shown.
2. depths presented in m – modified from original.

Table 7.4 describes the type of disturbance and rehabilitation required for each of the surface infrastructure types. The table also describes the reason for the change in land class.

From the *Australian Soil Classification* and SALIS there are three factors that may come into effect regarding the definition of soil depth in the LSC assessment scheme guideline:

- depth to a hardpan in the mining landscape (ie land which has been compacted by heavy machinery, noting that the impact of trafficking can be overcome by deep ripping);
- depth to rock (ie vegetation cannot grow in rock because of low plant available water capacity and inherent fertility); and
- most importantly the presence of a C horizon (ie the layer of soil above bedrock), which is defined as weathered rock or a mixture of weathered rock and newly developed soil in the *Australian Soil Classification*.

Fill used in construction will be sourced mostly from the excavation of the pit and will therefore be a mixture of soil and rock. In the rehabilitated land, areas that are likely to be underlain by rocky fill are equivalent to having a C horizon of weathered rock, so only the returned topsoil is counted as the overall soil depth.

Conservative assumptions for soil depth under infrastructure areas at closure have been made. Some surface infrastructure may be underlain by subsoil however, the depth of soil may also be constrained by chemical inhibition such as high salinity. Salt is highly water soluble and mobile and there is some potential that it may become concentrated overtime creating a chemical inhibition layer. The assessment shown in Table 7.4 conservatively assumes that salt has been built up under infrastructure. If it is found after rehabilitation that subsoil is not constrained by chemical inhibition then the overall soil depth may increase from the assumptions resulting in a higher capability LSC class.

Table 7.4 Reasons for LSC changes in the post mining land

Surface infrastructure	Disturbance and rehabilitation type	Justification for post-mining LSC
Mine void	Mine pit excavated into rock – rehabilitation involves leaving stable rock walls, shaping slopes with fill materials and overlaying with 0.25m topsoil.	LSC class 8, on base of void to pit lake recovery level and highwall. LSC class 6 on low wall slopes based on replaced soil depth of 0.25m (fill material is not equivalent to natural soil profile).
Dam walls and water body areas	Dam areas of natural contours which held water for extended periods of time and dam walls constructed with fill material – rehabilitation involves re-profiling and overlaying 0.25m topsoil.	LSC class 6, based on replaced soil depth of 0.25m
Soil stockpiles	Topsoil stockpiles placed on natural land contours, only topsoil disturbed – rehabilitation involves spreading of topsoil over underlying subsoil.	LSC class - the same as the pre-mining LSC, as the soil profile depth is now the same, and all other factors are still the same.
Overburden stockpiles	Overburden stockpiles re-profiled and overlaying with 0.25m topsoil.	LSC class 6, based on replaced soil depth of 0.25m (overburden material is not equivalent to natural soil profile).
Administration, temporary accommodation and construction facilities	Buildings placed on natural land contours, only topsoil disturbed – rehabilitation involves spreading of topsoil over underlying subsoil.	LSC class - the same as the pre-mining LSC, as the soil profile depth is now the same, and all other factors are still the same.
Overpass	Overpass footings placed on natural land contours, only topsoil disturbed – rehabilitation involves spreading of topsoil over underlying subsoil.	LSC class- the same as the pre-mining LSC, as the soil profile depth is now the same, and all other factors are still the same.
Minor tracks and roads (no cut and fill)	Roads or tracks built on existing land surface, topsoil removed, road base materials placed over the top. Rehabilitation involves the removal of road base and return of topsoil.	LSC class - the same as the pre-mining LSC, as the soil profile depth is now the same, and all other factors are still the same.
Constructed roadways and infrastructure areas	Roads and infrastructure areas created by cut and fill of existing land surface. Rehabilitation involves re-profiling the fill material to match surrounding contours and overlaying 0.25m topsoil.	LSC class 6, based on replaced soil depth of 0.25m.

The majority of the mining area will be rehabilitated to achieve LSC Class 6 land, which will still be suitable for grazing long term, however the proposed final land use is predominantly native vegetation. Therefore, the rehabilitation efforts will be tailored to this final land use.

8 Management and mitigation

8.1 Topsoil management

8.1.1 Soil volumes

There is adequate soil resources available for stripping and salvaging, which will be able to be used in post mining rehabilitation to achieve a soil depth of 0.25 to 0.28 m across the 494 ha of post mining landform. There is no proposed soil placement on the 82ha final void which is considered unsuitable for any agricultural land use. Further the realigned portion of Wybong Post Office Road is proposed to remain post mining as part of the regional road network and will therefore not require rehabilitation as will the various powerlines and their associated easements that are realigned and run through the MCCO Additional Project Area. To achieve LSC Class 6 land, a minimum of 0.25 m soil depth is required. The soil balance shows there is adequate volume available to form a potential coverage of 0.28 m. Therefore, there is a very small surplus of suitable soil material, however it should not be considered surplus given the small margin for soil loss and even distribution.

8.1.2 Current Soil Management Measures

The current soil management measures employed at the Mangoola Coal Mine are detailed in the Mangoola Coal Mining Operations Plan 2016 – 2019, and outlined below:

Topsoil is removed from any disturbed areas and stockpiled for use in rehabilitation works. Typically, the top 100 mm of soil is removed for this use. However, this is dependent on the quality of the topsoil. This material is characterised to determine the type and application rate that may be required for ameliorants.

Topsoil stockpiles are managed in a manner to preserve the quality and enhance rehabilitation outcomes. These techniques include:

- where possible topsoil is stripped when moist to maintain soil structure and reduce dust generation;
- viability of the seed bank in the topsoil will be maintained where possible (providing there is no threat from weed infestation);
- topsoil stockpiles are located away from watercourses, traffic areas and mining;
- level or gently sloping areas will be selected as stockpile sites to minimise erosion and potential soil loss;
- stockpiles created during the MOP term will be less than 3 metres high;
- stockpiles to be kept longer than six months will be sown with a suitable cover crop to minimise soil erosion and invasion of weed species;
- weed growth will be monitored and subsequently controlled if necessary;
- prior to re-spreading, weed growth may be scalped from the top of the stockpiles to minimise the transport of weeds into rehabilitated areas; and
- stockpiles will be appropriately sign posted to identify the area and minimise the potential for unauthorised use or disturbance.

Surface preparation activities for rehabilitated areas are conducted as soon as practicable following bulk shaping activities. The landform establishment activities include:

- rock piles created where appropriate;
- installation of habitat trees where appropriate;
- installation of other habitat features such as ponds where practical.
- placement of topsoil on prepared rehabilitation surface to approximately 100 mm;
- application of appropriate ameliorants as required to topsoil;
- integration of topsoil and ameliorants and seed bed preparation works such as harrowing/tilling; and
- seeding and planting according to final land use ecosystems.

8.1.3 Soil stripping procedure

A soil stripping procedure is outlined below, detailing measures to maximise the salvage of suitable topsoils and subsoils. These measures are consistent with leading practice and incorporate the full range of reasonable and feasible mitigation methods for soil stripping. They also include the soil handling measures that will minimise soil degradation (in terms of nutrients and micro-organisms present) and compaction, thus retaining its value for plant growth. Some of these measures are already practiced on site, however consideration should be given to including the techniques below.

The following soil stripping procedure should be considered:

- The area to be stripped should be clearly defined on the ground, avoiding any waterlogged or similarly constrained areas. The target depths of topsoil and subsoil to be stripped for each location will be clearly communicated to machinery operators and supervisors;
- A combination of suitable earthworks equipment should be used for stripping and placing soils in stockpiles. Machinery circuits should be located to minimise compaction of the stockpiled soil;
- All machinery brought onto the site for soil stripping should comply with any weed management protocols and biosecurity established for the site;
- Soil stockpile locations will be identified during planning and will be stripped of topsoil (not subsoil) before use;
- Any trees or vegetation present will be cleared prior to topsoil salvage;
- Topsoil and subsoil should be stripped to the required depths as nominated in this assessment and then stockpiled. Subsoil should be stripped and stockpiled separately where identified as suitable. Depending on compaction and recovery rates, deep ripping may be required to maximise topsoil recovery. Where soils are shallower, topsoil and subsoils can be stripped and stockpiled together;
- Handling and rehandling of stripped topsoil should be minimised as far as practicable by progressively stripping vegetation and soil only as needed for development activities;

- Soil stripping in very wet conditions should be avoided if practicable, because of the risk of compaction, nutrient deterioration and less volume of suitable materials being available. However, when possible, soils will be stripped when they are slightly moisture conditioned. This will assist in removal and retaining the soil structure; and
- To avoid dust hazards, stripping of soil during particularly dry conditions should be avoided where possible.

8.1.4 Soil stockpile management

Soil stockpile management procedures will be designed to minimise degradation of soil characteristics that are favourable for plant growth. These measures are consistent with leading practices and incorporate all reasonable and feasible mitigation methods.

The following management practices should be considered:

- Stockpiles should be located at an appropriate distance from water courses and dams (so they are not washed away);
- Where practical, topsoil and subsoil should be stockpiled separately. Where this is not possible, combined topsoil and subsoil stockpiles will still be built to the specifications for topsoil stockpiles;
- Topsoil stockpiles should be designed and constructed to a height of no greater than 3 m in order to limit anaerobic conditions being generated within the stockpile and to minimise deterioration of nutrients, soil biota and seed banks;
- Soil stockpiles should have a slope grade of 1V:4H or less to limit erosion potential;
- Subsoil stockpiles can be designed over 3 m in height; however, the slope grade needs to be considered for erosion control and should still be 1V:4H or less;
- The surface of the soil stockpiles should be left in a 'rough' condition to help promote water infiltration and minimise erosion via runoff. If required, sediment controls will be installed downstream of stockpile areas to collect any runoff;
- Overland water flow onto or across stockpile sites should be kept to a practical minimum and will not be concentrated to the extent that it causes visible soil erosion;
- Stockpiles should be seeded with an appropriate pasture grass mixture to stabilise the surface, restrict dust generation, minimise erosion and weed growth;
- After the stockpiles are established, machinery and vehicles should be excluded for general access (stockpile maintenance works excepted). The location should be marked on site maps to identify the stockpiles so that they are protected from future disturbance;
- The stockpile locations should be surveyed and data recorded about the soil types and volumes present; and
- The establishment of weeds on the stockpiles should be monitored and control programs implemented as required.

8.1.5 Topsoil application procedure

As part of the rehabilitation process soil will be applied to landforms once they are re-shaped and drainage works are complete. This may include contour or diversion banks with stable discharge points if required to manage runoff and ripping of compacted zones under infrastructure and other hardstand areas.

The topsoil application procedure will essentially be the reverse of the stripping procedure. It will be designed to minimise any degradation of soil characteristics, consistent with industry leading practice.

Generally, all soils should be applied at a thickness of approximately 0.25 m to provide sufficient depth for ripping and plant growth.

The following measures are designed to minimise the loss of soil during respreading on rehabilitated areas and promote successful vegetation establishment:

- The soil stripping assessment (Section 7.1) and soil balance (Section 7.2) should be reviewed throughout the operational phase of the MCCO Project used to inform the rehabilitation process. Specifically, it will assist in informing the depths and volume of soils to be reapplied in particular areas. The plan will take account of the relative erodibility of the soils, with more erodible material being placed on flatter areas to minimise the potential for erosion;
- After the area to be rehabilitated has been re-profiled and/or deep ripped, the subsoil will be spread onto the site, followed by the topsoil (or all at once if not stripped and stored separately);
- Soil should be respread in even layers at a thickness appropriate for the land capability of the area to be rehabilitated;
- Soils should be lightly scarified on the contour to encourage rainfall infiltration and minimise run-off;
- As soon as practicable after respreading, the soil should be seeded; and
- Erosion and sediment controls should be implemented where deemed necessary prior to vegetation establishment.

8.2 Contingency measures

If the topsoil stripping procedure is carried out as currently proposed, no contingency measures should be needed. However, if there is insufficient volume of topsoil available at the time of rehabilitation, or if the topsoil material has been degraded, the following contingency measures will be implemented:

- topsoil will be spread at a shallower thickness and/or only on selected parts of the site;
- subsoil will be used as a topsoil substitute rather than returned as subsoil under the topsoil; and
- fertilisers and other soil additives will be added to the topsoil and subsoil to improve fertility and structure.

Implementation of any of the above contingency measures would enable satisfactory rehabilitation to occur although re-establishment of the target levels of land capability may require additional materials and take longer.

8.3 Mitigation measures

8.3.1 Measures to prevent loss of soil resource

Any alterations to the soil balance or if site conditions are different than expected (eg shallow soil in places) the required volume of soil for rehabilitation should be re-calculated. An inventory of soil stripped should be prepared, so that if any significant deficit is identified, additional material can be sourced prior to rehabilitation. The recommendations made in the topsoil stripping procedure and the stockpiling procedure addresses all of these measures to prevent loss of soil resource.

8.3.2 Measures to manage soil erosion and sediment transport

The disturbance footprint largely sits over a Sodosol soil type. Exposure of sodic subsoils in these soils will increase the erosive potential of the soil surface, particularly on a slope. Therefore, soil erosion management should be implemented during construction activities. Drainage structures should be designed for the infrastructure areas to manage water runoff for the life of the operations. Sediment control measures should also be used during construction in accordance with the guideline *Managing Urban Stormwater, Volume 2E Mines and Quarries* (DECCD 2008).

To minimise the risk of loss from wind and water erosion to stockpiled topsoil, a vegetative cover should be established if proposed to be left longer than 3 months. Stockpiles should also be located where they are not exposed to overland or flood flow.

Soil may erode after the topsoil has been spread on the rehabilitated areas. Soil erosion and sediment control should be considered where there could potentially be off-site impacts to waterways, as well as impacts to the rehabilitation itself.

8.3.3 Measures to prevent soil contamination

Hydrocarbon management practices should be implemented to prevent hydrocarbon spills during construction activities (eg re-fuelling, maintenance, hydrocarbon storage) and spill containment materials should be available to clean-up spills if they occur. If any hydrocarbon spills were to occur during soil stripping, the impact could be isolated and clean-up procedures will mitigate any impacts from the spill. Areas to be used for long-term storage and handling of hydrocarbons and chemicals should be enclosed with concrete bunds.

Any construction material brought onto site should be clean and contaminant-free. This should be managed in accordance with procedures to be outlined in the Construction Environmental Management Plan.

Areas used for stockpiling of overburden and coal product should be compacted to minimise potential for water infiltration. If any contamination does occur, the soil material should be removed and disposed of appropriately. All surface water runoff from these stockpiles should be directed to the mine runoff dams. If the coal rejects are found to be potentially acid forming, the risk can be managed by adding fine limestone to the coal reject stockpile.

8.3.4 Measures to minimise soil degradation

To minimise structural decline of soil, the amount of compaction of soils during stripping and stockpiling should be minimised. This can be achieved by using suitable machinery, timing stripping where possible and stockpile development techniques. Nutrient decline will occur during stockpiling of soils, but can be minimised by managing stockpile methods and heights. Any nutrient decline can be amended at the time of rehabilitation by utilising fertilisers and amendment techniques (eg gypsum application). The recommendations made in the topsoil stripping procedure and the stockpiling procedure addresses all of these risks to soil degradation.

8.3.5 Methods to achieve successful rehabilitation

The soil stripping procedure has been designed to maximise the salvage of suitable materials. These measures are consistent with leading practice and incorporate the full range of reasonable and feasible mitigation methods for soil stripping, with the goal of minimising the degradation of soil nutrients and micro-organisms.

Stockpiles should be designed and located to prevent contamination, development of anaerobic conditions, and to avoid erosion and dust generation. The stockpiles should also be seeded with grasses so that they remain stable and be regularly inspected for weeds.

Where required, disturbed land should be re-profiled once surface structures are removed by re-instating depressions which were filled for mine development, removing dams and bunds so that water is not permanently retained and undertaking deep ripping of compacted areas.

Soil should be applied to provide sufficient depth for ripping and plant growth in a manner which minimises any degradation of soil characteristics. The topsoil balance plan presented in Table 7.2 should be reviewed and revised throughout the operational phase of the MCCO Project and prior to spreading, which will show the depths and volume of soils to be reapplied in particular areas. Soil should be applied at a thickness appropriate to support the intended LSC Class (LSC Class 6 = 0.25 m). The soil can then be contour-ripped and seeded.

9 Conclusions

The MCCO Additional Project Area was assessed by EMM for soil resources, land capability and the presence of BSAL. The findings have been detailed in this report. The proposed mining activities of the MCCO Project will restrict impacts on the land and soil resources, to areas within the MCCO Additional Disturbance Area.

The main soil type identified in the MCCO Additional Project Area is a Grey Sodosol, followed by Red-Orthic Tenosols, both of which generally occur on gently undulating slopes of low rolling hills on sandstone surface geology. This land is typical of the region, and is extensively cleared and used mainly for grazing improved pastures. Three other soil types (Brown Dermosols, Grey Kurosols, Brown Chromosols) were identified in the MCCO Additional Project Area. The Dermosol soil type occurs adjacent to Big Flat Creek. The Kurosol will not be disturbed by the project and the Chromosol is located in small singular locations within the MCCO Additional Project Area.

The MCCO Additional Project Area has been assessed through the Site Verification Application (SVA) process and is verified Non-BSAL. The assessment was undertaken in accordance with the Interim Protocol (NSW Government 2013). Subsequently, a Site Verification Certificate was issued by DPE on 10 December 2018 confirming the land as verified Non-BSAL.

The soil resources have been assessed for suitability in post mining landforms with a total volume of material available being 1,365,000 m^3. The soil balance was undertaken to result in a possible standard soil depth across the rehabilitated landform of between 0.25 m and 0.28 m, which should provide an adequate soil profile for the establishment, growth and resilience of native vegetation.

The Land and Soil Capability Assessment was undertaken in accordance with the LSC Assessment Scheme – second approximation (OEH 2012). This assessment found the majority of the site was considered LSC Class 5, with limited areas of Classes 3, 4 and 7. The proposed post mining LSC classes include Class 6 for the rehabilitated land (494 ha) and Class 8 for the final void (82 ha).

The proposed final land use within the MCCO Additional Project Area is for the majority of the site to have native vegetation established on the final landform. The soil profile may allow for potential grazing activities further down the track, however native vegetation is the preferred land use.

References

Baker DE & Eldershaw VJ 1993, *Interpreting soil analyses*, Department of Primary Industries, Queensland.

BOM 2017, *Climate classification maps*, Australian Government Bureau of Meteorology (accessed on 2nd August 2017 at http://www.bom.gov.au/jsp/ncc/climate_averages/climate-classifications/index.jsp)

DERM 2011, *Guidelines for applying the proposed strategic cropping land criteria*, Department of Environment and Resource Management. (accessed 22 November 2103, http://www.nrm.qld.gov.au/land/planning/pdf/strategic-cropping/scl-guidelines.pdf)

DLWC 1998, *Guidelines for the Use of Acid Sulfate Soil Risk Maps*, Department of Land and Water Conservation, March 1998.DLWC (2000) *Soil and Landscape Issues in Environmental Impact Assessment*, DLWC Technical Report No. 34, Department of Land and Water Conservation.

DLWC 2001, *Soil data entry handbook*, 3rd Edition, Department of Land and Water Conservation.

DPI 2013, Upper Hunter Agricultural Profile Factsheet No 1. June 2013, Department of Primary Industries

Gallant JC, McKenzie NJ, McBratney AB, 2008, Scale. In '*Guidelines for surveying soil and land resources'* (Eds NJ McKenzie, M J Grundy, R Webster, AJ Ringrose-Voase) 27–43. Second Edition. (CSIRO Publishing: Collingwood).

Gray JM and Murphy BW 2002, *Predicting Soil Distribution*, Joint Department of Land and Water Conservation (DLWC) and Australian Society for Soil Science Technical Poster, DLWC, Sydney.

Isbell RF 2016, *The Australian soil classification – 2nd Edition* CSIRO Publishing, Melbourne.

Keipert NL 2005, *Effect of different stockpiling procedures on topsoil characteristics in open cut coal mine rehabilitation in the Hunter Valley, New South Wales*. Submitted thesis for the degree of Doctor of Philosophy, Department of Ecosystem Management at The University of New England.

Kovac, M and Lawrie, J.W. 1991, *Soil landscapes of the Singleton 1:250 000 sheet*. Soil conservation service of NSW.

McKenzie NJ, Grundy MJ, Webster R & Ringrose-Voase AJ 2008, 2nd Edition, *Guidelines for surveying soil and land resources,* CSIRO Publishing, Melbourne.

NCST 2009, 3rd edition, *Australian soil and land survey handbook*, National Committee on Soil and Terrain CSIRO Publishing, Melbourne.

NSW Agriculture 2002, Agfact AC25: Agricultural Land Classification.

NSW DPE 2017, Hunter coalfield regional 1:100000 geology map Visited 7th August 2017 (accessed at http://www.resourcesandenergy.nsw.gov.au/miners-and-explorers/geoscience-information/products-and-data/maps/coalfield)

NSWG 2013, *Interim protocol for site verification and mapping of biophysical strategic agricultural land*. New South Wales Government.

OEH 2012, 2nd Edition, *The land and soil capability assessment scheme: second approximation.* Office of Environment and Heritage.

OEH 2017a, *Australian soil classification (ASC) soil type map of NSW*. Version 1.2 (v131024), Office of Environment and Heritage (http://www.environment.nsw.gov.au/eSpadeWebapp/).

OEH 2017b, *Great soil group soil type mapping of NSW* Version 1.2 (v131024), Office of Environment and Heritage (http://www.environment.nsw.gov.au/eSpadeWebapp/).

OEH 2017c, *Hydrological soil group mapping.* Version 1.2 (v131024), Office of Environment and Heritage (http://www.environment.nsw.gov.au/eSpadeWebapp/).

OEH 2017d, *Inherent soil fertility mapping*. Version 1.6 (v131024), Office of Environment and Heritage (http://www.environment.nsw.gov.au/eSpadeWebapp/).

OEH 2017e, *Land and Soil Capability Mapping of NSW*. Version 2.5 (v131024), Office of Environment and Heritage (http://www.environment.nsw.gov.au/eSpadeWebapp/)

OEH 2017f, NSW *Soil and land information System* (SALIS), Office of Environment and Heritage (http://www.environment.nsw.gov.au/eSpadeWebapp/)

OEH 2017g, Soil profile attribute data environment (eSPADE) online database. Office of Environment and Heritage (http://www.environment.nsw.gov.au/eSpadeWebapp/)

Peverill KI, Sparrow LA, Reuter DJ (eds) 1999, *Soil analysis: interpretation manual*, CSIRO Publishing, Collingwood.

Stace, H.C.T. 1968, *A handbook of Australian soils*. CSIRO and the International Society of Soil Science, Sydney

Appendix A

Representative survey site photographs

Appendix A

Representative survey site photographs

Site	Landscape	Profile
DERMOSOL		
A1		
5		

12

SODOSOL

10

23		
43		

47		
TENOSOL		
20		

21

37

KUROSOL

41		
48		

CHROMOSOL

19

53

Appendix B

Laboratory accreditation

Appendix B

Laboratory accreditation

NATA Accredited Laboratory

National Association of Testing Authorities, Australia
(ABN 59 004 379 748)

has accredited

Australian Laboratory Services Pty Ltd
Brisbane Laboratory
ALS Environmental Laboratory, ALS Mineral Laboratory

following demonstration of its technical competence
to operate in accordance with

ISO/IEC 17025

This facility is accredited in the field of

CHEMICAL TESTING

for the tests, calibrations and measurements shown on the
Scope of Accreditation issued by NATA

Jennifer Evans
Chief Executive Officer

Date of accreditation: 10 April 1970
Accreditation number: 825
Corporate Site Number: 818

NATA
WORLD RECOGNISED
ACCREDITATION

NATA is Australia's government-endorsed laboratory accreditor, and a leader in accreditation internationally.
NATA is a signatory to the international mutual recognition arrangements of the International Laboratory Accreditation Cooperation (ILAC) and the Asia Pacific Laboratory Accreditation Cooperation (APLAC).

NATA ACCREDITED LABORATORY

National Association of Testing Authorities, Australia

(ABN 59 004 379 748)

has accredited

Australian Laboratory Services Pty Ltd
Brisbane Microbiological Laboratory

following demonstration of its technical competence to operate in accordance with

ISO/IEC 17025

This facility is accredited in the field of

BIOLOGICAL TESTING

for the tests shown on the *Scope of Accreditation* issued by NATA

Jennifer Evans
Chief Executive Officer

Date of issue: 15 September 2016
Date of accreditation:16 June 2010
Accreditation number: 825
Corporate Site Number: 18958

Appendix C

Laboratory results

Appendix C

Laboratory results

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB1718053**	Page	: 1 of 23
Amendment	: **1**		
Client	: **EMM CONSULTING PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MS KYLIE DRAPALA	Contact	: Customer Services EB
Address	: 1/4 87 WICKHAM TERRACE SPRING HILL QLD 4000	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: 07 3839 1800	Telephone	: +61-7-3243 7222
Project	: Mangoola BSAL	Date Samples Received	: 01-Sep-2017 16:30
Order number	: ----	Date Analysis Commenced	: 04-Sep-2017
C-O-C number	: ----	Issue Date	: 16-Oct-2017 09:36
Sampler	: NICK JAMSON		
Site	: ----		
Quote number	: SYBQ/202/16		
No. of samples received	: 40		
No. of samples analysed	: 40		

ilac-MRA NATA

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Andrew Epps	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Ben Felgendrejeris		Brisbane Acid Sulphate Soils, Stafford, QLD
Greg Vogel	Laboratory Manager	Brisbane Acid Sulphate Soils, Stafford, QLD

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- ED006 (Exchangeable Cations on Alkaline Soils): It is recognised that the Exchangeable K LCS biases low, however this is deemed acceptable as the target concentration is at LOR and the Cation Exchange Capacity LCS is within acceptable limits.
- ED006(Exchangeable Cations on Alkaline Soils): Unable to calculate Magnesium/Potassium Ratio for some samples as the required results for Magnesium/Potassium are below LOR.
- ED007 (Exchangeable Cations): Calcium/Magnesium ratio could not be determined as both the Calcium and Magnesium results were less than reportable limits for sample EB1718053-028 (S23 (30-50cm) A2).
- EK057G (Nitrite as N): Sample EB1718053_022 (S10 (10-20cm) A2) was diluted due to matrix interference. LOR adjusted accordingly.
- Amendment (16/10/2017): This report has been amended as a result of a request to change sample identification numbers (IDs) received by ALS from K.Drapala on 16/10/2017. All analysis results are as per the previous report.
- EA058 Emerson: V. = Very, D. = Dark, L. = Light, VD. = Very Dark
- ED007 and ED008: When Exchangeable Al is reported from these methods, it should be noted that Rayment & Lyons (2011) suggests Exchange Acidity by 1M KCl - Method 15G1 (ED005) is a more suitable method for the determination of exchange acidity (H+ + Al3+).

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S47 (0-7cm)	S47 (7-13cm)	S47 (13-33cm)	S47 (40-60cm)	S47 (80-110cm)
			Client sampling date / time	[22-Aug-2017]	[22-Aug-2017]	[22-Aug-2017]	[22-Aug-2017]	[22-Aug-2017]
Compound	CAS Number	LOR	Unit	EB1718053-001	EB1718053-002	EB1718053-003	EB1718053-004	EB1718053-005
				Result	Result	Result	Result	Result
EA001: pH in soil using 0.01M CaCl extract								
pH (CaCl2)	----	0.1	pH Unit	4.5	4.7	7.5	7.4	5.3
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	5.4	6.0	8.2	8.1	5.9
EA008: Calcium Carbonate Equivalent								
CaCO3 Equivalent	----	0.01	%	4.64	1.82	2.39	2.54	0.60
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	40	26	496	582	455
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	3.2	2.0	12.3	13.1	5.6
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Very Dark Grayish Brown	Dark Gray	Dark Gray	Dark Gray	Grayish Brown
Texture	----	-	-	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam
Emerson Class Number	EC/TC	-	-	3	3	2	2	2
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	0.1	----	----	----	<0.1
Exchangeable Aluminium	----	0.1	meq/100g	<0.1	----	----	----	<0.1
ED006: Exchangeable Cations on Alkaline Soils								
Exchangeable Calcium	----	0.2	meq/100g	----	----	1.9	1.8	----
Exchangeable Magnesium	----	0.2	meq/100g	----	----	4.0	4.1	----
Exchangeable Potassium	----	0.2	meq/100g	----	----	<0.2	<0.2	----
Exchangeable Sodium	----	0.2	meq/100g	----	----	1.2	1.4	----
Cation Exchange Capacity	----	0.2	meq/100g	----	----	7.3	7.5	----
Exchangeable Sodium Percent	----	0.2	%	----	----	16.5	18.6	----
Calcium/Magnesium Ratio	----	0.2	-	----	----	0.5	0.4	----
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	4.4	3.2	----	----	----
Exchangeable Magnesium	----	0.1	meq/100g	3.5	3.6	----	----	----
Exchangeable Potassium	----	0.1	meq/100g	0.9	0.5	----	----	----
Exchangeable Sodium	----	0.1	meq/100g	0.4	0.5	----	----	----
Cation Exchange Capacity	----	0.1	meq/100g	9.3	7.9	----	----	----
Exchangeable Sodium Percent	----	0.1	%	3.9	6.3	----	----	----
Calcium/Magnesium Ratio	----	0.1	-	1.2	0.9	----	----	----
Magnesium/Potassium Ratio	----	0.1	-	3.8	6.6	----	----	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S47 (0-7cm)	S47 (7-13cm)	S47 (13-33cm)	S47 (40-60cm)	S47 (80-110cm)
			Client sampling date / time	[22-Aug-2017]	[22-Aug-2017]	[22-Aug-2017]	[22-Aug-2017]	[22-Aug-2017]
Compound	CAS Number	LOR	Unit	EB1718053-001	EB1718053-002	EB1718053-003	EB1718053-004	EB1718053-005
				Result	Result	Result	Result	Result
ED008: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	----	----	----	----	2.4
Exchangeable Magnesium	----	0.1	meq/100g	----	----	----	----	7.1
Exchangeable Potassium	----	0.1	meq/100g	----	----	----	----	0.2
Exchangeable Sodium	----	0.1	meq/100g	----	----	----	----	1.8
Cation Exchange Capacity	----	0.1	meq/100g	----	----	----	----	11.5
Exchangeable Sodium Percent	----	0.1	%	----	----	----	----	15.2
Calcium/Magnesium Ratio	----	0.1	-	----	----	----	----	0.3
Magnesium/Potassium Ratio	----	0.1	-	----	----	----	----	46.4
ED021: Bicarbonate Extractable Potassium (Colwell)								
Bicarbonate Extractable K (Colwell)	----	10	mg/kg	531	315	284	278	<200
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	10	<10	140	240	190
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	30	20	400	650	580
ED092: DTPA Extractable Metals								
ø Copper	7440-50-8	1.00	mg/kg	<1.00	<1.00	<1.00	<1.00	<1.00
ø Iron	7439-89-6	1.00	mg/kg	94.6	60.6	9.85	9.34	3.50
ø Manganese	7439-96-5	1.00	mg/kg	21.3	9.33	<1.00	<1.00	<1.00
ø Zinc	7440-66-6	1.00	mg/kg	1.96	<1.00	<1.00	<1.00	<1.00
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	<10	<10	<10	20	<10
Magnesium	7439-95-4	10	mg/kg	<10	<10	<10	20	<10
Sodium	7440-23-5	10	mg/kg	30	20	350	560	460
Potassium	7440-09-7	10	mg/kg	10	<10	<10	<10	<10
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	6580	4630	7380	8150	3540
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	0.3	0.3	<0.1	<0.1	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	0.1	0.8	0.3	<0.1	0.2

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S47 (0-7cm)	S47 (7-13cm)	S47 (13-33cm)	S47 (40-60cm)	S47 (80-110cm)
			Client sampling date / time	[22-Aug-2017]	[22-Aug-2017]	[22-Aug-2017]	[22-Aug-2017]	[22-Aug-2017]
Compound	CAS Number	LOR	Unit	EB1718053-001	EB1718053-002	EB1718053-003	EB1718053-004	EB1718053-005
				Result	Result	Result	Result	Result
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	0.4	1.1	0.3	<0.1	0.2
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	2110	930	420	270	70
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	2110	930	420	270	70
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	174	115	39	32	26
EK080: Bicarbonate Extractable Phosphorus (Colwell)								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	<5	<5	<5	<5	<5
EP004: Organic Matter								
Organic Matter	----	0.5	%	4.9	1.9	0.6	0.5	<0.5
Total Organic Carbon	----	0.5	%	2.8	1.1	<0.5	<0.5	<0.5

Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

Compound	CAS Number	LOR	Unit	S43 (0-10cm) A1	S43 (10-40cm) A21	S43 (47-67cm) A22	S43 (69-89cm) B2	S43 (1-1.2cm) B2
Client sampling date / time				[23-Aug-2017]	[23-Aug-2017]	[23-Aug-2017]	[23-Aug-2017]	[23-Aug-2017]
				EB1718053-006	EB1718053-007	EB1718053-008	EB1718053-009	EB1718053-010
				Result	Result	Result	Result	Result
EA001: pH in soil using 0.01M CaCl extract								
pH (CaCl2)	----	0.1	pH Unit	4.6	5.6	5.4	4.3	4.1
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	5.5	6.4	6.6	5.6	5.4
EA008: Calcium Carbonate Equivalent								
CaCO3 Equivalent	----	0.01	%	0.65	1.57	1.88	0.34	0.04
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	21	8	15	63	75
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	1.3	1.2	2.5	11.4	8.2
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Very Dark Grayish Brown	Light Gray	Light Brownish Gray	Light Yellowish Brown	Reddish Brown
Texture	----	-	-	Gravelly Sand	Gravelly Sand	Loamy Sand	Sandy Clay Loam	Sandy Clay Loam
Emerson Class Number	EC/TC	-	-	8	8	2	1	1
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	0.2	----	----	0.5	1.3
Exchangeable Aluminium	----	0.1	meq/100g	0.1	----	----	0.4	1.1
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	2.7	1.1	0.9	0.9	0.6
Exchangeable Magnesium	----	0.1	meq/100g	0.8	0.5	1.6	8.9	8.8
Exchangeable Potassium	----	0.1	meq/100g	0.6	0.2	0.2	0.7	0.6
Exchangeable Sodium	----	0.1	meq/100g	<0.1	<0.1	0.4	2.6	2.6
Cation Exchange Capacity	----	0.1	meq/100g	4.3	1.9	3.1	13.6	13.9
Exchangeable Sodium Percent	----	0.1	%	0.8	3.5	14.1	20.0	20.5
Calcium/Magnesium Ratio	----	0.1	-	3.4	2.2	0.6	0.1	<0.1
Magnesium/Potassium Ratio	----	0.1	-	1.4	3.4	7.9	12.6	15.2
ED021: Bicarbonate Extractable Potassium (Colwell)								
Bicarbonate Extractable K (Colwell)	----	10	mg/kg	378	<200	<200	257	299
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	10	<10	10	40	50
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	10	<10	<10	20	30
ED092: DTPA Extractable Metals								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S43 (0-10cm) A1	S43 (10-40cm) A21	S43 (47-67cm) A22	S43 (69-89cm) B2	S43 (1-1.2cm) B2
			Client sampling date / time	[23-Aug-2017]	[23-Aug-2017]	[23-Aug-2017]	[23-Aug-2017]	[23-Aug-2017]
Compound	CAS Number	LOR	Unit	EB1718053-006	EB1718053-007	EB1718053-008	EB1718053-009	EB1718053-010
				Result	Result	Result	Result	Result
ED092: DTPA Extractable Metals - Continued								
ø Copper	7440-50-8	1.00	mg/kg	<1.00	<1.00	<1.00	<1.00	<1.00
ø Iron	7439-89-6	1.00	mg/kg	**94.9**	**7.23**	**11.4**	**69.1**	**92.2**
ø Manganese	7439-96-5	1.00	mg/kg	**17.6**	<1.00	<1.00	<1.00	<1.00
ø Zinc	7440-66-6	1.00	mg/kg	**1.77**	<1.00	<1.00	<1.00	<1.00
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	<10	<10	<10	<10	<10
Magnesium	7439-95-4	10	mg/kg	<10	<10	<10	<10	<10
Sodium	7440-23-5	10	mg/kg	<10	<10	**10**	**40**	**40**
Potassium	7440-09-7	10	mg/kg	**20**	<10	<10	<10	<10
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**3800**	**2920**	**4280**	**10800**	**12500**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	<0.1	**0.2**	**0.4**	**0.6**	**0.5**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	<0.1	**0.2**	**0.4**	**0.6**	**0.5**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**1330**	**190**	**140**	**250**	**260**
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	**1330**	**190**	**140**	**250**	**260**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**175**	**83**	**55**	**40**	**48**
EK080: Bicarbonate Extractable Phosphorus (Colwell)								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	**10**	<5	<5	<5	<5
EP004: Organic Matter								
Organic Matter	----	0.5	%	**3.4**	**0.5**	<0.5	**0.5**	<0.5
Total Organic Carbon	----	0.5	%	**2.0**	<0.5	<0.5	<0.5	<0.5

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	A1 (0-9cm) A1	A1 (90-30cm) B21	A1 (30-50cm) B21	A1 (50-80cm) B21	A1 (85-110cm) B22
			Client sampling date / time	[27-Aug-2017]	[27-Aug-2017]	[27-Aug-2017]	[27-Aug-2017]	[27-Aug-2017]
Compound	CAS Number	LOR	Unit	EB1718053-011	EB1718053-012	EB1718053-013	EB1718053-014	EB1718053-015
				Result	Result	Result	Result	Result
EA001: pH in soil using 0.01M CaCl extract								
pH (CaCl2)	----	0.1	pH Unit	4.8	5.9	8.2	8.5	8.5
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	6.0	7.0	8.8	9.0	9.0
EA008: Calcium Carbonate Equivalent								
CaCO3 Equivalent	----	0.01	%	0.96	1.11	1.93	7.81	3.87
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	21	47	631	1170	1150
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	3.4	7.4	15.0	15.8	18.5
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Brown	Brown	Brown	Brown	Grayish Brown
Texture	----	-	-	Sandy Loam	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam
Emerson Class Number	EC/TC	-	-	3	1	1	3	3
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	<0.1	----	----	----	----
Exchangeable Aluminium	----	0.1	meq/100g	<0.1	----	----	----	----
ED006: Exchangeable Cations on Alkaline Soils								
Exchangeable Calcium	----	0.2	meq/100g	----	----	1.4	1.3	1.3
Exchangeable Magnesium	----	0.2	meq/100g	----	----	6.4	7.0	8.4
Exchangeable Potassium	----	0.2	meq/100g	----	----	0.3	0.4	0.4
Exchangeable Sodium	----	0.2	meq/100g	----	----	2.1	2.4	3.2
Cation Exchange Capacity	----	0.2	meq/100g	----	----	10.3	11.1	13.3
Exchangeable Sodium Percent	----	0.2	%	----	----	20.1	22.1	24.2
Calcium/Magnesium Ratio	----	0.2	-	----	----	0.2	<0.2	<0.2
Magnesium/Potassium Ratio	----	0.2	-	----	----	20.3	19.6	19.9
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	3.4	4.4	----	----	----
Exchangeable Magnesium	----	0.1	meq/100g	3.6	11.4	----	----	----
Exchangeable Potassium	----	0.1	meq/100g	0.9	0.7	----	----	----
Exchangeable Sodium	----	0.1	meq/100g	0.2	1.8	----	----	----
Cation Exchange Capacity	----	0.1	meq/100g	8.1	18.3	----	----	----
Exchangeable Sodium Percent	----	0.1	%	3.0	9.8	----	----	----
Calcium/Magnesium Ratio	----	0.1	-	0.9	0.4	----	----	----
Magnesium/Potassium Ratio	----	0.1	-	4.0	15.9	----	----	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	A1 (0-9cm) A1	A1 (90-30cm) B21	A1 (30-50cm) B21	A1 (50-80cm) B21	A1 (85-110cm) B22
			Client sampling date / time	[27-Aug-2017]	[27-Aug-2017]	[27-Aug-2017]	[27-Aug-2017]	[27-Aug-2017]
Compound	CAS Number	LOR	Unit	EB1718053-011	EB1718053-012	EB1718053-013	EB1718053-014	EB1718053-015
				Result	Result	Result	Result	Result
ED021: Bicarbonate Extractable Potassium (Colwell)								
Bicarbonate Extractable K (Colwell)	----	10	mg/kg	467	361	384	404	539
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	<10	<10	140	260	280
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	10	60	1020	1540	1780
ED092: DTPA Extractable Metals								
ø Copper	7440-50-8	1.00	mg/kg	<1.00	<1.00	<1.00	<1.00	1.37
ø Iron	7439-89-6	1.00	mg/kg	73.4	36.4	13.1	10.7	11.8
ø Manganese	7439-96-5	1.00	mg/kg	24.3	1.36	1.33	1.45	<1.00
ø Zinc	7440-66-6	1.00	mg/kg	<1.00	<1.00	<1.00	<1.00	<1.00
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	<10	<10	<10	20	10
Magnesium	7439-95-4	10	mg/kg	<10	<10	20	50	40
Sodium	7440-23-5	10	mg/kg	10	60	830	1250	1400
Potassium	7440-09-7	10	mg/kg	<10	<10	10	20	20
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	6850	7250	14500	17200	22600
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	<0.1	<0.1	0.2	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	<0.1	<0.1	0.1	0.2	0.6
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	<0.1	<0.1	0.1	0.4	0.6
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	1160	780	270	310	250
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	1160	780	270	310	250
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	206	138	92	106	114
EK080: Bicarbonate Extractable Phosphorus (Colwell)								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	A1 (0-9cm) A1	A1 (90-30cm) B21	A1 (30-50cm) B21	A1 (50-80cm) B21	A1 (85-110cm) B22
			Client sampling date / time	[27-Aug-2017]	[27-Aug-2017]	[27-Aug-2017]	[27-Aug-2017]	[27-Aug-2017]
Compound	CAS Number	LOR	Unit	EB1718053-011	EB1718053-012	EB1718053-013	EB1718053-014	EB1718053-015
				Result	Result	Result	Result	Result
EK080: Bicarbonate Extractable Phosphorus (Colwell) - Continued								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	<5	<5	<5	<5	<5
EP004: Organic Matter								
Organic Matter	----	0.5	%	**3.4**	**1.5**	**0.5**	**0.5**	<0.5
Total Organic Carbon	----	0.5	%	**2.0**	**0.9**	<0.5	<0.5	<0.5

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S20 (0-7cm) A1	S20 (10-30cm) A2	S20 (30-50cm) B2	S20 (50-70cm) B2	S20 (70-100cm) B2
			Client sampling date / time	[26-Aug-2017]	[26-Aug-2017]	[26-Aug-2017]	[26-Aug-2017]	[26-Aug-2017]
Compound	CAS Number	LOR	Unit	EB1718053-016	EB1718053-017	EB1718053-018	EB1718053-019	EB1718053-020
				Result	Result	Result	Result	Result
EA001: pH in soil using 0.01M CaCl extract								
pH (CaCl2)	----	0.1	pH Unit	4.7	5.1	5.4	6.3	6.2
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	5.6	6.4	6.6	7.6	7.4
EA008: Calcium Carbonate Equivalent								
CaCO3 Equivalent	----	0.01	%	1.57	0.09	1.16	2.49	0.80
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	11	10	17	22	28
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	<1.0	2.4	3.1	3.6	3.5
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Strong Brown	Yellowish Red	Yellowish Red	Reddish Yellow	Brown
Texture	----	-	-	Gravelly Sand	Sandy Loam	Sandy Loam	Gravelly Sand	Sandy Loam
Emerson Class Number	EC/TC	-	-	8	2	2	8	2
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	0.2	----	----	----	----
Exchangeable Aluminium	----	0.1	meq/100g	0.2	----	----	----	----
ED006: Exchangeable Cations on Alkaline Soils								
Exchangeable Calcium	----	0.2	meq/100g	----	----	----	<0.2	<0.2
Exchangeable Magnesium	----	0.2	meq/100g	----	----	----	1.3	1.6
Exchangeable Potassium	----	0.2	meq/100g	----	----	----	<0.2	<0.2
Exchangeable Sodium	----	0.2	meq/100g	----	----	----	<0.2	0.3
Cation Exchange Capacity	----	0.2	meq/100g	----	----	----	1.3	1.9
Exchangeable Sodium Percent	----	0.2	%	----	----	----	<0.2	16.2
Calcium/Magnesium Ratio	----	0.2	-	----	----	----	<0.2	<0.2
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	0.5	0.1	0.2	----	----
Exchangeable Magnesium	----	0.1	meq/100g	1.6	3.2	4.1	----	----
Exchangeable Potassium	----	0.1	meq/100g	0.2	0.2	0.2	----	----
Exchangeable Sodium	----	0.1	meq/100g	<0.1	0.3	0.5	----	----
Cation Exchange Capacity	----	0.1	meq/100g	2.5	3.8	5.2	----	----
Exchangeable Sodium Percent	----	0.1	%	2.8	6.9	10.5	----	----
Calcium/Magnesium Ratio	----	0.1	-	0.3	<0.1	<0.1	----	----
Magnesium/Potassium Ratio	----	0.1	-	6.8	18.3	16.8	----	----
ED021: Bicarbonate Extractable Potassium (Colwell)								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S20 (0-7cm) A1	S20 (10-30cm) A2	S20 (30-50cm) B2	S20 (50-70cm) B2	S20 (70-100cm) B2
			Client sampling date / time	[26-Aug-2017]	[26-Aug-2017]	[26-Aug-2017]	[26-Aug-2017]	[26-Aug-2017]
Compound	CAS Number	LOR	Unit	EB1718053-016	EB1718053-017	EB1718053-018	EB1718053-019	EB1718053-020
				Result	Result	Result	Result	Result
ED021: Bicarbonate Extractable Potassium (Colwell) - Continued								
Bicarbonate Extractable K (Colwell)	----	10	mg/kg	**251**	**225**	**250**	**279**	**284**
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	<10	<10	<10	**10**	**20**
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	<10	<10	**10**	<10	**20**
ED092: DTPA Extractable Metals								
ø Copper	7440-50-8	1.00	mg/kg	<1.00	<1.00	<1.00	<1.00	<1.00
ø Iron	7439-89-6	1.00	mg/kg	**10.4**	**10.2**	**5.88**	**5.81**	**6.11**
ø Manganese	7439-96-5	1.00	mg/kg	**5.22**	<1.00	<1.00	<1.00	<1.00
ø Zinc	7440-66-6	1.00	mg/kg	<1.00	<1.00	<1.00	<1.00	<1.00
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	<10	<10	<10	<10	<10
Magnesium	7439-95-4	10	mg/kg	<10	<10	<10	<10	<10
Sodium	7440-23-5	10	mg/kg	<10	**10**	**10**	**20**	**30**
Potassium	7440-09-7	10	mg/kg	<10	<10	<10	<10	<10
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**4180**	**4800**	**6130**	**6650**	**6990**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	**0.4**	**0.1**	<0.1	<0.1	**0.2**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	**0.4**	**0.1**	<0.1	<0.1	**0.2**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**360**	**90**	**80**	**90**	**90**
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	**360**	**90**	**80**	**90**	**90**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**97**	**66**	**61**	**59**	**60**
EK080: Bicarbonate Extractable Phosphorus (Colwell)								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S20 (0-7cm) A1	S20 (10-30cm) A2	S20 (30-50cm) B2	S20 (50-70cm) B2	S20 (70-100cm) B2
			Client sampling date / time	[26-Aug-2017]	[26-Aug-2017]	[26-Aug-2017]	[26-Aug-2017]	[26-Aug-2017]
Compound	CAS Number	LOR	Unit	EB1718053-016	EB1718053-017	EB1718053-018	EB1718053-019	EB1718053-020
				Result	Result	Result	Result	Result
EK080: Bicarbonate Extractable Phosphorus (Colwell) - Continued								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	<5	<5	<5	<5	<5
EP004: Organic Matter								
Organic Matter	----	0.5	%	**1.0**	<0.5	<0.5	<0.5	<0.5
Total Organic Carbon	----	0.5	%	**0.6**	<0.5	<0.5	<0.5	<0.5

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S10 (0-10cm) A1	S10 (10-20cm) A2	S10 (30-50cm) A2	S10 (60-85cm) B21	S10 (85-110cm) B22
			Client sampling date / time	[25-Aug-2017]	[25-Aug-2017]	[25-Aug-2017]	[25-Aug-2017]	[25-Aug-2017]
Compound	CAS Number	LOR	Unit	EB1718053-021	EB1718053-022	EB1718053-023	EB1718053-024	EB1718053-025
				Result	Result	Result	Result	Result
EA001: pH in soil using 0.01M CaCl extract								
pH (CaCl2)	----	0.1	pH Unit	4.8	5.1	7.6	8.5	8.2
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	5.7	6.4	8.5	9.1	8.9
EA008: Calcium Carbonate Equivalent								
CaCO3 Equivalent	----	0.01	%	1.06	2.08	1.57	1.47	1.72
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	20	25	346	974	672
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	3.6	2.2	11.6	16.3	13.4
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Very Dark Grayish Brown	Very Dark Grayish Brown	Grayish Brown	Grayish Brown	Pale Brown
Texture	----	-	-	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam
Emerson Class Number	EC/TC	-	-	3	3	1	2	1
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	<0.1	----	----	----	----
Exchangeable Aluminium	----	0.1	meq/100g	<0.1	----	----	----	----
ED006: Exchangeable Cations on Alkaline Soils								
Exchangeable Calcium	----	0.2	meq/100g	----	----	0.8	0.7	0.5
Exchangeable Magnesium	----	0.2	meq/100g	----	----	4.0	6.6	5.1
Exchangeable Potassium	----	0.2	meq/100g	----	----	<0.2	0.2	0.2
Exchangeable Sodium	----	0.2	meq/100g	----	----	1.4	2.8	2.2
Cation Exchange Capacity	----	0.2	meq/100g	----	----	6.3	10.4	8.0
Exchangeable Sodium Percent	----	0.2	%	----	----	21.6	27.2	27.3
Calcium/Magnesium Ratio	----	0.2	-	----	----	<0.2	<0.2	<0.2
Magnesium/Potassium Ratio	----	0.2	-	----	----	----	27.6	24.2
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	4.4	2.2	----	----	----
Exchangeable Magnesium	----	0.1	meq/100g	2.6	4.0	----	----	----
Exchangeable Potassium	----	0.1	meq/100g	0.9	0.3	----	----	----
Exchangeable Sodium	----	0.1	meq/100g	0.1	0.8	----	----	----
Cation Exchange Capacity	----	0.1	meq/100g	8.0	7.4	----	----	----
Exchangeable Sodium Percent	----	0.1	%	1.5	11.4	----	----	----
Calcium/Magnesium Ratio	----	0.1	-	1.7	0.6	----	----	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S10 (0-10cm) A1	S10 (10-20cm) A2	S10 (30-50cm) A2	S10 (60-85cm) B21	S10 (85-110cm) B22
			Client sampling date / time	[25-Aug-2017]	[25-Aug-2017]	[25-Aug-2017]	[25-Aug-2017]	[25-Aug-2017]
Compound	CAS Number	LOR	Unit	EB1718053-021	EB1718053-022	EB1718053-023	EB1718053-024	EB1718053-025
				Result	Result	Result	Result	Result
ED007: Exchangeable Cations - Continued								
Magnesium/Potassium Ratio	----	0.1	-	3.0	13.0	----	----	----
ED021: Bicarbonate Extractable Potassium (Colwell)								
Bicarbonate Extractable K (Colwell)	----	10	mg/kg	566	291	279	365	363
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	<10	<10	160	340	170
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	10	20	700	1640	1140
ED092: DTPA Extractable Metals								
ø Copper	7440-50-8	1.00	mg/kg	<1.00	<1.00	<1.00	<1.00	<1.00
ø Iron	7439-89-6	1.00	mg/kg	105	39.4	14.0	8.59	6.59
ø Manganese	7439-96-5	1.00	mg/kg	24.8	2.44	<1.00	<1.00	<1.00
ø Zinc	7440-66-6	1.00	mg/kg	1.55	<1.00	<1.00	<1.00	<1.00
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	<10	<10	<10	<10	<10
Magnesium	7439-95-4	10	mg/kg	<10	<10	<10	30	<10
Sodium	7440-23-5	10	mg/kg	10	20	570	1360	820
Potassium	7440-09-7	10	mg/kg	10	<10	<10	<10	<10
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	7190	5410	13400	14700	14700
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	<0.2	<0.1	<0.1	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	0.1	0.2	0.1	0.1	<0.1
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	0.1	0.2	0.1	0.1	<0.1
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	1640	510	310	210	370
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	1640	510	310	210	370
EK067G: Total Phosphorus as P by Discrete Analyser								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S10 (0-10cm) A1	S10 (10-20cm) A2	S10 (30-50cm) A2	S10 (60-85cm) B21	S10 (85-110cm) B22
			Client sampling date / time	[25-Aug-2017]	[25-Aug-2017]	[25-Aug-2017]	[25-Aug-2017]	[25-Aug-2017]
Compound	CAS Number	LOR	Unit	EB1718053-021	EB1718053-022	EB1718053-023	EB1718053-024	EB1718053-025
				Result	Result	Result	Result	Result
EK067G: Total Phosphorus as P by Discrete Analyser - Continued								
Total Phosphorus as P	----	2	mg/kg	**224**	**153**	**61**	**48**	**76**
EK080: Bicarbonate Extractable Phosphorus (Colwell)								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	<5	<5	<5	<5	<5
EP004: Organic Matter								
Organic Matter	----	0.5	%	**4.9**	**2.0**	**1.1**	**0.6**	<0.5
Total Organic Carbon	----	0.5	%	**2.8**	**1.1**	**0.6**	<0.5	<0.5

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S23 (0-10cm) A1	S23 (10-30cm) A2	S23 (30-50cm) A2	S23 (60-80cm) B2	S23 (100-120cm) B2
			Client sampling date / time	[25-Aug-2017]	[25-Aug-2017]	[25-Aug-2017]	[25-Aug-2017]	[25-Aug-2017]
Compound	CAS Number	LOR	Unit	EB1718053-026	EB1718053-027	EB1718053-028	EB1718053-029	EB1718053-030
				Result	Result	Result	Result	Result
EA001: pH in soil using 0.01M CaCl extract								
pH (CaCl2)	----	0.1	pH Unit	4.6	5.2	5.8	6.5	5.4
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	5.6	6.2	6.7	7.6	6.7
EA008: Calcium Carbonate Equivalent								
CaCO3 Equivalent	----	0.01	%	0.50	2.39	2.03	1.57	1.06
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	14	7	12	82	85
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	1.5	1.0	1.5	2.6	11.9
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Dark Brown	Light Brown	Light Brownish Gray	Grayish Brown	Light Brownish Gray
Texture	----	-	-	Loamy Sand	Gravelly Sand	Gravelly Sand	Sandy Clay Loam	Sandy Clay Loam
Emerson Class Number	EC/TC	-	-	3	8	8	2	1
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	0.2	----	----	----	----
Exchangeable Aluminium	----	0.1	meq/100g	0.1	----	----	----	----
ED006: Exchangeable Cations on Alkaline Soils								
Exchangeable Calcium	----	0.2	meq/100g	----	----	----	<0.2	----
Exchangeable Magnesium	----	0.2	meq/100g	----	----	----	1.2	----
Exchangeable Potassium	----	0.2	meq/100g	----	----	----	<0.2	----
Exchangeable Sodium	----	0.2	meq/100g	----	----	----	0.6	----
Cation Exchange Capacity	----	0.2	meq/100g	----	----	----	1.8	----
Exchangeable Sodium Percent	----	0.2	%	----	----	----	33.5	----
Calcium/Magnesium Ratio	----	0.2	-	----	----	----	<0.2	----
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	2.1	1.6	0.7	----	0.1
Exchangeable Magnesium	----	0.1	meq/100g	0.9	0.8	0.9	----	7.8
Exchangeable Potassium	----	0.1	meq/100g	0.4	0.2	<0.1	----	0.3
Exchangeable Sodium	----	0.1	meq/100g	<0.1	<0.1	0.3	----	3.4
Cation Exchange Capacity	----	0.1	meq/100g	3.6	2.7	2.0	----	11.5
Exchangeable Sodium Percent	----	0.1	%	2.3	3.6	14.0	----	29.3
Calcium/Magnesium Ratio	----	0.1	-	2.3	2.0	0.8	----	<0.1
Magnesium/Potassium Ratio	----	0.1	-	2.1	4.4	----	----	29.2
ED021: Bicarbonate Extractable Potassium (Colwell)								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S23 (0-10cm) A1	S23 (10-30cm) A2	S23 (30-50cm) A2	S23 (60-80cm) B2	S23 (100-120cm) B2
			Client sampling date / time	[25-Aug-2017]	[25-Aug-2017]	[25-Aug-2017]	[25-Aug-2017]	[25-Aug-2017]
Compound	CAS Number	LOR	Unit	EB1718053-026	EB1718053-027	EB1718053-028	EB1718053-029	EB1718053-030
				Result	Result	Result	Result	Result
ED021: Bicarbonate Extractable Potassium (Colwell) - Continued								
Bicarbonate Extractable K (Colwell)	----	10	mg/kg	**369**	**254**	<200	<200	<200
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	<10	<10	<10	**60**	**30**
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	<10	<10	<10	**60**	**50**
ED092: DTPA Extractable Metals								
ø Copper	7440-50-8	1.00	mg/kg	<1.00	<1.00	<1.00	<1.00	<1.00
ø Iron	7439-89-6	1.00	mg/kg	**43.9**	**15.4**	**6.12**	**6.44**	**29.0**
ø Manganese	7439-96-5	1.00	mg/kg	**33.8**	<1.00	<1.00	<1.00	<1.00
ø Zinc	7440-66-6	1.00	mg/kg	<1.00	<1.00	<1.00	<1.00	<1.00
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	<10	<10	<10	<10	<10
Magnesium	7439-95-4	10	mg/kg	<10	<10	<10	<10	<10
Sodium	7440-23-5	10	mg/kg	<10	<10	**10**	**90**	**60**
Potassium	7440-09-7	10	mg/kg	<10	<10	<10	<10	<10
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**4930**	**3360**	**2140**	**4880**	**12900**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	**0.5**	**0.5**	<0.1	<0.1	**0.2**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	**0.5**	**0.5**	<0.1	<0.1	**0.2**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**570**	**230**	**160**	**120**	**260**
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	**570**	**230**	**160**	**120**	**260**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**202**	**89**	**64**	**45**	**47**
EK080: Bicarbonate Extractable Phosphorus (Colwell)								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S23 (0-10cm) A1	S23 (10-30cm) A2	S23 (30-50cm) A2	S23 (60-80cm) B2	S23 (100-120cm) B2
			Client sampling date / time	[25-Aug-2017]	[25-Aug-2017]	[25-Aug-2017]	[25-Aug-2017]	[25-Aug-2017]
Compound	CAS Number	LOR	Unit	EB1718053-026	EB1718053-027	EB1718053-028	EB1718053-029	EB1718053-030
				Result	Result	Result	Result	Result
EK080: Bicarbonate Extractable Phosphorus (Colwell) - Continued								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	<5	<5	**5**	**7**	<5
EP004: Organic Matter								
Organic Matter	----	0.5	%	**2.5**	**0.8**	**0.6**	<0.5	<0.5
Total Organic Carbon	----	0.5	%	**1.4**	<0.5	<0.5	<0.5	<0.5

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S21 (0-9cm) A1	S21 (9-19cm) A1	S21 929-39cm) A2	S21 (60-90cm) B2	S21 (90-120cm) B2
			Client sampling date / time	[26-Aug-2017]	[26-Aug-2017]	[26-Aug-2017]	[26-Aug-2017]	[26-Aug-2017]
Compound	CAS Number	LOR	Unit	EB1718053-031	EB1718053-032	EB1718053-033	EB1718053-034	EB1718053-035
				Result	Result	Result	Result	Result
EA001: pH in soil using 0.01M CaCl extract								
pH (CaCl2)	----	0.1	pH Unit	4.9	5.3	5.3	5.6	5.0
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	5.7	6.2	6.2	6.3	6.1
EA008: Calcium Carbonate Equivalent								
CaCO3 Equivalent	----	0.01	%	1.77	1.21	1.06	1.01	1.36
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	18	7	4	4	4
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	2.7	4.6	4.0	4.8	4.2
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Dark Brown	Dark Brown	Strong Brown	Strong Brown	Strong Brown
Texture	----	-	-	Gravelly Sand	Gravelly Sand	Gravelly Sand	Gravelly Sand	Gravelly Sand
Emerson Class Number	EC/TC	-	-	8	8	8	8	8
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	<0.1	----	----	----	----
Exchangeable Aluminium	----	0.1	meq/100g	<0.1	----	----	----	----
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	1.7	1.7	1.4	1.3	1.3
Exchangeable Magnesium	----	0.1	meq/100g	0.7	0.8	0.4	0.9	0.5
Exchangeable Potassium	----	0.1	meq/100g	0.4	0.4	0.2	0.2	0.3
Exchangeable Sodium	----	0.1	meq/100g	<0.1	<0.1	<0.1	<0.1	<0.1
Cation Exchange Capacity	----	0.1	meq/100g	2.8	2.8	2.1	2.5	2.2
Exchangeable Sodium Percent	----	0.1	%	0.7	0.5	0.5	0.7	0.7
Calcium/Magnesium Ratio	----	0.1	-	2.4	2.1	3.5	1.4	2.6
Magnesium/Potassium Ratio	----	0.1	-	1.8	2.1	1.9	4.8	2.1
ED021: Bicarbonate Extractable Potassium (Colwell)								
Bicarbonate Extractable K (Colwell)	----	10	mg/kg	381	359	296	240	285
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	<10	<10	<10	<10	<10
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	<10	<10	<10	<10	<10
ED092: DTPA Extractable Metals								
ø Copper	7440-50-8	1.00	mg/kg	<1.00	<1.00	<1.00	<1.00	<1.00

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S21 (0-9cm) A1	S21 (9-19cm) A1	S21 929-39cm) A2	S21 (60-90cm) B2	S21 (90-120cm) B2
			Client sampling date / time	[26-Aug-2017]	[26-Aug-2017]	[26-Aug-2017]	[26-Aug-2017]	[26-Aug-2017]
Compound	CAS Number	LOR	Unit	EB1718053-031	EB1718053-032	EB1718053-033	EB1718053-034	EB1718053-035
				Result	Result	Result	Result	Result
ED092: DTPA Extractable Metals - Continued								
ø Iron	7439-89-6	1.00	mg/kg	**27.2**	**15.7**	**8.90**	**9.11**	**12.6**
ø Manganese	7439-96-5	1.00	mg/kg	**20.9**	**24.4**	**8.74**	**12.7**	**20.8**
ø Zinc	7440-66-6	1.00	mg/kg	**1.12**	<1.00	<1.00	<1.00	<1.00
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	<10	<10	<10	<10	<10
Magnesium	7439-95-4	10	mg/kg	<10	<10	<10	<10	<10
Sodium	7440-23-5	10	mg/kg	<10	<10	<10	<10	<10
Potassium	7440-09-7	10	mg/kg	**10**	<10	<10	<10	<10
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**3880**	**4280**	**3640**	**4340**	**3890**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	**1.4**	**0.6**	**0.4**	**0.1**	**0.5**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	**1.4**	**0.6**	**0.4**	**0.1**	**0.5**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**740**	**380**	**170**	**140**	**220**
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	**740**	**380**	**170**	**140**	**220**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**120**	**109**	**74**	**89**	**88**
EK080: Bicarbonate Extractable Phosphorus (Colwell)								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	<5	<5	<5	<5	<5
EP004: Organic Matter								
Organic Matter	----	0.5	%	**1.5**	**1.6**	**0.5**	<0.5	**0.6**
Total Organic Carbon	----	0.5	%	**0.9**	**0.9**	<0.5	<0.5	<0.5

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S37 (0-12cm)	S37 (12-40cm)	S37 (50-63cm)	S37 (63-83cm)	S37 (90-120cm)
			Client sampling date / time	[22-Aug-2017]	[22-Aug-2017]	[22-Aug-2017]	[22-Aug-2017]	[22-Aug-2017]
Compound	CAS Number	LOR	Unit	EB1718053-036	EB1718053-037	EB1718053-038	EB1718053-039	EB1718053-040
				Result	Result	Result	Result	Result
EA001: pH in soil using 0.01M CaCl extract								
pH (CaCl2)	----	0.1	pH Unit	5.0	5.3	5.7	6.2	6.6
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	5.9	6.2	6.4	6.8	7.1
EA008: Calcium Carbonate Equivalent								
CaCO3 Equivalent	----	0.01	%	1.42	1.52	1.88	1.06	0.04
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	12	8	10	10	10
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	1.8	1.9	3.8	3.4	5.1
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Dark Brown	Strong Brown	Strong Brown	Strong Brown	Brownish Yellow
Texture	----	-	-	Gravelly Sand	Gravelly Sand	Gravelly Sand	Gravelly Sand	Gravelly Sand
Emerson Class Number	EC/TC	-	-	8	8	8	8	8
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	<0.1	----	----	----	----
Exchangeable Aluminium	----	0.1	meq/100g	<0.1	----	----	----	----
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	1.8	1.0	1.2	1.3	1.2
Exchangeable Magnesium	----	0.1	meq/100g	0.7	0.4	0.6	0.8	0.8
Exchangeable Potassium	----	0.1	meq/100g	0.5	0.3	0.4	0.3	0.2
Exchangeable Sodium	----	0.1	meq/100g	<0.1	<0.1	<0.1	<0.1	<0.1
Cation Exchange Capacity	----	0.1	meq/100g	3.0	1.8	2.2	2.5	2.4
Exchangeable Sodium Percent	----	0.1	%	0.5	0.9	1.1	1.4	2.2
Calcium/Magnesium Ratio	----	0.1	-	2.6	2.5	2.0	1.6	1.5
Magnesium/Potassium Ratio	----	0.1	-	1.3	1.2	1.6	2.7	4.3
ED021: Bicarbonate Extractable Potassium (Colwell)								
Bicarbonate Extractable K (Colwell)	----	10	mg/kg	474	362	413	330	288
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	<10	<10	10	10	<10
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	<10	<10	<10	<10	<10
ED092: DTPA Extractable Metals								
ø Copper	7440-50-8	1.00	mg/kg	<1.00	<1.00	<1.00	<1.00	<1.00

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S37 (0-12cm)	S37 (12-40cm)	S37 (50-63cm)	S37 (63-83cm)	S37 (90-120cm)
			Client sampling date / time	[22-Aug-2017]	[22-Aug-2017]	[22-Aug-2017]	[22-Aug-2017]	[22-Aug-2017]
Compound	CAS Number	LOR	Unit	EB1718053-036	EB1718053-037	EB1718053-038	EB1718053-039	EB1718053-040
				Result	Result	Result	Result	Result
ED092: DTPA Extractable Metals - Continued								
ø Iron	7439-89-6	1.00	mg/kg	**57.7**	**9.00**	**7.87**	**5.30**	**4.73**
ø Manganese	7439-96-5	1.00	mg/kg	**25.6**	**8.10**	**6.08**	<1.00	<1.00
ø Zinc	7440-66-6	1.00	mg/kg	**1.43**	<1.00	<1.00	<1.00	<1.00
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	<10	<10	<10	<10	<10
Magnesium	7439-95-4	10	mg/kg	<10	<10	<10	<10	<10
Sodium	7440-23-5	10	mg/kg	<10	<10	<10	<10	<10
Potassium	7440-09-7	10	mg/kg	**10**	**10**	**10**	**10**	<10
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**3040**	**2510**	**2890**	**3020**	**2770**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	**0.1**	<0.1	<0.1	<0.1	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	**1.0**	**0.6**	**0.3**	**0.2**	**0.2**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	**1.1**	**0.6**	**0.3**	**0.2**	**0.2**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**530**	**160**	**130**	**110**	**110**
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	**530**	**160**	**130**	**110**	**110**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**361**	**108**	**126**	**121**	**117**
EK080: Bicarbonate Extractable Phosphorus (Colwell)								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	<5	<5	<5	**7**	<5
EP004: Organic Matter								
Organic Matter	----	0.5	%	**1.6**	<0.5	<0.5	<0.5	<0.5
Total Organic Carbon	----	0.5	%	**0.9**	<0.5	<0.5	<0.5	<0.5

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB1720219**	Page	: 1 of 12
Client	: **EMM CONSULTING PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MS KYLIE DRAPALA	Contact	: Customer Services EB
Address	: 1/4 87 WICKHAM TERRACE SPRING HILL QLD 4000	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: 07 3839 1800	Telephone	: +61-7-3243 7222
Project	: Mangoola BSAL	Date Samples Received	: 29-Sep-2017 13:40
Order number	: ----	Date Analysis Commenced	: 03-Oct-2017
C-O-C number	: ----	Issue Date	: 11-Oct-2017 16:55
Sampler	: NICK JAMSON		
Site	: ----		
Quote number	: SYBQ/202/16		
No. of samples received	: 20		
No. of samples analysed	: 20		

ilac-MRA NATA

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Andrew Epps	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Satishkumar Trivedi	Acid Sulfate Soils Supervisor	Brisbane Acid Sulphate Soils, Stafford, QLD

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- ED006(Exchangeable Cations on Alkaline Soils): Unable to calculate Magnesium/Potassium Ratio for EB1720219-020 as the required results for Magnesium/Potassium are below LOR.
- ED006(Exchangeable Cations on Alkaline Soils): Unable to calculate Calcium/Magnesium Ratio for EB1720219-020 as the required results for Calcium/Magnesium are below LOR.
- ED007(Exchangeable Cations): Unable to calculate Magnesium/Potassium Ratio for some samples as the required results for Magnesium/Potassium are below LOR.
- ED037 (Alkalinity): NATA accreditation does not cover the performance of this service.
- ED006 (Exchangeable Cations on Alkaline Soils): It is recognised that the Exchangeable K LCS biases low, however this is deemed acceptable as the target concentration is at LOR and the Cation Exchange Capacity LCS is within acceptable limits.
- EA058 Emerson: V. = Very, D. = Dark, L. = Light, VD. = Very Dark
- ED007 and ED008: When Exchangeable Al is reported from these methods, it should be noted that Rayment & Lyons (2011) suggests Exchange Acidity by 1M KCl - Method 15G1 (ED005) is a more suitable method for the determination of exchange acidity ($H^+ + Al^{3+}$).

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S41 10-30cm	S41 30-50cm	S41 0-10cm	S41 50-70cm	S41 90-120cm
			Client sampling date / time	[24-Aug-2017]	[24-Aug-2017]	[24-Aug-2017]	[24-Aug-2017]	[24-Aug-2017]
Compound	CAS Number	LOR	Unit	EB1720219-001	EB1720219-002	EB1720219-003	EB1720219-004	EB1720219-005
				Result	Result	Result	Result	Result
EA001: pH in soil using 0.01M CaCl extract								
pH (CaCl2)	----	0.1	pH Unit	5.0	5.1	4.8	4.0	3.9
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	5.9	6.0	5.5	5.5	5.3
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	5	5	22	42	47
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	4.6	4.2	3.5	18.6	14.8
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Dark Grey	Brown	Dark Brown	Brown	Reddish Brown
Texture	----	-	-	Rocks	Rocks	Rocks	Silty Clay Loam	Silty Clay Loam
Emerson Class Number	EC/TC	-	-	8	8	8	1	1
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	<0.1	<0.1	<0.1	2.4	3.8
Exchangeable Aluminium	----	0.1	meq/100g	<0.1	<0.1	<0.1	1.9	2.7
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	1.1	1.8	4.1	0.1	<0.1
Exchangeable Magnesium	----	0.1	meq/100g	0.8	0.9	1.3	4.8	6.6
Exchangeable Potassium	----	0.1	meq/100g	0.1	0.1	0.3	0.5	0.5
Exchangeable Sodium	----	0.1	meq/100g	0.1	<0.1	<0.1	1.7	2.1
Cation Exchange Capacity	----	0.1	meq/100g	----	----	----	9.5	13.0
Cation Exchange Capacity	----	0.1	meq/100g	2.2	3.0	5.8	----	----
Exchangeable Sodium Percent	----	0.1	%	5.4	2.8	1.3	24.3	22.4
Calcium/Magnesium Ratio	----	0.1	-	1.4	2.0	3.2	<0.1	<0.1
Magnesium/Potassium Ratio	----	0.1	-	6.3	7.1	3.9	10.3	12.4
ED021: Bicarbonate Extractable Potassium (Colwell)								
Bicarbonate Extractable K (Colwell)	----	10	mg/kg	<200	<200	291	331	350
ED037: Alkalinity								
ø Total Alkalinity as CaCO3	----	1	mg/kg	117	288	1310	288	207
ø Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	117	288	1310	288	207
ø Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	<5	<5	<5	<5	<5
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	<10	<10	10	40	40
ED045G: Chloride by Discrete Analyser								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S41 10-30cm	S41 30-50cm	S41 0-10cm	S41 50-70cm	S41 90-120cm
			Client sampling date / time	[24-Aug-2017]	[24-Aug-2017]	[24-Aug-2017]	[24-Aug-2017]	[24-Aug-2017]
Compound	CAS Number	LOR	Unit	EB1720219-001	EB1720219-002	EB1720219-003	EB1720219-004	EB1720219-005
				Result	Result	Result	Result	Result
ED045G: Chloride by Discrete Analyser - Continued								
Chloride	16887-00-6	10	mg/kg	<10	<10	**10**	**20**	**20**
ED092: DTPA Extractable Metals								
ø Copper	7440-50-8	1.00	mg/kg	<1.00	<1.00	<1.00	<1.00	<1.00
ø Iron	7439-89-6	1.00	mg/kg	**22.8**	**29.6**	**191**	**76.3**	**44.3**
ø Manganese	7439-96-5	1.00	mg/kg	<1.00	**1.11**	**26.4**	<1.00	<1.00
ø Zinc	7440-66-6	1.00	mg/kg	<1.00	<1.00	**7.31**	<1.00	<1.00
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	<10	<10	<10	<10	<10
Magnesium	7439-95-4	10	mg/kg	<10	<10	<10	<10	<10
Sodium	7440-23-5	10	mg/kg	<10	<10	<10	**40**	**30**
Potassium	7440-09-7	10	mg/kg	<10	<10	<10	<10	<10
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**3060**	**2950**	**4260**	**9960**	**7200**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	**0.1**	**0.7**	**3.3**	**0.2**	**0.2**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	**0.1**	**0.7**	**3.3**	**0.2**	**0.2**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**260**	**380**	**1510**	**310**	**230**
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	**260**	**380**	**1510**	**310**	**230**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**86**	**107**	**221**	**72**	**45**
EK080: Bicarbonate Extractable Phosphorus (Colwell)								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	<5	<5	<5	<5	<5
EP004: Organic Matter								
Organic Matter	----	0.5	%	**0.8**	**1.5**	**5.1**	**0.6**	<0.5
Total Organic Carbon	----	0.5	%	<0.5	**0.8**	**2.9**	<0.5	<0.5

Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

Compound	CAS Number	LOR	Unit	S48 110-130cm	S48 90-110cm	S48 0-10cm	S48 20-40cm	S48 50-80cm
Client sampling date / time				[24-Aug-2017]	[24-Aug-2017]	[24-Aug-2017]	[24-Aug-2017]	[24-Aug-2017]
				EB1720219-006	EB1720219-007	EB1720219-008	EB1720219-009	EB1720219-010
				Result	Result	Result	Result	Result
EA001: pH in soil using 0.01M CaCl extract								
pH (CaCl2)	----	0.1	pH Unit	4.0	4.1	4.7	5.1	4.7
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	4.9	5.0	5.8	6.1	5.9
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	16	12	11	3	3
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	14.6	9.0	4.3	3.4	4.7
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Yellowish Red	Yellowish Red	Dark Brown	Dark Brown	Dark Brown
Texture	----	-	-	Silty Clay Loam	Silty Clay Loam	Rocks	Rocks	Rocks
Emerson Class Number	EC/TC	-	-	4	4	8	8	8
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	4.3	2.7	0.2	----	0.4
Exchangeable Aluminium	----	0.1	meq/100g	3.5	2.1	<0.1	----	0.3
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	0.3	0.2	3.0	2.2	0.7
Exchangeable Magnesium	----	0.1	meq/100g	4.7	2.7	1.1	0.9	1.6
Exchangeable Potassium	----	0.1	meq/100g	0.1	<0.1	0.8	0.2	<0.1
Exchangeable Sodium	----	0.1	meq/100g	0.1	<0.1	<0.1	<0.1	<0.1
Cation Exchange Capacity	----	0.1	meq/100g	9.5	5.6	5.1	----	2.7
Cation Exchange Capacity	----	0.1	meq/100g	----	----	----	3.4	----
Exchangeable Sodium Percent	----	0.1	%	2.4	2.8	0.4	0.7	2.0
Calcium/Magnesium Ratio	----	0.1	-	<0.1	<0.1	2.7	2.4	0.4
Magnesium/Potassium Ratio	----	0.1	-	31.6	----	1.4	3.7	----
ED021: Bicarbonate Extractable Potassium (Colwell)								
Bicarbonate Extractable K (Colwell)	----	10	mg/kg	<200	<200	495	235	<200
ED037: Alkalinity								
ø Total Alkalinity as CaCO3	----	1	mg/kg	126	108	414	216	90
ø Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	126	108	414	216	90
ø Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	<5	<5	<5	<5	<5
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	20	20	<10	<10	<10
ED045G: Chloride by Discrete Analyser								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S48 110-130cm	S48 90-110cm	S48 0-10cm	S48 20-40cm	S48 50-80cm
			Client sampling date / time	[24-Aug-2017]	[24-Aug-2017]	[24-Aug-2017]	[24-Aug-2017]	[24-Aug-2017]
Compound	CAS Number	LOR	Unit	EB1720219-006	EB1720219-007	EB1720219-008	EB1720219-009	EB1720219-010
				Result	Result	Result	Result	Result
ED045G: Chloride by Discrete Analyser - Continued								
Chloride	16887-00-6	10	mg/kg	<10	<10	<10	<10	<10
ED092: DTPA Extractable Metals								
ø **Copper**	7440-50-8	1.00	mg/kg	<1.00	<1.00	<1.00	<1.00	<1.00
ø **Iron**	7439-89-6	1.00	mg/kg	**11.8**	**9.94**	**67.6**	**8.54**	**6.88**
ø **Manganese**	7439-96-5	1.00	mg/kg	<1.00	<1.00	**58.5**	**6.30**	<1.00
ø **Zinc**	7440-66-6	1.00	mg/kg	<1.00	<1.00	**1.02**	<1.00	<1.00
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	<10	<10	<10	<10	<10
Magnesium	7439-95-4	10	mg/kg	<10	<10	<10	<10	<10
Sodium	7440-23-5	10	mg/kg	**10**	<10	<10	<10	<10
Potassium	7440-09-7	10	mg/kg	<10	<10	**10**	<10	<10
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**10800**	**4800**	**5850**	**5330**	**4630**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	**0.5**	**0.3**	**2.2**	**0.6**	**0.2**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	**0.5**	**0.3**	**2.2**	**0.6**	**0.2**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**180**	**140**	**1200**	**320**	**160**
EK062: Total Nitrogen as N (TKN + NOx)								
^ **Total Nitrogen as N**	----	20	mg/kg	**180**	**140**	**1200**	**320**	**160**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**76**	**112**	**228**	**148**	**127**
EK080: Bicarbonate Extractable Phosphorus (Colwell)								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	<5	<5	<5	<5	<5
EP004: Organic Matter								
Organic Matter	----	0.5	%	**0.7**	<0.5	**4.9**	**1.1**	**0.6**
Total Organic Carbon	----	0.5	%	<0.5	<0.5	**2.8**	**0.6**	<0.5

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S5 70-90cm	S5 90-120cm	S5 30-50cm	S5 10-30cm	S5 0-10cm
			Client sampling date / time	[27-Aug-2017]	[27-Aug-2017]	[27-Aug-2017]	[27-Aug-2017]	[27-Aug-2017]
Compound	CAS Number	LOR	Unit	EB1720219-011	EB1720219-012	EB1720219-013	EB1720219-014	EB1720219-015
				Result	Result	Result	Result	Result
EA001: pH in soil using 0.01M CaCl extract								
pH (CaCl2)	----	0.1	pH Unit	5.7	6.1	5.6	5.8	5.1
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	6.0	7.1	6.4	6.8	6.0
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	755	282	581	108	86
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	12.4	8.0	14.9	10.2	5.0
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Brown	Greyish Brown	Greyish Brown	Greyish Brown	Dark Greyish Brown
Texture	----	-	-	Silty Clay Loam	Sandy Clay	Silty Clay Loam	Silty Clay Loam	Silty Loam
Emerson Class Number	EC/TC	-	-	2	1	1	1	7
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	----	----	----	----	0.1
Exchangeable Aluminium	----	0.1	meq/100g	----	----	----	----	<0.1
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	----	1.6	----	3.5	3.4
Exchangeable Magnesium	----	0.1	meq/100g	----	5.3	----	8.2	5.0
Exchangeable Potassium	----	0.1	meq/100g	----	0.3	----	0.5	0.8
Exchangeable Sodium	----	0.1	meq/100g	----	3.1	----	1.6	0.5
Cation Exchange Capacity	----	0.1	meq/100g	----	----	----	----	9.8
Cation Exchange Capacity	----	0.1	meq/100g	----	10.4	----	13.9	----
Exchangeable Sodium Percent	----	0.1	%	----	30.3	----	11.7	5.4
Calcium/Magnesium Ratio	----	0.1	-	----	0.3	----	0.4	0.7
Magnesium/Potassium Ratio	----	0.1	-	----	15.9	----	16.0	6.6
ED008: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	1.6	----	2.4	----	----
Exchangeable Magnesium	----	0.1	meq/100g	4.6	----	6.3	----	----
Exchangeable Potassium	----	0.1	meq/100g	0.2	----	0.3	----	----
Exchangeable Sodium	----	0.1	meq/100g	1.0	----	1.3	----	----
Cation Exchange Capacity	----	0.1	meq/100g	7.6	----	10.4	----	----
Exchangeable Sodium Percent	----	0.1	%	13.9	----	12.4	----	----
Calcium/Magnesium Ratio	----	0.1	-	0.3	----	0.4	----	----
Magnesium/Potassium Ratio	----	0.1	-	17.8	----	19.8	----	----
ED021: Bicarbonate Extractable Potassium (Colwell)								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S5 70-90cm	S5 90-120cm	S5 30-50cm	S5 10-30cm	S5 0-10cm
			Client sampling date / time	[27-Aug-2017]	[27-Aug-2017]	[27-Aug-2017]	[27-Aug-2017]	[27-Aug-2017]
Compound	CAS Number	LOR	Unit	EB1720219-011	EB1720219-012	EB1720219-013	EB1720219-014	EB1720219-015
				Result	Result	Result	Result	Result
ED021: Bicarbonate Extractable Potassium (Colwell) - Continued								
Bicarbonate Extractable K (Colwell)	----	10	mg/kg	331	270	364	358	472
ED037: Alkalinity								
ø Total Alkalinity as CaCO3	----	1	mg/kg	414	450	864	783	2380
ø Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	414	450	864	783	2380
ø Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	<5	<5	<5	<5	<5
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	250	60	180	10	30
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	1290	410	960	140	110
ED092: DTPA Extractable Metals								
ø Copper	7440-50-8	1.00	mg/kg	1.11	<1.00	1.24	1.21	<1.00
ø Iron	7439-89-6	1.00	mg/kg	19.6	5.10	39.7	39.2	91.4
ø Manganese	7439-96-5	1.00	mg/kg	54.2	6.76	9.52	18.6	96.0
ø Zinc	7440-66-6	1.00	mg/kg	<1.00	<1.00	<1.00	<1.00	3.45
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	10	<10	<10	<10	<10
Magnesium	7439-95-4	10	mg/kg	20	<10	10	<10	<10
Sodium	7440-23-5	10	mg/kg	850	290	650	90	70
Potassium	7440-09-7	10	mg/kg	<10	<10	<10	<10	20
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	8210	6740	11700	11000	9370
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	0.4
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	0.3	<0.1	<0.1	<0.1	0.2
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	0.3	<0.1	<0.1	<0.1	0.6
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	190	120	300	540	2030
EK062: Total Nitrogen as N (TKN + NOx)								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S5 70-90cm	S5 90-120cm	S5 30-50cm	S5 10-30cm	S5 0-10cm
			Client sampling date / time	[27-Aug-2017]	[27-Aug-2017]	[27-Aug-2017]	[27-Aug-2017]	[27-Aug-2017]
Compound	CAS Number	LOR	Unit	EB1720219-011	EB1720219-012	EB1720219-013	EB1720219-014	EB1720219-015
				Result	Result	Result	Result	Result
EK062: Total Nitrogen as N (TKN + NOx) - Continued								
^ Total Nitrogen as N	----	20	mg/kg	**190**	**120**	**300**	**540**	**2030**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**103**	**70**	**77**	**100**	**268**
EK080: Bicarbonate Extractable Phosphorus (Colwell)								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	<5	<5	<5	<5	**6**
EP004: Organic Matter								
Organic Matter	----	0.5	%	**0.7**	<0.5	**0.7**	**0.9**	**2.3**
Total Organic Carbon	----	0.5	%	<0.5	<0.5	<0.5	**0.5**	**1.4**

Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

			Client sample ID	S12 0-10cm	S12 10-25cm	S12 50-70cm	S12 90-120cm	S12 25-40cm
			Client sampling date / time	[27-Aug-2017]	[27-Aug-2017]	[27-Aug-2017]	[27-Aug-2017]	[27-Aug-2017]
Compound	CAS Number	LOR	Unit	EB1720219-016	EB1720219-017	EB1720219-018	EB1720219-019	EB1720219-020
				Result	Result	Result	Result	Result
EA001: pH in soil using 0.01M CaCl extract								
pH (CaCl2)	----	0.1	pH Unit	4.8	4.7	4.6	4.5	7.4
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	5.8	5.9	5.8	5.6	8.6
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	17	7	22	11	133
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	4.8	5.9	11.8	7.6	6.3
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Very Dark Brown	Brown	Brown	Brown	Brown
Texture	----	-	-	Silty Loam	Silty Clay Loam	Silty Clay Loam	Sandy Clay	Silty Clay Loam
Emerson Class Number	EC/TC	-	-	7	4	4	1	4
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	<0.1	<0.1	0.3	<0.1	----
Exchangeable Aluminium	----	0.1	meq/100g	<0.1	<0.1	0.2	<0.1	----
ED006: Exchangeable Cations on Alkaline Soils								
Exchangeable Calcium	----	0.2	meq/100g	----	----	----	----	0.3
Exchangeable Magnesium	----	0.2	meq/100g	----	----	----	----	<0.2
Exchangeable Potassium	----	0.2	meq/100g	----	----	----	----	<0.2
Exchangeable Sodium	----	0.2	meq/100g	----	----	----	----	<0.2
Cation Exchange Capacity	----	0.2	meq/100g	----	----	----	----	0.4
Exchangeable Sodium Percent	----	0.2	%	----	----	----	----	<0.2
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	3.7	1.6	3.2	2.8	----
Exchangeable Magnesium	----	0.1	meq/100g	1.8	1.2	7.5	5.0	----
Exchangeable Potassium	----	0.1	meq/100g	0.9	0.5	0.4	0.3	----
Exchangeable Sodium	----	0.1	meq/100g	<0.1	<0.1	0.6	1.6	----
Cation Exchange Capacity	----	0.1	meq/100g	----	----	12.1	----	----
Cation Exchange Capacity	----	0.1	meq/100g	6.5	3.4	----	9.8	----
Exchangeable Sodium Percent	----	0.1	%	0.7	0.9	5.1	16.5	----
Calcium/Magnesium Ratio	----	0.1	-	2.0	1.3	0.4	0.6	----
Magnesium/Potassium Ratio	----	0.1	-	1.9	2.6	17.0	16.0	----
ED021: Bicarbonate Extractable Potassium (Colwell)								
Bicarbonate Extractable K (Colwell)	----	10	mg/kg	481	343	372	295	341
ED037: Alkalinity								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S12 0-10cm	S12 10-25cm	S12 50-70cm	S12 90-120cm	S12 25-40cm
			Client sampling date / time	[27-Aug-2017]	[27-Aug-2017]	[27-Aug-2017]	[27-Aug-2017]	[27-Aug-2017]
Compound	CAS Number	LOR	Unit	EB1720219-016	EB1720219-017	EB1720219-018	EB1720219-019	EB1720219-020
				Result	Result	Result	Result	Result
ED037: Alkalinity - Continued								
ø Total Alkalinity as CaCO3	----	1	mg/kg	**1650**	**819**	**369**	**126**	**2390**
ø Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	**1650**	**819**	**369**	**126**	**2300**
ø Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	<5	<5	<5	<5	**90**
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	<10	<10	**30**	**20**	**40**
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	**10**	<10	<10	<10	**140**
ED092: DTPA Extractable Metals								
ø Copper	7440-50-8	1.00	mg/kg	<1.00	<1.00	<1.00	<1.00	<1.00
ø Iron	7439-89-6	1.00	mg/kg	**107**	**19.1**	**22.7**	**5.79**	**16.7**
ø Manganese	7439-96-5	1.00	mg/kg	**119**	**37.1**	**10.1**	**3.60**	**27.5**
ø Zinc	7440-66-6	1.00	mg/kg	**3.12**	<1.00	<1.00	<1.00	<1.00
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	<10	<10	<10	<10	<10
Magnesium	7439-95-4	10	mg/kg	<10	<10	<10	<10	<10
Sodium	7440-23-5	10	mg/kg	<10	<10	**20**	<10	**130**
Potassium	7440-09-7	10	mg/kg	**20**	<10	<10	<10	<10
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**5670**	**5160**	**13600**	**6100**	**5200**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	**0.4**	<0.1	<0.1	<0.1	<0.1
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	**0.4**	<0.1	<0.1	<0.1	<0.1
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**1900**	**400**	**360**	**120**	**280**
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	**1900**	**400**	**360**	**120**	**280**
EK067G: Total Phosphorus as P by Discrete Analyser								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S12 0-10cm	S12 10-25cm	S12 50-70cm	S12 90-120cm	S12 25-40cm
			Client sampling date / time	[27-Aug-2017]	[27-Aug-2017]	[27-Aug-2017]	[27-Aug-2017]	[27-Aug-2017]
Compound	CAS Number	LOR	Unit	EB1720219-016	EB1720219-017	EB1720219-018	EB1720219-019	EB1720219-020
				Result	Result	Result	Result	Result
EK067G: Total Phosphorus as P by Discrete Analyser - Continued								
Total Phosphorus as P	----	2	mg/kg	**297**	**147**	**129**	**112**	**126**
EK080: Bicarbonate Extractable Phosphorus (Colwell)								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	**6**	<5	<5	<5	<5
EP004: Organic Matter								
Organic Matter	----	0.5	%	**3.4**	**0.8**	**0.6**	**0.6**	<0.5
Total Organic Carbon	----	0.5	%	**2.0**	<0.5	<0.5	<0.5	<0.5

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB1721328**	Page	: 1 of 8
Client	: **EMM CONSULTING PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MS KYLIE DRAPALA	Contact	: Customer Services EB
Address	: 1/4 87 WICKHAM TERRACE SPRING HILL QLD 4000	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: 07 3839 1800	Telephone	: +61-7-3243 7222
Project	: Mangoola BSAL	Date Samples Received	: 16-Oct-2017 14:20
Order number	: ----	Date Analysis Commenced	: 17-Oct-2017
C-O-C number	: ----	Issue Date	: 25-Oct-2017 13:30
Sampler	: NICHOLAS JAMSON		
Site	: ----		
Quote number	: SYBQ/202/16		
No. of samples received	: 10		
No. of samples analysed	: 10		

ilac-MRA NATA

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ben Felgendrejeris		Brisbane Acid Sulphate Soils, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- ED021 (Bicarbonate Extractable K Colwell) LOR for some samples have been raised due to matrix interference.
- ED006 (Exchangeable Cations on Alkaline Soils): Magnesium/Potassium ratio could not be determined as both the Magnesium and Potassium results were less than reportable limits for some samples.
- EA058 Emerson: V. = Very, D. = Dark, L. = Light, VD. = Very Dark
- ED007 and ED008: When Exchangeable Al is reported from these methods, it should be noted that Rayment & Lyons (2011) suggests Exchange Acidity by 1M KCl - Method 15G1 (ED005) is a more suitable method for the determination of exchange acidity (H+ + Al3+).

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S53, 0-10cm A1	S53, 10-30cm A2	S53, 30-50cm A2	S53, 50-70cm B2	S53, 100-120cm B2
			Client sampling date / time	24-Aug-2017 00:00	24-Aug-2017 00:00	24-Aug-2017 00:00	24-Aug-2017 00:00	24-Aug-2017 00:00
Compound	CAS Number	LOR	Unit	EB1721328-001	EB1721328-002	EB1721328-003	EB1721328-004	EB1721328-005
				Result	Result	Result	Result	Result
EA001: pH in soil using 0.01M CaCl extract								
pH (CaCl2)	----	0.1	pH Unit	4.7	5.5	5.8	6.2	6.6
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	5.5	6.5	6.6	7.1	7.8
EA008: Calcium Carbonate Equivalent								
CaCO3 Equivalent	----	0.01	%	4.88	4.82	7.09	7.92	4.72
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	27	6	6	16	35
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	4.1	4.3	4.6	6.6	7.1
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Very Dark Brown	Dark Brown	Dark Brown	Brown	Brown
Texture	----	-	-	Sand	Sand	Sand	Sandy Loam	Sandy Loam
Emerson Class Number	EC/TC	-	-	8	8	8	3	3
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	<0.1	----	----	----	----
Exchangeable Aluminium	----	0.1	meq/100g	<0.1	----	----	----	----
ED006: Exchangeable Cations on Alkaline Soils								
Exchangeable Calcium	----	0.2	meq/100g	----	----	----	----	0.7
Exchangeable Magnesium	----	0.2	meq/100g	----	----	----	----	1.0
Exchangeable Potassium	----	0.2	meq/100g	----	----	----	----	<0.2
Exchangeable Sodium	----	0.2	meq/100g	----	----	----	----	<0.2
Cation Exchange Capacity	----	0.2	meq/100g	----	----	----	----	1.7
Exchangeable Sodium Percent	----	0.2	%	----	----	----	----	<0.2
Calcium/Magnesium Ratio	----	0.2	-	----	----	----	----	0.7
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	----	2.0	1.7	1.8	----
Exchangeable Magnesium	----	0.1	meq/100g	----	0.6	0.8	1.7	----
Exchangeable Potassium	----	0.1	meq/100g	----	0.2	0.1	0.1	----
Exchangeable Sodium	----	0.1	meq/100g	----	<0.1	<0.1	0.1	----
Cation Exchange Capacity	----	0.1	meq/100g	----	2.9	2.7	3.8	----
Exchangeable Sodium Percent	----	0.1	%	----	0.8	1.8	3.7	----
Calcium/Magnesium Ratio	----	0.1	-	----	3.3	2.1	1.0	----
Magnesium/Potassium Ratio	----	0.1	-	----	2.3	5.6	16.7	----
ED008: Exchangeable Cations								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S53, 0-10cm A1	S53, 10-30cm A2	S53, 30-50cm A2	S53, 50-70cm B2	S53, 100-120cm B2
			Client sampling date / time	24-Aug-2017 00:00	24-Aug-2017 00:00	24-Aug-2017 00:00	24-Aug-2017 00:00	24-Aug-2017 00:00
Compound	CAS Number	LOR	Unit	EB1721328-001	EB1721328-002	EB1721328-003	EB1721328-004	EB1721328-005
				Result	Result	Result	Result	Result
ED008: Exchangeable Cations - Continued								
Exchangeable Calcium	----	0.1	meq/100g	**2.9**	----	----	----	----
Exchangeable Magnesium	----	0.1	meq/100g	**0.8**	----	----	----	----
Exchangeable Potassium	----	0.1	meq/100g	**0.4**	----	----	----	----
Exchangeable Sodium	----	0.1	meq/100g	<0.1	----	----	----	----
Cation Exchange Capacity	----	0.1	meq/100g	**4.3**	----	----	----	----
Exchangeable Sodium Percent	----	0.1	%	<0.1	----	----	----	----
Calcium/Magnesium Ratio	----	0.1	-	**3.6**	----	----	----	----
Magnesium/Potassium Ratio	----	0.1	-	**2.2**	----	----	----	----
ED021: Bicarbonate Extractable Potassium (Colwell)								
Bicarbonate Extractable K (Colwell)	----	10	mg/kg	**439**	**235**	<200	<200	<200
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	<10	<10	<10	**10**	**30**
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	<10	<10	<10	<10	<10
ED092: DTPA Extractable Metals								
ø Copper	7440-50-8	1.00	mg/kg	<1.00	<1.00	<1.00	<1.00	<1.00
ø Iron	7439-89-6	1.00	mg/kg	**93.0**	**9.83**	**4.46**	**5.42**	**5.90**
ø Manganese	7439-96-5	1.00	mg/kg	**51.0**	**6.67**	**3.62**	**5.61**	**3.72**
ø Zinc	7440-66-6	1.00	mg/kg	**1.46**	<1.00	<1.00	<1.00	<1.00
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	<10	<10	<10	<10	<10
Magnesium	7439-95-4	10	mg/kg	<10	<10	<10	<10	<10
Sodium	7440-23-5	10	mg/kg	<10	<10	<10	**20**	**40**
Potassium	7440-09-7	10	mg/kg	**20**	<10	<10	<10	<10
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**4500**	**4030**	**4220**	**6540**	**10300**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	**0.1**	<0.1	<0.1	<0.1	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	**10.6**	**1.0**	**0.4**	**0.4**	**0.4**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)

Compound	CAS Number	LOR	Unit	S53, 0-10cm A1	S53, 10-30cm A2	S53, 30-50cm A2	S53, 50-70cm B2	S53, 100-120cm B2
Client sampling date / time				24-Aug-2017 00:00	24-Aug-2017 00:00	24-Aug-2017 00:00	24-Aug-2017 00:00	24-Aug-2017 00:00
				EB1721328-001	EB1721328-002	EB1721328-003	EB1721328-004	EB1721328-005
				Result	Result	Result	Result	Result
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	10.7	1.0	0.4	0.4	0.4
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	990	260	150	150	130
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	1000	260	150	150	130
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	199	98	76	58	61
EK080: Bicarbonate Extractable Phosphorus (Colwell)								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	<5	<5	<5	<5	<5
EP004: Organic Matter								
Organic Matter	----	0.5	%	2.3	0.7	0.6	0.6	<0.5
Total Organic Carbon	----	0.5	%	1.3	<0.5	<0.5	<0.5	<0.5

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S19, 0-10cm A1	S19, 11-25cm A3	S19, 25-45cm B21	S19, 75-95cm B21	S19, 95-120cm B22
			Client sampling date / time	27-Aug-2017 00:00	27-Aug-2017 00:00	27-Aug-2017 00:00	27-Aug-2017 00:00	27-Aug-2017 00:00
Compound	CAS Number	LOR	Unit	EB1721328-006	EB1721328-007	EB1721328-008	EB1721328-009	EB1721328-010
				Result	Result	Result	Result	Result
EA001: pH in soil using 0.01M CaCl extract								
pH (CaCl2)	----	0.1	pH Unit	5.5	4.2	5.5	5.7	6.3
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	6.6	6.6	6.6	6.6	7.4
EA008: Calcium Carbonate Equivalent								
CaCO3 Equivalent	----	0.01	%	3.85	3.28	3.54	2.97	3.95
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	25	7	6	7	47
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	2.3	2.5	3.5	4.1	7.0
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Very Dark Brown	Dark Brown	Dark Brown	Dark Yellowish Brown	Dark Yellowish Brown
Texture	----	-	-	Sand	Sand	Sand	Sand	Sandy Loam
Emerson Class Number	EC/TC	-	-	8	8	8	8	2
ED006: Exchangeable Cations on Alkaline Soils								
Exchangeable Calcium	----	0.2	meq/100g	----	----	----	----	0.6
Exchangeable Magnesium	----	0.2	meq/100g	----	----	----	----	0.5
Exchangeable Potassium	----	0.2	meq/100g	----	----	----	----	<0.2
Exchangeable Sodium	----	0.2	meq/100g	----	----	----	----	<0.2
Cation Exchange Capacity	----	0.2	meq/100g	----	----	----	----	1.1
Exchangeable Sodium Percent	----	0.2	%	----	----	----	----	<0.2
Calcium/Magnesium Ratio	----	0.2	-	----	----	----	----	1.0
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	2.4	1.6	1.6	1.4	----
Exchangeable Magnesium	----	0.1	meq/100g	1.0	0.6	0.3	0.2	----
Exchangeable Potassium	----	0.1	meq/100g	0.7	0.3	0.3	0.3	----
Exchangeable Sodium	----	0.1	meq/100g	<0.1	<0.1	<0.1	<0.1	----
Cation Exchange Capacity	----	0.1	meq/100g	4.2	2.6	2.3	2.0	----
Exchangeable Sodium Percent	----	0.1	%	0.5	0.5	0.8	1.7	----
Calcium/Magnesium Ratio	----	0.1	-	2.4	2.7	5.3	7.0	----
Magnesium/Potassium Ratio	----	0.1	-	1.6	1.7	1.0	0.8	----
ED021: Bicarbonate Extractable Potassium (Colwell)								
Bicarbonate Extractable K (Colwell)	----	10	mg/kg	408	237	<200	<200	300
ED040S : Soluble Sulfate by ICPAES								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S19, 0-10cm A1	S19, 11-25cm A3	S19, 25-45cm B21	S19, 75-95cm B21	S19, 95-120cm B22
			Client sampling date / time	27-Aug-2017 00:00	27-Aug-2017 00:00	27-Aug-2017 00:00	27-Aug-2017 00:00	27-Aug-2017 00:00
Compound	CAS Number	LOR	Unit	EB1721328-006	EB1721328-007	EB1721328-008	EB1721328-009	EB1721328-010
				Result	Result	Result	Result	Result
ED040S : Soluble Sulfate by ICPAES - Continued								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	<10	<10	<10	<10	**30**
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	<10	<10	<10	<10	**50**
ED092: DTPA Extractable Metals								
ø Copper	7440-50-8	1.00	mg/kg	<1.00	<1.00	<1.00	<1.00	<1.00
ø Iron	7439-89-6	1.00	mg/kg	**29.7**	**9.00**	**6.04**	**5.29**	**7.93**
ø Manganese	7439-96-5	1.00	mg/kg	**33.1**	**19.0**	**9.35**	<1.00	**1.41**
ø Zinc	7440-66-6	1.00	mg/kg	**1.04**	<1.00	<1.00	<1.00	<1.00
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	<10	<10	<10	<10	<10
Magnesium	7439-95-4	10	mg/kg	<10	<10	<10	<10	<10
Sodium	7440-23-5	10	mg/kg	<10	<10	<10	<10	**50**
Potassium	7440-09-7	10	mg/kg	**30**	<10	<10	<10	<10
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**2760**	**2600**	**2420**	**2160**	**3280**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	**0.3**	<0.1	<0.1	<0.1	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	**4.0**	**0.7**	**0.4**	**1.8**	**0.3**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	**4.3**	**0.7**	**0.4**	**1.8**	**0.3**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**1130**	**220**	**140**	**110**	**130**
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	**1130**	**220**	**140**	**110**	**130**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**176**	**108**	**90**	**107**	**66**
EK080: Bicarbonate Extractable Phosphorus (Colwell)								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	<5	<5	<5	<5	<5
EP004: Organic Matter								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	S19, 0-10cm A1	S19, 11-25cm A3	S19, 25-45cm B21	S19, 75-95cm B21	S19, 95-120cm B22
			Client sampling date / time	27-Aug-2017 00:00	27-Aug-2017 00:00	27-Aug-2017 00:00	27-Aug-2017 00:00	27-Aug-2017 00:00
Compound	CAS Number	LOR	Unit	EB1721328-006	EB1721328-007	EB1721328-008	EB1721328-009	EB1721328-010
				Result	Result	Result	Result	Result
EP004: Organic Matter - Continued								
Organic Matter	----	0.5	%	**3.3**	**0.9**	**0.7**	<0.5	**0.6**
Total Organic Carbon	----	0.5	%	**1.9**	**0.5**	<0.5	<0.5	<0.5

Appendix D

Land and soil capability assessment

Land and Soil Capability Assessment

Mangoola Coal Continued Operations (MCCO) Project

Prepared for Mangoola Coal Operations Pty Limited
May 2019

EMM Brisbane
Level 10, 87 Wickham Terrace
Spring Hill QLD 4000

T 07 3648 1200
E info@emmconsulting.com.au

www.emmconsulting.com.au

Land and Soil Capability Assessment

Mangoola Coal Continued Operations (MCCO) Project

Report Number

B17193 LSC

Client

Mangoola Coal Operations Pty Limited

Date

May 2019

Version

v2

Document Control

Version	Date	Prepared by	Reviewed by
V01	June 2018	K Drapala	T Rohde
V02	May 2019		C Richards

This report has been prepared in accordance with the brief provided by the client and has relied upon the information collected at the time and under the conditions specified in the report. All findings, conclusions or recommendations contained in the report are based on the aforementioned circumstances. The report is for the use of the client and no responsibility will be taken for its use by other parties. The client may, at its discretion, use the report to inform regulators and the public.

Table of Contents

Tables

Figures

1 Introduction

EMM Consulting Pty Limited (EMM) has been engaged by Mangoola Coal Operations Pty Limited (Mangoola) to complete a Land and Soil Capability (LSC) Assessment for the Mangoola Coal Continued Operations Project (MCCO Project). The purpose of the assessment is to form part of an Environmental Impact Statement being prepared by Umwelt Environmental and Social Consultants (Umwelt) to support an application for development consent under Division 4.1 and 4.7 of Part 4 of the Environmental Planning and Assessment Act 1979 (EP&A Act) for the MCCO Project.

1.1 Purpose of this Report

This report is focused on meeting the requirements of *The land and soil capability assessment scheme* (OEH 2012). The land and soil capability assessment scheme (OEH 2012) outlines the process to assess the limitations of land-use based on the biophysical characteristics of the land. It should be noted that the tables enclosed within this report are either directly replicated or adapted from OEH 2012.

1.2 Overview of the Land and Soil Capability Scheme

Land capability is based on an assessment of the biophysical characteristics of the land, the extent to which this will limit a particular type of land use, and the current technology that is available for the management of the land. It provides information on the broad agricultural land uses most physically suited to an area, that is, the uses with the best match between the physical requirements of the use and the physical qualities of the land, and the potential hazards and limitations associated with specific uses over a site. It can provide guidance on the inputs and management requirements associated with different intensities of agricultural land use (OEH 2012).

The LSC Scheme concentrates on the assessment of the likely land degradation hazards associated with implementing a broad agricultural land use on an area of land. The objective is to prevent on-site and off-site environmental degradation. The LSC Scheme generally applies to low intensity, dry-land agriculture, however, it can identify some of the hazards that may influence more intense land uses. The LSC Scheme has the capacity to be applied at the paddock, farm, regional and state scale, and it relies on general land, climate and soil information.

The LSC assessment scheme uses the biophysical features of the land and soil including landform position, slope gradient, drainage, climate, soil type and soil characteristics to derive detailed rating tables for a range of land and soil hazards. These hazards include water erosion, wind erosion, soil structure decline, soil acidification, salinity, waterlogging, shallow soils and mass movement. Each hazard is given a rating between 1 (best, highest capability land) and 8 (worst, lowest capability land). The final LSC class of the land is based on the most limiting hazard.

An explanation of each of the eight hazards or limitations assessed to determine the overall LSC class is contained in Section 5 of the *land and soil capability assessment scheme 2nd approximation* (OEH 2012). These hazards were assessed for the MCCO Additional Project Area and presented separately in Sections 3 to 10 of this report, with a summary table presented in Section 11. The land and soil capability (LSC) classes present on a property are determined at the farm scale for each soil management unit (SMU). This is done using the information collected during the field survey and supplemented with information gathered during the desktop assessment. Table 1.1 outlines the information required to make an assessment of land and soil capability classes and their definitions (OEH 2012). Table 1.2 provides definitions of the land and soil capability classes.

Table 1.1 Data requirements for determining LSC classes (OEH 2012)

	Water erosion	Wind erosion	Soil structure decline	Soil acidification	Salinity	Water-logging	Shallow soils and rock	Mass movement
NSW Division	✓							
Sand dune or mobile sand body	✓							
Slope %	✓							✓
Scree or talus slope								✓
Footslope or drainage plain receiving high run-on	✓							
Gully erosion or sodic dispersible subsoils	✓							
Annual rainfall		✓		✓				✓
Wind erosive power		✓						
Exposure to wind		✓						
Surface soil texture		✓	✓	✓				
Surface soil texture modifier			✓					
Great Soil Group				✓				
pH of surface soil				✓				
Surface soil modifier				✓				
Parent material				✓				
Recharge potential of landscape					✓			
Discharge potential of landscape					✓			
Salt store of landscape					✓			
Waterlogging duration						✓		
Return period of waterlogging						✓		
Rocky outcrop							✓	
Soil depth							✓	
Presence of existing mass movement								✓

Table 1.2 Land and soil capability classes - general definitions (EOH 2012)

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

2 New South Wales land divisions

The land and soil capability assessment scheme (OEH 2012) applies different criteria to properties depending on their location in New South Wales (NSW). Under the *Crown Lands Act of 1884*, NSW was divided into the three land division zones of Western, Central and Eastern. The first step in the assessment process is to determine which zone the property exists in. This can be determined by locating the property on the map in Figure 2.1.

Figure 2.1 Map of NSW land divisions

This can be achieved through examination of the 1907 Map of New South Wales. The MCCO Additional Project Area is located within the Eastern Land Division.

3 Assessment of water erosion LSC class

Table 3.1 outlines the assessment table for determining water erosion LSC classes. The assessment has been based on the criteria applicable to the Eastern Land Division. Table 3.2 outlines the results table for water erosion LSC classes for each of the detailed sites in the project area.

Table 3.1 Water erosion LSC class assessment table (OEH 2012)

NSW division	Slope class (%) for each LSC class							
	Class 1	**Class 2**	**Class 3**	**Class 4[1]**	**Class 5[2]**	**Class 6**	**Class 7**	**Class 8**
Eastern and Central divisions	<1	1 to <3	3 to <10 or 1 to <3 with slopes >500m length	10 to <20	10 to <20	20 to <33	33 to <50	>50
Western division[3]	<1	1 to <3 or <1 for hardsetting red soils	1 to 3	3 to 5	3 to 5	5 to 33	33 to 50	>50

Notes: 1.No gully erosion or sodic/dispersible soils are present.
2. Gully erosion and/or sodic/dispersible soils are present.
3. Western CMA provided advice on slope classes.

Table 3.2 Water erosion LSC classes for the SMUs within the MCCO Additional Project Area

Site ID	Slope (%)[1]	Slope class (%)[1]	Water Erosion LSC class
Dermosol			
55(A1)	3	3 to <10%	3
4	2	1 to <3%	2
5	3	3 to <10%	3
12	2	1 to <3%	2
Kurosol			
41	5	3 to <10%	3
48	6	3 to <10%	3
54	11	10 to 20%	4
Tenosol			
37	3	3 to <10%	3
20	3	3 to <10%	3
21	3	3 to <10%	3
22	3	3 to <10%	3
28	3	3 to <10%	3

Table 3.2 Water erosion LSC classes for the SMUs within the MCCO Additional Project Area

Site ID	Slope (%)[1]	Slope class (%)[1]	Water Erosion LSC class
29	3	3 to <10%	3
30	4	3 to <10%	3
45	2	1 to <3%	2
46	3	3 to <10%	3
49	5	3 to <10%	3
52	5	3 to <10%	3
Sodosol			
1	2	1 to <3%	2
2	4	3 to <10%	3
3	4	3 to <10%	3
6	4	3 to <10%	3
7	4	3 to <10%	3
8	3	3 to <10%	3
9	3	3 to <10%	3
10	3	3 to <10%	3
11	2	1 to <3%	2
13	10	10 to 20%	4
14	8	3 to <10%	3
15	5	3 to <10%	3
16	3	3 to <10%	3
17	3	3 to <10%	3
18	2	1 to <3%	2
23	4	3 to <10%	3
24	5	3 to <10%	3
25	3	3 to <10%	3
26	3	3 to <10%	3
27	1	3 to <10%	3
31	3	3 to <10%	3
32	3	3 to <10%	3
33	10	10 to 20%	4
34	5	3 to <10%	3
35	3	3 to <10%	3
36	1	1 to <3%	2
38	3	3 to <10%	3
39	2	1 to <3%	2

Table 3.2 Water erosion LSC classes for the SMUs within the MCCO Additional Project Area

Site ID	Slope (%)[1]	Slope class (%)[1]	Water Erosion LSC class
40	4	3 to <10%	3
42	7	3 to <10%	3
43	3	3 to <10%	3
44	3	3 to <10%	3
47	4	3 to <10%	3
50	5	3 to <10%	3
51	4	3 to <10%	3
Chromosol			
19	3	3 to <10%	3
53	5	3 to <10%	3

4 Assessment of wind erosion LSC class

To determine the wind erosion LSC class of surface soils assessment of the following four hazards are required:

1. wind erodibility;
2. wind erosion power;
3. exposure to wind; and
4. average yearly rainfall.

4.1 Wind erodibility

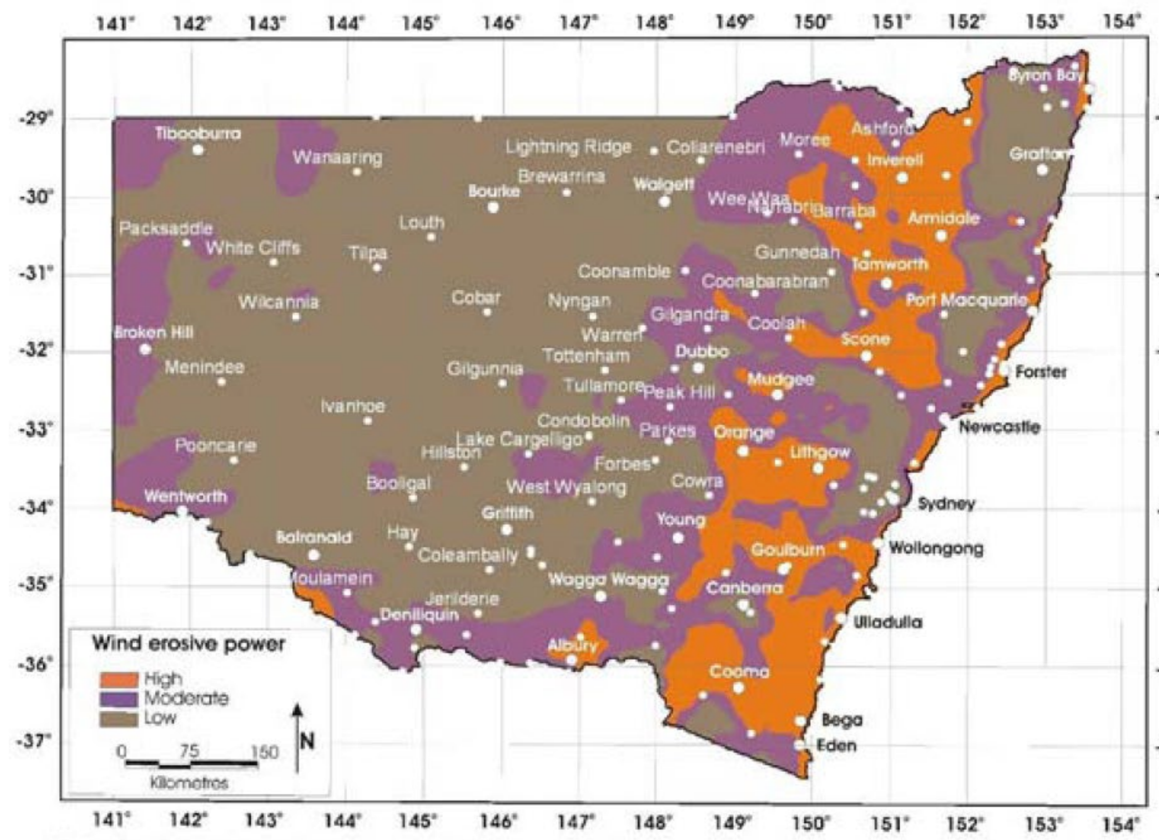
Table 4.1 outlines the assessment criteria used to determine the wind erodibility hazard of surface soil.

Table 4.1 Wind erodibility hazard of surface soils (OEH 2012)

Wind erodibility class of surface soil	Surface soil texture
Low	Loams, clay loams or clays (all with >13% clay)
Moderate	Fine sandy loams or sandy loams (all with 6–13% clay); also includes organic peats
High	Loamy sands or loose sands (all with <6% clay).

4.2 Wind erosion power

Figure 4.1 outlines the assessment figure for determining wind erosion power.



Source: NSW Department of Trade and Investment (undated).

Figure 4.1 Wind erosive power (NSW Department of Trade and Investment in OEH 2012)

4.3 Exposure to wind

Table 4.2 outlines the assessment criteria used to determine the exposure to wind class of surface soils.

Table 4.2 Exposure to wind (OEH 2012)

Exposure to wind class of surface soil	Site exposure to prevailing winds
Low	Sheltered locations in valleys or in the lee of hills
Moderate	Intermediate situations – not low or high exposure locations
High	Hilltops, cols or saddles, open plains or exposed coastal locations

4.4 Average yearly rainfall

The mean annual rainfall for the MCCO Project Area is 625 mm as sourced from http://www.bom.gov.au/climate/data/ in August 2017 (BOM 2017).

4.5 Wind erosion LSC classes

Table 4.3 outlines the assessment table for determining wind erosion LSC classes. The MCCO Additional Project Area falls in the Low scale for wind erosive power (from Figure 4.1) and the annual average rainfall is 625 mm.

Table 4.3 has been shaded for the sections that do not apply to the site based on wind erosive power and average annual rainfall. Table 4.4 outlines the results table for wind erosion LSC classes.

Table 4.3 Wind erosion LSC class assessment table (OEH 2012)

Wind erodibility class of surface soil	Wind erosive power	Exposure to wind	Average annual rainfall (mm)			
			>500	300–500	200 to <300	<200
Low	Low	Low	1	2	3	6
		Moderate	1	2	3	6
		High	2	3	4	7
	Moderate	Low	1	2	3	6
		Moderate	2	3	4	6
		High	3	4	5	7
	High	Low	2	3	4	6
		Moderate	3	4	5	7
		High	4	5	6	7
Moderate	Low	Low	2	3	4	7
		Moderate	3	4	5	7
		High	4	5	6	8
	Moderate	Low	2	3	4	6
		Moderate	3	4	5	7
		High	4	5	6	8
	High	Low	3	4	5	7
		Moderate	4	5	6	8
		High	5	6	7	8
High	Low	Low	3	4	5	7
		Moderate	4	5	6	8
		High	5	6	7	8
	Moderate	Low	4	5	6	8
		Moderate	5	6	7	8
		High	6	7	8	8
	High	Low	5	6	7	8
		Moderate	6	7	8	8
		High	7 (8*)	8	8	8

* Mobile sand bodies such as coastal beaches, foredunes and blowouts are Class 8.

Table 4.4 Wind erosion LSC classes for the SMUs within the project area

Site ID	Surface soil texture	Wind erodibility class	Landform element	Site morphology	Local relief	Exposure to wind	Wind Erosion LSC class
Dermosol							
A1	sandy clay loam	Low	valley flat	flat	extremely low (<9m)	Moderate	1
4	clay loam	Low	valley flat	flat	extremely low (<9m)	Moderate	1
5	clay loam	Low	valley flat	flat	extremely low (<9m)	Moderate	1
12	clay loam	Low	valley flat	flat	extremely low (<9m)	Moderate	1
Kurosol							
41	sandy clay loam	Moderate	hillslope	midslope	very low (9-30 m)	Moderate	3
48	sandy clay loam	Moderate	hillslope	open depression	extremely low (<9m)	Moderate	3
54	sandy loam	Moderate	hillslope	upper slope	very low (9-30 m)	Moderate	3
Tenosol							
37	sandy loam	Moderate	valley flat	lower slope	extremely low (<9m)	Moderate	3
20	loamy sand	High	hillslope	lower slope	very low (9-30 m)	Low	3
21	sandy loam	Moderate	valley flat	lower slope	very low (9-30 m)	Low	2
22	clayey sand	High	valley flat	lower slope	extremely low (<9m)	Low	3
28	sandy loam	Moderate	valley flat	flat	extremely low (<9m)	Moderate	3
29	sandy loam	Moderate	valley flat	lower slope	very low (9-30 m)	Low	2
30	sandy loam	Moderate	valley flat	lower slope	extremely low (<9m)	Low	2
45	loamy sand	High	valley flat	flat	extremely low (<9m)	Moderate	4
46	Sandy loam	Moderate	hillslope	midslope	extremely low (<9m)	Moderate	3
49	clayey sand	High	hillslope	midslope	very low (9-30 m)	Moderate	4
52	sandy clay loam	Moderate	hillslope	midslope	extremely low (<9m)	Moderate	3
Sodosol							
1	sandy loam	Moderate	valley flat	flat	very low (9-30 m)	Moderate	3
2	sandy loam	Moderate	hillslope	lower slope	extremely low (<9m)	Moderate	3

Table 4.4 Wind erosion LSC classes for the SMUs within the project area

Site ID	Surface soil texture	Wind erodibility class	Landform element	Site morphology	Local relief	Exposure to wind	Wind Erosion LSC class
3	sandy loam	Moderate	hillslope	lower slope	extremely low (<9m)	Moderate	3
6	sandy loam	Moderate	hillslope	lower slope	extremely low (<9m)	Moderate	3
7	sandy loam	Moderate	hillslope	lower slope	extremely low (<9m)	Moderate	3
8	sandy loam	Moderate	valley flat	flat	extremely low (<9m)ion	Moderate	3
9	Sandy clay loam	Low	valley flay	flat	extremely low (<9m)	Moderate	1
10	sandy clay loam	Low	valley flat	flat	extremely low (<9m)	Moderate	1
11	sandy loam	Moderate	valley flat	flat	extremely low (<9m)	Moderate	3
13	Sandy loam	Moderate	hillslope	midslope	very low (9-30 m)	Moderate	3
14	sandy clay loam	Low	hillslope	upper slope	extremely low (<9m)	Moderate	1
15	sandy clay loam	Low	hillslope	midslope	extremely low (<9m)	Moderate	1
16	sandy clay loam	Low	valley flat	flat	extremely low (<9m)	Moderate	1
17	sandy loam	Moderate	valley flat	lower slope	extremely low (<9m)	Moderate	3
18	sandy clay loam	Low	valley flat	flat	extremely low (<9m)	Moderate	1
23	sandy clay loam	Low	valley flat	lower slope	extremely low (<9m)	Moderate	1
24	sandy loam	Moderate	hillslope	midslope	extremely low (<9m)	Moderate	3
25	sandy loam	Moderate	valley flat	flat	extremely low (<9m)	Moderate	3
26	sandy loam	Moderate	valley flat	flat	extremely low (<9m)	Moderate	3
27	sandy clay loam	Low	valley flat	flat	extremely low (<9m)	Moderate	1
31	sandy loam	Moderate	valley flat	lower slope	extremely low (<9m)	Moderate	3
32	sandy clay loam	Low	valley flat	lower slope	extremely low (<9m)	Moderate	1
33	sandy clay loam	Low	hillslope	upper slope	extremely low (<9m)	Moderate	1

Table 4.4 Wind erosion LSC classes for the SMUs within the project area

Site ID	Surface soil texture	Wind erodibility class	Landform element	Site morphology	Local relief	Exposure to wind	Wind Erosion LSC class
34	sandy clay loam	Low	valley flat	lower slope	extremely low (<9m)	Moderate	1
35	silty loam	Low	valley flat	flat	very low (9-30 m)	Moderate	1
36	sandy clay loam	Low	drainage depression	open depression	very low (9-30 m)	Moderate	1
38	sandy clay loam	Low	valley flat	flat	extremely low (<9m)	Moderate	1
39	sandy loam	Moderate	valley flat	flat	extremely low (<9m)	Moderate	3
40	sandy clay loam	Low	valley flat	lower slope	extremely low (<9m)	Moderate	1
42	sandy clay loam	Low	hillslope	upperslope	extremely low (<9m)	Moderate	1
43	sandy loam	Moderate	valley flat	lower slope	extremely low (<9m)	Moderate	3
44	sandy loam	Moderate	valley flat	lower slope	extremely low (<9m)	Moderate	3
47	sandy clay loam	Low	valley flat	lower slope	extremely low (<9m)	Moderate	1
50	sandy clay loam	Low	hillslope	lowerslope	very low (9-30 m)	Moderate	1
51	sandy clay loam	Low	valley flat	lower slope	extremely low (<9m)	Moderate	1
Chromosol							
19	sandy loam	Moderate	valley flat	flat	extremely low (<9m)	Moderate	3
53	sandy clay loam	Moderate	hillslope	midslope	very low (9-30 m)	Moderate	3

5 Assessment of soil structural decline LSC class

Table 5.1 outlines the assessment table for determining soil structural decline LSC classes. Table 5.2 provides further information on the surface soil properties of clays to be used in collaboration with Table 5.1.

Table 5.1 outlines the results table for soil structural decline hazard for LSC classes in the MCCO Additional Project Area.

Table 5.1 Soil structural decline LSC class assessment table (OEH 2012)

Field texture (surface soils)	Modifier	Outcome - surface soil type	LCS class
Loose sand	Nil	Loose sand	1
Sandy loam	Nil	Fragile light textured surface soil	3
Fine sandy loam	Normal	Fragile light textured soil	3
	High levels of silt and very fine sand (>60%)	Fragile light textured soil – very hardsetting	4
Loam	Normal	Fragile medium textured soil	3
	Friable/ferric[1]	Friable medium textured soils – includes dark, friable loam soils	1
	High levels of silt and very fine sand	Fragile medium textured soil – very hardsetting	4
	Mildly sodic	Mildly sodic loam surface soil	4
	Moderately sodic	Moderately sodic loam surface soil	6
Clay loam	Normal	Fragile medium textured soil	3
	Friable/ferric[1]	Friable clay loam surface soil – includes dark, friable clay loam soils	1
	High levels of silt and very fine sand (>60%)	Fragile medium textured soil – very hardsetting	4
	Mildly sodic	Mildly sodic clay loam surface soil	4
	Moderately sodic	Moderately sodic clay loam surface soil	6
Clay	Friable/ferric[1]	Friable clay surface soil	2
	Strongly self-mulching	Strongly self-mulching surface soil	1
	Weakly self-mulching	Weakly self-mulching surface soil	3
	Mildly sodic	Mildly sodic/coarsely structured clay surface soil	4
	Moderately sodic	Moderately sodic/coarsely structured clay surface soil	6
	Strongly sodic	Strongly sodic surface soil	7
Highly organic soils	Mineral soils with high organic matter[2]	Mineral soils with high organic matter	-[2]
	Organosol/peat soils[3]	Organic/peat soils	7

[1] The occurrence of friable or ferric surface soils is associated with (a) basaltic or basic parent materials and soils of the Ferrosols groups in the Australian Soil Classification or the Krasnozems and Euchrozem Great Soil Groups, and (b) the dark loam surface soils of the Chernozems and Prairie Soils on alluvial flats.
[2] Loosely defined here as soils with over 8% organic carbon. These soils revert to the LSC class determined by the mineral component of the soils.
[3] Organosols have organic material layers over 0.4 m thick with minimum organic carbon of 12% if sands or 18% if clays (Isbell 2002).

Table 5.2 Guidelines for evaluating some surface soil properties of clays

Sodicity/size of soil structural units	Character of surface soil
Very low exchangeable sodium (<3%), high exchangeable calcium, strongly swelling clays (smectitic) as in Vertosols (GSG Black Earths) Peds/aggregates 2–5 mm in an air dry condition	Strongly self-mulching surface soil
Low exchangeable sodium (3–5%), moderate exchangeable calcium, moderately swelling clays (illitic, interstratified, kaolinitic) as in many Dermosols and fertile Chromosols (GSG, Krasnozems, Euchrozems and others) Peds/aggregates 5–10 mm in an air dry condition	Weakly self-mulching surface soil
Moderate levels of exchangeable sodium (5–8%), often moderately low exchangeable calcium relative to exchangeable magnesium (ratio <2:1) Peds/aggregates 10–20 mm in an air dry condition	Mildly sodic surface soils
High levels of exchangeable sodium (8–15%), often low exchangeable calcium relative to exchangeable magnesium (ratio <1:1) Peds/aggregates 20–50 mm in an air dry condition	Moderately sodic surface soils
Very high levels of exchangeable sodium (>15%), often very low exchangeable calcium relative to exchangeable magnesium (ratio <0.5:1) Peds/aggregates >50 mm in an air dry condition	Strongly sodic surface soils

Table 5.3 Soil structural decline LSC classes for the SMUs within the MCCO Additional Project Area

Site ID	Field texture (surface soils)	Modifier	Outcome - surface soil type	Soil structural decline LSC class
Dermosol				
A1	sandy clay loam	Mildly sodic	Mildly sodic clay loam surface soil	4
4	clay loam	Normal	Fragile medium textured soil	3
5	clay loam	Mildly sodic	Mildly sodic clay loam surface soil	4
12	clay loam	Normal	Fragile medium textured soil	3
Kurosol				
41	sandy clay loam	Normal	Fragile medium textured soil	3
48	sandy clay loam	Normal	Fragile medium textured soil	3
54	sandy loam	Nil	Fragile light textured surface soil	3
Tenosol				
37	sandy loam	Nil	Fragile light textured surface soil	3
20	loamy sand	Nil	Fragile light textured surface soil	3
21	sandy loam	Nil	Fragile light textured surface soil	3

Table 5.3 Soil structural decline LSC classes for the SMUs within the MCCO Additional Project Area

Site ID	Field texture (surface soils)	Modifier	Outcome - surface soil type	Soil structural decline LSC class
22	clayey sand	Nil	Fragile light textured surface soil	3
28	sandy loam	Nil	Fragile light textured surface soil	3
29	sandy loam	Nil	Fragile light textured surface soil	3
30	sandy loam	Nil	Fragile light textured surface soil	3
45	loamy sand	Nil	Fragile light textured surface soil	3
46	sandy loam	Nil	Fragile light textured surface soil	3
49	clayey sand	Nil	Fragile light textured surface soil	3
52	sandy clay loam	Normal	Fragile medium textured soil	3
Sodosol				
1	sandy loam	Nil	Fragile light textured surface soil	3
2	sandy loam	Nil	Fragile light textured surface soil	3
3	sandy loam	Nil	Fragile light textured surface soil	3
6	sandy loam	Nil	Fragile light textured surface soil	3
7	sandy loam	Nil	Fragile light textured surface soil	3
8	sandy loam	Nil	Fragile light textured surface soil	3
9	sandy clay loam	Normal	Fragile medium textured soil	3
10	sandy clay loam	Normal	Fragile medium textured soil	3
11	sandy loam	Nil	Fragile light textured surface soil	3
13	sandy loam	Nil	Fragile light textured surface soil	3
14	sandy clay loam	Normal	Fragile medium textured soil	3
15	sandy clay loam	Normal	Fragile medium textured soil	3
16	sandy clay loam	Normal	Fragile medium textured soil	3
17	sandy loam	Nil	Fragile light textured surface soil	3
18	sandy clay loam	Normal	Fragile medium textured soil	3
23	sandy clay loam	Normal	Fragile medium textured soil	3
24	sandy loam	Nil	Fragile light textured surface soil	3
25	sandy loam	Nil	Fragile light textured surface soil	3
26	sandy loam	Nil	Fragile light textured surface soil	3
27	sandy clay loam	Normal	Fragile medium textured soil	3
31	sandy loam	Nil	Fragile light textured surface soil	3
32	sandy clay loam	Normal	Fragile medium textured soil	3
33	sandy clay loam	Normal	Fragile medium textured soil	3
34	sandy clay loam	Normal	Fragile medium textured soil	3
35	silty loam	Nil	Fragile light textured surface soil	3
36	sandy clay loam	Normal	Fragile medium textured soil	3

Table 5.3 Soil structural decline LSC classes for the SMUs within the MCCO Additional Project Area

Site ID	Field texture (surface soils)	Modifier	Outcome - surface soil type	Soil structural decline LSC class
38	sandy clay loam	Normal	Fragile medium textured soil	3
39	sandy loam	Nil	Fragile light textured surface soil	3
40	sandy clay loam	Normal	Fragile medium textured soil	3
42	sandy clay loam	Normal	Fragile medium textured soil	3
43	sandy loam	Nil	Fragile light textured surface soil	3
44	sandy loam	Nil	Fragile light textured surface soil	3
47	sandy clay loam	Normal	Fragile medium textured soil	3
50	sandy clay loam	Normal	Fragile medium textured soil	3
51	sandy clay loam	Normal	Fragile medium textured soil	3
Chromosol				
19	sandy loam	Nil	Fragile light textured surface soil	3
53	sandy clay loam	Normal	Fragile medium textured soil	3

6 Assessment of soil acidification LSC class

Soil acidification is determined through a combination of buffering capacity of the soil surface, mean annual rainfall and pH of the natural soil surface. Buffering capacity of the soil surface can be determined through three different processes: the Great Soil Group, the surface soil texture or the geology of the area. For the MCCO Project the surface soil texture was used (Table 6.1). Table 6.2 is the assessment table that uses the buffering capacity information to determine the LSC class. The mean annual rainfall is 625 mm, so the sections of the table that are not relevant to the site rainfall have been shaded in grey. Table 6.3 outlines the results table for soil acidification LSC classes.

Table 6.1 Estimating buffering capacity of the soil surface by surface soil texture (OEH 2012)

Surface soil texture	Buffering capacity of surface soil
Sands and sandy loams – no calcium carbonate	VL (Very Low)
Sands and sandy loams – with calcium carbonate	M (Moderate)
Fine sandy loams – no calcium carbonate	L (Low)
Fine sandy loams – with calcium carbonate	M (Moderate)
Loams and clay loams – no calcium carbonate	M (Moderate)
Loams and clay loams – with calcium carbonate	H (High)
Dark loams and clay loams (e.g. topsoils in Chernozems and Prairie Soils)	H (High)
Clays – no calcium carbonate	H (High)
Clays – with calcium carbonate	VH (Very High)
Clays – with high shrink–swell	VH (Very High)

The following textures described in the field survey were not specifically listed in Table 6.1, so the buffering capacity was assumed by using the equivalent clay percentages derived from the Texture triangle diagram on international fractions (NCST 2009).

Table 6.2 Estimated buffering capacity of the soil surface by surface soil texture (OEH 2012)

Surface soil texture	Buffering capacity of surface soil
Silty clay loam	M (Moderate)
Sandy clay loam	M (Moderate)
Silty loam	M (Moderate)
Clay loam sandy	M (Moderate)
Loamy sand	L (Low)
Clayey sand	L (Low)

Table 6.2 Soil acidification LSC class assessment table (OEH 2012)

Texture/ buffering capacity	pH of the natural surface soil				
	<4.0 (CaCl2) <4.7 (water)	4.0–4.7 (CaCl2) 4.7–5.5 (water)	4.7–6.0 (CaCl2) 5.5–6.7 (water)	6.0–7.5 (CaCl2) 6.7–8.0 (water)	>7.5 (CaCl2) >8.0 (water)
Mean annual rainfall <550 mm					
Very low	6*	5	4	3	n/a
Low	5	5	3	3	n/a
Moderate	5	4	3	2	1
High	4	3	2	1	1
Very high	n/a	n/a	1	1	1
Mean annual rainfall 550–700 mm					
Very low	6*	5	5	4	n/a
Low	5	5	4	3	n/a
Moderate	5	4	3	3	1
High	n/a	n/a	2	2	1
Very high	n/a	n/a	1	1	1
Mean annual rainfall 700–900 mm					
Very low	6*	5	5	4	n/a
Low	6*	5	4	4	n/a
Moderate	5	4	3	3	2
High	n/a	n/a	2	2	1
Very high	n/a	n/a	2	1	1
Mean annual rainfall >900 mm or irrigation					
Very low	6*	5	5*	4	n/a
Low	6*	4	4	3*	n/a
Moderate	5	4	3	3	2
High	5	3	2	2	1
Very high	5	3	2	1	1

Based on natural pH status, buffering capacity and climate
* These lands usually have very low fertility.

Table 6.3 Soil acidification LSC classes for the SMUs within the MCCO Additional Project Area

Site ID	Surface soil texture	Buffering capacity of surface soil	pH of the natural surface soil (water)	Soil acidification LSC class
Dermosol				
A1	sandy clay loam	Moderate	6.3	3
4	clay loam	Moderate	6.7	3
5	clay loam	Moderate	7	3
12	clay loam	Moderate	7.1	3
Kurosol				
41	sandy clay loam	Moderate	5.5	4

Table 6.3 Soil acidification LSC classes for the SMUs within the MCCO Additional Project Area

Site ID	Surface soil texture	Buffering capacity of surface soil	pH of the natural surface soil (water)	Soil acidification LSC class
48	sandy clay loam	Moderate	6	3
54	sandy loam	Low	6.1	4
Tenosol				
37	sandy loam	Low	5.9	4
20	loamy sand	Low	6.3	4
21	sandy loam	Low	6.3	4
22	clayey sand	Low	7.5	3
28	sandy loam	Low	6.1	4
29	sandy loam	Low	6.8	3
30	sandy loam	Low	6.9	3
45	loamy sand	Low	6	4
46	sandy loam	Low	6	4
49	clayey sand	Low	6	4
52	sandy clay loam	Moderate	5.8	3
Sodosol				
1	sandy loam	Low	5.5	4
2	sandy loam	Low	6	4
3	sandy loam	Low	5.5	4
6	sandy loam	Low	6	4
7	sandy loam	Low	6	4
8	sandy loam	Low	5.5	4
9	sandy clay loam	Moderate	6	3
10	sandy clay loam	Moderate	6	3
11	sandy loam	Low	7.3	3
13	sandy loam	Low	6.5	3
14	sandy clay loam	Moderate	6.3	3
15	sandy clay loam	Moderate	6.3	3
16	sandy clay loam	Moderate	5.8	3
17	sandy loam	Low	5.8	4
18	sandy clay loam	Moderate	5.9	3
23	sandy clay loam	Moderate	6.7	3
24	sandy loam	Low	6.5	4
25	sandy loam	Low	7	3
26	sandy loam	Low	7.1	3
27	sandy clay loam	Moderate	6	3

Table 6.3 Soil acidification LSC classes for the SMUs within the MCCO Additional Project Area

Site ID	Surface soil texture	Buffering capacity of surface soil	pH of the natural surface soil (water)	Soil acidification LSC class
31	sandy loam	Low	6.9	3
32	sandy clay loam	Moderate	7.2	3
33	sandy clay loam	Moderate	5.9	3
34	sandy clay loam	Moderate	5.9	3
35	silty loam	Low	5.9	4
36	sandy clay loam	Moderate	6	3
38	sandy clay loam	Moderate	5.9	3
39	sandy loam	Low	5.8	4
40	sandy clay loam	Moderate	6.5	3
42	sandy clay loam	Moderate	5.8	3
43	sandy loam	Low	6.1	4
44	sandy loam	Low	5.9	4
47	sandy clay loam	Moderate	5.6	3
50	sandy clay loam	Moderate	6.1	3
51	sandy clay loam	Moderate	5.5	3
Chromosol				
19	sandy loam	Low	7.4	3
53	sandy clay loam	Low	5.8	4

7 Assessment of salinity LSC class

Salinity hazard is determined as a result of recharge potential, discharge potential and salt store. Table 7.1 and Figure 7.1 summarises the supporting information for decision making, while Table 7.2 is the assessment table for salinity LSC classes. Table 7.3 outlines the results table for salinity LSC classes.

Table 7.1 A summary of salinity LSC notes (OEH 2012)

Factor	Notes	Example	Information Source
Recharge potential	Recharge potential is the potential for water from rainfall, irrigation or streams to infiltrate past the plant root zone into the underlying groundwater system. This can occur over a whole landscape, or a component of the landscape, where water readily infiltrates soil, sediment or rock. Typically recharge areas have permeable, shallow and/or stony soils and fractured and/or weathered rock.	Recharge potential is highest where there is high rainfall relative to evaporation, low leaf area and plant water use, low water-holding capacity, and high permeability of the soils, regolith and rocks. Under natural conditions it relates to the climate, land use and hydrological characteristics of the catchment. It is exacerbated by land-use practices that disturb the vegetation cover or soil surface.	The value assigned for recharge potential is a qualitative assessment based on aerial photography, field observation and/or available literature, in particular soil landscape maps and reports.
Discharge potential	Discharge potential is the potential for groundwater to flow from the saturated zone to the land surface. It is a function of position in the landscape, depth to water table, groundwater pressure, soil type, substrate permeability and evapotranspiration. Discharge may occur as leakage to streams, evaporation from shallow water tables, or as springs and wet areas where water tables intersect the land surface or where narrow breaks occur in low permeability layers above confined aquifers.	Discharge potential is highest when recharge rates are greater than the amount of water that leaves the groundwater system through base flow and evapotranspiration. Typical discharge areas are low in the landscape and have high water tables, or higher in the landscape if sub-surface barriers impede groundwater flow.	The value assigned for discharge potential is a qualitative assessment based on aerial photography, field observation and/or available literature, in particular soil landscape maps and reports.
Salt store	Salt stores are high for many soils, regolith materials and rock types. This will depend on weathering characteristics, geological structures, rock and soil type, depth of the various materials and salt flux.	It is possible to have areas of low salt store and still have a salinity hazard due to evaporative concentration of salts at the soil surface. Conversely, areas of high salt store can have a lower hazard due to low rainfall. For example, in areas of low rainfall and low slope, salinity hazard can be low.	Figure 7.1 provides a broad indication of salt stores throughout NSW. This map is generalised and local information should be used where available.

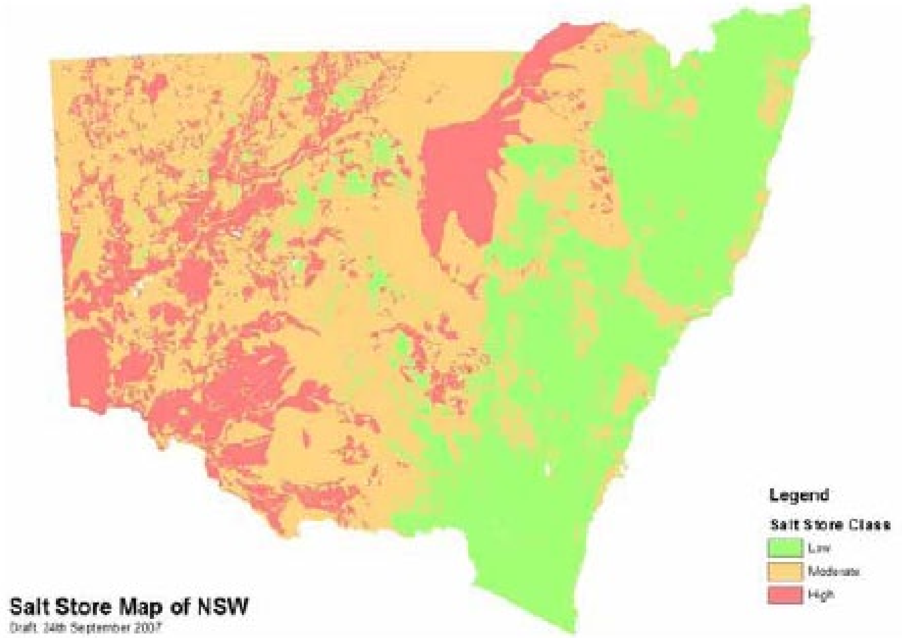


Figure 7.1 Salt store map of NSW (OEH 2012)

The MCCO Additional Project Area is located in a moderate salt store region, so the parts of Table 7.2 that pertain to high and low salt store have been shaded as they are not relevant.

Table 7.2 Salinity LSC class assessment table (OEH 2012)

Recharge potential	Discharge potential	Salt store	LSC class
Low	Low	Low	1
		Moderate	3
		High	4
	Moderate	Low	1
		Moderate	4
		High	4
	High	Low	1
		Moderate	4
		High	5
Moderate	Low	Low	1
		Moderate	3
		High	4
	Moderate	Low	2
		Moderate	5
		High	6
	High	Low	1 (3) *
		Moderate	6
		High	6
High	Low	Low	1
		Moderate	4
		High	5
	Moderate	Low	3 (2) *
		Moderate	4
		High	7
	High	Low	2 (3) *
		Moderate	6
		High	7

* The values in brackets are more accurate and should be used in preference to the original

Table 7.3 Salinity LSC classes for the SMUs within the MCCO Additional Project Area

Site ID	Recharge Potential	Discharge Potential	Salt store	Salinity LSC class
Dermosol				
A1	Low	Low	Moderate	3
4	Low	Low	Moderate	3
5	Low	Low	Moderate	3
12	Low	Low	Moderate	3
Kurosol				
41	Moderate	Low	Moderate	5

Table 7.3 Salinity LSC classes for the SMUs within the MCCO Additional Project Area

Site ID	Recharge Potential	Discharge Potential	Salt store	Salinity LSC class
48	Moderate	Low	Moderate	5
54	Moderate	Low	Moderate	5
Tenosol				
37	Low	Low	Moderate	3
20	Low	Low	Moderate	3
21	Low	Low	Moderate	3
22	Low	Low	Moderate	3
28	Low	Low	Moderate	3
29	Low	Low	Moderate	3
30	Low	Low	Moderate	3
45	Low	Low	Moderate	3
46	Low	Low	Moderate	3
49	Low	Low	Moderate	3
52	Low	Low	Moderate	3
Sodosol				
1	Low	Low	Moderate	3
2	Low	Low	Moderate	3
3	Low	Low	Moderate	3
6	Low	Low	Moderate	3
7	Low	Low	Moderate	3
8	Low	Low	Moderate	3
9	Low	Low	Moderate	3
10	Low	Low	Moderate	3
11	Low	Low	Moderate	3
13	Low	Low	Moderate	3
14	Low	Low	Moderate	3
15	Low	Low	Moderate	3
16	Low	Low	Moderate	3
17	Low	Low	Moderate	3
18	Low	Low	Moderate	3
23	Low	Low	Moderate	3
24	Low	Low	Moderate	3
25	Low	Low	Moderate	3
26	Low	Low	Moderate	3
27	Low	Low	Moderate	3
31	Low	Low	Moderate	3
32	Low	Low	Moderate	3
33	Low	Low	Moderate	3
34	Low	Low	Moderate	3
35	Low	Low	Moderate	3
36	Low	Low	Moderate	3
38	Low	Low	Moderate	3

Table 7.3 Salinity LSC classes for the SMUs within the MCCO Additional Project Area

Site ID	Recharge Potential	Discharge Potential	Salt store	Salinity LSC class
39	Low	Low	Moderate	3
40	Low	Low	Moderate	3
42	Low	Low	Moderate	3
43	Low	Low	Moderate	3
44	Low	Low	Moderate	3
47	Low	Low	Moderate	3
50	Low	Low	Moderate	3
51	Low	Low	Moderate	3
Chromosol				
19	Low	Low	Moderate	3
53	Moderate	Low	Moderate	5

8 Assessment of waterlogging LSC class

Table 8.1 outlines the assessment table for determining waterlogging LSC classes and Table 8.2 provides the results.

The typical waterlogging duration was not known, but the presence of mottling was used to distinguish the degree of waterlogging. Soil profiles which were logged as "imperfectly drained" with 20-50% mottles in the B horizon were classed as 4 (i.e. waterlogged every 2-3 years, for 2-3 months duration). Soils that were logged as poorly-drained but were not classified as Hydrosol were assumed to be LSC class 5.

Table 8.1 Waterlogging LSC class assessment table (OEH 2012)

Typical waterlogging duration (months)	Return period	Typical soil drainage*	LSC class**
0	every year	rapidly drained and well drained	1
0–0.25	every year	moderately well drained	2
0.25–2	every year	imperfectly drained	3
2–3	every 2 to 3 years	imperfectly drained	4
2–3	every year	imperfectly drained	5
>3	every year	poorly drained	6
Almost permanently	every year	very poorly drained	8

* NCST (2009, p.202–4)
** Based on slope position, climate and length of time soils are wet.

Table 8.2 Waterlogging LSC classes for the SMUs within the project area

Site ID	Typical soil drainage	Waterlogging LSC class
Dermosol		
A1	moderately well drained	2
4	moderately well drained	2
5	poorly drained (20-50% mottles)	5
12	poorly drained (20-50% mottles)	5
Kurosol		
41	poorly drained (20-50% mottles)	5
48	poorly drained (20-50% mottles)	5
54	moderately well drained	2
Tenosol		
37	rapidly drained	1
20	well drained	1
21	rapidly drained	1

Table 8.2 Waterlogging LSC classes for the SMUs within the project area

Site ID	Typical soil drainage	Waterlogging LSC class
22	well drained	1
28	well drained	1
29	well drained	1
30	well drained	1
45	well drained	1
46	well drained	1
49	well drained	1
52	well drained	1
Sodosol		
1	poorly drained (20-50% mottles)	5
2	poorly drained (20-50% mottles)	5
3	poorly drained (20-50% mottles)	5
6	imperfect	4
7	poorly drained (20-50% mottles)	5
8	poorly drained (20-50% mottles)	5
9	poorly drained (20-50% mottles)	5
10	imperfect	4
11	poorly drained (20-50% mottles)	5
13	poorly drained (20-50% mottles)	5
14	poorly drained (20-50% mottles)	5
15	poorly drained (20-50% mottles)	5
16	poorly drained (20-50% mottles)	5
17	poorly drained (20-50% mottles)	5
18	well drained	1
23	poorly drained (20-50% mottles)	5
24	imperfect	4
25	poorly drained (20-50% mottles)	5
26	moderately well drained	2
27	poorly drained (20-50% mottles)	5
31	poorly drained (20-50% mottles)	5
32	poorly drained (20-50% mottles)	5
33	poorly drained (20-50% mottles)	5
34	poorly drained (20-50% mottles)	5
35	moderately well drained	2
36	poorly drained (20-50% mottles)	5

Table 8.2 Waterlogging LSC classes for the SMUs within the project area

Site ID	Typical soil drainage	Waterlogging LSC class
38	imperfect	3
39	Imperfect	3
40	poorly drained (20-50% mottles)	5
42	poorly drained (20-50% mottles)	5
43	poorly drained (20-50% mottles)	5
44	poorly drained (20-50% mottles)	5
47	imperfect	4
50	poorly drained (20-50% mottles)	5
51	poorly drained (20-50% mottles)	5
Chromosol		
19	moderately well drained	2
53	poorly drained (20-50% mottles)	5

9 Assessment of shallow soils and rockiness LSC class

Table 9.1 outlines the assessment table for determining shallow soils and rockiness LSC classes and Table 9.2 provides the results.

Table 9.1 Shallow soils and rockiness LSC class assessment table (OEH 2012)

Rocky outcrop (% coverage)*	Soil depth (cm)	LSC class**
Nil	>100	1
	>100	2
	75– <100	3
<30 (localised*)	50– <75	4
	25– <50	6
	0– <25	7
	>100	4
30–50 (widespread*)	75–100	5
	25–75	6
	<25	7
	>100	6
50–70 (widespread*)	50–100	6
	25– <50	7
	<25	7
>70	n/a	8

* Rock outcrop limitation from soil landscape report.
** Based on rocky outcrop and soil depth

Table 9.2 Shallow soils and rockiness LSC classes for each soil type

Site ID	Rocky outcrop (% coverage)	Soil depth (cm)	Soil depth category (cm)	Shallow soils and rockiness LSC class
Dermosol				
A1	Nil	>120	>100	1
4	Nil	>120	>100	1
5	Nil	>120	>100	1
12	Nil	>120	>100	1
Kurosol	Nil	>120	>100	

Table 9.2 Shallow soils and rockiness LSC classes for each soil type

Site ID	Rocky outcrop (% coverage)	Soil depth (cm)	Soil depth category (cm)	Shallow soils and rockiness LSC class
41	Nil	>120	>100	1
48	Nil	>120	>100	1
54	Nil	>120	>100	1
Tenosol	Nil	>120	>100	
37	Nil	>120	>100	1
20	Nil	>120	>100	1
21	Nil	>120	>100	1
22	Nil	>120	>100	1
28	Nil	>120	>100	1
29	Nil	>120	>100	1
30	Nil	>120	>100	1
45	Nil	>120	>100	1
46	Nil	>120	>100	1
49	Nil	>120	>100	1
52	Nil	>120	>100	1
Sodosol	Nil	>120	>100	
1	Nil	>120	>100	1
2	Nil	>120	>100	1
3	Nil	>120	>100	1
6	Nil	>120	>100	1
7	Nil	>120	>100	1
8	Nil	>120	>100	1
9	Nil	>120	>100	1
10	Nil	>120	>100	1
11	Nil	>120	>100	1
13	Nil	>120	>100	1
14	Nil	>120	>100	1
15	Nil	>120	>100	1
16	Nil	>120	>100	1
17	Nil	>120	>100	1
18	Nil	>120	>100	1
23	Nil	>120	>100	1
24	Nil	>120	>100	1
25	Nil	>120	>100	1

Table 9.2 Shallow soils and rockiness LSC classes for each soil type

Site ID	Rocky outcrop (% coverage)	Soil depth (cm)	Soil depth category (cm)	Shallow soils and rockiness LSC class
26	Nil	>120	>100	1
27	Nil	>120	>100	1
31	Nil	>120	>100	1
32	Nil	>120	>100	1
33	Nil	>120	>100	1
34	Nil	>120	>100	1
35	Nil	>120	>100	1
36	Nil	>120	>100	1
38	Nil	>120	>100	1
39	Nil	>120	>100	1
40	Nil	>120	>100	1
42	Nil	>120	>100	1
43	Nil	>120	>100	1
44	Nil	>120	>100	1
47	Nil	>120	>100	1
50	Nil	>120	>100	1
51	Nil	>120	>100	1
Chromosol				
19	Nil	>120	>100	1
53	Nil	>120	>100	1

10 Assessment of mass movement LSC class

Table 10.1 outlines the assessment table for determining mass movement LSC classes. The mean annual rainfall for the nearest long-term weather station (Scone) is 625 mm, so therefore is in the over 500 mm category on the table. Table 10.2 provides the results.

Table 10.1 Mass movement LSC class assessment table (OEH 2012)

Mean annual rainfall (mm)	Mass movement present	Slope class (%)	LSC class
<500	No	n/a	1
	Yes	n/a	8
>500	No	n/a	1
	Yes	<20	6
		>20–50	7
		50 or any scree or talus slope	8

Note that scree or talus slopes go automatically into Class 8

Table 10.2 Mass movement LSC classes for the SMUs within the project area

Site ID	Mass movement present	Slope class (%)	Mass movement LSC class
Dermosol			
A1	No	n/a	1
4	No	n/a	1
5	No	n/a	1
12	No	n/a	1
Kurosol	No	n/a	
41	No	n/a	1
48	No	n/a	1
53	No	n/a	1
54	No	n/a	1
Tenosol	No	n/a	
37	No	n/a	1
20	No	n/a	1
21	No	n/a	1

Table 10.2 Mass movement LSC classes for the SMUs within the project area

Site ID	Mass movement present	Slope class (%)	Mass movement LSC class
22	No	n/a	1
28	No	n/a	1
29	No	n/a	1
30	No	n/a	1
45	No	n/a	1
46	No	n/a	1
49	No	n/a	1
52	No	n/a	1
Sodosol	No	n/a	
1	No	n/a	1
2	No	n/a	1
3	No	n/a	1
6	No	n/a	1
7	No	n/a	1
8	No	n/a	1
9	No	n/a	1
10	No	n/a	1
11	No	n/a	1
13	No	n/a	1
14	No	n/a	1
15	No	n/a	1
16	No	n/a	1
17	No	n/a	1
18	No	n/a	1
19	No	n/a	1
23	No	n/a	1
24	No	n/a	1
25	No	n/a	1
26	No	n/a	1
27	No	n/a	1
31	No	n/a	1
32	No	n/a	1
33	No	n/a	1
34	No	n/a	1
35	No	n/a	1

Table 10.2 Mass movement LSC classes for the SMUs within the project area

Site ID	Mass movement present	Slope class (%)	Mass movement LSC class
36	No	n/a	1
38	No	n/a	1
39	No	n/a	1
40	No	n/a	1
42	No	n/a	1
43	No	n/a	1
44	No	n/a	1
47	No	n/a	1
50	No	n/a	1
51	No	n/a	1

11 Assessment of LSC classes for soil management units

Data for the assessment was sourced from field survey observations, desktop analysis and soil laboratory analysis. The results for each site that was assessed are presented in Table 11.1.

A map has been produced that shows the spatial distribution of the LSC classes (Figure 11.1)

Table 11.1 Summary of LSC classes across the Project Area

SMUs	Water Erosion LSC class	Wind Erosion LSC class	Soil structural decline LSC class	Soil acidification LSC class	Salinity LSC class	Waterlogging LSC class	Shallow soils and rockiness LSC class	Mass movement LSC class	SMULSC class
Dermosol									
55(A1)	3	1	4	3	3	2	1	1	4
4	2	1	3	3	3	2	1	1	3
5	3	1	4	3	3	5	1	1	5
12	2	1	3	3	3	5	1	1	5
Kurosol									
41	3	3	3	4	5	5	1	1	5
48	3	3	3	3	5	5	1	1	5
54	4	3	3	4	5	2	1	1	5
Tenosol									
37	3	3	3	4	3	1	1	1	4
20	3	3	3	4	3	1	1	1	4
21	3	2	3	4	3	1	1	1	4
22	3	3	3	3	3	1	1	1	3
28	3	3	3	4	3	1	1	1	4
29	3	2	3	3	3	1	1	1	3
30	3	2	3	3	3	1	1	1	3
45	2	4	3	4	3	1	1	1	4
46	3	3	3	4	3	1	1	1	4
49	3	4	3	4	3	1	1	1	4
52	3	3	3	3	3	1	1	1	3
Sodosol									
1	2	3	3	4	3	5	1	1	5
2	3	3	3	4	3	5	1	1	5
3	3	3	3	4	3	5	1	1	5

Table 11.1 Summary of LSC classes across the Project Area

SMUs	Water Erosion LSC class	Wind Erosion LSC class	Soil structural decline LSC class	Soil acidification LSC class	Salinity LSC class	Waterlogging LSC class	Shallow soils and rockiness LSC class	Mass movement LSC class	SMULSC class
6	3	3	3	4	3	4	1	1	4
7	3	3	3	4	3	5	1	1	5
8	3	3	3	4	3	5	1	1	5
9	3	1	3	3	3	5	1	1	5
10	3	1	3	3	3	4	1	1	4
11	2	3	3	3	3	5	1	1	5
13	4	3	3	3	3	5	1	1	5
14	3	1	3	3	3	5	1	1	5
15	3	1	3	3	3	5	1	1	5
16	3	1	3	3	3	5	1	1	5
17	3	3	3	4	3	5	1	1	5
18	2	1	3	3	3	1	1	1	3
23	3	1	3	3	3	5	1	1	5
24	3	3	3	4	3	4	1	1	4
25	3	3	3	3	3	5	1	1	5
26	3	3	3	3	3	2	1	1	3
27	3	1	3	3	3	5	1	1	5
31	3	3	3	3	3	5	1	1	5
32	3	1	3	3	3	5	1	1	5
33	4	1	3	3	3	5	1	1	5
34	3	1	3	3	3	5	1	1	5
35	3	1	3	4	3	2	1	1	4
36	2	1	3	3	3	5	1	1	5
38	3	1	3	3	3	3	1	1	3
39	2	3	3	4	3	3	1	1	4
40	3	1	3	3	3	5	1	1	5
42	3	1	3	3	3	5	1	1	5
43	3	3	3	4	3	5	1	1	5
44	3	3	3	4	3	5	1	1	5
47	3	1	3	3	3	4	1	1	4
50	3	1	3	3	3	5	1	1	5
51	3	1	3	3	3	5	1	1	5

Chromosol

Table 11.1 Summary of LSC classes across the Project Area

SMUs	Water Erosion LSC class	Wind Erosion LSC class	Soil structural decline LSC class	Soil acidification LSC class	Salinity LSC class	Waterlogging LSC class	Shallow soils and rockiness LSC class	Mass movement LSC class	SMULSC class
19	3	3	3	3	3	2	1	1	3
53	3	3	3	4	5	5	1	1	5

Figure 11.1 Land and soil capability class – pre-mining

12 Conclusion

12.1 Relationship between soil type and LSC classes

The Sodosols have generally been classified as Class 5 based on the ESP chemical barrier in the B horizon and significant mottling in the subsoil. This means the soils are generally suited to either grazing, forestry or nature conservation. Some sites within the Sodosol soil type are LSC class 4 and 3 which means potentially capable of higher intensity agriculture, but from a property perspective would not be feasible for such small areas to be used in this way. Within the MCCO Additional Project Area a large part of these soils have been cleared for grazing. The Kurosols have also been classified as Class 5 based on poor drainage and surface acidity.

The Tenosols have been classified as Class 3 and 4. However the areas are split into two sections within the MCCO Additional Project Area, and surrounded by the LSC Class 5 sodosols, which makes the feasibility of higher intensity agriculture, uncertain. So, whilst the results of the LSC assessment means these soils are potentially capable of cropping with restricted cultivation, pasture cropping and grazing, significant inputs would be required to make higher intensity agriculture feasible. Slope would also form a restriction on some agriculture.

The Dermosol ranged in LSC classification from Class 3 to Class 5, drainage and soil structure decline within these soils adjacent to Big Flat Creek. The two sites that were classified as Class 3 and 4 and would be capable of some cropping and grazing, however the areas are too small and isolated to make such ventures feasible at the property scale.

Figure 6.1 shows the LSC classes and notes the total area (43.29 ha) of LSC Class 3 land, which is split between four separate areas, the largest within the disturbance area being 19.83 ha. The LSC Class 3 polygon in the west (11.83 ha) which includes points S29 and S30 lies outside the disturbance area, and should remain undisturbed during mining. A portion of the LSC Class 3 polygons in the north (15.89 ha) and the south (20.04 ha) will be disturbed by the proposed project.

The regional scale mapping in the north west edge of the MCCO Additional Project Area, of LSC Class 7 has been maintained for mapping purposes and included in Figure 6.1. Note there were no field inspection sites located within this area, and therefore the mapping of LSC class 7 is considered unverified on a property scale, and only the regional mapping is presented. The slopes and the expected shallow soils within this area are considered viable justifications for the regional mapping.

12.2 Distribution of LSC classes

The LSC assessment has mapped 79.12% of the project area as moderate (Class 4 – 31.29%) to moderate-low (Class 5 – 47.83%) capability land. This means that the land has moderate to high limitations for high impact land uses, which will restrict cropping, high intensity grazing and horticulture (OEH 2012). These limitations can only be managed with the implementation of suitable soil conservation measures.

15.28% of the project area has been mapped as unconfirmed very low capability (Class 7), suitable for a limited set of land uses such as light grazing, selective forestry and nature conservation. The steep slopes are expected to contribute to this classification from increased wind and water erodibility and shallow soils.

Areas of Class 3, high capability land occurred over approximately 5.60% of the project area. The individual areas of Class 3 are equal to or less than 20 ha.

Table 12.1 shows the number of hectares of each land class in the project area.

Table 12.1 Land and soil capability classes in the Project Area

Class	Capability	Land in the project area	Hectares (ha)	%
Land capable of a wide variety of land uses (cropping, grazing, horticulture, forestry, nature conservation)				
1	Extremely high	None	0	
2	Very high	None	0	
3	High	Tenosols, Dermosols, Sodosols, Chromosols	69.49	5.60
Land capable of a variety of land uses (cropping with restricted cultivation, pasture cropping, grazing, some horticulture, forestry, nature conservation)				
4	Moderate	Sodosols, Tenosols, Dermosols	388.81	31.29
5	Moderate–low	Sodosols, acidic Tenosols, Kurosols	594.30	47.83
Land capable for a limited set of land uses (grazing, forestry and nature conservation)				
6	Low	None	0	
Land generally incapable of agricultural land use (selective forestry and nature conservation)				
7	Very low	Steep slopes, shallow soils (Tenosols/ possible Rudosols)	189.90	15.28
8	Extremely low	None	0	

Notes: 1.modified description from OEH 2012.

References

Australian Bureau of Meteorology http://www.bom.gov.au/climate/data/ (visited 09 August 2017)

OEH (2012) *Land and soil capability assessment scheme.* NSW government.

Appendix E

Biophysical strategic agricultural land assessment

Appendix E

Biophysical strategic agricultural land assessment

Biophysical Strategic Agricultural Land Verification Assessment

Mangoola Coal Continued Operations Project

Prepared for Mangoola Coal Operations Pty Limited | 20 June 2018

Suite 1, Level 4, 87 Wickham Terrace
Spring Hill QLD 4000

T +61 7 3839 1800
F +61 7 3839 1866
E info@emmconsulting.com.au

www.emmconsulting.com.au

Biophysical Strategic Agricultural Land Verification Assessment

Report

Report B17193RP3 | Prepared for Mangoola Coal Operations Pty Limited | 20 June 2018

Prepared by	**Kylie Drapala**	Approved by	**Jeromy Claridge**
Position	Senior environment scientist	Position	Associate environment scientist
Signature		Signature	
Date	20 June 2018	Date	20 June 2018

Document Control

Version	Date	Prepared by	Reviewed by
V0-1	10 November 2017	K Drapala	T Rohde D Sullivan (Umwelt)
V0-2	3 April 2018	K Drapala	D Sullivan (Umwelt)
V1.0	22 May 2018	K Drapala	J Claridge, Mangoola
V1.1	15 June 2018	K Drapala	J Claridge
V1.2	26 July 2018	K Drapala	J Claridge

EMM

T +61 (0)7 3839 1800 | F +61 (0)7 3839 1866

Suite 1 | Level 4 | 87 Wickham Terrace | Spring Hill | Queensland | 4000 | Australia

www.emmconsulting.com.au

Table of contents

Table of contents *(Cont'd)*

Appendices

Tables

Tables

Figures

Photographs

1 Introduction

EMM Consulting Pty Limited (EMM) has been engaged by Mangoola Coal Operations Pty Limited (Mangoola) to complete a biophysical strategic agricultural land (BSAL) assessment (the assessment) for the Mangoola Coal Continued Operations Project (MCCO Project). The purpose of the assessment is to support an application for a Site Verification Certificate (SVC) as required by the *Upper Hunter Strategic Regional Land Use Plan 2012* (SRLUP) and to form part of an Environmental Impact Statement being prepared by Umwelt Australia Pty Ltd (Umwelt) to support an application for development consent under Division 4.1 of Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) for the MCCO Project.

1.1 Project Background

Mangoola Coal Mine is an existing open cut coal mine located approximately 20 kilometres (km) west of Muswellbrook and 10 km north of Denman in the Upper Hunter Valley of New South Wales (NSW) (Figure 1.1). Mangoola has operated the Mangoola Coal Mine in accordance with Project Approval (PA) 06_0014 (as modified) since mining commenced in September 2010.

The MCCO Project will allow for the continuation of mining at Mangoola Coal Mine into a new mining area to the immediate north of the existing operations. The MCCO Project Area is defined as the area including the existing approved operations for Mangoola Coal Mine along with the MCCO Additional Project Area as shown on Figure 1.1.

The MCCO Project generally comprises:

- open cut mining at up to the same rate as that currently approved (13.5 Million tonnes per annum (Mtpa) of run of mine (ROM) coal) using truck and excavator mining methods;
- mining in a new area located north of the existing Mangoola Coal Mine and Wybong Road, south of Ridgelands Road and east of the 500 kV Electricity Transmission Line (ETL);
- construction of a haul road overpass over Big Flat Creek and Wybong Road to provide access from the existing mine to the MCCO Project;
- establishment of two out-of-pit overburden emplacement areas including a culvert crossing of Big Flat Creek to provide access to the emplacement area;
- distribution of overburden between the MCCO Project and Mangoola Coal Mine in order to optimise the final landform design of the integrated operation. The design of the emplacement areas and final landform will be refined throughout the assessment process;
- realignment of a portion of Wybong Post Office Road;
- the use of all existing or approved infrastructure and equipment for the Mangoola Coal Mine with some minor additions to the existing mobile equipment fleet;
- construction of a water management system to manage sediment laden water runoff, divert clean water catchment, provide flood protection from .0Big Flat Creek and provide for reticulation of mine water. The water management system will be connected to the Mangoola Coal Mine;

- establishment of a final landform in line with current design standards at Mangoola Coal Mine including use of micro-relief;
- rehabilitation of the MCCO Project using the same revegetation techniques as at Mangoola Coal Mine;
- a likely construction workforce of approximately 120 persons. No change to the existing approved operational workforce; and
- continued use of the mine access for the Mangoola Coal Mine and access to/from Wybong Road, Wybong Post Office Road or Ridgelands Road to the MCCO Project for construction, emergency services and ongoing operational environmental monitoring.

The MCCO Project is State Significant Development as defined under State Environmental Planning Policy (State and Regional Development) 2011 and requires development consent under Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). A Preliminary Environmental Assessment (PEA) has been prepared for the MCCO Project and Secretary's Environmental Assessment Requirements (SEARs) (Ref No. SSD 8642) have been provided by the Department of Planning & Environment (DPE).

1.2 Project area

There are no proposed changes to the mining areas or approved disturbance areas at the existing and approved Mangoola Coal Mine as part of the MCCO Project with these areas being entirely within existing mining leases held by Mangoola. As such, the site verification certificate (SVC) application is only related to the land within the MCCO Additional Project Area (see Figure 1.2).

The MCCO Additional Project Area, is 1,053 hectares (ha) and is shown on Figure 1.2 . This area also represents the SVC application area for the Biophysical Strategic Agricultural Land (BSAL) assessment. The SVC application area comprises the area over which new mining leases may be required plus a 100 metre (m) buffer (the SVC application area), as per the *Interim protocol for site verification and mapping of biophysical strategic agricultural land* (OEH 2013) (the Interim Protocol), and is 1,243 ha. It is also shown on Figure 1.2.

It should be noted that under clause 17A(2) of the *State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007* (the Mining SEPP), mining development, as defined for the purposes of the SVC, does not include development on land outside of a proposed mining lease. Therefore, any MCCO Project components outside the proposed mining lease are not subject to the SVC process.

1.3 Policy framework

The site verification policy framework is set out in the SRLUP and Mining SEPP.

The NSW Government released the SRLUP in 2012 to "provide greater protection for valuable agricultural land and better balance competing land uses". This was to be by "identifying and protecting strategic agricultural land, protecting valuable water resources and providing greater certainty for companies wanting to invest in mining and coal seam gas projects in regional NSW". The SRLUP provides a strategic framework and a range of initiatives to balance agriculture and resource development.

The SVC process was established in 2013 by an amendment to the Mining SEPP. The Mining SEPP amendment included addition of the following aims in Clause 2(d):

(i) to recognise the importance of agricultural resources, and

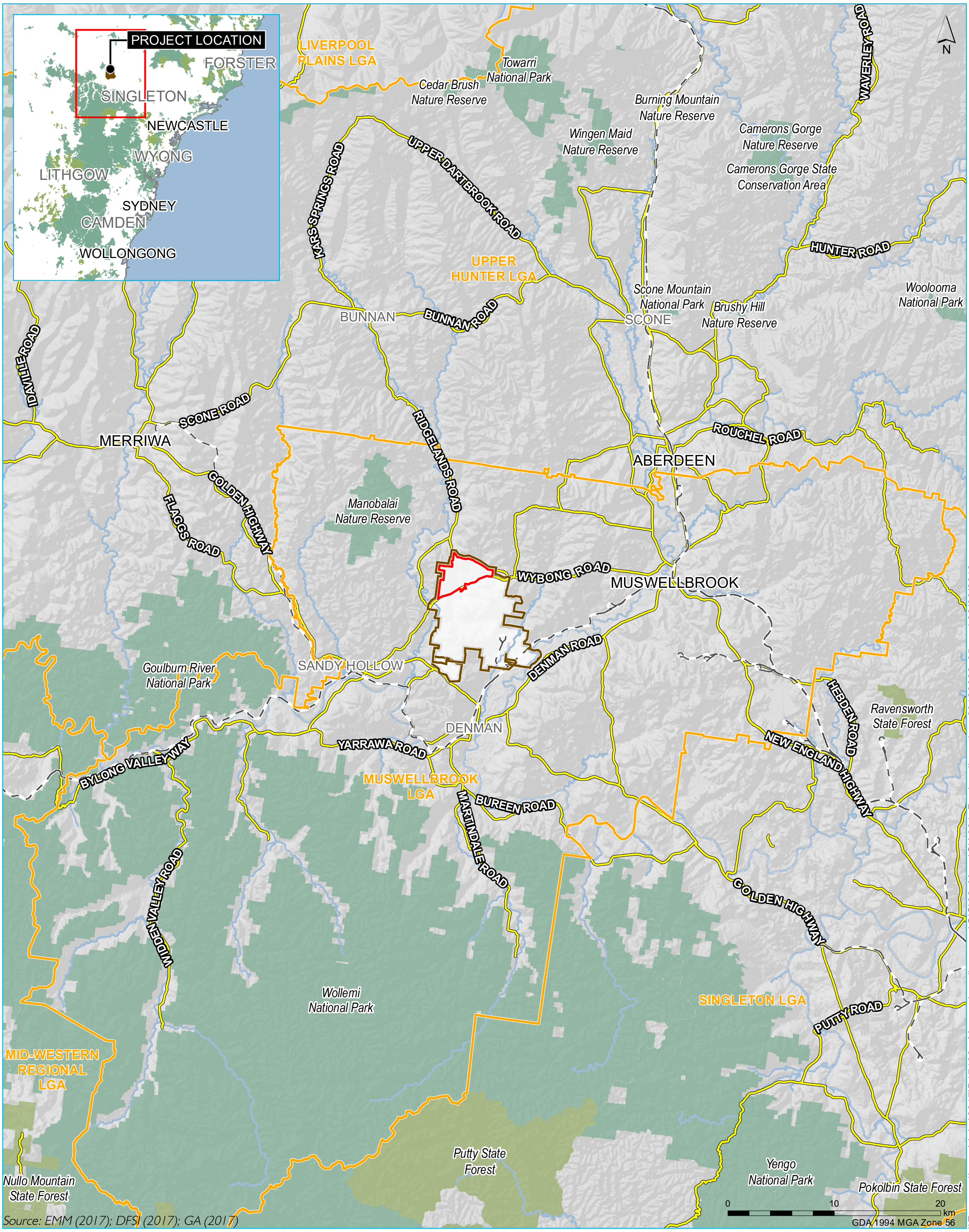
(ii) to ensure protection of strategic agricultural land and water resources, and

(iii) to ensure a balanced use of land by potentially competing industries, and

(iv) to provide for the sustainable growth of mining, petroleum and agricultural industries.

The SRLUP seeks to identify and map the two categories of strategic agricultural land. First, land with a rare combination of natural resources which make it very valuable for agriculture (known as BSAL). Second, land which is important to a highly significant and clustered industry such as wine making or horse breeding, known as Critical Industry Clusters (CICs). Further discussion of BSAL and CICs is provided in Section 2.

The SRLUP applies to mining proposals that are State Significant Development under the Mining SEPP and require a new or extended mining lease. In such cases proponents are required to confirm whether or not they are to be situated on strategic agricultural land. The MCCO Project is a State significant mining proposal which requires a new mining lease and so the SRLUP applies.



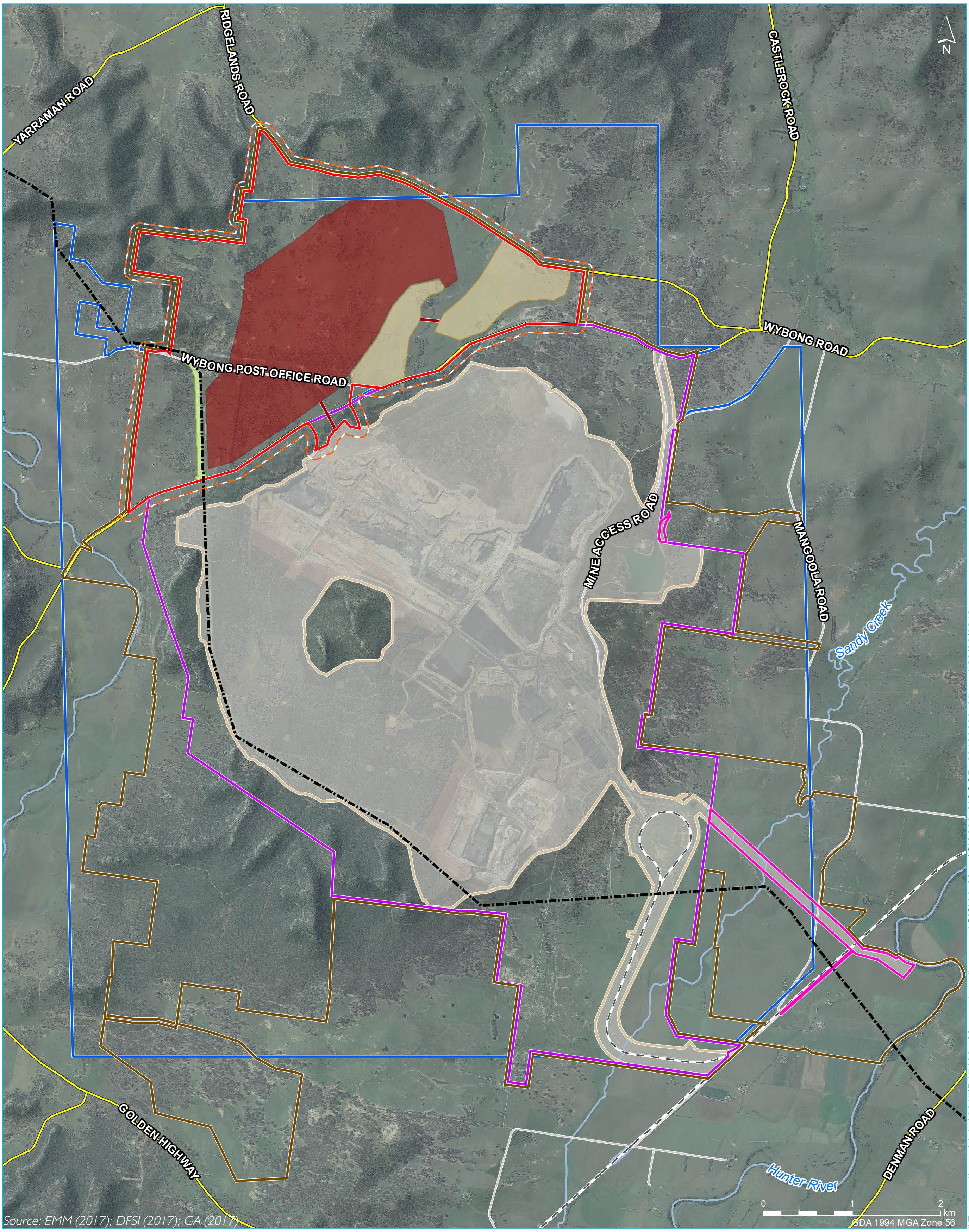
\\Emmsvr1\emm\Jobs\2017\B17193 - Mangoola soil surveys\GIS\02_Maps\SIA001_RegionalLocation_20180622_05.mxd 22/06/2018

KEY

- MCCO project area
- MCCO additional project area
- Local Government Area (LGA) boundary
- Rail line
- Main road
- Watercourse / drainage line
- NPWS reserve
- State forest

Regional locality plan

Mangoola Coal Continued Operations Project
BSAL assessment
Figure 1.1



\\Emmsvr1\emm\Jobs\2017\B17193 - Mangoola soil surveys\GIS\02_Maps\SIA002_MCCOP_20180629_05.mxd 29/06/2018

KEY

- ML 1626
- ML 1747
- MCCO project area
- MCCO additional project area
- MCCO additional project area - 100m buffer
- Approved Mangoola Coal Mine disturbance area
- AL9 boundary
- Proposed overpass
- MCCO proposed additional mining area
- Proposed emplacement area
- Indicative Wybong Post Office Road realignment
- 500kV transmission line
- Main road
- Local road
- Rail line
- Watercourse / drainage line

Mangoola Coal Continued Operations project layout

Mangoola Coal Continued Operations Project

BSAL assessment

Figure 1.2

EMM

2 Strategic agricultural land assessment

2.1 Critical industry clusters

The NSW Government (2012) *Draft Guideline for site verification of critical industry clusters* provides guidance for identifying the existence of CICs. They are mapped on the Strategic Agricultural Land Map (attached to the Mining SEPP) and comprise land which is important to a highly significant and clustered industry, such as wine making or horse breeding.

The draft guideline describes a CIC as a "localised concentration of interrelated productive industries based on an agricultural product that provides significant employment opportunities and contributes to the identity of the region". It specifies that a CIC must meet the following criteria:

- there is a concentration of enterprises that provides clear development and marketing advantages and is based on an agricultural product;
- the productive industries are interrelated;
- it consists of a unique combination of factors such as location, infrastructure, heritage and natural resources;
- it is of a national and/or international importance;
- it is an iconic industry that contributes to the region's identity; and
- it is potentially substantially impacted by coal seam gas or mining proposals.

There are two CICs in NSW (an equine and a viticulture CIC) which have been mapped in the Upper Hunter. The Strategic Agricultural Land Map within the Mining SEPP shows that there are no CICs within the MCCO Additional Project Area. The closest CIC areas are equine CIC located approximately 0.3 km from the south-west and directly north of the MCCO Additional Project Area (see Figure 2.1). The draft guideline states that "projects located outside the mapped CIC are not required to seek site verification". The MCCO Project is outside any mapped CIC. Therefore, the SVC Application Area does not contain CICs and Mangoola is not required to seek a site verification or gateway certificate in respect of CICs.

2.2 Biophysical strategic agricultural land

BSAL is defined in the Interim Protocol as:

> land with a rare combination of natural resources highly suitable for agriculture. These lands intrinsically have the best quality landforms, soil and water resources which are naturally capable of sustaining high levels of productivity and require minimal management practices to maintain this high quality. BSAL is able to be used sustainably for intensive purposes such as cultivation. Such land is inherently fertile and generally lacks significant biophysical constraints.

The NSW Government has mapped BSAL across the whole of NSW, based on a desktop study, and the resultant maps accompany the Mining SEPP. The BSAL shown on the maps comprises land which meets the following criteria (as described in the Interim Protocol):

- access to a reliable water supply; and

- access to a reliable water supply; and
- falls under soil fertility classes ‘high’ or ‘moderately high’ under the NSW Office of Environment and Heritage (OEH) *Draft Inherent General Fertility* Mapping *of NSW* (OEH 2017a), where it is also present with land capability classes I, II or III under OEH’s *Land and Soil Capability Mapping of NSW*; or
- falls under soil fertility classes ‘moderate’ under OEH’s *Draft Inherent General Fertility* Mapping *of NSW*, where it is also present with land capability classes I or II under OEH’s *Land and Soil Capability Mapping of NSW* (OEH 2017b).

These maps have generally not been verified by site investigations and site verification in accordance with the Interim Protocol is required to confirm whether or not land is actually BSAL.

The NSW Government’s BSAL Map within the Mining SEPP indicates that there is no BSAL in the MCCO Additional Project Area. Figure 2.1 presents the NSW Government’s regional scale BSAL map for the area. BSAL has been mapped nearby, south-west of the MCCO Additional Project Area adjacent to Wybong Creek. This land has not been confirmed as BSAL by site investigations.

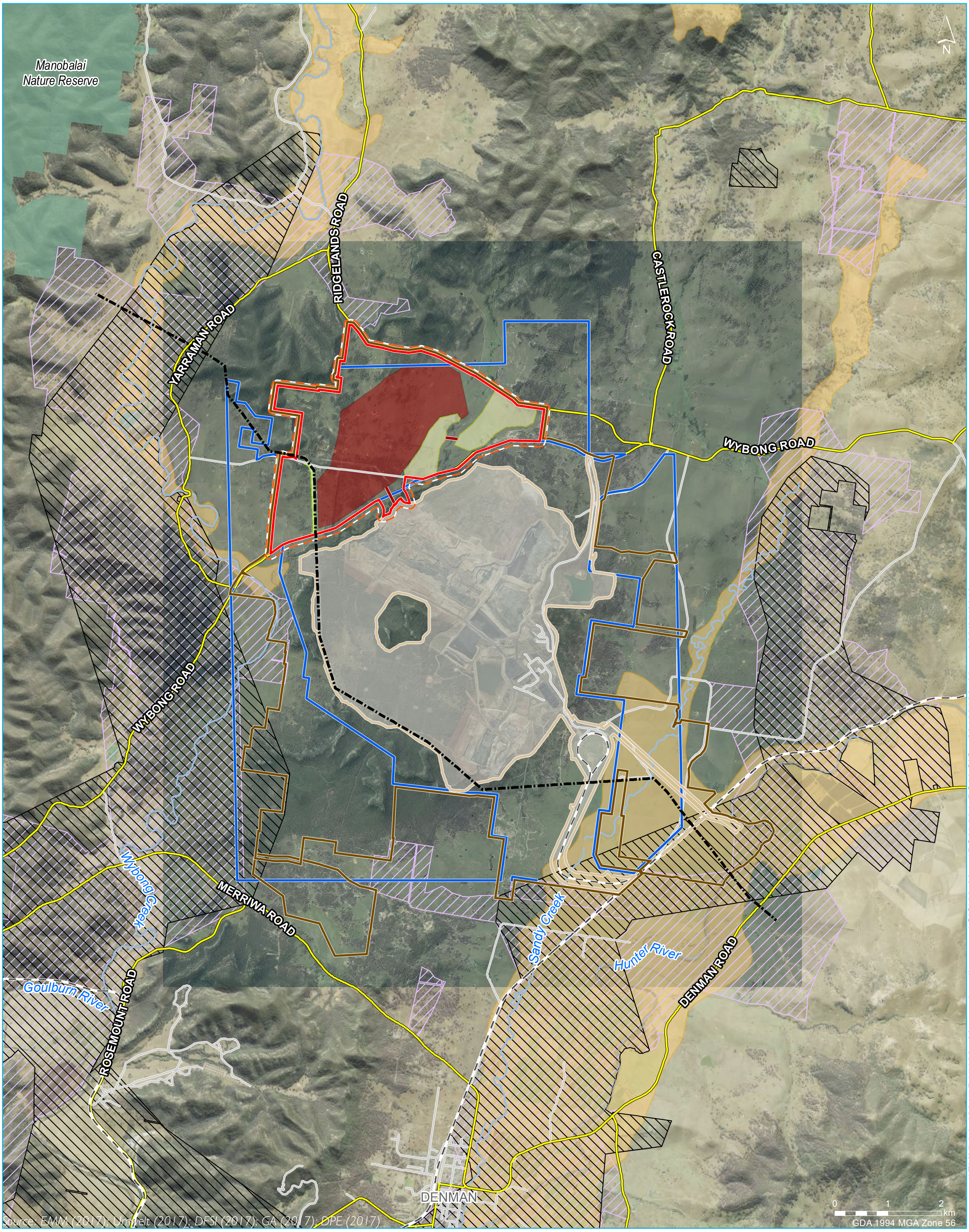
Notwithstanding, the Interim Protocol states that “due to the regional scale of the maps, it is important that appropriate processes are in place to provide for verification that particular sites are in fact BSAL. Verification can apply to both mapped and unmapped BSAL areas.” The Mining SEPP requires certain types of development (including the MCCO Project) verify whether or not any land within the proposed mining lease areas is BSAL.

The Interim Protocol outlines the steps and criteria to establish whether an area is BSAL. The criteria relate to:

- slope;
- rock outcrop;
- surface rock fragments;
- gilgais;
- soil fertility;
- effective rooting depth to a physical barrier;
- soil drainage;
- soil pH;
- salinity; and
- effective rooting depth to a chemical barrier.

Figure 2.2 shows the order in which the site verification criteria must be assessed and the decision making sequence to establish whether or not BSAL is present at a particular site. For land to be classified as BSAL, it must meet all of the criteria in Figure 2.2. If any of the criteria are not met, the land is not BSAL and later steps in the assessment are not relevant. In addition, the Interim Protocol specifies a minimum area for BSAL of 20 ha. If the area subject to assessment falls below 20 ha at any point of the assessment because of exclusion of land that does not meet the criteria, then the land is not BSAL and there is no need to continue the assessment. Therefore, for land to be classified as BSAL, it must have access to a reliable water supply; meet all of the criteria in Figure 2.2; and be a contiguous area of at least 20 ha. If any of these criteria are not met, the land is not BSAL. A detailed description of the BSAL classification rules and analysis methods used in this assessment is provided in Appendix B.

It is noted that Figure 2.2 is a direct extract from the Interim Protocol and has a misprint in Step 12. The actual effective rooting depth criteria for a site to be classified as BSAL (as used in the MCCO Project's assessment) is greater than or equal to 750 millimetres (mm) (not 75 mm). This is correctly shown in respect of physical barriers in Step 8 of the flow chart, and quoted elsewhere in the Interim Protocol in relation to chemical barriers, for example in Section 6.10: "BSAL soils must have an effective rooting depth to a chemical barrier greater or equal to 750 mm".



KEY

- MCCO project area
- MCCO additional project area
- MCCO additional project area - 100m buffer
- Approved Mangoola Coal Mine disturbance area
- AL9 boundary
- Proposed overpass
- MCCO proposed additional mining area
- Proposed emplacement area
- Indicative Wybong Post Office Road realignment
- Biophysical Strategic Agricultural Land
- Critical Industry Cluster (Viticulture)
- Critical Industry Cluster (Equine)
- 500kV transmission line
- Main road
- Local road
- Rail line
- Watercourse / drainage line
- NPWS reserve

NSW Government mapped BSAL and CIC's

Mangoola Coal Continued Operations Project
BSAL assessment
Figure 2.1

EMM

\\emmsvr1\EMM\Jobs\2017\B17193 - Mangoola soil surveys\GIS\02_Maps\BSAL001_BSALCICs_20180522_03.mxd 22/05/2018

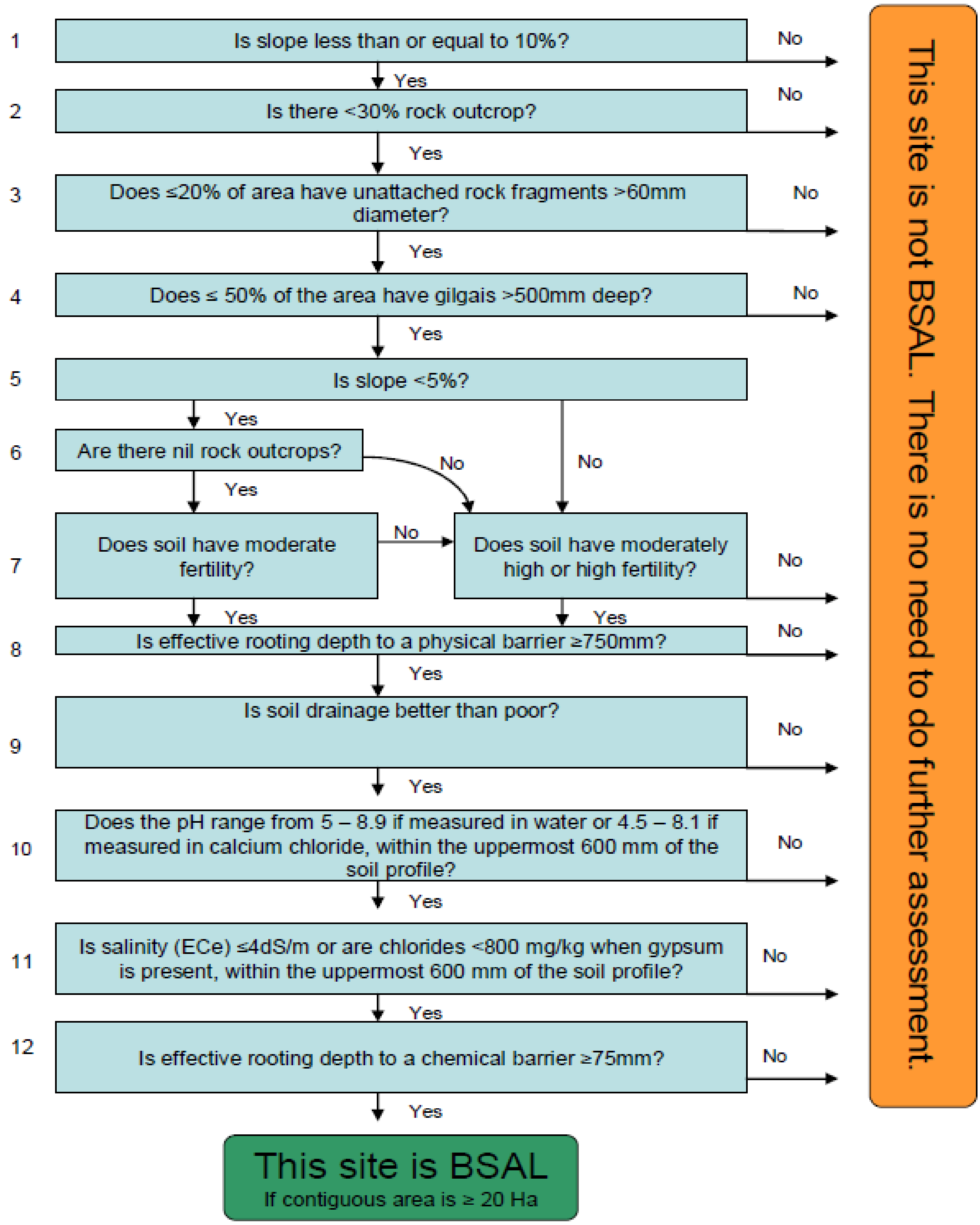


Figure 2.2 Interim Protocol flow chart for the site assessment of BSAL

2.2.1 Statement of qualification

This Biophysical Strategic Agricultural Land Verification Assessment report has been prepared by Kylie Drapala and Nicholas Jamson of EMM Consulting Pty Limited (EMM) in accordance with the Interim Protocol. Kylie is a senior soil scientist and Nicholas is a graduate soil scientist. The assessment and report have been reviewed and authorised by Dr Timothy Rohde, who is a certified professional soil scientist (Soil Science Australia).

2.2.2 Interim protocol checklist

The Interim Protocol provides a checklist of requirements for a BSAL site verification assessment report. The checklist is reproduced in Table 2.1, with reference to where each of the requirements has been addressed in this report.

Table 2.1 Interim protocol checklist

Requirement	Reference
Method, analysis and data	
A qualified soil scientist is overseeing the verification assessment and has signed off on the quality and extent of the work.	Sections 2.
Laboratories for soil samples are compliant with AS ISO/IEC17025.	Appendix B
Results with 15% of threshold levels are analysed in a laboratory.	Appendix B
All soil profile descriptions are recorded and submitted to the NSW Soil and Land Information System (SALIS).	Survey data was recorded on SALIS soil data cards and submitted to OEH for entry into the SALIS database.
Laboratory data is supplied to OEH using their standard spreadsheet templates.	Laboratory data has been provided to OEH in the OEH template.
Report	
Reporting requirements for site verification criteria as described in Appendix 1 of the Interim Protocol.	Table 5.1 and Appendix C.
Three 1:25,000 maps showing base level information, soil types and BSAL.	Figures 1.1, 4.1 and 5.1.
GIS output files and metadata statements.	GIS output files and metadata statements are provided with the SVC application.
Laboratory report.	Appendix B

3 BSAL verification methods and initial steps

3.1 Introduction

The Interim Protocol prescribes four initial steps in verifying BSAL:

- Step 1: identify the project area which will be assessed for BSAL;
- Step 2: confirm access to a reliable water supply;
- Step 3: choose the appropriate approach to map the soils information; and
- Step 4: risk assessment.

These steps are addressed in Sections 3.2 to 3.5 respectively. Section 3.6 describes the field-based survey methodology, including site selection and soils analysis, as well as a review of regional soil, geology and topographic mapping by others.

3.2 Project Area

The MCCO Additional Project Area is also the SVC application area, which is 1,053 ha and is shown in Figure 1.1. The BSAL verification assessment area comprises the SVC application area plus a 100 m buffer, as per the Interim Protocol, and is 1,243 ha. It is also shown on Figure 1.2. The MCCO Additional Project Area is predominately freehold land which is owned by Mangoola, with some crown land and public roads.

3.3 Water supply

The MCCO Additional Project Area has a reliable water supply, defined in the Interim Protocol as rainfall of 350 mm or more per annum in nine out of 10 years. Weather records from the nearby locations of Doyles Creek (61130) and Scone Airport AWS (061363) (BoM 2017) indicate that for the past 97 years (1920-2017) rainfall has been in the range of 320-1224 mm per annum with a mean of 647 mm at Doyles Creek and for 26 years (1991-2017), rainfall has been in the range of 362-902 mm per annum, with a mean of 625 mm at Scone airport (Bureau of Meteorology 2017).

The MCCO Additional Project Area is within the "North Coast Fractured and Porous Rock Groundwater Sources 2016" and it would be classified as less productive groundwater, not meeting the highly productive groundwater classification.

The MCCO Additional Project Area is also within the area covered by the "Water Sharing Plan for the Wybong Creek Water Source 2003", which was repealed and replaced by the "Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009". Analysis of the requirements for reliable surface water resulted in a likely classification of not reliable surface water.

3.4 Land access and mapping approach

Sufficient land was able to be accessed within the SVC application area to satisfy on-site soil sampling density requirements specified in the Interim Protocol. The survey focused intensely on the proposed areas of disturbance with a reduced effort in fringe areas where no disturbance is proposed (example to west of proposed Wybong Post Office Road realignment).

A manual mapping method has been employed based on the site specific survey properties and landscape characteristics, including vegetation, topography, aerial imagery and existing soil and geological mapping.

The assessment and soil mapping has used soil type map units instead of soil landscape units. Soil landscape units are more appropriate for situations where there is more variability in soil types. They are typically used in areas where there may be a single dominant soil type but two or three common sub-dominants. For the MCCO Additional Project Area, soil map units were chosen due to the relatively low variability observed. The soil map units are referred to as 'soil types' in this report for simplicity.

3.5 Survey sampling density

To determine the density of soil sampling required, the Interim Protocol recommends risks to agricultural resources and enterprises be evaluated using guidance in Appendix 3 of the Interim Protocol. Risks can be classified as low, medium or high. The Interim Protocol stipulates that sampling densities should be one site per 25 to 400 ha (1:25,000 to 1:100,000) for low risk activities and one site per 5 to 25 ha (1:25,000) for high risk activities (Gallant et al. 2008).

The MCCO Project involves the continuation of mining at Mangoola Coal Mine into a new mining area to the immediate north of the existing operations on land which is not mapped BSAL, based on the NSW Government's BSAL map, an extract of which is shown in Figure 2.1. All infrastructure and disturbance will be on land largely owned by Mangoola. Direct surface disturbance for the MCCO Project, estimated at approximately 665 ha, will largely involve the MCCO proposed additional mining area and emplacement areas.

The development and operation of the mine will have long term impacts (≥20 years) on the direct mine area. Some stockpile and infrastructure areas would have a temporary land use change at that location. Post-mining, the mine infrastructure will be decommissioned and these areas rehabilitated.

Based on the above, a risk assessment was undertaken for the MCCO Additional Project Area using the risk ranking matrix in the Interim Protocol. The results are presented in Table 3.1. It is noted that, based on the consequence descriptors in Appendix 3 of the Interim Protocol, the preliminary risk assessments are for an unmitigated scenario, which is not realistic. In practice, mitigation and management measures will be developed and implemented to avoid and minimise impacts to agriculture.

Table 3.1 Preliminary agricultural risk assessment (unmitigated scenario)

Aspect	Probability[1]	Consequences[1]	Rating[1]	Comments
MCCO Additional Project Area	A - almost certain	1 - severe	A1 - high	**Applicable consequence descriptor from risk assessment matrix in Appendix 3 of Interim Protocol:** Permanent and irreversible impacts. **EMM comments:** This risk rating applies only to the mining area where a final void will remain. Areas of infrastructure and overburden emplacement areas will be decommissioned and these areas rehabilitated to a state of similar land capability to their current state, allowing for a lower risk ranking. Despite the above the high risk ranking has been applied conservatively across the MCCO Additional Project Area.

Note: 1. Based on the probability and consequence descriptors in Appendix 3 of the Interim Protocol and an unmitigated scenario, which is not realistic. In practice, mitigation and management measures will be implemented to avoid and minimise impacts to agriculture.

3.6 Field based sampling methodology

3.6.1 Survey guidelines

All field assessment methods used in this survey have been conducted in accordance with the following guidelines:

- *Guidelines for surveying soil and land resources* (McKenzie et al 2008);
- *Australian soil and land survey handbook* (NCST 2009);
- *The Australian soil classification* (Isbell 2002);
- *Soil data entry handbook* (DLWC 2001);
- *Interim protocol for site verification and mapping of biophysical strategic agricultural land* (NSW Government (NSWG 2013).

This survey has taken particular note of the requirements of the Interim protocol. The field survey therefore required investigation at three different levels of intensity (the sites):

- check sites - low intensity investigation, high repetition, randomised locations and a limited description;
- detailed sites - high intensity investigation, moderate repetition, randomised locations and a detailed description; and
- profiles pits - very high intensity investigation, low repetition, targeted locations and a detailed description.

3.6.2 Survey density

A soil survey density target of at least one site per 5-25 ha was adopted for BSAL verification purposes.

A total of 55 sites were surveyed within the MCCO Additional Project Area and an average survey density of about one site per 18 ha was achieved. The average survey density achieved meets the target adopted (as per the Interim Protocol), which was at least one site per 25 ha. Of the 55 sites, all were described in detail using the SALIS detailed soil data card to at least Suborder (of which 14 were subjected to laboratory analysis and classified to Family level). This is in accordance with the relevant guidelines. Due to small areas of coverage of two identified soil types (Kurosol and Chromosol), these only had two samples subjected to laboratory analysis, instead of the recommended three.

3.6.3 Site selection

Initial positioning of the soil survey sites was based on stratified random sampling across the MCCO Additional Project Area, though designed to provide a relatively even distribution of detailed and check sites. In accordance with the requirements of stratified random sampling, a greater frequency of sampling was proposed for soil types that cover a greater proportion of the MCCO Additional Project Area. Also, topographic maps were reviewed to ensure surveying was representative of the different landform types in the MCCO Additional Project Area.

The exact locations of the sites were finalised with consideration to land access constraints, site factors, past disturbance, vegetation cover, proposed disturbance locations and achieving good sample coverage. The sites are shown in Figure 4.1.

Soil survey sites for a BSAL assessment fall into three categories:

- Exclusion sites - fail a readily apparent landscape requirement for BSAL, such as excessive slope, rock outcrop, surface rockiness or gilgai micro relief. Soil profile descriptions or survey are not necessary.
- Detailed sites - soil profiles are described in sufficient detail to allow all major physical and chemical soil features of relevance to BSAL verification to be clearly established.
- Check sites - examined in sufficient detail to enable categorisation according to a soil type and soil map unit.

Guidance in the Interim Protocol and the National Committee on Soil and Terrain (NCST) (2009) *Australian Soil and Land Survey Field Handbook* (the Handbook) was followed in the site assessments. The Interim Protocol suggests that each soil type identified should be examined in detail and samples analysed from at least three sites from each of the soil types. The Handbook suggests:

- 10-30% of sites should be described in detail;
- 1-5% of the sites described in detail should be subject to soil analysis; and
- remaining sites should be used as check sites.

In this way, a total of 55 soil survey sites were assessed using the test pitting technique, all of which were recorded using the SALIS detailed soil data card (of which 14 were subjected to laboratory analysis). This meant that all relevant guidance in the Handbook was achieved or exceeded, with 100% of the sites described in detail and 25% of these subject to analysis.

For the purpose of BSAL verification, a site was defined as occurring within a 10-20 m radius of the point of observation of the soil profile. Soil profile data were recorded in the field on SALIS data cards. Photographic records of detailed sites and their soil profiles were taken in the field using a digital camera and are presented in Appendix A.

3.6.4 Review of available mapping

The soil survey sites were initially planned based on the proposed disturbance areas, a review of Australian Soil Resource Information System (ASRIS) regional soil maps, geology maps and topographic maps. Regional soil mapping and information from the NSW Government's online soil mapping database eSPADE, released in 2014, was also reviewed.

3.6.5 Soils analysis

Physical and chemical analysis was undertaken on selected soil samples at a NATA accredited laboratory (Table 3.2). A summary of the number of samples analysed from each soil type present in the MCCO Additional Project Area is presented in Table 3.3.

Table 3.2 Laboratory analysis

Physical analysis	Chemical analysis
dispersion;	organic carbon;
soil texture;	pH (water and $CaCl_2$);
other specified significant soil characteristics where these occurred.	total and available nitrogen;
	available phosphorus;
	exchangeable potassium;
	cation exchange capacity;
	exchangeable sodium;
	exchangeable calcium;
	exchangeable magnesium;
	exchangeable aluminium;
	soluble cations;
	chloride;
	metals (copper, iron, zinc, manganese, aluminium, molybdenum); and
	electrical conductivity.

Table 3.3 Samples analysed from each soil type

Soil types	Number of sites subjected to laboratory analysis	Site numbers	No. of depths analysed
Tenosol	3	20, 21, 37	15
Dermosol	3	55(A1), 5, 12	15
Sodosol	5	10, 23, 43, 47	25
Kurosol	2	41, 48,	10
Chromosol	2	53, 19*	10

*Chromosols not mapped as under 20ha

4 Soil descriptions

4.1 Overview

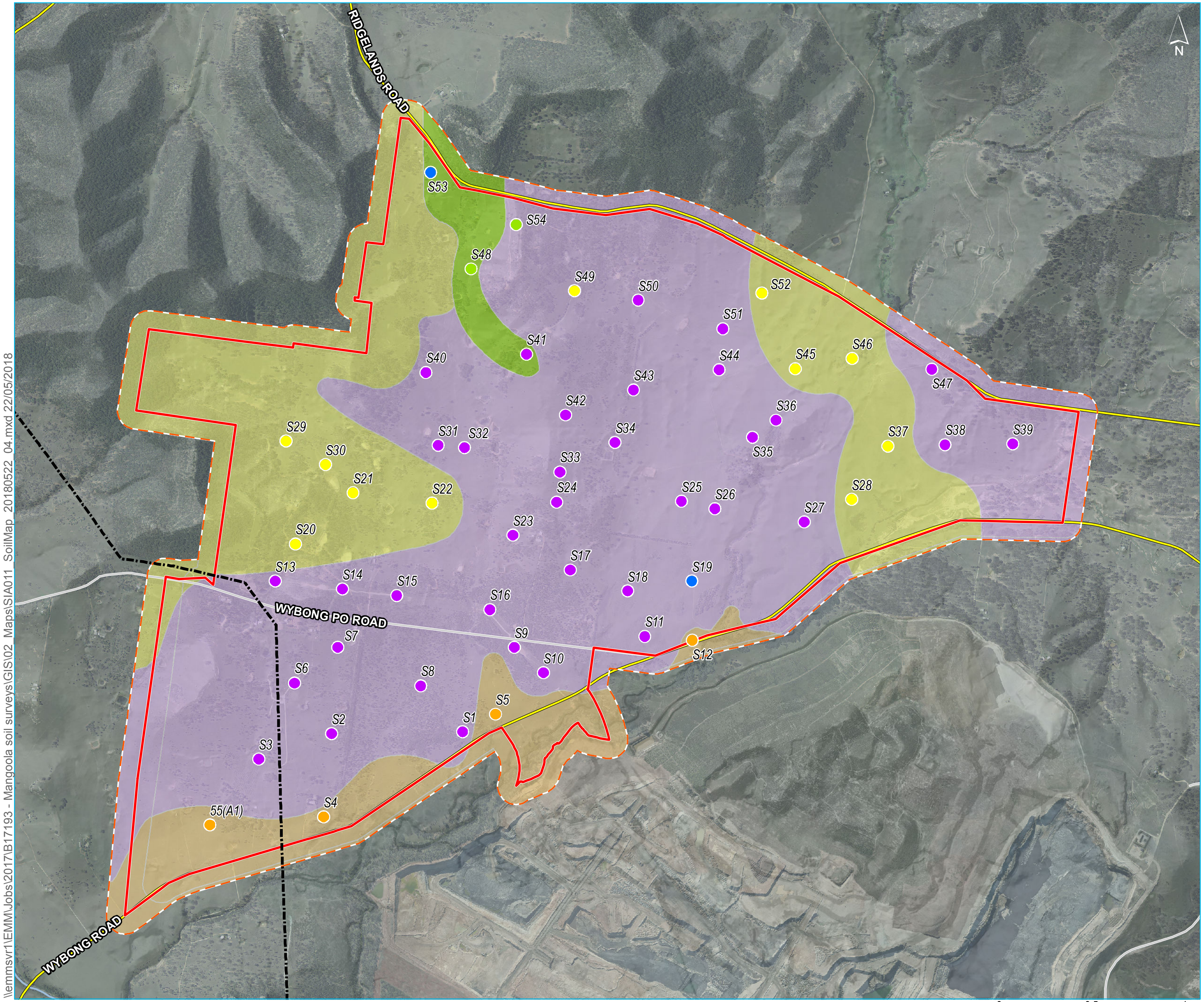
4.1.1 Results summary

The soil survey mapped four major soil types within the MCCO Additional Project Area (Table 4.1), Tenosols, Dermosols, Sodosols and Kurosols. Two Chromosol sites were identified however not mapped due to the singular locations and areas being under 20 ha. Laboratory analysis further identified the soil o Subgroup level as Mesotrophic Mesonatric Grey Sodosols, Basic Arenic Red-Orthic Tenosols, Magnesic-Natric Grey Kurosols, Sodic Eutrophic Brown Dermosols and Mottled Mesotrophic Brown Chromosols. Figure 4.1 presents the spatial distribution of the soil types within the MCCO Additional Project Area.

Table 4.1 Soil types in the project area

ASC[1] order (Soil type)	Total area mapped within project area (inc. 100m buffer)	
	(ha)	(%)
Sodosol	769.1	61.8
Tenosol	328.9	26.4
Kurosol	33.5	2.8
Dermosol	111.0	8.9
Chromosol	0	0
TOTAL	1243[2]	99.9[2]

Note: 1 *Australian Soil Classification*
2 not 100% due to rounding



\\emmsvr1\EMM\Jobs\2017\B17193 - Mangoola soil surveys\GIS\02_Maps\SIA011_SoilMap_20180522_04.mxd 22/05/2018

Source: EMM (2017); DFSI (2017); GA (2017)

KEY

- MCCO additional project area
- MCCO additional project area - 100m buffer
- 500kV transmission line
- Main road
- Local road
- Watercourse / drainage line

Soil test pit

- Chromosol
- Dermosol
- Kurosol
- Sodosol
- Tenosol

Soil type

- Dermosol
- Kurosol
- Sodosol
- Tenosol

Soil type distribution of the project area

Mangoola Coal Continued Operations Project
BSAL assessment
Figure 4.1

EMM

4.2 Red-Orthic Tenosol

Orthic Tenosols are characterised by a weakly developed B horizon, usually in terms of colour, texture or structure or a combination of these. These soils typically contain loamy sand to sandy loam in the A horizon and loamy sand textures throughout the B profile. The soil surface is without coarse fragments and of firm condition when dry. The identified basic arenic red-orthic Tenosols have coarse fragments distributed within the profile. There can be up to 2-10% small sized gravel distributed within the B horizon. The subsoils typically have no segregations or mottles. A soil profile description for a typical Arenic Red-Orthic Tenosol is provided in Table 4.2 and a general landscape is shown in Photograph 4.1.

Table 4.2 Basic Arenic Red-Orthic Tenosol typical soil profile summary

ASC:	Horizon name and average depth (m)	Colour, mottles and bleach	Moisture, laboratory pH (median) and drainage	Texture and structure	Coarse fragments, segregations and roots
	A1 0.0-0.19	Greyish brown, 7.5YR4/3 and no mottles or bleaching.	Dry, pH 5.7 and rapidly drained.	Sandy loam, weak pedality, sub-angular blocky structure.	No surface rock, few coarse fragments, no segregations and many roots.
	A2 0.19-0.40	Reddish brown 5YR4/4 and no mottles or bleaching	Moderately moist, pH 5.2 and rapidly drained.	Sandy loam, weak pedality, crumb structure.	Few coarse fragments, no segregations and few roots.
	B21 0.40-1.2 (some variation across sites)	Light red 2.5YR6/6 and no mottles or bleaching	Moderately moist, pH 5.9 and rapidly drained.	Loamy sand, weak pedality, crumb structure.	Few coarse fragments, no segregations

Notes: *1. Description in accordance with the Australian Soil and Land Survey Field Handbook (NCST 2009). Some profiles will vary*

2. pH are laboratory results and the median values are presented

3. Based on profile no. 29

Photograph 4.1 Basic Arenic Red-Orthic Tenosol (site 29)

The Arenic Red-Orthic Tenosol soil unit occurred on slopes and crests of undulating hills on sandstone and conglomerate surface geology and along the slopes of Big Flat Creek.. It is expected that some Rudosol soils will occur on crests and upper slopes of hills to the very west of the MCCO Additional Project Area. This general mix of Tenosol and Rudosol soil is in agreement with the existing mapping. Land associated with this soil has been extensively cleared for grazing, however scattered pockets of vegetation remain. The steep hillslopes have remained vegetated.

The Basic Arenic Red-Orthic Tenosols are not strongly acid with pH generally above 5.5. The profile tends to be slightly gravelly with very weak to no pedality and a sandy texture. Arenic Tenosols tend to have low water holding capacity and the sandy textures tend to have very low inherent fertility (Peverill et al 2005). The macronutrients (P,N,K) and the micronutrients (Ca, Mg, Na, Cu) are mostly low, which could restrict agriculture although fertiliser could amend these concentrations. The cation exchange capacity (CEC) is also very low, which also may present some fertility issues. While the soil profile extended beyond 1 m, the soils contained a sandy texture and low recorded fertility.

All soil chemistry results are given in Table 4.3. The soil chemistry constituent values highlighted in the 'soil sufficiency' column are agricultural industry benchmarks (Baker and Eldershaw 1993; Department of the Environment and Resource Management (DERM) 2011; Peverill, Sparrow and Reuter 1999) and have been referenced in interpreting the laboratory results. The outcomes are presented in the comments column, and are in reference to the median values with increasing depth. A summary of the agricultural potential of the Basic Arenic Red-Orthic Tenosol is given in Table 4.4.

Table 4.3 Basic Arenic Red-Orthic Tenosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.12	A2 0.12-0.4	B21 0.4-1.2	Comments on median values (in increasing depth)
pH_{water}	pH units	6.0-7.5	5.8 (5.6-6.2)	6.2 (6.2-6.2)	6.7 (6.1-7.6)	mild acidity (top of A horizon) to neutral (B horizon).
EC – saturated extract (EC_{se})	deciSemins per metre (dS/m)	<1.9	0.18 (0.25-0.09)	0.09 (0.06-0.11)	0.18 (0.06-0.39)	Very low soil salinity.
Chloride (Cl^-)	Milligrams per kilogram (mg/kg)	<800	<10	<10	10 (<10-20)	Not restrictive.
Macronutrients						
Nitrite + Nitrate as N (Sol.)	mg/kg	>15	0.85 (0.4-1.4)	0.5 (0.4-0.6)	0.2 (0.1-0.5)	Deficient throughout profile.
Total N	mg/kg	>1500	502 (360-740)	165 (160-170)	117 (80-220)	Deficient.
P (Colwell)	mg/kg	>10	2.5 (2.5-2.5)	2.5 (2.5-2.5)	2.5 (3-7)	Deficient.
K (Acid Extract)	mg/kg	>117	366 (251-474)	329 (296-362)	288 (225-413)	Sufficient.
K (Total)	mg/kg	>150	7.5 (5-10)	7.5 (5-10)	6.1 (5-10)	Deficient.
Micronutrients						
Cu	mg/kg	>0.3	<1	<1	<1	Low (inconclusive).
Zn	mg/kg	>0.5 (pH<7) >0.8 (pH>7)	0.8 (0.5-1.43)	<1	<1	Moderate in A horizon, Low (inconclusive).
Mn	mg/kg	>2	19.0 (5.2-25.6)	8.4 (8.1-8.7)	4.7 (0.5-20.8)	High (A horizon) to moderate (B horizon).
Exchangeable cations						
CEC	milliequivalents per 100 grams (meq/100 g)	12-25	2.7 (2.5-3)	1.9 (1.8-2.1)	2.6 (1.3-5.2)	Very low.
Ca	meq/100 g	>5	1.4 (0.5-1.8)	1.2 (1-1.4)	0.7 (0.1-1.3)	Very low.
Mg	meq/	>1	0.95	0.4	1.5	Low (A horizon) to

Table 4.3 Basic Arenic Red-Orthic Tenosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.12	A2 0.12-0.4	B21 0.4-1.2	Comments on median values (in increasing depth)
	100 g		(0.7-1.6)	(0.4-0.4)	(0.5-4.1)	moderate (B horizon).
Na	meq/ 100 g	<0.7	<0.1	<0.1	0.3 (0.1-0.5)	Very low.
K	meq/ 100 g	>0.3	0.3 (0.2-0.5)	0.25 (0.2-0.3)	0.3 (0.1-0.5)	Low
ESP	%	<6	1.1 (0.-2.8)	0.7 (0.5-0.9)	4.4 (0.1-16.2)	Non-sodic.
Ca:Mg ratio		>2	1.85 (0.3-2.6)	3 (2.5-3.5)	1.0 (0.05-2.6)	Stable A horizon. Unstable B horizon.
Organic Carbon (OC)	%	>1.2	0.82 (0.6-0.9)	<0.5	<0.5	Low (A1 horizon) to very low (A2 and B horizons).

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

Table 4.4 Basic Arenic Red-Orthic Tenosol agricultural use summary

Elements	Comments
pH_{water}	Acidic at the surface, progressing to neutral with depth. Would restrict some agriculture.
EC	Very low salinity levels that would not restrict agriculture.
Cl	Acceptable chloride levels that would not restrict agriculture.
Fertility	
Macronutrients	Mostly low levels of macronutrients, which present fertility issues. Would restrict agriculture.
Micronutrients	Low to moderate levels of micronutrients. Would restrict some agriculture.
CEC	Very low CEC, which may present some fertility issues.
Fertility ranking	**Relative Fertility of ASC Classes (NSW Government 2013):** Moderately low - Tenosol (order), Orthic (suborder), any (soil <1000mm and solum is light sandy textured (sandy to sandy loams) (Great group) **EMM applied Relative Fertility of ASC Classes (lab and field data applied to Murphy et al. 2007):** Moderately low (Group 2) - While the soils are deep the texture is sandy and the tested fertility is very low **Explanation (Murphy et al. 2007):** Low fertilities that generally only support plants suited to grazing. Generally deficient in nitrogen, phosphorus and many other elements.
ESP	Low ESP at surface, some sodicity at depth, which may not restrict agriculture.
Ca:Mg ratio	A mostly stable Ca:Mg ratio in the topsoil, but decreasing with depth to levels that suggest soil instability.
OC	Indicative of good structural condition and structural stability in the A1 horizon. Low levels below this horizon.
Major limitations to agriculture	Macronutrients (eg nitrate, total N, P, K extract) Micronutrients (eg Ca, Mg, Na)

4.3 Brown Dermosol

Brown Dermosols are moderately to well developed depending on the landform element with which they are associated, and do not have strong texture contrast. The parent materials of Dermosols range from siliceous, intermediate to mafic in composition with siliceous and intermediate in the local area. The identified Sodic Eutrophic Brown Dermosols surface soils are of moderately high fertility, moderately permeable and poorly drained. The Dermosols have saline, sodic B horizons and very slightly acidic A horizons. The soil surface is mostly without coarse fragments and of firm condition. Eutrophic Brown Dermosols generally have few coarse fragments distributed in the lower A and upper B horizons. Subsoils commonly have red and orange mottling with no segregations. Sod and tussock marsh vegetation were observed in some locations. A soil profile description for a typical Sodic Eutrophic Brown Dermosols is provided in Table 4.5.

Table 4.5 Dermosol typical soil profile summary

ASC:	Horizon name and average depth (m)	Colour, mottles and bleach	Moisture, laboratory pH (median) and drainage	Texture and structure	Coarse fragments, segregations and roots
	A1 0.0-0.09	Greyish brown, 7.5YR4/3 and no mottles or bleaching.	Dry, pH 5.9 and imperfectly drained.	Sandy clay loam, strong pedality, sub-angular blocky structure.	No surface rock, few coarse fragments, no segregations and many roots.
	B21 0.09-0.60	Reddish brown 2.5YR4/4 and no mottles or bleaching	Moderately moist, pH 7.2 and poorly drained.	Medium clay, moderate pedality, sub-angular blocky structure.	Few coarse fragments, no segregations and few roots.
	B22 0.60-1.2	Dark brown 7.5YR3/3 and no mottles or bleaching	Moderately moist, pH 6.8 and poorly drained.	Medium clay, moderate pedality, sub-angular blocky structure.	Few coarse fragments, no segregations

Notes: 1. Description in accordance with the Australian Soil and Land Survey Field Handbook (NCST 2009).
2. pH are laboratory results and the median values are presented
3. Based on profile no. 12. Some profiles will vary

Sodic Eutrophic Grey Dermosols occur on gently inclined rolling low hills associated with the localised back plain or meander of Big Flat Creek. Within the MCCO Additional Project Area, land use on this soil type is primarily for grazing (north of Wybong Road) with riparian zones adjacent to Big Flat Creek south of Wybong Road remaining vegetated (Photograph 4.2).

Photograph 4.2 Sodic Eutrophic Brown Dermosol (site 12)

Eutrophic Brown Dermosols are of moderately high fertility. The Sodic Eutrophic Brown Dermosols of the site are low to moderate fertility, moderately permeable, poorly drained and have saline and sodic subsoils with slightly acidic A horizons.

Soil chemistry results are given in Table 4.6, the soil chemistry constituent values highlighted in the 'soil sufficiency' column are agricultural industry benchmarks (Baker and Eldershaw 1993; Department of the Environment and Resource Management (DERM) 2011; Peverill, Sparrow and Reuter 1999) and have been referenced in interpreting the laboratory results. The outcomes are presented in the comments column, and are in reference to the median values with increasing depth. A summary of the agricultural potential of Sodic Eutrophic Brown Dermosols is given in Table 4.7.

Table 4.6 Sodic Eutrophic Brown Dermosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.09	B21 0.09-0.6	B22 0.6-1.2	Comments on median values (in increasing depth)
pH_{water}	pH units	6.0-7.5	5.9 (5.8-6)	6.4 (4.7-8.5)	5.8 (4.5-8.5)	Generally neutral to alkaline.
EC_{se}	dS/m	<1.9	0.3 (0.1-0.7)	3.5 (0.06-10.0)	3.3 (0.09-9.8)	Low soil salinity (A horizon), saline B horizon, except site 12
Cl	mg/kg	<800	43 (10-110)	618 (5-1540)	596 (5-1780)	Median is not restrictive. Site 5 and A1(55) exceed in lower B horizon.

Table 4.6 Sodic Eutrophic Brown Dermosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.09	B21 0.09-0.6	B22 0.6-1.2	Comments on median values (in increasing depth)
Macronutrients						
Nitrite + Nitrate as N (Sol.)	mg/kg	>15	0.35 (0.05-0.6)	0.12 (0.05-0.4)	0.23 (0.05-0.6)	Deficient throughout profile.
Total N	mg/kg	>1500	1696 (1,160-2,030)	354 (120-780)	243 (120-360)	Sufficient (A horizon) deficient in upper B horizon.
P (Colwell)	mg/kg	>10	4.8 (2.5-6)	<5	<5	Very low
K (Acid Extract)	mg/kg	>117	473 (467-481)	350 (270-404)	402 (295-539)	Sufficient
K (Total)	mg/kg	>150	15 (5-20)	7.2 (5-20)	6.6 (5-10)	Deficient
Micronutrients						
Cu	mg/kg	>0.3	0.5 (0.5-0.5)	0.72 (5-20)	0.79 (0.5-1.37)	Low (inconclusive) A horizon, moderate B horizon.
Zn	mg/kg	>0.5 (pH<7) >0.8 (pH>7)	2.3 (0.5-3.45)	0.5 (0.5-0.5)	0.5 (0.5-0.5)	Moderate A horizon, Low (inconclusive) B horizon.
Mn	mg/kg	>2	79.7 (24.3-119)	17 (133-54.2)	4.7 (0.5-10.1)	Moderate (A horizon) to very low (B horizon).
Exchangeable cations						
CEC	meq/ 100g	12-25	8.1 (6.-9.8)	9.5 (0.4-18.3)	11.7 (9.8-13.3)	Low (A horizon, upper B horizon) moderate B horizon
Ca	meq/ 100g	>5	3.5 (3.4-3.7)	2.0 (0.3-4.4)	2.4 (1.3-3.2)	Low throughout profile
Mg	meq/ 100g	>1	3.4 (1.8-5)	5.6 (0.1-11.4)	6.9 (5-8.4)	Moderate throughout profile
Na	meq/ 100g	<0.7	0.25 (0.05-0.5)	1.49 (0.05-3.1)	1.8 (0.6-3.2)	Low in A horizon to very high (B horizon)
K	meq/ 100g	>0.3	0.86 (0.8-0.9)	0.36 (0.1-0.7)	0.36 (0.3-0.4)	High (A horizon) to mod (B horizons).
ESP	%	<6	3 (0.7-5.4)	13.4 (0.1-30.3)	15.2 (5.1-24.2)	Sodic B horizon
Ca:Mg ratio		>2	1.2 (0.7-2)	0.4 (0.1-1.3)	0.3 (0.1-0.6)	Unstable soil profile
OC	%	>1.2	1.8 (1.4-2)	0.35 (0.25-0.9)	0.25 (0.25-0.25)	Mod (A horizon) to v low (B horizons).

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

Table 4.7 Dermosol agricultural use summary

Elements	Comments
pH_{water}	Mildly acidic throughout the profile. Would restrict some agriculture.
EC	Saline B horizon that may restrict some agriculture.
Cl	Acceptable chloride levels that would not restrict agriculture.
Fertility	
Macronutrients	Deficient in some macronutrients, which present fertility issues. Would restrict agriculture.
Micronutrients	Low to moderate levels of micronutrients. Would restrict some agriculture.
CEC	Very low CEC, which may present some fertility issues.
Fertility ranking	**Relative Fertility of ASC Classes (NSW Government 2013):** Moderately high - Dermosol (order), Brown(sub-order), Eutrophic (Great group) **EMM applied Relative Fertility of ASC Classes (lab and field data applied to Murphy et al. 2007):** Moderately low (Group 2) - Classified due to sodic subsoil and low fertility **Explanation (Murphy et al. 2007):** Low fertilities that generally only support plants suited to grazing. Generally deficient in soluble N, P and many other elements. Highly sodic subsoils.
ESP	Moderate ESP at surface, High sodicity in B horizon from 0.1 m. Would restrict agriculture.
Ca:Mg ratio	Low Ca:Mg ratio in the topsoil and decreasing with depth to levels that suggest high soil instability.
OC	Indicative of good structural condition in the A1 horizon. Low levels below this horizon.
Major limitations to agriculture	Macronutrients (eg nitrate and nitrite, P, total K) Micronutrients (eg Ca, Na, Cu)

4.4 Grey Sodosol

Grey Sodosols show strong texture contrast with sandy clay loams over light to medium clays. These soils are generally not highly acidic with pH above 5.5 and have highly sodic B horizons. The Sodosols are associated with surface geology which is siliceous to intermediate in composition. The surface is generally hard setting. The identified Mesotrophic Mesonatric Grey Sodosols have very low agricultural potential with high sodicity. This can lead to high erodibility, poor structure and low permeability. A soil profile description for a typical Mesotrophic Mesonatric Grey Sodosols is provided in Table 4.8.

The Mesotrophic Mesonatric Grey Sodosol is the most common soil type across the MCCO Additional Project Area, occurring on all slopes and crests of low rolling hills in the lower west, centre and far east of the project area (Photograph 4.3). Land characterised by this soil type has been extensively cleared associated with historical grazing activities.

Table 4.8 Sodosol typical soil profile summary

ASC:	Horizon name and average depth (m)	Colour, mottles and bleach	Moisture, laboratory pH (median) and drainage	Texture and structure	Coarse fragments, segregations and roots
	A1 0.0-0.10	Brown, 7.5YR4/3 and no mottles or bleaching.	Dry, pH 6.0 and imperfectly drained.	Sandy clay loam, strong pedality, sub-angular blocky structure.	No surface rock, no coarse fragments, no segregations and many roots.
	A2 0.10-0.20	Light gray 10YR7/2 dry, no mottles, bleaching	Dry, pH 6.7 and imperfectly drained	Sandy loam, massive, sandy structure,	Abundant fine gravel fragments, no segregations.
	B21 0.20-0.85	Dark brown 7.5YR3/3 and no mottles or bleaching	Moderately moist, pH 7.9 and poorly drained.	Light medium clay, strong pedality, sub-angular blocky structure.	Few coarse fragments, no segregations and few roots.
	B22 0.85-1.20	Dark brown 7.5YR3/3 and no mottles or bleaching	Moderately moist, pH 8.0 and imperfectly drained.	Light medium clay, strong pedality, sub-angular blocky structure.	Few coarse fragments, no segregations

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

2. pH are laboratory results and the median values are presented

3. Based on profile no 10. Some profiles will vary

Photograph 4.3 Mesotrophic Mesonatric Grey Sodosol (site 10)

The pH of the surface is slightly acidic progressing to neutral with depth. The macronutrients (N, P, K) and the micronutrients (Cu, Ca, Mg) are mostly low which could restrict agriculture, although fertiliser could amend these concentrations. The CEC is also very low, which also may present some fertility issues. Salinity and Cl concentrations become restrictive in the B horizon from 0.2 m. Salt tolerant species (ie *junkus acutus*) have been identified on this soil type, particularly around sites 11 and 18. High sodicity and small Ca to Mg ratios indicate an unstable subsoil prone to dispersion.

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

Table 4.9 Grey Sodosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.10	A2 0.10-0.2	B21 0.2-0.85	B22 0.85-1.2	Comments on median values (in increasing depth)
pH_{water}	pH units	6.0-7.5	5.55 (5.4-5.7)	6.3 (6.0-6.6)	7.0 (5.4-9.1)	7.7 (5.9-8.9)	Mild acidity (top of A horizon) to mildly alkaline (B horizon).
EC_{se}	dS/m	<1.9	0.24 (0.1-0.38)	0.22 (0.09-0.36)	1.56 (0.08-6.52)	3.69 (3.04-4.50)	Subsoil salinity
Cl	mg/kg	<800	13.7 (<10-30)	11 (<10-20)	357 (<10-1640)	692 (400-1140)	Restrictive subsoil
Macronutrients							
Nitrite + Nitrate as N (Sol.)	mg/kg	>15	0.26 (005-0.5)	0.48 (0.2-1.1)	0.22 (0.05-0.6)	0.15 (0.05-0.3)	Extremely low throughout profile.
Total N	mg/kg	>1500	1412 (570-2110)	400 (140-930)	224 (120-310)	282 (70-420)	Deficient.
P (Colwell)	mg/kg	>10	4.3 (<5-10)	<5	3.5 (<5-7)	<5	Very low.
K (Acid Extract)	mg/kg	>117	461 (369-566)	212 (100-315)	214 (100-365)	256 (100-363)	Sufficient.
K (Total)	mg/kg	>150	11.25 (5-20)	<10	<10	<10	Deficient throughout profile
Micronutrients							
Cu	mg/kg	>0.3	<0.5	<0.5	<0.5	<0.5	Low (inconclusive).
Zn	mg/kg	>0.5 (pH<7) >0.8 (pH>7)	1.4 (0.5-1.96)	<0.5	<0.5	<0.5	Sufficient (A horizon), low (inconclusive) B horizon.
Mn	mg/kg	>2	24.3 (17.6-33.8)	2.6 (0.5-9.33)	<1	<1	High (A horizon) to very low (B horizon).
Exchangeable cations							
CEC	meq/ 100g	12-25	6.3 (3.6-9.3)	4.6 (1.9-7.9)	8.5 (1.8-13.9)	8.5 (7.3-11.5)	Very low.
Ca	meq/	>5	3.4	1.8	0.5	1.65	Low (A horizon) to

Table 4.9 Grey Sodosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.10	A2 0.10-0.2	B21 0.2-0.85	B22 0.85-1.2	Comments on median values (in increasing depth)
	100g		(2.1-4.4)	(0.9-3.2)	(0.1-0.9)	(0.5-2.4)	moderate (B horizon).
Mg	meq/ 100g	>1	1.95 (0.8-3.5)	2.1 (0.5-4)	5.4 (0.9-8.4)	5.0 (4.0-7.1)	Moderate (A horizons) to high (B horizon).
Na	meq/ 100g	<0.7	0.15 (0.05-0.4)	0.36 (0.05-0.8)	1.95 (0.3-3.4)	1.65 (1.2-2.2)	Very low.
K	meq/ 100g	>0.3	0.7 (0.4-0.9)	0.28 (0.2-0.5)	0.29 (0.05-0.7)	0.15 (0.1-0.2)	Moderate (A1 horizon) to low (A2 and B horizons).
ESP	%	<6	2.1 (0.8-3.9)	7.7 (3.5-14.1)	23.7 (14-3.5)	19.4 (15.2-27.3)	Sodic (A2 and B horizon).
Ca:Mg ratio		>2	2.15 (1.2-3.4)	1.26 (0.6-2.2)	0.18 (0.05-0.8)	0.32 (0.1-0.5)	Stable A horizon. Unstable B horizon.
OC	%	>1.2	2.25 (1.4-2.8)	0.59 (0.25-1.1)	0.3 (0.25-0.6)	0.25 (0.25-0.25)	Moderate (A1 horizon) to very low (A2 and B horizons).

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

Table 4.10 Sodosol agricultural use summary

Elements	Comments
pH_{water}	Slightly acidic at the surface, progressing to neutral with depth.
EC	Moderate subsoil salinity that would restrict some agriculture.
Cl	Acceptable chloride levels that would not restrict agriculture.
Fertility	
Macronutrients	Mostly low levels of macronutrients, which present fertility issues. Would restrict agriculture.
Micronutrients	Low to moderate levels of micronutrients. Would restrict some agriculture.
CEC	Very low CEC, which may present some fertility issues.
Fertility ranking	**Relative Fertility of ASC Classes (NSW Government 2013):** Moderately low - Sodosol (order), Grey (suborder), any (great group) **EMM applied Relative Fertility of ASC Classes (lab and field data applied to Murphy et al. 2007):** Moderately low - Group 2 **Explanation (Murphy et al. 2007):** Low fertilities that generally only support plants suited to grazing. Generally deficient in phosphorus, P and many other elements.
ESP	Low ESP at surface, sodicity from 0.1 m which would restrict agriculture.
Ca:Mg ratio	A mostly stable Ca:Mg ratio in the topsoil, but decreasing with depth to levels that suggest soil instability.
OC	Indicative of good structural condition and structural stability in the A1 horizon. Low levels below this horizon.
Major limitations to agriculture	Macronutrients (eg nitrate, total N, P, K) Micronutrients (eg Ca, Mg, Na)

Table 4.10 Sodosol agricultural use summary

Elements	Comments
	Sodicity (ESP > 6 in the subsoil)

4.5 Grey Kurosol

A very small percentage of the MCCO Additional Project Area is covered by Magnesic-Natric Grey Kurosols. These soils have a strong texture contrast with a strongly acid B horizon that may or may not be sodic. They appear to be a transition soil associated with gentle to moderate slopes and influenced by their location in the landscape and the quaternary depositional geology (Photograph 4.4). Magnesic-Natric Grey Kurosols have very low agricultural potential with high acidity (pH < 5.5) and low chemical fertility. Moisture loving vegetation profiles were observed in areas of open depressions. A soil profile description for a typical Magnesic-Natric Grey Kurosols is provided in Table 4.11.

Table 4.11 Kurosol typical soil profile summary

ASC:	Horizon name and average depth (m)	Colour, mottles and bleach	Moisture, laboratory pH (median) and drainage	Texture and structure	Coarse fragments, segregations and roots
	A1 0.0-0.10	Brown, 7.5YR4/3 and no mottles or bleaching.	Dry, pH 6.0 and poorly drained.	Sandy clay loam, moderate pedality, sub-angular blocky structure.	No surface rock, no coarse fragments, no segregations and many roots.
	A2 0.10-0.90	Dull brown 7.5YR5/3 and no mottles or bleaching	Dry, pH 6.2 and poorly drained.	Sandy loam, single grained, sandy fabric.	Many coarse fragments, no segregations and few roots.
	B21 0.90-1.20	Dark brown 7.5YR3/3, Many orange and grey mottles.	Moderately moist, pH 5.2 and poorly drained.	Medium clay, moderate pedality, sub-angular blocky structure.	Few coarse fragments, no segregations

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

2. pH are laboratory results and the median values are presented

3. Based on profile no 48. Some profiles vary.

Photograph 4.4 Mottled Magnesic-Natric Grey Kurosols (site 48)

The Grey Kurosol is acidic in the upper B horizon and mildly acidic throughout the horizon. The surface is generally hard set with no surface fragments but fine gravel dispersed through the A horizon. The soil type has been cleared for grazing in the project area. The macronutrients (P, K) and the micronutrients (Cu, Ca, Mg) are mostly low which could restrict agriculture, although fertiliser could amend these concentrations. The CEC is also very low, which also may present some fertility issues.

Soil chemistry results for the Magnesic-Natric Grey Kurosol are presented in Table 4.12. The soil chemistry constituent values highlighted in the 'soil sufficiency' column are agricultural industry benchmarks (Baker and Eldershaw 1993; Department of the Environment and Resource Management (DERM) 2011; Peverill, Sparrow and Reuter 1999) and have been referenced in interpreting the laboratory results. The outcomes are presented in the comments column, and are in reference to the median values with increasing depth. A summary of the agricultural potential of Mottled Magnesic-Natric Grey Kurosol is presented in Table 4.13.

Table 4.12 Magnesic-Natric Grey Kurosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.10	A2 0.10-0.9	B21 0.9-1.2	Comments on median values (in increasing depth)
pH_{water}	pH units	6.0-7.5	5.6 (5.5-5.8)	6.1 (5.9-6.6)	5.1 (4.9-5.5)	Mild acidity (top of A horizon) to acidity (B horizon).
EC_{se}	dS/m	<1.9	0.19 (0.1-0.25)	0.72 (0.03-4.07)	0.19 (0.08-0.31)	Very low soil salinity.
Cl	mg/kg	<800	6.6 (<5-10)	<5	12.5 (<5-20)	Not restrictive.

Table 4.12 Magnesic-Natric Grey Kurosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.10	A2 0.10-0.9	B21 0.9-1.2	Comments on median values (in increasing depth)
Macronutrients						
Nitrite + Nitrate as N (Sol.)	mg/kg	>15	5.4 (2.2-10.7)	0.5 (0.1-1)	0.3 (0.2-0.5)	Very low throughout profile.
Total N	mg/kg	>1500	1236 (1,000-1,510)	255 (150-380)	215 (140-310)	Deficient.
P (Colwell)	mg/kg	>10	<5	<5	<5	Very low.
K (Acid Extract)	mg/kg	>117	408 (291-495)	145 (100-235)	220 (100-350)	Sufficient in profile.
K (Total)	mg/kg	>150	11.6 (5-20)	<5	<5	Very low
Micronutrients						
Cu	mg/kg	>0.3	<5	<5	<5	Low (inconclusive).
Zn	mg/kg	>0.5 (pH<7) >0.8 (pH>7)	3.2 (1.0-7.3)	<5	<5	Sufficient (A hroizon), low (inconclusive) in B.
Mn	mg/kg	>2	45.3 (26.4-58.5)	3.11 (0.5-6.6)	<5	High (A horizon) to low (B horizon).
Exchangeable cations						
CEC	meq/100g	12-25	5.06 (4.3-5.8)	2.81 (2.2-3.4)	9.4 (5.6-13)	Very low.
Ca	meq/100g	>5	3.3 (2.9-4.1)	1.58 (0.7-2.2)	0.16 (0.05-0.3)	Low (A horizon) to very low (B horizon).
Mg	meq/100g	>1	1.06 (0.8-1.3)	0.9 (0.6-1.6)	4.7 (2.7-6.6)	Moderate (A1 and B horizons).
Na	meq/100g	<0.7	0.5 (<0.5-0.5)	0.05 (0.05-0.1)	0.98 (0.05-2.01)	Very low.
K	meq/100g	>0.3	0.5 (0.3-0.8)	0.12 (0.05-0.2)	0.28 (0.05-0.5)	Mod (A1 horizon) to very low (A2 and B horizon).
ESP	%	<6	0.73 (0.4-1.3)	2.25 (0.7-5.4)	12.9 (2.4-24.3)	Sodic subsoil (transition soil sample).
Ca:Mg ratio		>2	3.1 (2.7-3.6)	1.9 (0.4-3.3)	<0.1	Stable A horizon. Unstable B horizon.
OC	%	>1.2	2.3 (1.3-2.9)	0.7 (0.6-0.8)	<0.5	Moderate (A1 horizon) to very low (B horizon).

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

Table 4.13 Kurosol agricultural use summary

Elements	Comments
pH_{water}	Acidic at the surface, progressing to neutral with depth. Would restrict some agriculture.
EC	Very low salinity levels that would not restrict agriculture.
Cl	Acceptable chloride levels that would not restrict agriculture.
Fertility	
Macronutrients	Mostly very low levels of macronutrients, which present fertility issues. Would restrict agriculture.
Micronutrients	Low to moderate levels of micronutrients. Would restrict some agriculture.
CEC	Very low CEC, which may present some fertility issues.
Fertility ranking	**Relative Fertility of ASC Classes (NSW Government 2013):** Moderately low - Kurosol (order), any (suborder), Magnesic-Natric (Great group) **EMM applied Relative Fertility of ASC Classes (lab and field data applied to Murphy et al. 2007):** Moderately low (Group 2) **Explanation (Murphy et al. 2007):** Low fertilities that generally only support plants suited to grazing. Generally deficient in phosphorus, P and many other elements.
ESP	Low ESP at surface, some sodicity at depth, which may not restrict agriculture.
Ca:Mg ratio	A mostly stable Ca:Mg ratio in the topsoil, but decreasing with depth to levels that suggest soil instability.
OC	Indicative of good structural condition and structural stability in the A1 horizon. Low levels below this horizon.
Major limitations to agriculture	Macronutrients (eg nitrate, total N, potassium, K) Micronutrients (eg Ca, Mg, Na)

4.6 Brown Chromosol

Two surveyed soil profiles have been classified as Mottled Mesotrophic Brown Chromosols (site 19 and 53). These are soils with a strong texture contrast between the A and B horizons and where the upper part of the B horizon is neither sodic or acidic. The Chromosols on site may be a boundary, or transition soil type. The sites occur on gently undulating hills (Photograph 4.5). Chromosols have moderate agricultural potential with moderate chemical fertility and water-holding capacity. They can be susceptible to soil acidification and soil structure decline. A soil profile description for a typical Mottled Mesotrophic Brown Chromosol is shown in Table 4.14.

Table 4.14 Chromosol typical soil profile summary

ASC:	Horizon name and average depth (m)	Colour, mottles and bleach	Moisture, laboratory pH (median) and drainage	Texture and structure	Coarse fragments, segregations and roots
	A1 0.0-0.10	Brown, 7.5YR4/3 and no mottles or bleaching.	Dry, pH 5.8 and moderately drained.	Sandy clay loam, moderate pedality, sub-angular blocky structure.	No surface rock, no coarse fragments, no segregations and many roots.
	A2 0.10-0.50	Dull brown 10YR4/2 and no mottles	Dry, pH 6.0 and imperfectly drained.	Sandy loam, weak pedality, sandy fabric.	Common coarse fragments, no segregations and few roots.
	B21 0.50-1.20	Dull brown 7.5YR3/3	Moderately moist, pH 7.0 and poorly drained.	Light clay, moderate pedality, sub-angular blocky structure.	Common coarse fragments, no segregations

Notes: *1. Description in accordance with the Australian Soil and Land Survey Field Handbook (NCST 2009).*
2. pH are laboratory results and the median values are presented
3. based on profile no. 54. Some profiles will vary

Photograph 4.5 Mottled Mesotrophic Brown Chromosol (site 19)

The Brown Chromosol surface is soft with no surface fragments but fine gravel dispersed through the lower A horizon and B horizon. The soil type has been cleared for grazing in the MCCO Additional Project Area. The soil chemistry results show levels contributing to very poor actual soil fertility. The macronutrients (potassium, P and K) and the micronutrients (Cu, Ca and Mg) are very low which could restrict agriculture, although fertiliser could amend these concentrations. The CEC is also very low, which also may present some fertility issues.

Soil chemistry results for the Mottled Mesotrophic Brown Chromosol are presented in Table 4.15. The soil chemistry constituent values highlighted in the 'soil sufficiency' column are agricultural industry benchmarks (Baker and Eldershaw 1993; Department of the Environment and Resource Management (DERM) 2011; Peverill, Sparrow and Reuter 1999) and have been referenced in interpreting the laboratory results. The outcomes are presented in the comments column, and are in reference to the median values with increasing depth. A summary of the agricultural potential of Mottled Mesotrophic Brown Chromosol is presented in Table 4.16.

Table 4.15 Mottled Mesotrophic Brown Chromosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.10	A2 0.10-0.5	B21 0.5-1.2	Comments on median values (in increasing depth)
pH_{water}	pH units	6.0-7.5	6.0 (5.5-6.6)	6.5 (6.5-6.6)	7.4 (7.1-7.8)	Neutral profile.
EC_{se}	dS/m	<1.9	0.30 (025-0.35)	0.08 (0.05-0.11)	0.25 (0.13-0.31)	Very low soil salinity.
Cl	mg/kg	<800	<10	<10	20 (<10-50)	Not restrictive.
Macronutrients						
Nitrite + Nitrate as N (Sol.)	mg/kg	>15	7.5 (4.3-10.7)	0.8 (0.4-1.8)	0.3 (0.3-0.4)	Very low throughout profile.
Total N	mg/kg	>1500	1065 (1,000-1,130)	176 (110-260)	136 (130-150)	Deficient.
P (Colwell)	mg/kg	>10	<5	<5	<5	Very low.
K (Acid Extract)	mg/kg	>117	423 (408-439)	236 (235-237)	300 (300-300)	Sufficient in profile.
K (Total)	mg/kg	>150	25 (20-30)	<10	<10	Very low
Micronutrients						
Cu	mg/kg	>0.3	<0.5	<0.5	<0.5	Low (inconclusive).
Zn	mg/kg	>0.5 (pH<7) >0.8 (pH>7)	1.25 (1.0-1.4)	<1	<1	Sufficient (A horizon), low (inconclusive) in B.
Mn	mg/kg	>2	42 (33-51)	9.6 (3.6-19)	3.5 (1.4-5.6)	High (A horizon) to moderate (B horizon).
Exchangeable cations						
CEC	meq/ 100g	12-25	4.2 (4.2-4.3)	2.5 (2-2.9)	2.2 (1.1-3.8)	Very low.
Ca	meq/ 100g	>5	2.6 (2.4-2.9)	1.6 (1.4-2)	1.0 (0.6-1.8)	Low (A horizon) to very low (B horizon).
Mg	meq/ 100g	>1	0.9 (0.8-1)	0.5 (0.2-0.8)	1.0 (0.5-1.7)	Low (A1 and B horizons).

Table 4.15 Mottled Mesotrophic Brown Chromosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.10	A2 0.10-0.5	B21 0.5-1.2	Comments on median values (in increasing depth)
Na	meq/ 100g	<0.7	<0.1	<0.1	0.1 <0.1-0.1)	Very low.
K	meq/ 100g	>0.3	0.5 (0.4-0.7)	0.2 (0.1-0.3)	0.1 (0.1-0.1)	Mod (A1 horizon) to very low (A2 and B horizon).
ESP	%	<6	0.27 (0.05-0.5)	1.1 (0.5-1.8)	1.3 (<1-3.7) (	Low in profile.
Ca:Mg ratio		>2	3 (2.4-3.6)	4.0 (2.1-7.0)	0.9 (0.7-1)	Stable A horizon. Unstable B horizon.
OC	%	>1.2	1.6 (1.3-1.9)	<1	<1	Moderate (A1 horizon) to very low (B horizon).

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

Table 4.16 Chromosol agricultural use summary

Elements	Comments
pH_{water}	Neutral throughout profile. Would not restrict agriculture.
EC	Very low salinity levels that would not restrict agriculture.
Cl	Acceptable chloride levels that would not restrict agriculture.
Fertility	
Macronutrients	Mostly very low levels of macronutrients, which present fertility issues. Would restrict agriculture.
Micronutrients	Low to moderate levels of micronutrients. Would restrict some agriculture.
CEC	Very low CEC, which may present some fertility issues.
Fertility ranking	**Relative Fertility of ASC Classes (NSW Government 2013):** Moderately High - Chromosol (order), any (suborder), Mesotrophic (Great group) **EMM applied Relative Fertility of ASC Classes (lab and field data applied to Murphy et al. 2007):** Moderately low (Group 2) **Explanation (Murphy et al. 2007):** Low fertilities that generally only support plants suited to grazing. Generally deficient in phosphorus, P and many other elements.
ESP	Low ESP, which may not restrict agriculture.
Ca:Mg ratio	A mostly stable Ca:Mg ratio in the topsoil, but decreasing with depth to levels that suggest soil instability.
OC	Indicative of good structural condition and structural stability in the A1 horizon. Low levels below this horizon.
Major limitations to agriculture	Macronutrients (eg nitrate, total N, P, K) Micronutrients (eg Ca, Mg, Na)

4.7 Comparison with soil mapping by others

The ASRIS and eSPADE soil mapping in the MCCO Additional Project Area are very similar and have been grouped together for this comparison. There are some broad similarities between the existing ASRIS and eSPADE soil mapping, and the field-based soil survey results from this assessment, in terms of soil orders present and general patterns of distribution. The comparison results are summarised below.

Southern border of the MCCO Additional Project Area:

- ASRIS and eSPADE mapping: Dominated by Sodosols;
- EMM soil survey: Sodosols, with Dermosols adjacent to Big Flat Creek.

Western and north-western part of the MCCO Additional Project Area:

- ASRIS and eSPADE mapping: dominated by Tenosols/Rudosols and Sodosols;
- EMM soil survey: dominated by a larger expanse of Tenosols. It is expected that Rudosols may occur on the steeper slopes on the very western edge of the MCCO Additional Project Area. A small area of Kurosols occurs in the north-west.

Eastern and central parts of the MCCO Additional Project Area:

- ASRIS and eSPADE mapping: dominated by Sodosols only;
- EMM soil survey: dominated by Sodosols with an expanse of Tenosols towards the eastern side of the MCCO Additional Project Area.

The ASRIS or eSPADE mapping did not identify any Kurosols or Dermosols within the MCCO Additional Project Area. Field investigations found the Sodosols and Tenosols to be the dominant soil types, in agreement with the existing soil mapping, with the Kurosol and Dermosol occurring in smaller areas. The ASRIS and eSPADE data was not used further in this assessment. The assessments and soil mapping within this report have been based on results of field surveys and laboratory analyses from the current study, which were conducted in accordance with the Interim Protocol. In particular, the field and laboratory investigations for this study provided information which confirmed the presence or absence of various soil orders, including the following:

- Kurosols: small area of Kurosol identified in the north-west. These soils were texture contrast, all with acidic B horizons and one sample also confirmed as having a sodic B horizon; and
- Dermosols: small areas of Dermosols were identified adjacent to Big Flat Creek on the southern border of the MCCO Additional Project Area. Some of these sites had sodic B horizons. The structure of these soils varied between sites, however they did not have a strong texture contrast.

5 BSAL verification

For land to be classified as BSAL it must have access to a reliable water supply; meet all of the criteria presented in Figure 2.2; and be a contiguous area of at least 20 ha. Under the Interim Protocol if any individual criterion is not met, the site is not BSAL. The BSAL verification criteria have been evaluated for the MCCO Additional Project Area, based on analysis of field, laboratory and remotely sensed data. Section 2.2 explains the BSAL exclusion criteria and more detail is provided in Appendix C. Section 5.2 presents the results of the BSAL assessment and more detail is provided in Appendix D.

5.1 Exclusion criteria

5.1.1 Slope

A slope assessment for the MCCO Additional Project Area was conducted using a digital elevation model and site observations were made using a hand held clinometer. Areas with slopes greater than 10% were identified as BSAL exclusion areas.

5.1.2 Rock outcrop

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

5.1.3 Surface rockiness

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

5.1.4 Gilgai

Gilgai microrelief is a natural soil feature of mounds and depressions commonly associated with cracking clays or Vertosols. The review of NSW regional soils mapping indicated that gilgai microrelief was unlikely to be present within the MCCO Additional Project Area and this was supported by the field observations.

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

5.1.5 Soil fertility

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

The BSAL assessment has proceeded using the criteria of the Interim Protocol. In addition to this actual soil fertility has been assessed for the site soils using chemical analysis and agricultural industry 'soil sufficiency' benchmarks sourced from Baker and Eldershaw (1993); Department of the Environment and Resource Management (DERM) (2011), and Peverill, Sparrow and Reuter (1999).

5.1.6 Effective rooting depth

Effective rooting depth refers to the depth of soil in which roots can function effectively. That is, above any physical or chemical barrier.

Physical and chemical barriers were identified in the field and recorded on SALIS data cards, and/or by laboratory analysis. In the context of BSAL, the depth of soil material from the surface to a physical barrier such as bedrock, weathered rock, hard pans or continuous gravel layers was noted during field surveys. Chemical barriers were identified based on laboratory analysis of soil profile samples, being where limiting values of soil pH, chloride content, electrical conductivity, exchangeable sodium percentage and/or the calcium to magnesium ratio (Ca:Mg) exist.

Survey sites with a physical or chemical barrier to rooting depth at less than 750 mm were identified as BSAL exclusion areas.

5.1.7 Drainage

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

5.1.8 Soil pH

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

5.1.9 Soil salinity

Soil salinity was measured in the laboratory. Sites where soil salinity in the uppermost 600 mm of the soil profile had any of the following properties were identified as BSAL exclusion areas:

- electrical conductivity of greater than 4 deciSiemens per metre (dS/m); or
- the presence of chlorides at 800 milligrams/kilogram (mg/kg) or more, with gypsum present.

5.2 Results of BSAL assessment

Detailed survey sites in the MCCO Additional Project Area which were subject to soil analysis (Table 3.3) have been classified according to their soil type under the ASC, to family level. These survey sites were assessed against each of the BSAL criteria specified in the Interim Protocol, to determine whether or not the criterion is satisfied. These analysed survey sites represent the soil types on site and it is assumed that the results will apply across all other survey sites not laboratory analysed. The detailed results are provided in Appendix D and summarised in Table 5.1, using the following code:

- yes (Y) highlighted in green, for a decisive 'yes' to meeting the subject criterion for BSAL;
- no (N) highlighted in orange, where a site fails the BSAL verification criteria but assessment against subsequent criteria is required to determine whether the site is BSAL or not (applies to criteria 5 to 7b); and
- N highlighted in red, for a decisive 'no' to meeting the subject criterion, meaning the site is excluded as BSAL on this basis alone.

Table 5.1 BSAL verification assessment by soil survey site

Site no.[1]	ASC soil type (to Sub Group)	BSAL verification criteria															Is the site BSAL?
		Water	1	2	3	4	5	6	7a	7b	8	9	10	11	12	Area	
		Access to reliable water supply?	Slope ≤ 10%?	< 30% rock outcrop?	≤ 20% of area has unattached rock fragments > 60 mm diameter?	≤ 50% of the area has gilgais > 500 mm deep?	Slope < 5 %?	Nil rock outcrops?	Moderate soil fertility or higher? (applicable for sites <5% slope)	Moderately high or high soil fertility? Applicable for sites > 5% and <10% slope)	Effective rooting depth to physical barrier is ≥750 mm?	Soil drainage is better than poor?	pH 5-8.9 if measured in water or 4.5-8.1 if measured in calcium chloride, within the uppermost 600 mm of the soil profile?	Salinity is ≤ 4 dS/m or chlorides < 800 mg/kg when gypsum is present, within the uppermost 600 mm of the soil profile?	Effective rooting depth to a chemical barrier is ≥750 mm?	Is the contiguous area ≥20 ha?	
20	Basic Arenic Red-Orthic Tenosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	No
21	Basic Arenic Red-Orthic Tenosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	No
37	Basic Arenic Red-Orthic Tenosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	No
55A1	Sodic Eutrophic Brown Dermosol	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	N	N	Y	No
5	Sodic Eutrophic Brown Dermosol	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	N	N	Y	No
12	Mottled-Sodic Eutrophic Brown Dermosol	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Y	No
10	Mesotrophic Hypernatric Grey Sodosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	N	N	N	Y	No
23	Mesotrophic Mottled-Hypernatric Grey Sodosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y	Y	Y	Y	No

Table 5.1 BSAL verification assessment by soil survey site

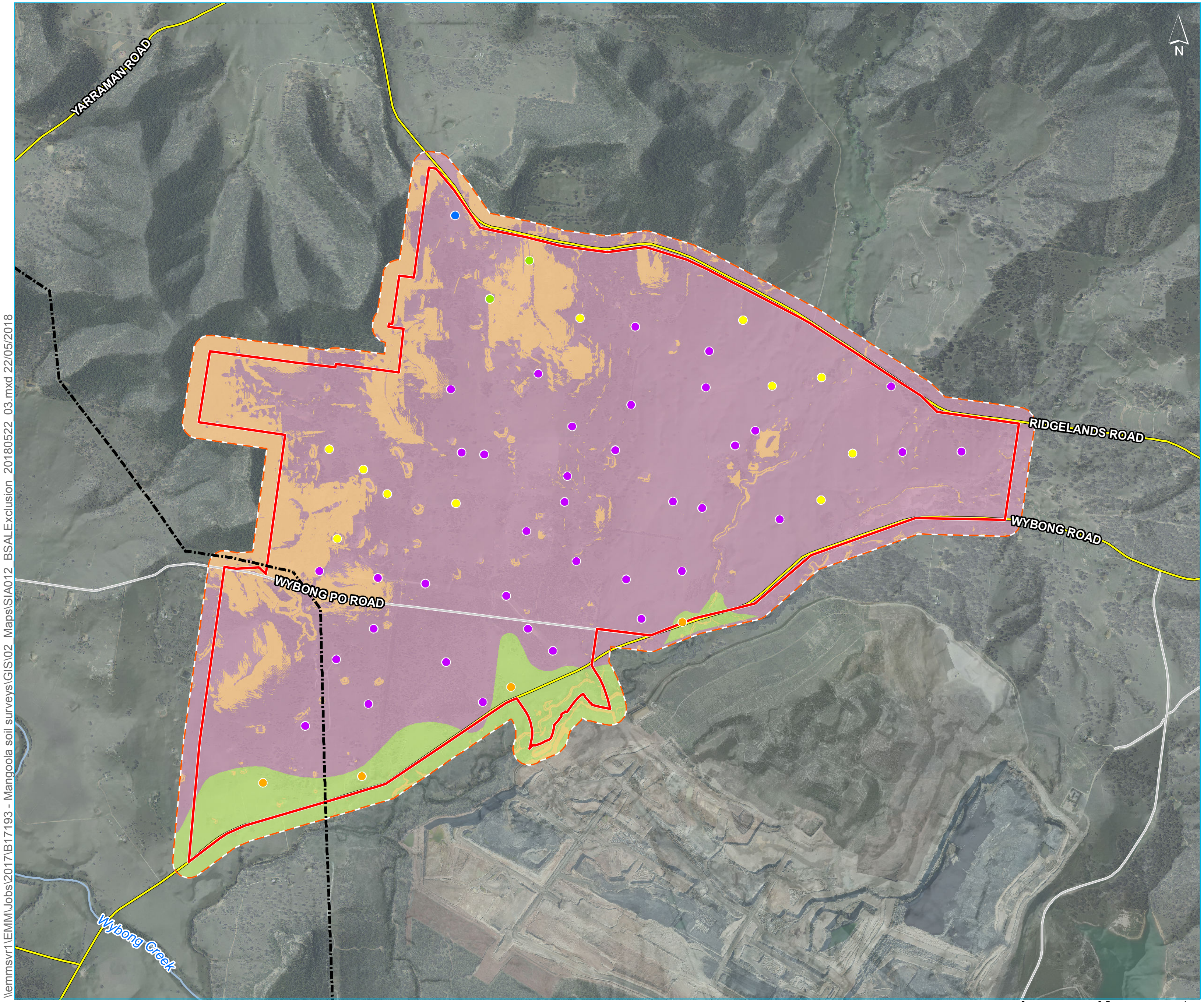
Site no.[1]	ASC soil type (to Sub Group)	BSAL verification criteria															Is the site BSAL?
		Water	1	2	3	4	5	6	7a	7b	8	9	10	11	12	Area	
		Access to reliable water supply?	Slope ≤ 10%?	< 30% rock outcrop?	≤ 20% of area has unattached rock fragments > 60 mm diameter?	≤ 50% of the area has gilgais > 500 mm deep?	Slope < 5 %?	Nil rock outcrops?	Moderate soil fertility or higher? (applicable for sites <5% slope)	Moderately high or high soil fertility? Applicable for sites > 5% and <10% slope)	Effective rooting depth to physical barrier is ≥750 mm?	Soil drainage is better than poor?	pH 5-8.9 if measured in water or 4.5-8.1 if measured in calcium chloride, within the uppermost 600 mm of the soil profile?	Salinity is ≤ 4 dS/m or chlorides < 800 mg/kg when gypsum is present, within the uppermost 600 mm of the soil profile?	Effective rooting depth to a chemical barrier is ≥750 mm?	Is the contiguous area ≥20 ha?	
43	Mesotrophic Mottled-Mesonatric Grey Sodosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y	Y	Y	Y	No
47	Mesotrophic Mesonatric Grey Sodosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	N	N	Y	No
41	Mottled Magnesic-Natric Grey Kurosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y	Y	Y	Y	No
48	Mottled Magnesic-Natric Grey Kurosol	Y	Y	Y	Y	Y	N	Y	N	N	Y	N	Y	Y	Y	Y	No
19	Mottled Mesotrophic Brown Chromosol	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	N	No
53	Mottled Mesotrophic Brown Chromosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y	Y	Y	N	No

Note: 1. Refer to Figure 4.1 for the locations of survey sites.

The results in Table 5.1 show that there is no BSAL in the MCCO Additional Project Area or wider assessment area (inclusive of 100m buffer). Most areas and/or soils fail the BSAL tests on multiple criteria. The principal exclusion criteria across the assessment area are shown in Figure 5.1 and are summarised as follows:

- physical and chemical soil characteristics for BSAL exclusion areas:
  - Sodic Eutrophic Brown Dermosols were excluded because of generally poor drainage. Chemical tests also showed the soils have very low actual fertility;
  - Mesotrophic Mesonatric Grey Sodosols were excluded because of low soil fertility and chemical barriers;
  - Mottled Magnesic-Natric Grey Kurosols were excluded because of low soil fertility and drainage.
  - Mottled Mesotrophic Brown Chromosols where excluded due to their area although chemical tests showed the soils have very low actual fertility.
- steep slope BSAL exclusion areas (slopes greater than 10%) occur in much of the western part of the MCCO Additional Project Area associated with an elevated ridge (as shown on Figure 5.1). Some central hills also contain slopes greater than 10%.

Most soils also do not meet other BSAL criteria. For example many of the soils have high salinity (ECe greater than 4 dS/m and/or chloride greater than or equal to 800 mg/kg) and chemical barriers to plant rooting such as sodicity (exchangeable sodium percentage greater than or equal to 15%). Further detail is provided in the BSAL verification assessment tables in Appendix D.



Source: EMM (2017); DFSI (2017); GA (2017)

\\emmsvr1\EMM\Jobs\2017\B17193 - Mangoola soil surveys\GIS\02_Maps\SIA012_BSALExclusion_20180522_03.mxd 22/05/2018

BSAL exclusion map

Mangoola Coal Continued Operations Project
BSAL assessment
Figure 5.1

6 Conclusion

A robust site verification assessment has been conducted, by certified professional soil scientists, following the relevant guidelines. This has included field surveys, laboratory analyses and geospatial slope analysis techniques to analyse soils and landforms across the assessment area and determine whether the BSAL criteria shown in Figure 2.2 were met. The BSAL verification assessment area was defined as the land that may be subject to a future mining lease application plus a 100 m buffer. This resulted in a total assessment area of approximately 1,193 ha.

Field-based site surveys and laboratory analyses of soils were undertaken based on recommendations in the Handbook and Interim Protocol. Soil type boundaries were identified by manual mapping methods based on existing information, survey results, geology and topography.

Five soil types were identified in the SVC application area: Tenosols, Dermosols, Sodosols, Kurosols, and Chromosols. Only four of these were mapped based on area, greater than 20 hectares, with the Chomosol excluded.

Each soil type was assessed against the BSAL verification criteria and no soil type was found to satisfy the criteria, with most failing multiple physical and chemical criteria. In addition, an analysis of slope in the MCCO Additional Project Area determined that some land failed the slope criterion. The result is that no CIC or BSAL is present in the MCCO Additional Project Area or wider assessment area, a conclusion that is consistent with the results of the NSW Government's BSAL mapping.

Based on the assessment results, Mangoola are required to apply for a SVC as opposed to a Gateway Certificate. This BSAL verification assessment has been prepared in accordance with the Interim Protocol to accompany the SVC application. As the MCCO Project is not on Strategic Agricultural Land, the Gateway Process does not apply and the project does not need to go through the gateway process. Nonetheless any agricultural impacts will be comprehensively assessed through an Agricultural Impact Statement that will form part of the EIS, and will be assessed by the relevant agencies at the development application stage.

.

References

Baker DE & Eldershaw VJ 1993, *Interpreting soil analyses*, Department of Primary Industries, Queensland.

BOM, 2017, *Climate classification maps*, Australian Government Bureau of Meteorology (accessed on 2nd August 2017 at http://www.bom.gov.au/jsp/ncc/climate_averages/climate-classifications/index.jsp)

CSIRO, 2014, Australian soil resource information system, (accessed on 2nd August 207 at http://www.asris.csiro.au/).

DERM 2011, *Guidelines for applying the proposed strategic cropping land criteria*, Department of Environment and Resource Management. (accessed 22 November 2103, http://www.nrm.qld.gov.au/land/planning/pdf/strategic-cropping/scl-guidelines.pdf)

DLWC, 2001, *Soil data entry handbook*, 3rd Edition, Department of Land and Water Conservation.

DPI, 2012, *Upper Hunter Strategic Regional Land Use Policy*. New South Wales Government.

Gallant JC, McKenzie NJ, McBratney AB, 2008, Scale. In 'Guidelines for surveying soil and land resources' (Eds NJ McKenzie, M J Grundy, R Webster, AJ Ringrose-Voase) 27–43. Second Edition. (CSIRO Publishing: Collingwood).

Isbell RF, 2002, The Australian soil classification, CSIRO Publishing, Melbourne.

McKenzie NJ, Grundy MJ, Webster R & Ringrose-Voase AJ, 2008, 2nd Edition, *Guidelines for surveying soil and land resources,* CSIRO Publishing, Melbourne.

Murphy BW, Eldridge DJ, Chapman GA and McKane DJ 2007, *Soils of New South Wales* in *Soils their properties and management* (3rd edition), Eds PEV Charman and BW Murphy, Oxford University Press: Melbourne.

NCST, 2009, 3rd edition, *Australian soil and land survey handbook*, National Committee on Soil and Terrain CSIRO Publishing, Melbourne.

NSW Government, 2012, *Draft Guideline for site verification of critical industry clusters*

NSW Government, 2013, *Interim protocol for site verification and mapping of biophysical strategic agricultural land,* New South Wales Government.

NSW Government, 2016, *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources*, New South Wales Government.

NSW Office of Water (NOW) 2013c, *Reliable surface water in NSW June 2013*, spatial data set, received on 1 October 2014.

OEH, 2017a, Inherent soil fertility mapping of NSW. Version 1.6 (v131024), Office of Environment and Heritage (http://www.environment.nsw.gov.au/eSpadeWebapp/).

OEH, 2017b, *Land and Soil Capability Mapping of NSW*. Version 2.5 (v131024), Office of Environment and Heritage (http://www.environment.nsw.gov.au/eSpadeWebapp/)

Peverill KI, Sparrow LA, Reuter DJ (eds) 1999, *Soil analysis: interpretation manual*, CSIRO Publishing, Collingwood.

Stace, H.C.T, Hubble, G.D., Brewer, R, Northcote, K.H, Sleeman, J.R, Mulcahy, M.J, and Hallsworth, E.G 1968, A Handbook of Australian Soils, Rellim, Glenside, SA, Australia.

24 September 2018

Suite 1, Level 4, 87 Wickham Terrace
Spring Hill QLD 4000
PO Box 10424, Adelaide Street
Brisbane, QLD 4000

T +61 7 3839 1800
F +61 7 3839 1866
E info@emmconsulting.com.au

www.emmconsulting.com.au

Daniel Sullivan

Umwelt (Australia) Pty Ltd
75 York Street
Teralba, NSW 2284

Re: B17193 Mangoola BSAL response for OEH

Dear Daniel,

Please find a response to each of OEH's itemised queries shown in Table 1.0, below. Most responses are very straight forward and a review of the field notes has allowed for some further information to be supplied.

Two changes to the BSAL report itself would result from these queries. The first is a change to Figure 4.1, the soil map, where the Kurosol soil type is extended slightly following further review of topography and field notes of landscape observations, and Site 41 is correctly identified as a Kurosol. The second is a change to Appendix A, where the correct profile would be shown for Site 12. The amended Figure 4.1 is attached to this response.

Table 1.0 Response to OEH queries for Mangoola North BSAL assessment

OEH comment	EMM response
In the Kurosol map unit, only 1 of the 3 detailed site are classified as a Kurosol; the others are a Chromosol and Sodosol. The *Interim protocol* (p.14) requires >70% of profiles within a unit to be of the dominant soil type. There's also a Kurosol (profile 54) sitting just outside the mapped Kurosol unit.	Site 41 is a Kurosol and has been assessed in the BSAL report as a Kurosol. Site 41 should have been reclassified in SALIS following the field collection once fully investigated. This has been rectified in the SALIS spreadsheet. The Kurosol mapping was initially based on topography and field observations of vegetation and landform. Field notes suggest the soil type boundary in the landscape is highly variable. Following a further assessment to incorporate the Kurosol survey site, the boundary of the Kurosol can be amended. This change still considers topography and landscape features as well as the variability observed. The change results in the following soil type areas: **Soil type** — **Area (hectares)** Dermosol — 111.04 Kurosol — 35.65 Sodosol — 767.00 Tenosol — 328.97 **Total** — **1242.66**
1. All 55 sites are classified as 'detailed' in SALIS, i.e., require full ASC to Family level and laboratory soil testing (see *Interim protocol*, section 9.4.2, p.11). However, lab data etc. has only been provided for 14 of these sites. We assume that all sites without	This is correct, the remaining sites are check sites and this has been updated in the spreadsheet.

	lab data are check sites.	
2.	Photos are moderate to poor in quality and occasionally appear to be either missing, unusable or assigned to the wrong site, e.g., no usable photo for profile 5 (appears to have supplied photo for profile 4), the photo for site 12 has one image in report and something different in the high resolution photo folder, profile 9 has no profile photo.	I have cross checked the photographs using the original file transfers and the photograph metadata rather than the photos in the file structure. Where a photo is missing, it has not been taken by the field technician and further training on checking all requirements has been provided. The wrong profile has been supplied for profile 5. Unfortunately there is no useable photo for this profile. Some incorrect photos have been copied into the Site 12 folder, Photographs: P8271330, P8271331, P8271332, P8271333 and P8271334 are not of site 12 and should be removed. Appendix A of the BSAL report shows the incorrect profile photograph. The correct profile is shown below.  **Site 12 soil profile**
3.	Soil exposures in backhoe pits have not been sufficiently prepared for either soil description or photography (see *Australian soil and land Survey handbook - Guidelines for conducting surveys* p.192) – the pits are narrow and are not always oriented to place the working face in direct sunlight, meaning that some of the profiles are strongly shadowed, and the working faces have not been cleaned to remove smearing from the backhoe bucket so that soil layers can be clearly identified and soil structure, colour and mottling made more visible.	This was identified. The soil surveyor has received further training on the requirements in order to produce a good quality photograph of the soil profile and to organise and record all photos in order and ensure they are correct. The surveyor was able to adequately characterise the soil horizons and appropriate sample locations whilst in the pit on site.
4.	The laboratory soil test spreadsheet provided by the proponent contains a number of errors:	
	a. Test methods must use National test codes; a list is provided in the template and assigning of National codes should be checked with the lab who processed the samples.	ALS Brisbane could not confirm a Rayment and Lyons equivalent code for all of these. The ALS laboratory methodologies section included in their QA/QC compliance assessment of which an example is

		attached to this response. The methods left blank do not have a Rayment and Lyons equivalent code available and have been based on other standards. The calculated values (eg Ca:Mg ratio) have been removed and placed as a note at the end of the spreadsheet. The Munsell colour and texture have also been relocated to notes as the field records are used in the assessment.
	b. There are discrepancies between profile numbers in the spreadsheet and in the report, e.g., A1/53 in the spreadsheet appears to be A1/55 in the report.	The laboratory test is identified as A1 but this site has subsequently been given a numeric code of 55. A mistake in the laboratory sheet reported number 53.
	c. Profile numbers cannot contain letters or characters, e.g., A1/53.	The laboratory test is identified as A1 but this site has subsequently been given a numeric code of 55.
	d. Sample numbers cannot contain letters or characters, e.g., 'EB1720219001' should be '1720219001'.	The lettering has been removed
	e. Station number is not required.	Updated
	f. Fraction should be defaulted as '1' if not known or used by the lab.	Updated
	g. Both EC and ECe should be given in the results.	Both values have not both been supplied in the laboratory reporting and therefore are not included here.
	h. Some profiles are described in SALIS as described in a 'pit' whilst the spreadsheet has them described with 'auger'.	All samples have been collected from a pit. This was a reporting error that has been rectified in the spreadsheet.
	i. Munsell colour (551.01) requires data in Munsell notation, e.g. '10YR 4/3'.	Laboratory has only noted colour. Remove and use colour supplied in SALIS.
	j. Laboratory texture data can be loaded into one of the following test methods: Incitec-Pivot (552.02), McDonald (552.01) and Northcote (552.03). The list of possible options for each are given below.	The field texture analysis has been used in the assessment and the laboratory data has been removed. The laboratory noted it has used McDonald reference for texture.
5.	For profile 19, OEH queries layer 3's texture of 'sandy loam' as the soil looks heavier-textured in the photo. OEH also queries the horizon codes given; we also note that the laboratory test results describe different horizons to those in the profile description. Also, while profile 19 is classified as a Sodosol in SALIS it is described as a Chromosol in the report (pp.39-40) and in the GIS data.	Site 19 should have been reclassified in SALIS as a Chromosol after the laboratory results were received. The assessment has been undertaken on the basis that this is a Chromosol. The horizon codes used in SALIS for the B horizon are incorrect. It should be B21 and B22, which was recorded by the field technician. The field technician indicated the profile was very granular. The laboratory texture, although not being relied on for the assessment indicated a sand and loamy sand in the B horizon. The texture is reported as measured in the field.
6.	For profile 21, OEH queries the B2 horizon texture of 'loamy sand' as the soil looks heavier-textured in the photo.	The field technician indicated the profile was very granular. The laboratory texture, although not being relied on for the assessment indicated a gravelly sand. The texture is reported as measured in the field.
7.	For profile 37, OEH queries the B2 horizon texture	The field technician indicated the profile was very granular.

	of 'sandy loam' as the soil looks heavier-textured in the photo.	The laboratory texture, although not being relied on for the assessment indicated a gravelly sand. The texture is reported as measured in the field.
8.	For profile 48, OEH queries the B2 horizon texture of 'sandy loam' as the soil looks heavier-textured in the photo.	For site 48 the B2 texture is recorded in SALIS as medium clay. The A2 texture was recorded as sandy loam.
9.	For profile 53, OEH queries the description of this soil as 'poorly drained'. The site is on a 6% slope and has no vegetation suggesting waterlogging. Subsoils are moderately structured and, while mottled (soil description indicates from >50 cm) are not of a colour that would suggest poor drainage. We suggest this profile is more appropriately described as 'imperfectly drained'.	I agree. This has been amended in the SALIS spreadsheet to 'imperfectly drained'.
10.	Moist Munsell colours are missing for almost all layers (use of moist colours is a standard soil description requirement; see *Australian soil and land survey field handbook*, p.159), colours have almost exclusively been supplied as Dry Munsell colours. Some layers[1] have no colour specified at all.	Moist Munsell colours were not recorded by the field technician. The dry Munsell colour from some field notes have not been transposed into the SALIS record. These have been amended.
11.	Some layers[2] are missing fabric; whilst not explicitly listed in the *Interim protocol*, fabric is a basic soil descriptive element.	The following has been updated in the field sheet from field notes and photographs 17 B2 - rough-faced peds 19 A1 - sandy 21 A1 - sandy 21 B1 - rough-faced peds 21 B2 - rough-faced peds 29 A1 - rough-faced peds 29 B2 - rough-faced peds 32 A - rough-faced peds 40 B2 - rough-faced peds 42 B2- rough-faced peds 54 A1 - sandy 55 B21- rough-faced peds 55 B22- rough-faced peds
12.	Some layers[3] are missing dominant ped shape.	The sites that have had this missing information inserted from the field notes are: 1 A1 - sub-angular blocky 3 B2 - sub-angular blocky 7 B2 - sub-angular blocky 9 A1 - crumb 12 B21 - sub-angular blocky 15 A2 - sub-angular blocky 23 B2 - sub-angular blocky Where the grade of pedality has been classified as massive or single grain, these are viewed as non-pedal and a dominant ped size or shape has not been provided.
13.	Some layers[4] are missing dominant ped size.	The sites that have had this missing information inserted from the field notes are: 24 B2 - 20-50 mm 31 A1 - 5-10 mm (also inserted subdominant ped shape - sub angular blocky)

	47 B21 - 20-50 mm (no record of subdominant peds in field notes - removed) 48 A1 - 5-10 mm Where the grade of pedality has been classified as massive or single grain, these are viewed as non-pedal and a dominant ped size or shape has not been provided.
14. Profile 44 (layers 1 and 2) is missing dominant mottle type.	Mottles 'not evident'. This has been added.
15. Some layers[5] are missing dominant mottle contrast.	These sites have been updated from the field notes with 'distinct' in all of them 17 B2 23 B2 43 B2
16. Profile 17 (layer 3) is missing subdominant mottle contrast.	Both dominant and subdominant mottle contrast is distinct in the field notes. This has been inserted.
17. Some layers[6] are missing segregation type (may just be 'not evident').	These have been updated with 'not-evident' 4 A1 and B21 12 A1
18. Substrate has been described as 'not evident' for all profiles. Whilst not an explicit requirement of the *Interim protocol* this is an important soil descriptive element.	From the field surveyors notes, no record or observations of encountering substrate on site are found. A desktop review of the geology of the area may provide further information, however without direct observations this information is not included.
19. Profile 49 is missing rock outcrop.	'Nil' has been entered for the site.
20. Profile 55 is missing microrelief.	'none' has been added
21. Profile 31 and 35 are missing groundcover.	Spreadsheet has been updated with: Profile 31 - 85% from photos Profile 35 - 90% from photo
22. Profile 22, 29 and 33 are missing estimated effective rooting depth.	Spreadsheet has been updated with: Profile 22 - 1.2 m Profile 29 - 1.2 m Profile 33 - 0.6 m
23. Profile 46 and 53 are missing base of observation.	Spreadsheet has been updated with: Profile 46 - layer continues Profile 53 - layer continues
24. Profile 20 is missing horizon code.	Profile horizon 'B2' added

Please contact me with any further queries.

Yours sincerely

Kylie Drapala
Senior Environment Scientist
kdrapala@emmconsulting.com.au

Brief Method Summaries

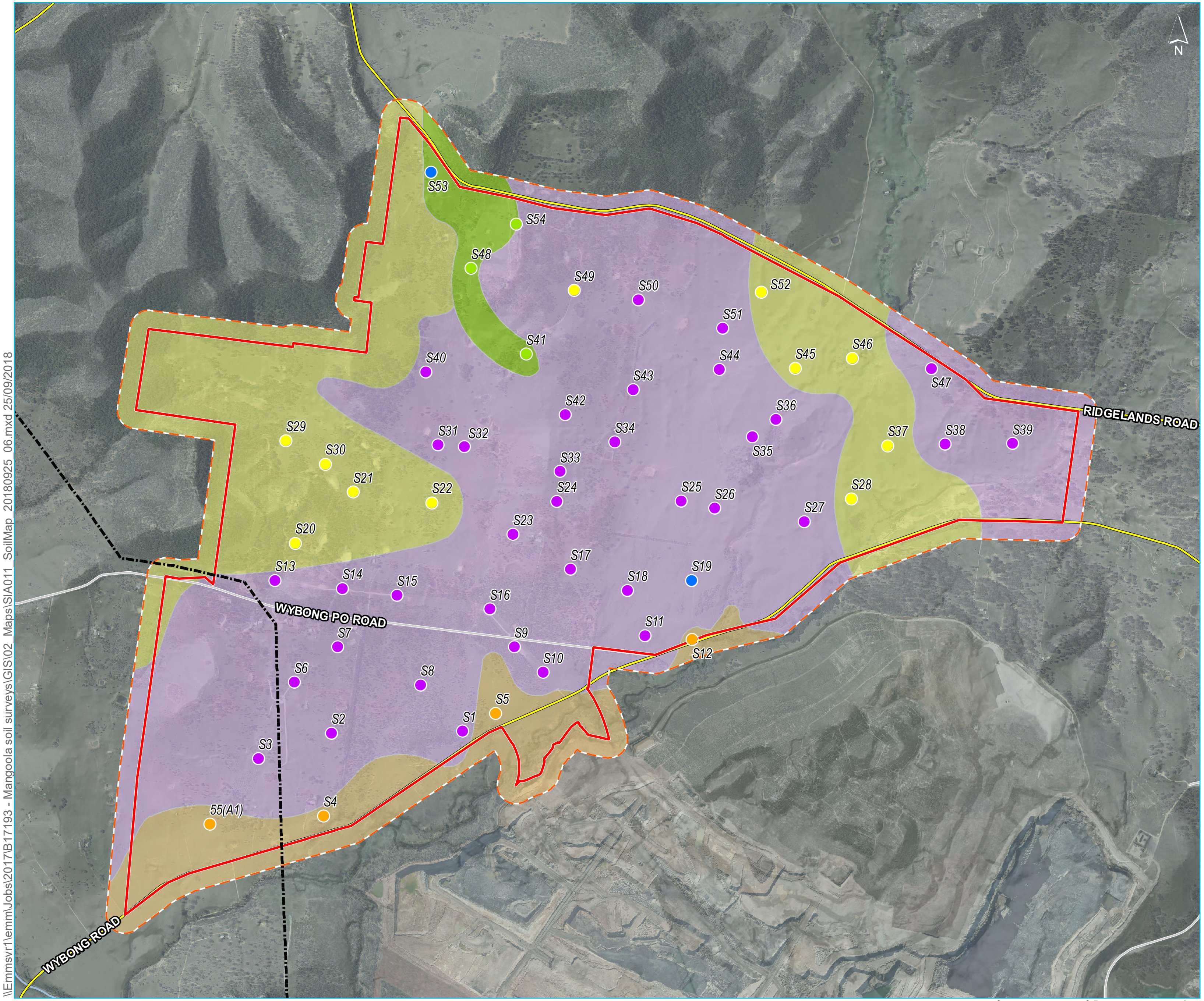
The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	Method	Matrix	Method Descriptions
pH in soil using a 0.01M CaCl2 extract	EA001	SOIL	In house: Referenced to Rayment and Lyons (2011) 4B3 (mod.) or 4B4 (mod.) 10 g of soil is mixed with 50 mL of 0.01M CaCl2 and tumbled end over end for 1 hour. pH is measured from the continuous suspension. This method is compliant with NEPM (2013) Schedule B(3)
pH (1:5)	EA002	SOIL	In house: Referenced to Rayment and Lyons 4A1 and APHA 4500H+. pH is determined on soil samples after a 1:5 soil/water leach. This method is compliant with NEPM (2013) Schedule B(3)
Calcium Carbonate Equivalent	EA008	SOIL	In house: Referenced to ASTM C602.90.- Calcium carbonate equivalent is calculated by measuring the amount of acid consumed by the sample after the addition of a known excess of standard hydrochloric acid. The CCE of the sample is obtained by determining the amount of unconsumed acid by titration with standardised sodium hydroxide.
Electrical Conductivity (1:5)	EA010	SOIL	In house: Referenced to Rayment and Lyons 3A1 and APHA 2510. Conductivity is determined on soil samples using a 1:5 soil/water leach. This method is compliant with NEPM (2013) Schedule B(3)
Moisture Content	EA055	SOIL	In house: A gravimetric procedure based on weight loss over a 12 hour drying period at 105-110 degrees C. This method is compliant with NEPM (2013) Schedule B(3) Section 7.1 and Table 1 (14 day holding time).
Emerson Aggregate Test	EA058	SOIL	In house: Referenced to AS1289.3.8.1. Testing is performed only on soils with suitable aggregates; sands and gravels are usually unsuitable for this test. The test classifies the behaviour of soil aggregates, when immersed, on their coherence in water.
Exchange Acidity by 1M Potassium Chloride	ED005	SOIL	In house: referenced to Rayment and Lyons, (2011), method 15G1. This method is unsuitable for near neutral and alkaline soils. NATA accreditation does not cover performance of this service.
Exchangeable Cations on Alkaline Soils	ED006	SOIL	In house: Referenced to Soil Survey Test Method C5. Soluble salts are removed from the sample prior to analysis. Cations are exchanged from the sample by contact with alcoholic ammonium chloride at pH 8.5. They are then quantitated in the final solution by ICPAES and reported as meq/100g of original soil.
Exchangeable Cations	ED007	SOIL	In house: Referenced to Rayment & Lyons (2011) Method 15A1. Cations are exchanged from the sample by contact with Ammonium Chloride. They are then quantitated in the final solution by ICPAES and reported as meq/100g of original soil. This method is compliant with NEPM (2013) Schedule B(3) (Method 301)
Exchangeable Cations with pre-treatment	ED008	SOIL	In house: Referenced to Rayment & Higginson (2011) Method 15A2. Soluble salts are removed from the sample prior to analysis. Cations are exchanged from the sample by contact with Ammonium Chloride. They are then quantitated in the final solution by ICPAES and reported as meq/100g of original soil. This method is compliant with NEPM (2013) Schedule B(3) (Method 301)
Bicarbonate Extractable K (Colwell)	ED021	SOIL	In house: Referenced to Rayment & Higginson (2011) Method 18A1 Potassium is extracted from the soil using 0.5M NaHCO3 at a 1:100 soil:solution ratio and determined by ICP.
Major Anions - Soluble	ED040S	SOIL	In house: Soluble Anions are determined off a 1:5 soil / water extract by ICPAES.
Chloride Soluble By Discrete Analyser	ED045G	SOIL	In house: Referenced to APHA 4500-Cl- E. The thiocyanate ion is liberated from mercuric thiocyanate through sequestration of mercury by the chloride ion to form non-ionised mercuric chloride.in the presence of ferric ions the librated thiocynate forms highly-coloured ferric thiocynate which is measured at 480 nm. Analysis is performed on a 1:5 soil / water leachate.
DTPA Extractable Metals	* ED092	SOIL	In house: Referenced to Rayment and Higginson (2011) 12A1

Analytical Methods	Method	Matrix	Method Descriptions
Cations - soluble by ICP-AES	ED093S	SOIL	In house: Referenced to APHA 3120; USEPA SW 846 - 6010 (ICPAES) Water extracts of the soil are analyzed for major cations by ICPAES. The ICPAES technique ionises samples in a plasma, emitting a characteristic spectrum based on metals present. Intensities at selected wavelengths are compared against those of matrix matched standards. This method is compliant with NEPM (2013) Schedule B(3)
Total Metals by ICP-AES	EG005T	SOIL	In house: Referenced to APHA 3120; USEPA SW 846 - 6010. Metals are determined following an appropriate acid digestion of the soil. The ICPAES technique ionises samples in a plasma, emitting a characteristic spectrum based on metals present. Intensities at selected wavelengths are compared against those of matrix matched standards. This method is compliant with NEPM (2013) Schedule B(3)
Buchi Ammonia	EK055	SOIL	In house: Referenced to APHA 4500-NH3 B&G, H Samples are steam distilled (Buchi) prior to analysis and quantified using titration, FIA or Discrete Analyser.
Nitrite as N - Soluble by Discrete Analyser	EK057G	SOIL	In house: Referenced to APHA 4500-NO3- B. Nitrite in a water extract is determined by direct colourimetry by Discrete Analyser.
Nitrate as N - Soluble by Discrete Analyser	EK058G	SOIL	In house: Referenced to APHA 4500-NO3- F. Nitrate in the 1:5 soil:water extract is reduced to nitrite by way of a chemical reduction followed by quantification by Discrete Analyser. Nitrite is determined seperately by direct colourimetry and result for Nitrate calculated as the difference between the two results.
Nitrite and Nitrate as N (NOx)- Soluble by Discrete Analyser	EK059G	SOIL	In house: Thermo Scientific Method D08727 and NEMI (National Environmental Method Index) Method ID: 9171. This method covers the determination of total oxidised nitrogen (NOx-N) and nitrate (NO3-N) by calculation, Combined oxidised Nitrogen (NO2+NO3) in a water extract is determined by direct colourimetry by Discrete Analyser.
TKN as N By Discrete Analyser	EK061G	SOIL	In house: Referenced to APHA 4500-Norg-D Soil samples are digested using Kjeldahl digestion followed by determination by Discrete Analyser.
Total Nitrogen as N (TKN + NOx) By Discrete Analyser	EK062G	SOIL	In house: Referenced to APHA 4500 Norg/NO3- Total Nitrogen is determined as the sum of TKN and Oxidised Nitrrogen, each determined seperately as N.
Total Phosporus By Discrete Analyser	EK067G	SOIL	In house: Referenced to APHA 4500 P-B&F This procedure involves sulfuric acid digestion and quantification using Discrete Analyser.
Bicarbonate Extractable P (Colwell)	EK080	SOIL	In house: Referenced to Rayment & Higginson (2011) Method 9B1 Phosphorus is extracted from the soil using 0.5M NaHCO3 at a 1:100 soil:solution ratio and determined by FIA.
Organic Matter	EP004	SOIL	In house: Referenced to AS1289.4.1.1 - 1997. Dichromate oxidation method after Walkley and Black. This method is compliant with NEPM (2013) Schedule B(3).

Preparation Methods	Method	Matrix	Method Descriptions
pH in soil using a 0.01M CaCl2 extract	EA001-PR	SOIL	In house: Referenced to Rayment and Higginson 4B1, 10 g of soil is mixed with 50 mL of 0.01M CaCl2 and tumbled end over end for 1 hour. pH is measured from the continuous suspension. This method is compliant with NEPM (2013) Schedule B(3) (Method 103)
Exchangeable Cations Preparation Method (Alkaline Soils)	ED006PR	SOIL	In house: Referenced to Rayment and Lyons 2011 method 15C1.
Exchangeable Cations Preparation Method	ED007PR	SOIL	In house: Referenced to Rayment & Higginson (1992) method 15A1. A 1M NH4Cl extraction by end over end tumbling at a ratio of 1:20. There is no pretreatment for soluble salts. Extracts can be run by ICP for cations.
Bicarbonate Extractable K (Colwell)	ED021PR	SOIL	In house: Referenced to Rayment & Higginson (1992) Method 18A1 Potassium is extracted from the soil using 0.5M NaHCO3 at a 1:100 soil:solution ratio and determined by ICP.
DTPA Extraction for Cu, Zn, Mn, Fe (2 hour leach)	ED092PR	SOIL	In house: Referenced to Rayment & Higginson (1992) Method 12A1 2 hour end over end tumbler extraction with 0.005M DTPA at a ratio of 1:2. Extracts can be run by ICP for metals.

Preparation Methods	*Method*	*Matrix*	*Method Descriptions*
TKN/TP Digestion	EK061/EK067	SOIL	In house: Referenced to APHA 4500 Norg- D; APHA 4500 P - H. Macro Kjeldahl digestion.
Drying at 85 degrees, bagging and labelling (ASS)	EN020PR	SOIL	In house
1:5 solid / water leach for soluble analytes	EN34	SOIL	10 g of soil is mixed with 50 mL of reagent grade water and tumbled end over end for 1 hour. Water soluble salts are leached from the soil by the continuous suspension. Samples are settled and the water filtered off for analysis.
Hot Block Digest for metals in soils sediments and sludges	EN69	SOIL	In house: Referenced to USEPA 200.2. Hot Block Acid Digestion 1.0g of sample is heated with Nitric and Hydrochloric acids, then cooled. Peroxide is added and samples heated and cooled again before being filtered and bulked to volume for analysis. Digest is appropriate for determination of selected metals in sludge, sediments, and soils. This method is compliant with NEPM (2013) Schedule B(3) (Method 202)
Organic Matter	EP004-PR	SOIL	In house: Referenced to AS1289.4.1.1 - 1997. Dichromate oxidation method after Walkley and Black. This method is compliant with NEPM (2013) Schedule B(3) (Method 105)



\\Emmsvr1\emm\Jobs\2017\B17193 - Mangoola soil surveys\GIS\02_Maps\SIA011_SoilMap_20180925_06.mxd 25/09/2018

Source: EMM (2017); DFSI (2017)

KEY
- MCCO additional project area
- MCCO additional project area - 100m buffer
- 500kV transmission line
- Main road
- Local road
- Watercourse / drainage line

Soil test pit
- Chromosol
- Dermosol
- Kurosol
- Sodosol
- Tenosol

Soil type
- Dermosol
- Kurosol
- Sodosol
- Tenosol

Soil type distribution of the project area

Mangoola Coal Continued Operations Project
Soil assessment
Figure 4.1

EMM

Site Verification Certificate

Mangoola Coal Continued Operations Project – (SVC 9512)

Part 4AA, Division 3 of *State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007*

Pursuant to clause 17C(1) of the *State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007*, I determine the application made by Mangoola Coal Operations Pty Ltd by issuing this certificate.

I certify that in my opinion, having regard to the criteria in the *Interim protocol for site verification and mapping of biophysical strategic agricultural land*, the Verification Application Area land specified in Schedule 1 is not Biophysical Strategic Agricultural Land.

The reasons for forming this opinion against relevant criteria, are contained in Schedule 2.

Deputy Secretary
As delegate of the Secretary
Date certificate issued: 10 December 2018

This certificate will remain current for 5 years from the date of issue.

SCHEDULE 1

KEY

- ML 1626
- ML 1747
- MCCO project area
- MCCO additional project area
- MCCO additional project area - 100m buffer
- Approved Mangoola Coal Mine disturbance area
- AL9 boundary
- Proposed overpass
- MCCO proposed additional mining area
- Proposed emplacement area
- Indicative Wybong Post Office Road realignment
- 500kV transmission line
- Main road
- Local road
- Rail line
- Watercourse / drainage line

Mangoola Coal Continued Operations project layout

Mangoola Coal Continued Operations Project
BSAL assessment
Figure 1.2

EMM

SCHEDULE 2

Relevant criteria	Consideration
Soil slope	No Exclusion Zone for land areas greater than 10% slope were identified and excluded from the soil survey.
Contiguous land	No Exclusion Zone for land areas less than 20 contiguous hectares total size were identified and excluded from the soil survey.
Physical constraints	Soil types identified in the soil survey include various limitations to land use including poor drainage, structure decline, acidity and shallow soils. In accordance with the Interim Protocol, this excludes these soil types from being considered BSAL.