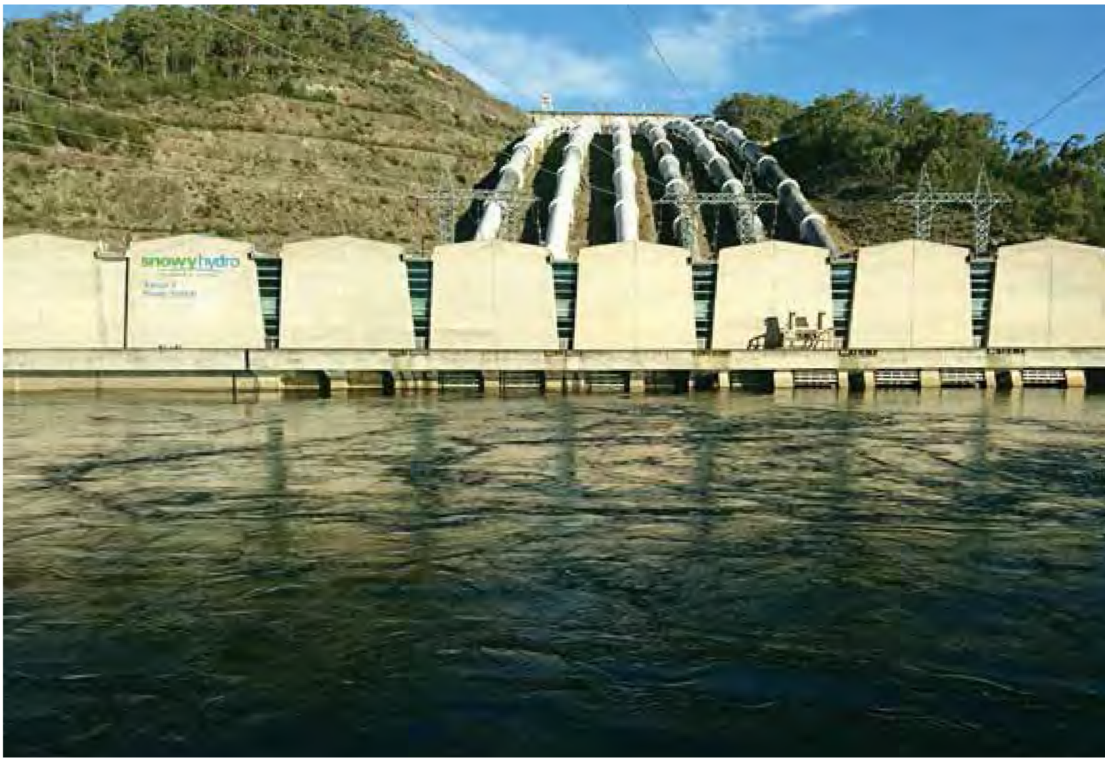
APPENDIX H

SOIL AND LAND ASSESSMENT

Soils and land assessment

Exploratory Works for Snowy 2.0

Prepared for Snowy Hydro Limited
July 2017



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Soil and land assessment

Exploratory Works for Snowy 2.0

Prepared for Snowy Hydro Limited | 13 July 2018

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Soil and land assessment

Final

Report Soil and Land Assessment | Prepared for Snowy Hydro Limited | 13 July 2018

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Position	Soil and Rehabilitation	Position	Land capability and rehabilitation services manager
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Date	13 July 2018	Date	13 July 2018

Document Control

Version	Date	Prepared by	Reviewed by
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1 Introduction

1.1 The project

Snowy Hydro Limited (Snowy Hydro) proposes to develop Snowy 2.0, a large scale pumped hydro-electric storage and generation project which would increase hydro-electric capacity within the existing Snowy Mountains Hydro-electric Scheme (Snowy Scheme). This would be achieved by establishing a new underground hydro-electric power station that would increase the generation capacity of the Snowy Scheme by almost 50%, providing an additional 2,000 megawatts (MW) generating capacity, and providing approximately 350,000 megawatt hours (MWh) of storage available to the National Electricity Market (NEM) at any one time, which is critical to ensuring system security as Australia transitions to a decarbonised NEM. Snowy 2.0 will link the existing Tantangara and Talbingo reservoirs within the Snowy Scheme through a series of underground tunnels and hydro-electric power station.

Snowy 2.0 has been declared to be State significant infrastructure and critical State significant infrastructure (CSSI) by the NSW Minister for Planning under the provisions of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) and is defined in Clause 9 of Schedule 5 of the *State Environmental Planning Policy (State and Regional Development) 2011* (SRD SEPP). Separate applications and environmental impact statements (EIS) for different phases of Snowy 2.0 are being submitted under Part 5, Division 5.2 of the EP&A Act. This technical assessment has been prepared to support an EIS for Exploratory Works to undertake investigative works to gather important technical and environmental information for the main Snowy 2.0 project. The main project will be subject of a separate application and EIS next year.

The purpose of Exploratory Works for Snowy 2.0 is primarily to gain a greater understanding of the conditions at the proposed location of the power station, approximately 850 metres (m) below ground level. Understanding factors such as rock conditions (such as stress conditions) and ground temperature is essential to inform decisions about the precise location of the power station cavern and confirm the cavern construction methods.

Exploratory Works comprises:

- an exploratory tunnel to the site of the underground power station for Snowy 2.0;
- horizontal and other test drilling, investigations and analysis in situ at the proposed cavern location and associated areas, and around the portal construction pad, access roads and excavated rock management areas all within the disturbance footprint;
- a portal construction pad for the exploratory tunnel;
- an accommodation camp for the Exploratory Works construction workforce;
- road works and upgrades providing access and haulage routes during Exploratory Works;
- barge access infrastructure, to enable access and transport by barge on Talbingo reservoir;
- excavated rock management, including subaqueous placement within Talbingo Reservoir;
- services infrastructure such as diesel-generated power, water and communications; and
- post-construction revegetation and rehabilitation, management and monitoring.

1.2 Purpose of this report

This soil and land assessment supports the EIS for Exploratory Works. It documents the assessment methods and results, the initiatives built into the project design to avoid and minimise associated impacts, to soil and land resources, and the mitigation and management measures proposed to address any residual impacts not able to be avoided.

1.3 Location of Exploratory Works

Snowy 2.0 and Exploratory Works are within the Australian Alps, in southern NSW. The regional location of Exploratory Works is shown on Figure 1.1. Snowy 2.0 is within both the Snowy Valleys and Snowy Monaro Regional local government areas (LGAs), however Exploratory Works is entirely within the Snowy Valleys LGA. The majority of Snowy 2.0 and Exploratory Works are within Kosciuszko National Park (KNP). The area in which Exploratory Works will be undertaken is referred to herein as the project area, and includes all of the surface and subsurface elements further discussed in Section 2.1.

Exploratory Works is predominantly in the Ravine region of the KNP. This region is between Talbingo Reservoir to the north-west and the Snowy Mountains Highway to the east, which connects Adaminaby and Cooma in the south-east to Talbingo and Tumut to the north-west of the KNP. Talbingo Reservoir is an existing reservoir that forms part of the Snowy Scheme. The reservoir, approximately 50 kilometres (km) north-west of Adaminaby and approximately 30 km east-north-east of Tumbarumba, is popular for recreational activities such as boating, fishing, water skiing and canoeing.

The nearest large towns to Exploratory Works are Cooma and Tumut. Cooma is approximately one hour and forty five minutes drive (95 km) south-east of Lobs Hole. Tumut is approximately half an hour (45 km) north of Talbingo. There are several communities and townships near the project area including Talbingo, Tumbarumba, Batlow, Cabramurra and Adaminaby. Talbingo and Cabramurra were built for the original Snowy Scheme workers and their families. Adaminaby was relocated to alongside the Snowy Mountains Highway from its original location (now known as Old Adaminaby) in 1957 due to the construction of Lake Eucumbene. Talbingo and Adaminaby provide a base for users of the Selwyn Snow Resort in winter. Cabramurra was modernised and rebuilt in the early 1970s and is owned and operated by Snowy Hydro. It is still used to accommodate Snowy Scheme employees and contractors. Properties within Talbingo are now predominantly privately owned. Snowy Hydro now only owns 21 properties within the town.

Other attractions and places of interest in the vicinity of the project area include Selwyn Snow Resort, the Yarrangobilly Caves complex and Kiandra. Kiandra has special significance as the first place in Australia where recreational skiing was undertaken and is also an old gold rush town.

The project area is shown on Figure 1.2 and comprises:

- **Lobs Hole:** Lobs Hole will accommodate the excavated rock emplacement areas, an accommodation camp as well as associated infrastructure, roads and laydown areas close to the portal of the exploratory tunnel and portal construction pad at a site east of the Yarrangobilly River;
- **Talbingo Reservoir:** installation of barge access infrastructure near the existing Talbingo Spillway, at the northern end of the Talbingo Reservoir, and also at Middle Bay, at the southern end of the reservoir, near the Lobs Hole facilities, and installation of a submarine cable from the Tumut 3 power station to Middle Bay, providing communications to the portal construction pad and accommodation camp. A program of subaqueous rock placement is also proposed;

- **Mine Trail Road** will be upgraded and extended to allow the transport of excavated rock from the exploratory tunnel to sites at Lobs Hole that will be used to manage excavated material, as well as for the transport of machinery and construction equipment and for the use of general construction traffic; and

- several sections of **Lobs Hole Ravine Road** will be upgraded in a manner that protects the identified environmental constraints present near the current alignment.

The project is described in more detail in Chapter 2.

1.4 Proponent

Snowy Hydro is the proponent for Exploratory Works. Snowy Hydro is an integrated energy business – generating energy, providing price risk management products for wholesale customers and delivering energy to homes and businesses. Snowy Hydro is the fourth largest energy retailer in the NEM and is Australia's leading provider of peak, renewable energy.

1.5 Assessment guidelines and requirements

This land and soil assessment has been prepared following the appropriate guidelines, policies and industry requirements, and in consultation with relevant government agencies.

Guidelines and policies referenced are as follows:

- *Interim Protocol for Site Verification and Mapping of Biophysical Strategic Land* (NSW Government 2013);

- *Soil and Landscape Issues in Environmental Impact Assessment* (DLWC 2000);

- *Acid Sulfate Soils Assessment Guidelines* (Ahern et al. 1998);

- *The land and soil capability assessment scheme (OEH 2012);* and

- *Agfact AC25: Agricultural Land Classification* (NSW Agriculture, 2002).

This soil and land assessment has been prepared in accordance with the Secretary's Environmental Assessment Requirements (SEARs) for Exploratory Works, issued first on 17 May 2018 and revised on 20 June 2018, as well as relevant governmental assessment requirements, guidelines and policies, and in consultation with the relevant government agencies.

The SEARs must be addressed in the EIS. Table 1.1 lists the matters relevant to this assessment and where they are addressed in this report.

Table 1.1 Relevant matters raised in SEARs

Requirement	Section addressed
An assessment of the likely impacts of the development on the environment, focusing on the specific issues identified below, including:	
• An assessment of impacts of the project on soils and land capability of the site and surrounds.	Section 6

To inform preparation of the SEARs, the Department of Planning and Environment (DPE) invited relevant government agencies to advise on matters to be addressed in the EIS. These matters were taken into account by the Secretary for DPE when preparing the SEARs.

1.5.1 Other relevant reports

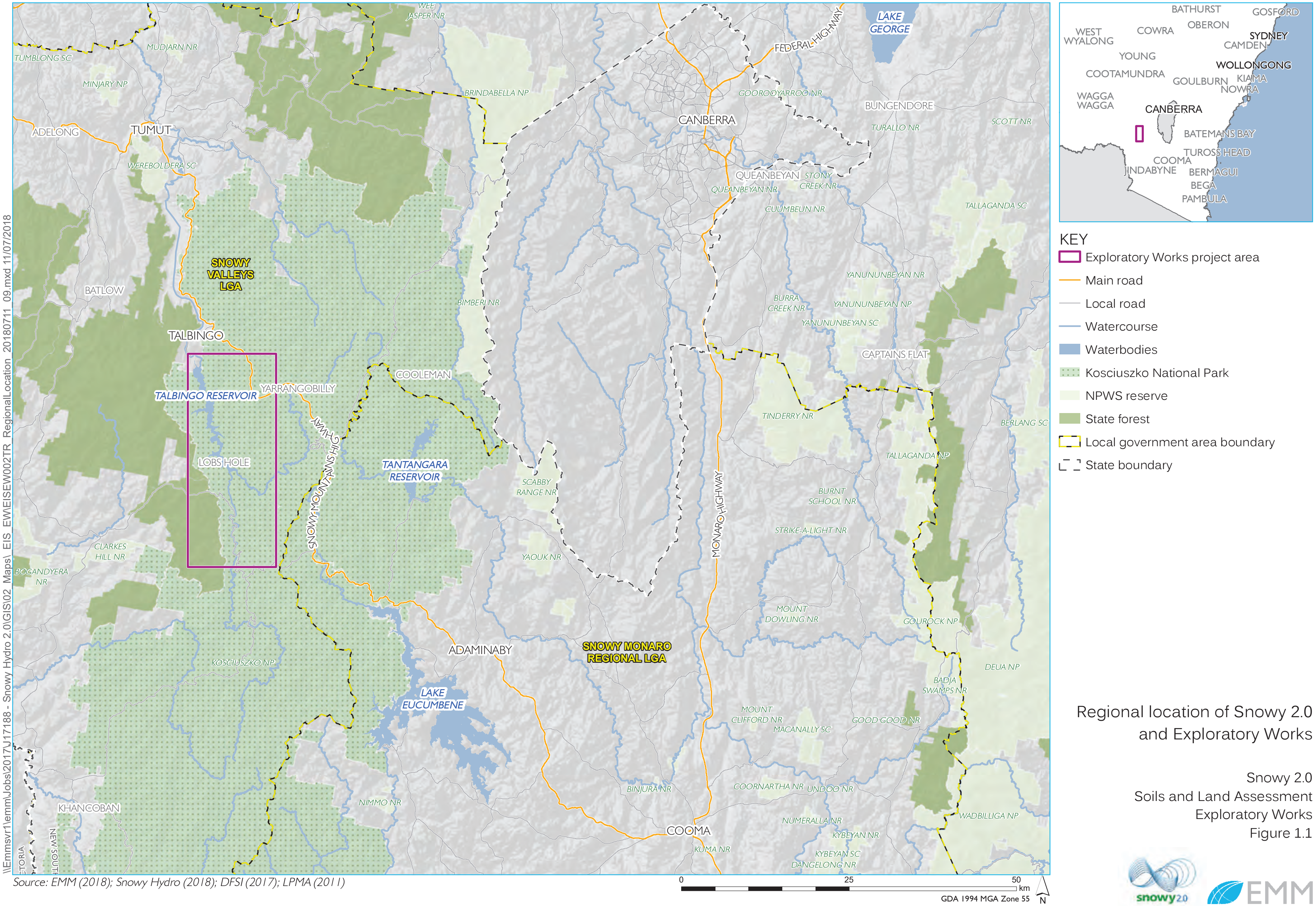
This soil and land assessment has been prepared with reference to other technical reports that were prepared as part of the Exploratory Works EIS. The other relevant reports referenced in this assessment are listed below.

- Biodiversity development assessment (EMM 2018) – Appendix F of the EIS
- Dredging and dredging impact assessment (RHDHV 2018) – Appendix C of the EIS
- Barge access infrastructure (RHDHV 2018) – Appendix L of the EIS
- Subaqueous excavated rock placement assessment (RHDHV 2018) – Appendix D of the Barge access infrastructure (Appendix L of the EIS)
- Groundwater assessment (EMM 2018) – Appendix N of the EIS
- Rehabilitation strategy (SMEC 2018) – Appendix E of the EIS

1.6 Scope and purpose of this report

The scope of the land and soil assessment is as follows:

- to address the SEARs and government agency assessment requirements relating to soil and land resources;
- to describe, classify and map the soils within the soils assessment area;
- to assess the suitability of soil units for recovery and use as topsoil/growth media in the rehabilitation of areas impacted during operations;
- to identify any potentially problematic soil, such as acid sulfate soils, highly sodic, acidic or saline soil, that may require special management if disturbed during project activities;
- to assess the immediate and long term impacts of Exploratory Works on the soil resources and land and soil capability; and
- to identify appropriate soil management measures.



Source: EMM (2018); Snowy Hydro (2018); DFSI (2017); LPMA (2011)

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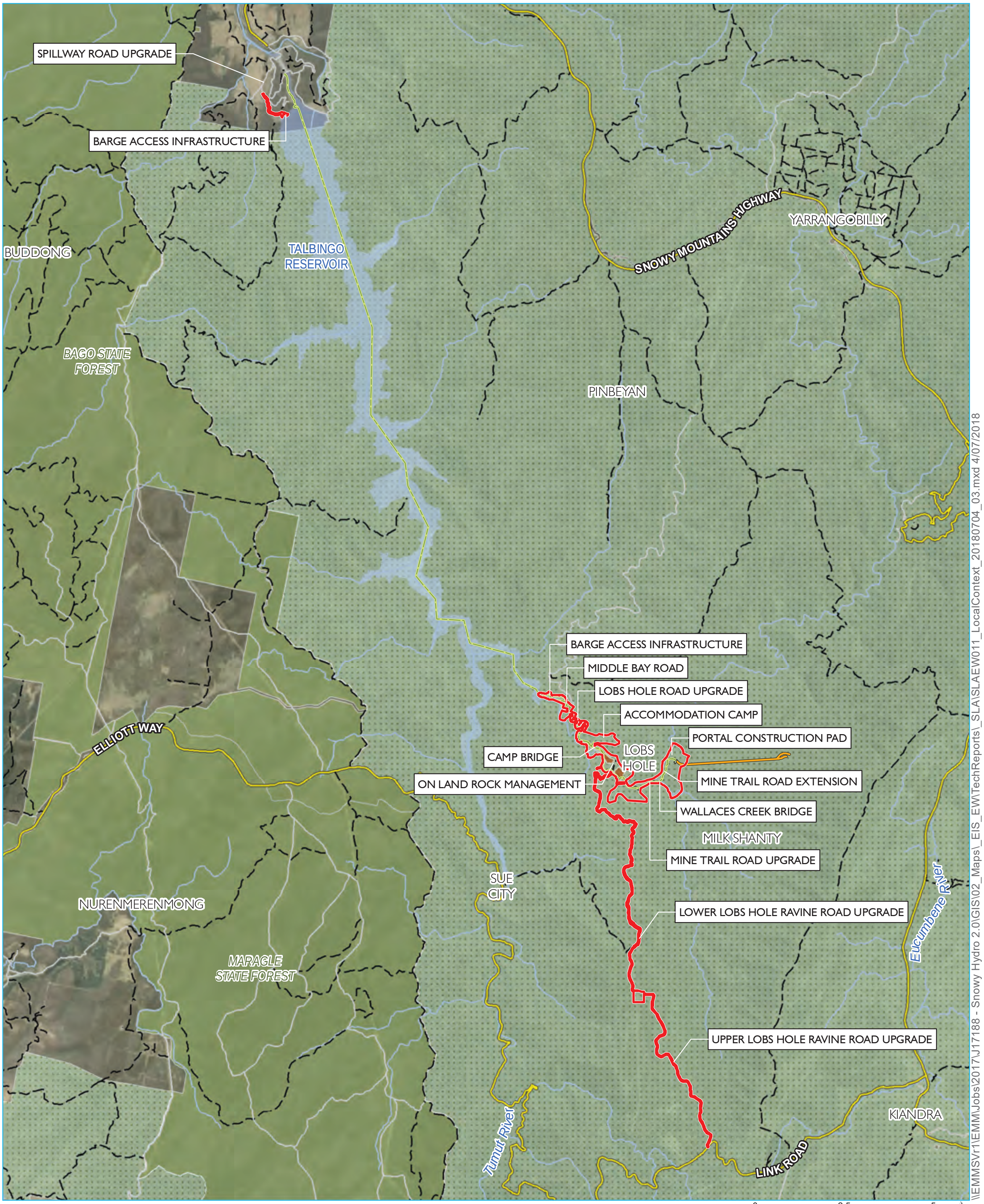
Regional location of Snowy 2.0 and Exploratory Works

Snowy 2.0
Soils and Land Assessment
Exploratory Works
Figure 1.1



Source: EMM (2018); Snowy Hydro (2018); Robert Bird (2018); SMEC (2018); DFSI (2017); GA (2015); LPMA (2011)

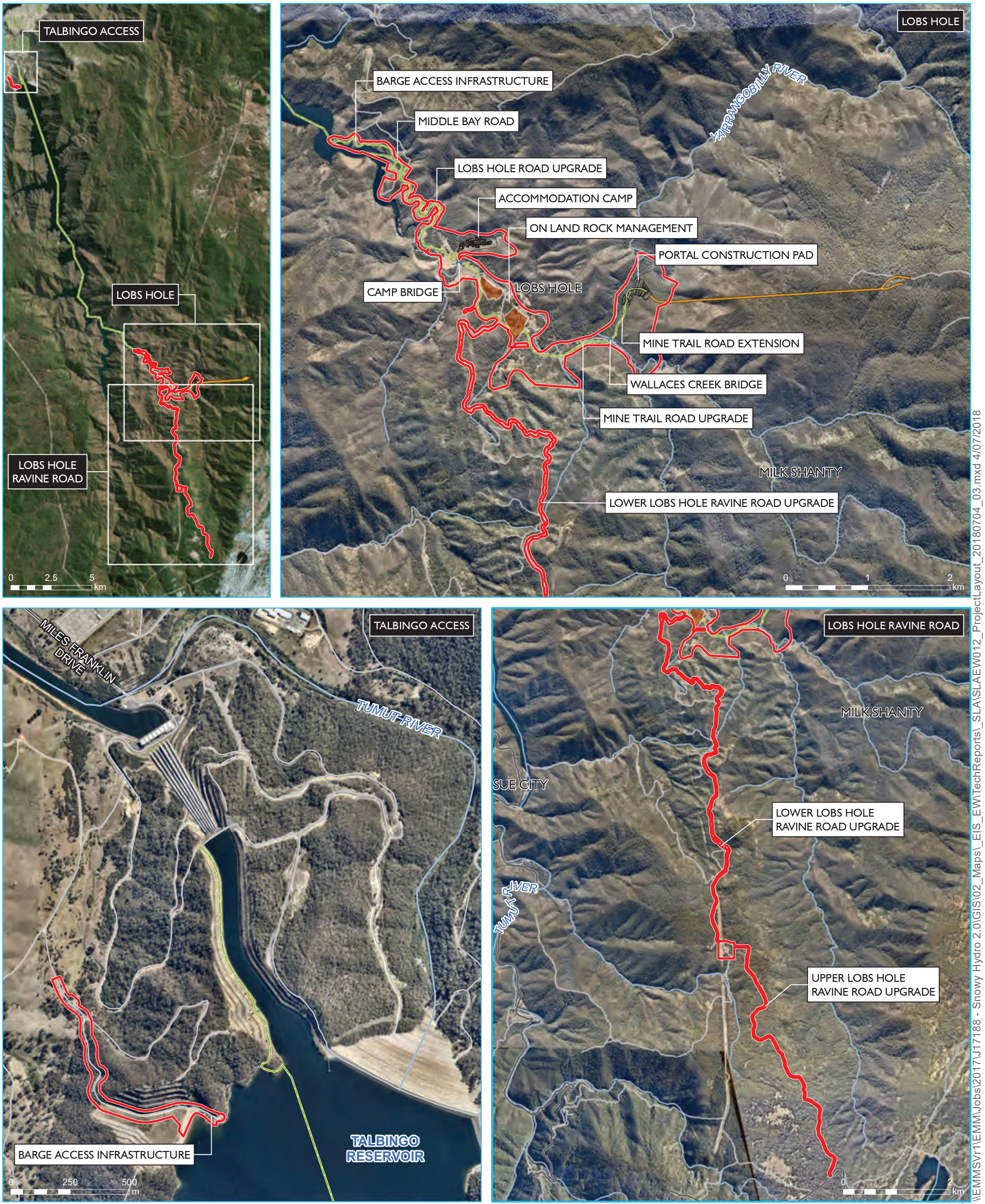
0 2.5 5 km
GDA 1994 MGA Zone 55
N

KEY

- Soils assessment area
- Portal construction pad and accommodation camp conceptual layout
- Exploratory tunnel
- Communications cable
- On land rock management
- Main road
- Local road
- Vehicular track
- Perennial watercourse
- Scheme storage
- Kosciuszko National Park
- State forest

Local context

Snowy 2.0
Soil and Land Assessment
Exploratory Works
Figure 1.2



Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); Robert Bird (2018); DFSI (2017); LPMA (2011)

GDA 1994 MGA Zone 55

N

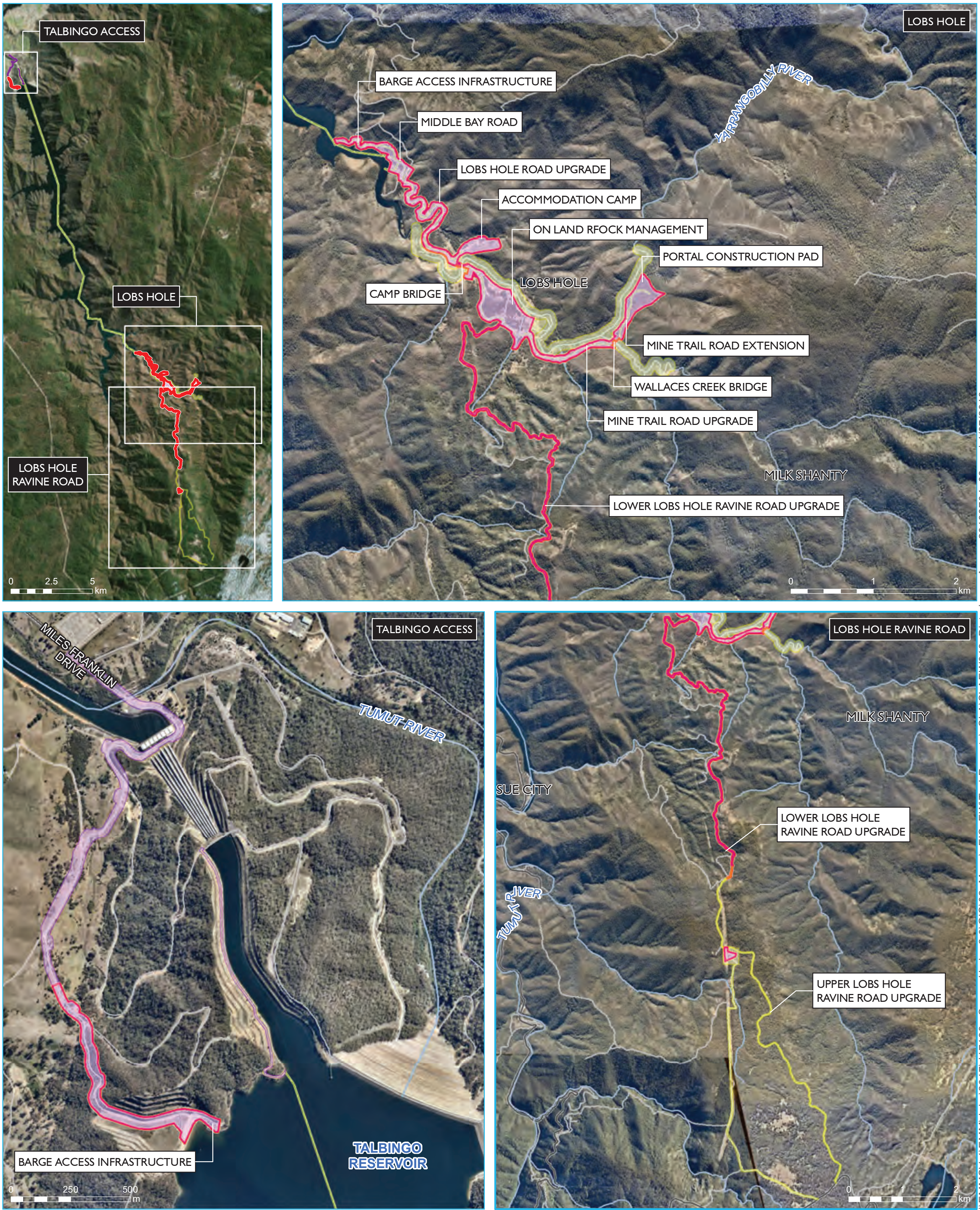
KEY

- Soils assessment area
- Permanent bridge
- On land rock management
- Portal construction pad and accommodation camp conceptual layout
- Exploratory tunnel
- Communications cable
- Main road
- Local road or track
- Watercourse

Indicative project layout

Snowy 2.0
Soil and Land Assessment
Exploratory Works
Figure 1.3

snowy 2.0 EMM



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Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); Robert Bird (2018); DFSI (2017); LPMA (2011)

GDA 1994 MGA Zone 55

N

KEY

- Main road
- Local road or track
- Watercourse
- Communications cable
- Soils disturbance area
- Disturbance footprint
- Avoidance footprint

Indicative disturbance areas

Snowy 2.0
Soil and Land Assessment
Exploratory Works
Figure 1.4

snowy2.0 EMM

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 of the soils assessment area, including field assessment and laboratory analysis (Section 4); and
- an assessment of potential impacts on soil resources (Section 6) and proposed management and mitigation methods (Section 7).

2.2 Desktop survey

Existing information on soils and soil environments for the soils assessment area was sourced from the following regional mapping published by government departments and Snowy Hydro Limited. The relevant information has been summarised and presented in Section 3:

- *Wagga Wagga 1:250,000 geological sheet (Adamson & Loudon 1966)*;
- *Australian soil classification (ASC) soil type map of NSW* (OEH 2018a);
- *Great soil group soil type mapping of NSW* (OEH 2018b);
- *Hydrological soil group mapping* (OEH 2018c);
- *Inherent soil fertility mapping* (OEH 2018d);
- *Land and soil capability classes mapping* (OEH 2018e);
- *Atlas of Australian Acid Sulfate Soils* (Fitzpatrick et al. 2011);
- *NSW soil and land information system* (SALIS) (OEH 2018f);
- *Soil profile attribute data environment* (eSPADE) online database (OEH 2018g);
- *State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007* (Mining SEPP) - Strategic Agricultural Land Map of NSW (DP&I 2013);
- *Soils of the Australian Alps Factsheet* (Mason 2014); and
- *Snowy 2.0 Feasibility Study* (Snowy Hydro Limited 2017).

2.3 Field survey

2.3.1 Survey guidelines

All field assessment methods used in the survey have been conducted generally 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);
- *Acid sulfate soils manual* (Stone et al 1998);
- *Soil data entry handbook* (DLWC 2001);
- *Interim protocol for site verification and mapping of biophysical strategic agricultural land* (NSW Government 2013); and
- *Site investigations for urban salinity (*DLWC 2002).

The field survey utilised investigation at two different levels of intensity (the sites):

- check sites - low intensity investigation, high repetition, randomised locations and a limited description; and
- detailed sites - high intensity investigation, moderate repetition, randomised locations, a detailed description and a select number of samples sent for laboratory analysis.

2.3.2 Survey sampling density

A total of 35 sites were surveyed within and immediately adjacent to the Exploratory Works disturbance footprint. The average survey density achieved meets the conservative target adopted, which was at least one site per 25 ha (11 sites) and one site per 1 km of access track (18 sites). All of these sites were described in detail using the SALIS detailed soil data card.

Targeted sampling was also undertaken on areas mapped as potentially being acid sulfate soils on the Atlas of Australian Acid Sulfate Soils (Fitzpatrick et al. 2011). A density was set at every 100 m along access tracks and two sites per ha in accordance with the Acid Sulfate Soils Manual (Stone et al. 1998). This equates to twenty six sample sites.

2.3.3 Site selection

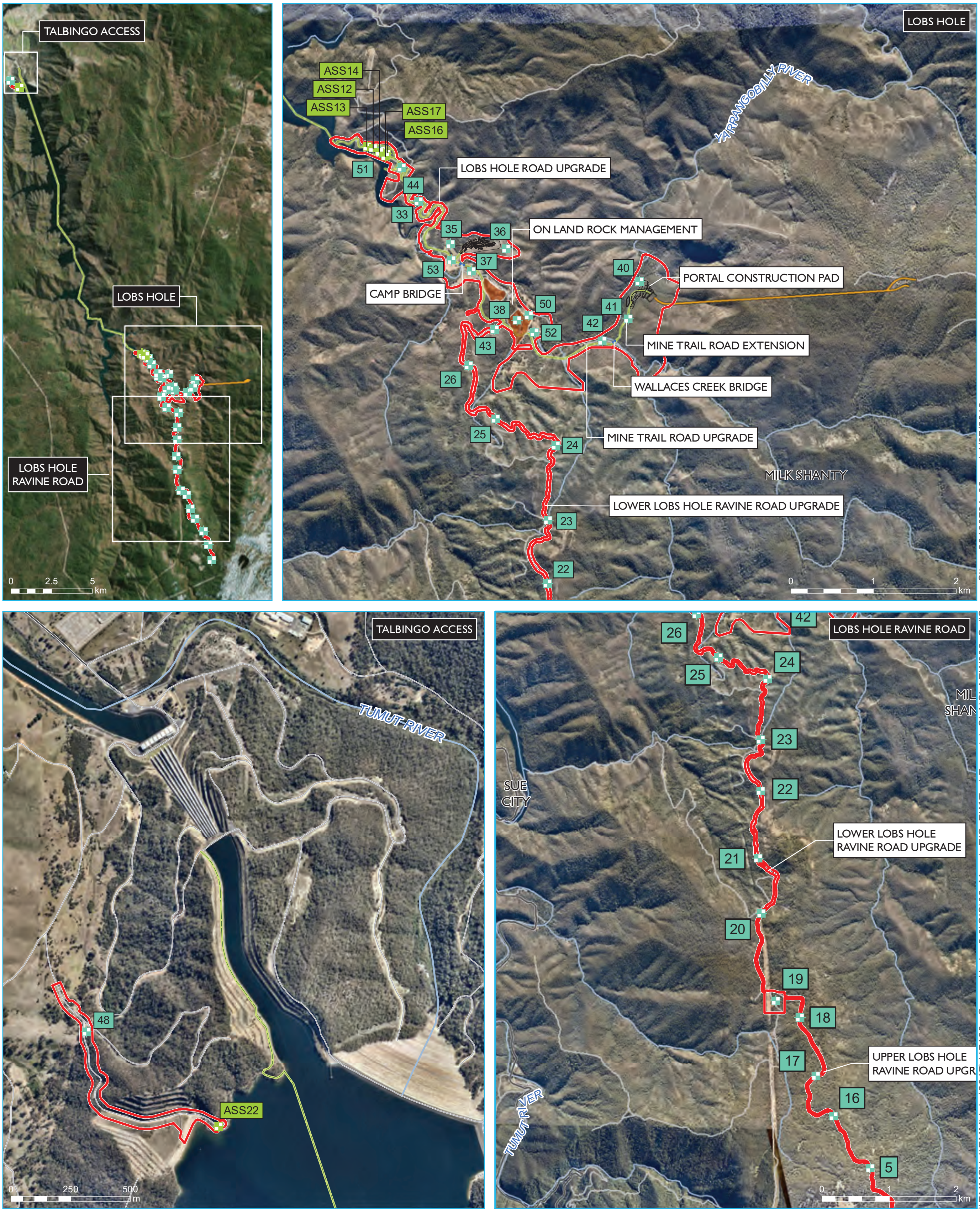
Initial positioning of the soil survey sites was based on stratified random sampling across the soils assessment area, though designed to provide a relatively even distribution of detailed and check sites. In accordance with the requirements of stratified random sampling, a greater frequency of sampling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

The exact locations of the sites were finalised with consideration to land access constraints and site factors, particularly past disturbance, vegetation cover and infrastructure. These constraints meant that some sites initially identified were not available or suitable for surveying. In these inaccessible or unsuitable areas, the nearest available locations with similar landscape features were sampled and spatial co-ordinates recorded. The sites are shown in Figure 2.1.

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 soil survey. 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 29 sites were assessed using the hang auger technique, all of which were recorded using the SALIS detailed soil data card. The six acid sulfate soil sampling sites were not described using the SALIS detailed soil data card. Eleven sites were subjected to laboratory analysis for soil and land capability with four additional sites subjected to laboratory analysis for acid sulfate soils characterisation.



Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); Robert Bird (2018); DFSI (2017); LPMA (2011)

GDA 1994 MGA Zone 55

N

KEY

- Soil sample site
- ASS sample site
- Soils assessment area
- Permanent bridge
- On land rock management
- Portal construction pad and accommodation camp conceptual layout
- Exploratory tunnel
- Communications cable
- Main road
- Local road or track
- Watercourse

Soil survey sites

Snowy 2.0
Soil and Land Assessment
Exploratory Works
Figure 2.1

snowy 2.0 EMM

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2.3.4 Timing of surveys

The soil survey was undertaken over six days from 14-19 April 2018.

2.3.5 Sampling method

Soil sampling was carried out primarily using a hand auger. This method created a typical disturbance area of approximately 100 x 100 millimetres (mm) to a depth of at least 1.2 m, or up to 2 m in the case of the sites for acid sulfate soils characterisation. Soil core holes were backfilled immediately upon completion of classification and sampling to minimise disturbance and risk to native flora.

Field observations were recorded (including GPS locations) and SALIS data completed and submitted to NSW OEH. Soils are described with photographs in Section 4. Soil profiles were assessed in accordance with the *Australian Soil and Land Survey Handbook* (NCST 2009). Soils subjected to laboratory analysis were described to family level using the Australian Soil Classification. Photographic records of survey sites and their soil profiles were taken in the field using a digital camera. Photographs of representative soil profiles subjected to laboratory analysis are presented in Section 4 and Appendix C.

During the field surveys, observations of surface geology were made. Geology is an important determinant of soil characteristics and a strong relationship between the two has been identified within the soils assessment area.

2.4 Laboratory testing

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* (NSWG 2013); and

- *The land and soil capability assessment scheme: second approximation* (OEH 2012).

In the majority of cases the analysis undertaken meets or exceeds the requirements of these two guidelines. The remaining sites conform with the nationally accepted standards laid out in the *Australian soil and land survey handbook* (NCST 2009). A National Association of Testing Authorities (NATA) accredited laboratory (ALS Global) was used to ensure that laboratory analysis was undertaken using scientifically correct methods.

Two levels of analysis were undertaken relevant to the importance of each soil survey point. In ascending importance:

- check sites were analysed in the field for texture and pH only using accepted methods described in the Australian soil and land survey field handbook (NCST 2009); and

- detailed sites were sampled with representative sites receiving full laboratory analysis.

Physical and chemical analysis was undertaken on selected soil samples (Table 2.1). A summary of the number of samples analysed from each soil type present in the soils assessment area is presented in Table 2.2. The laboratory accreditation is included in Appendix A and full laboratory results, including the naming of analytical method and sampling depths, are included in Appendix B.

Table 2.1 Laboratory analytes

Physical Soil Properties	Chemical Analyses
Soil texture	Organic matter and organic carbon
Moisture content	pH_{water}
Emerson aggregate test	EC
	Total nitrogen, nitrate and nitrite (N)[1]
	Total and extractable phosphorus (P)[1]
	Extractable potassium (K)[1]
	Soluble cations (calcium (Ca), magnesium (Mg), sodium (Na), potassium (K))
	Soluble chloride (Cl-) and sulfate (SO_4^{2-})
	Cation exchange capacity (CEC)
	Exchangeable cations (Al, Na, Ca, K, Mg) Exchangeable sodium percentage (ESP)
	Calcium carbonate equivalent
	DTPA extractable metals (iron (Fe), copper (Cu), zinc (Zn), manganese (Mn))
	Total metals (Al and molybdenum (Mo))
	Chromium Suite which may include (subject to laboratory decision tree)[2]: • chromium reducible sulfur (CRS); • pH_{KCL} and titratable actual acidity (TAA); • acid neutralising capacity (ANC); and S_{NAS} (retained acidity).

Notes: *1. Topsoil samples only.*
2. Acid sulfate soils characterisation samples only.

Table 2.2 Samples analysed from each soil type

Soil types	Number of sites subjected to laboratory analysis	Site numbers	Horizons analysed
Tenosol	2	40, 41	4
Kandosol	7	4, 19, 23, 35, 37, 42, 51	30
Dermosol	2	52,26	5
Vertosol	1	50	5

2.5 Mapping approach

A manual mapping method has been employed based on the survey soil descriptions, landscape characteristics, vegetation, topography, aerial imagery and existing NSW soil and geological mapping.

The 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 soils assessment 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

The soils assessment area is located within the western extent of the Australian Alps. The climate of the Australian Alps is influenced by three features of the general circulatory system affecting south-eastern Australia (Brown and Millner, 1988):

- the latitudinal position of the westerly airstream that encircles the southern hemisphere;
- the influence of depressions lying off the east coast of NSW; and
- the occasional intrusion of moist tropical air masses from northern Australia.

Rainfall characteristics within the Yarrangobilly River catchment were determined using available information from regional Bureau of Meteorology (BoM) rainfall gauges and rainfall maps that are also produced by BoM. The following rainfall gauges are located within proximity to the Yarrangobilly River catchment and provide the best available information on rainfall within the catchment:

- Talbingo (72131) – this gauge is located within the township of Talbingo, approximately 3.5 km to the north of the Tumut 3 Power Station and 26 km to the north-west of Lobs Hole. The gauge elevation is 395 m AHD, which is approximately 150 to 200 m lower than levels at Lobs Hole (550 to 600 m AHD).
- Cabramurra SMHEA AWS (72161) – this gauge is located approximately 8 km to the south-west of the head waters of Wallaces Creek, which is a major tributary to the Yarrangobilly River catchment. The gauge elevation is 1,482 m AHD.
- Yarrangobilly Caves (72141) – this gauge is located centrally in the Yarrangobilly River catchment. The gauge elevation is 980 m AHD.

Table 3.1 presents key information and statistical data from the three gauges.

Table 3.1 Rainfall statistics[1]

Rainfall[2] Statistics (annualised)		**Talbingo (72131)**	**Cabramurra SMHEA AWS (72161)**	**Yarrangobilly Caves (72141)**
Rainfall Record		1997 - present	1996 - present	1906 – 1919 1978 - present
Distance from Lobs Hole	(km)	25 km to the north west	15 km to the south	15 km to the north-east
Elevation (m AHD)	(m AHD)	395	1482	980
Average Rainfall	(mm/year)	952	1178	1169
Lowest Rainfall	(mm/year)	361	567	552
5th Percentile Rainfall	(mm/year)	663	877	818
10th Percentile rainfall	(mm/year)	771	992	905
Median rainfall	(mm/year)	946	1202	1158
90th Percentile rainfall	(mm/year)	1220	1386	1511

Table 3.1 Rainfall statistics[1]

Rainfall[2] Statistics (annualised)		Talbingo (72131)	Cabramurra SMHEA AWS (72161)	Yarrangobilly Caves (72141)
95th Percentile rainfall	(mm/year)	1313	1427	1535
Highest rainfall	(mm/year)	1343	1634	1902

Notes: 1.Data sourced from BoM website (climate data online).

2. Some precipitation will occur as snow fall but has been referred to as rainfall to maintain consistency with other sections in the EIS.

The median annual rainfall depth contours shown in Figure 4.2 indicate that median rainfall within the Yarrangobilly River catchment ranges from 1,400 mm/year in the head water catchments to the 950 mm/year at Lobs Hole. The spatial variation in median rainfall generally reflects the variation in topography within the catchment.

Figure 4.1 plots the 10^{th}, 50^{th} and 90^{th} percentile monthly rainfall depths that have been calculated by BoM from the Talbingo (72131) gauge record. This information indicates that the highest and most consistent rainfall occurs in winter to early spring. Rainfall in summer is more variable with significant differences between the 10^{th} and 90^{th} percentile monthly rainfall depths.

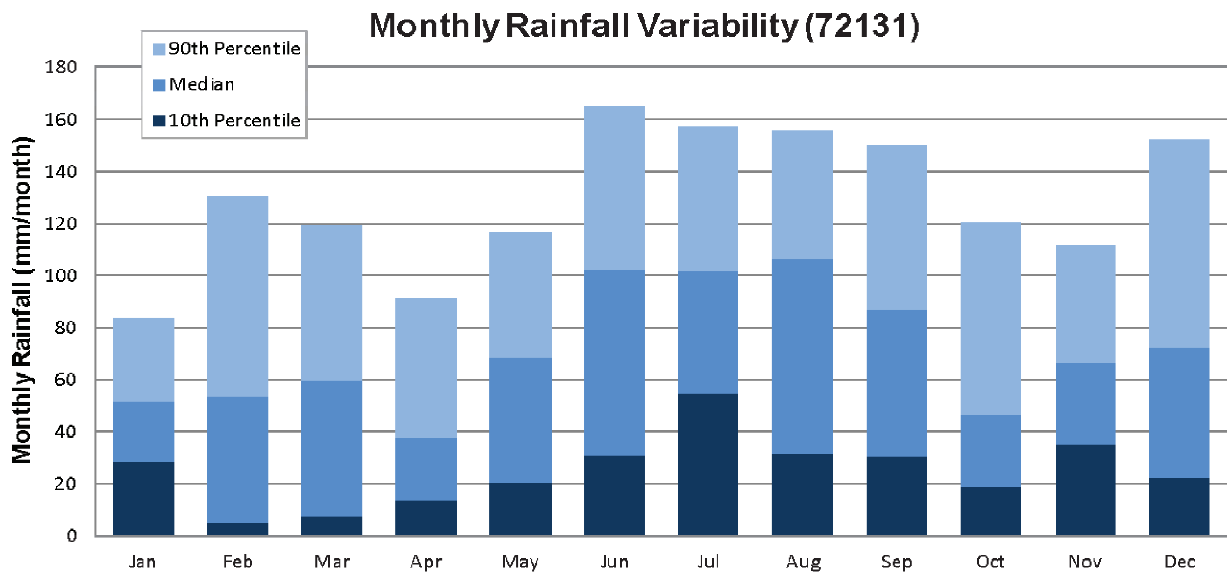
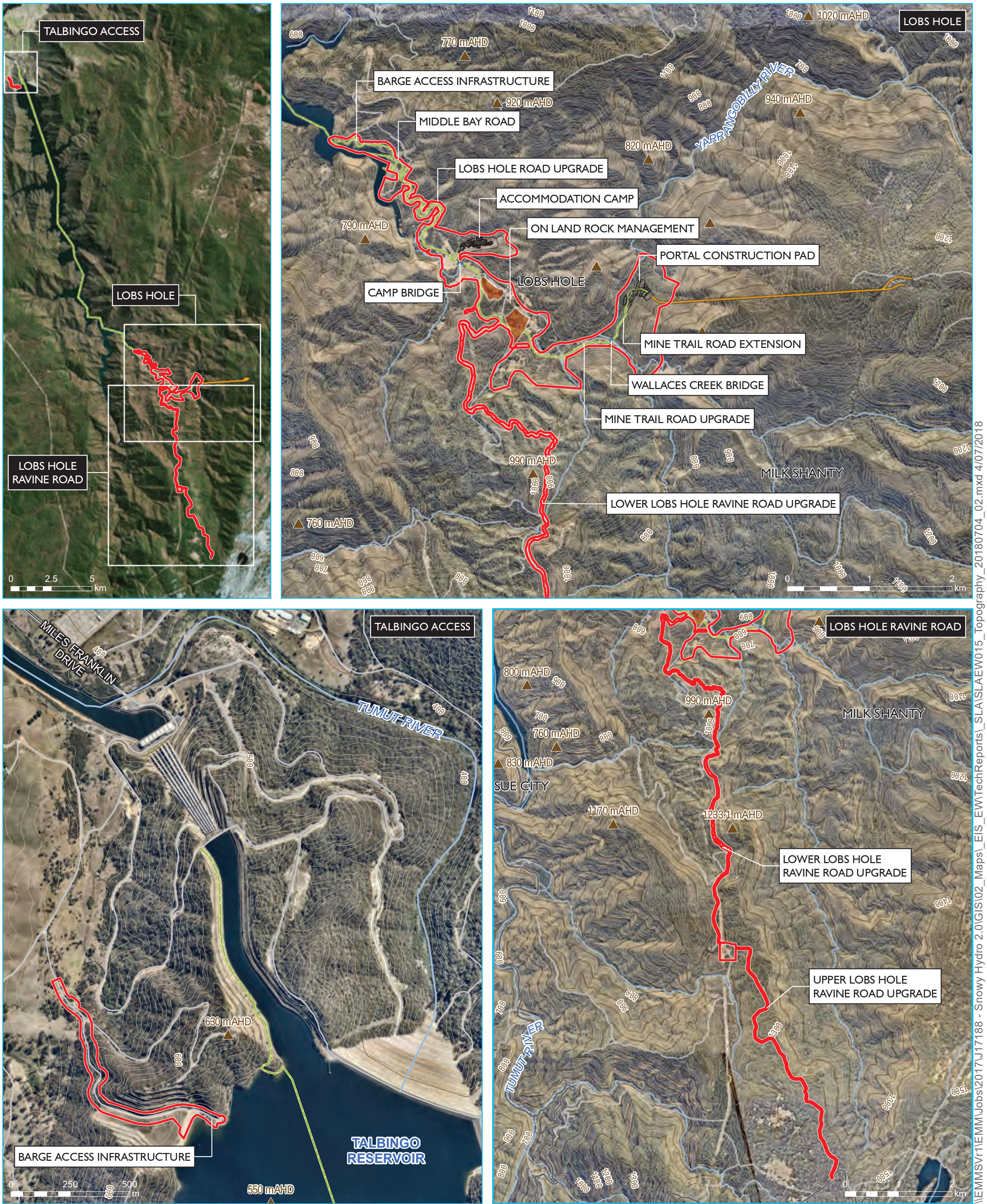


Figure 3.1 Monthly rainfall variability at Talbingo

3.2 Topography

As previously discussed, the Exploratory works will be undertaken in the KNP which is a part of the Australian Alps national heritage listing and contains landscapes with high scenic values. The Australian Alps landscape is characterised by peaked ranges, and broad, forested valleys, and is the only true alpine environment in NSW (NPWS 2003). Elevation across the soils assessment area ranges from 550-1,200 m.



Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); Robert Bird (2018); DFSI (2017); LPMA (2011)

GDA 1994 MGA Zone 55

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KEY

- Soils assessment area
- Permanent bridge
- On land rock management
- Portal construction pad and accommodation camp conceptual layout
- Exploratory tunnel
- Communications cable
- Main road
- Local road or track
- Watercourse
- Spot height (trig station)
- Contour (100m)
- Contour (10m)

Topography and landform

Snowy 2.0
Soil and Land Assessment
Exploratory Works
Figure 3.2

3.3 Surface hydrology

The Exploratory Works will be adjacent to the lower reach of the Yarrangobilly River within the catchment of the Murrumbidgee River. The Yarrangobilly River is a major watercourse that flows into the Talbingo Reservoir approximately 1.5 km downstream of the Exploratory Works project area. The Yarrangobilly River catchment is wholly within the KNP and is characterised by a range of subalpine grasslands and woodlands and montane dry sclerophyll forests.

Other watercourses within proximity to the Exploratory Works include Stable Creek, Wallaces Creek, Cave Gully and two unnamed first order water courses. All of these watercourses are tributaries to the Yarrangobilly River.

3.4 Ecology

Significant field surveys were by EMM across the Exploratory Works project area. The Biodiversity development assessment (EMM 2018) revealed that native vegetation within the Exploratory Works area reflects past land use. Historical use of Lobs Hole for the movement of stock, as a settlement and copper mining to 1917 and more contemporarily for recreation, have resulted in significant amounts of clearing and disturbance of vegetation in the area. Native vegetation and fauna habitats have been modified by past disturbances associated with land clearing, livestock grazing and weed invasion. Vegetation mapping identified nine PCTs within the Exploratory Works project area, which were stratified into 28 vegetation zones on the basis of broad condition state. Seventeen vegetation zones show significant levels of disturbance, while a further four show some degree of impact. Seven vegetation zones are considered representative of relatively intact vegetation of high quality. Vegetation integrity scores reflect this condition, with scores varying between 4.2 and 71.3.

Threatened species surveys did not identify any threatened flora species within or adjacent to the Exploratory Works survey area. Ten threatened fauna species have been recorded within or adjacent to the Exploratory Works survey area; five ecosystem credit species and five species credit species. A significant result was the identification of a population of the critically endangered Smoky Mouse along a ridge associated with the upper sections of Lobs Hole Ravine Road. This species is known from a limited number of extant sites in NSW. Other species identified include the Gang-gang Cockatoo and Masked Owl, with breeding habitat for these two species identified along the upper sections of Lobs Hole Ravine Road and in the riparian zone of the Yarrangobilly River. The Eastern Pygmy-possum was recorded at numerous locations within the Exploratory Works survey area, from the upper reaches of Lobs Hole Ravine Road to Lobs Hole. A healthy population of the Booroolong Frog was recorded along the entire length of the Yarrangobilly River within and adjacent to the Exploratory Works project area; this population is likely to extend upstream to at least Blue Creek Firetrail.

3.5 Geology

3.5.1 Regional geological mapping

The soils assessment area is in the Australian Alps and South Eastern Highlands bioregions and the Murrumbidgee River catchment. The geology of the alpine area comprises granites that have formed faulted, stepped ranges at the point where the South Eastern Highlands in NSW turn west into Victoria (NPWS 2003). More recent volcanic activity produced basalts and, in the Pleistocene, the cold climate superimposed glacial features on the landscape. The Australian Alps bioregion was the only part of the mainland to have been affected by Pleistocene glaciation and contains a variety of unique glacial and periglacial landforms above 1,100 m altitude, all of which are outside of the study area.

The South Eastern Highlands are part of the Lachlan fold belt that runs through the eastern states as a complex series of metamorphosed Ordovician to Devonian sandstones, shales and volcanic rocks intruded by numerous granite bodies and deformed by four episodes of folding, faulting and uplift. The general structural trend in this bioregion is north-south and the topography strongly reflects this (NPWS 2003).

Overlying the older Ordovician to Devonian units, a regionally extensive weathered zone is assumed to exist consisting of a mixture of colluviums, regolith and weathered basement rocks. Tertiary aged basalts also exist within this zone.

The *Wagga Wagga 1:250,000 geological sheet* (Adamson & Loudon 1966) and *Canberra 1:250,000 geological sheet* (Best et al. 1964) outlines surface geological units found within the soils assessment area. During the soil surveys, observations of surface geology were made. Geology is an important determinant of soil type.

The *Kosciuszko National Park Plan of Management* (DEC 2006) outlines a geodiversity (non-living component of the park) conservation strategy aimed at protecting all rocks, landforms and soils at risk of degradation. The plan identifies scree slopes, which occur along the Lobs Hole Ravine Road, as having geodiversity value for Kosciuszko National Park.

KEY

- Soils assessment area
- Portal construction pad and accommodation camp conceptual layout
- Exploratory tunnel
- On land rock management
- Communications cable
- Perennial watercourse
- Long Plain Fault (interpreted)

Geology (1:250,000)

- *w* - Water

Quaternary

- *Qa* - Alluvium

Tertiary

- *Tbm* - Basalt

Cainozoic

- *Cz* - Unknown (undifferentiated)

Devonian

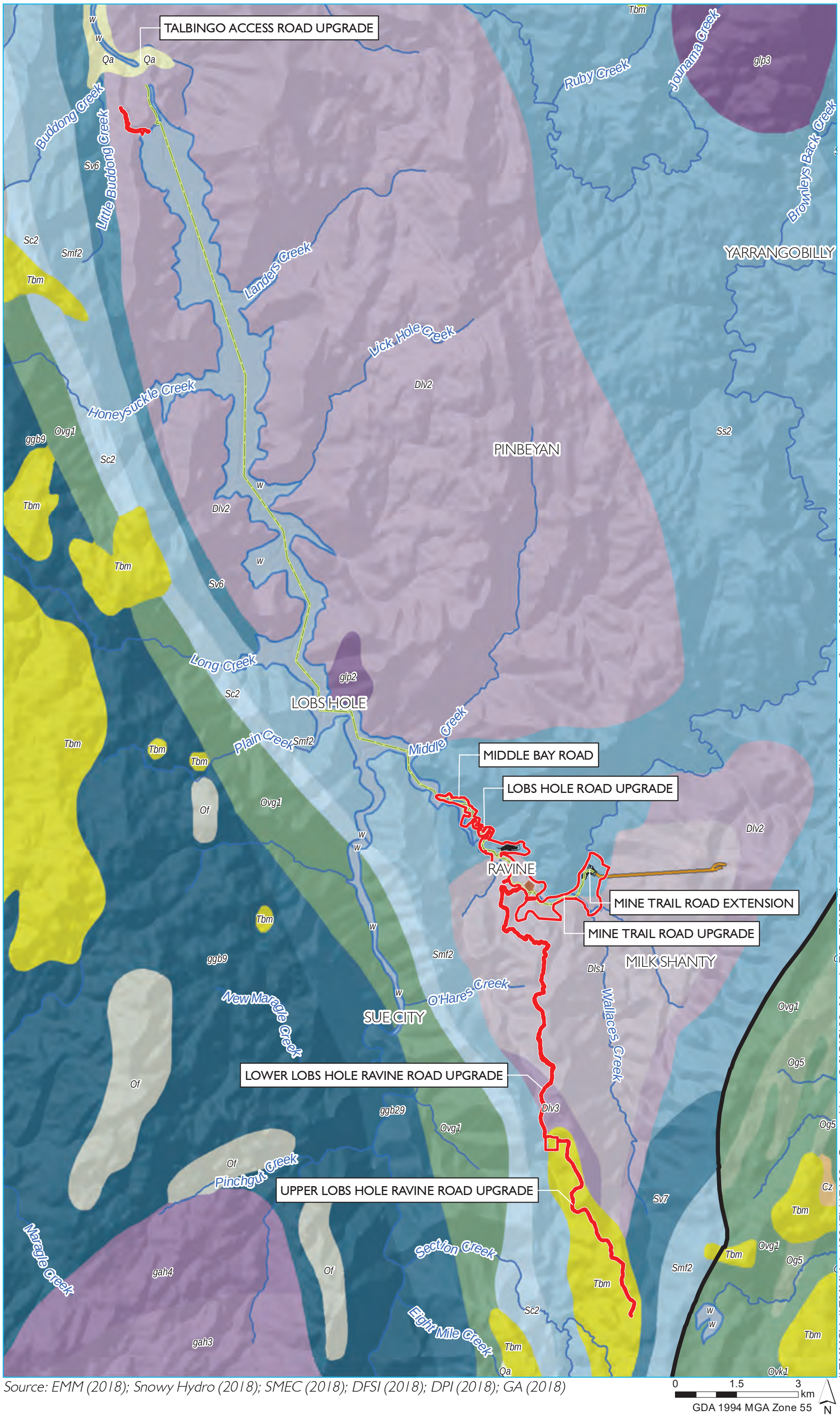
- *Dls1* - Byron Range Group (undifferentiated)
- *Dlv2* - Boraig Group (unnamed)
- *Dlv3* - Black Range Group (Mountain Creek Volcanics)
- *gah3* - Free Damper Suite (Free Dampier Adamellite)
- *gah4* - Free Damper Suite (Pennyweight Adamellite)
- *glp2* - Tumut Granites (Lobs Hole Adamellite)
- *glp3* - Bogong Suite (Bogong Granite)

Silurian

- *Sc2* - Unknown (Tumut Ponds Sepentinite)
- *Smf2* - Unknown (Jackalass Slate)
- *Ss2* - Bredbo Group (Ravine Beds/Yarrangobilly Limestone)
- *Sv5* - Young Suite (Goobarragandra Volcanics)
- *Sv6* - Unknown (Blowering Formation)
- *Sv7* - Unknown (Kings Cross Formation)
- *ggb29* - Tom Groggin Suite (Rough Creek Tonalite)
- *ggb9* - Tom Groggin Suite (Green Hills Granodiorite)

Ordovician

- *Of* - Adaminaby Group (Adaminaby Group)
- *Og5* - Unknown (Shaw Hill Gabbro)
- *Ovg1* - Unknown (Gooandra Volcanics)
- *Ovk1* - Kiandra Group (unnamed)



Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); DFSI (2018); DPI (2018); GA (2018)

Surface geology of the study area

Snowy 2.0
Soil and Land Assessment
Exploratory Works
Figure 3.3

snowy 2.0 EMM

3.5.2 Hydrogeology

The Groundwater Assessment (Appendix J to the EIS) identifies the following groundwater units within the soils assessment area:

- localised unconsolidated shallow Quaternary gravels episodically recharged through rainfall/flooding events; and
- deep groundwater associated with deeper fractured rock (ie Ravine Beds).

The groundwater quality results are reasonably comparable between the different target formations across the soils assessment area. The pH is slightly alkaline, averaging 7.5. Salinity varies across the soils assessment area, fresher (201 µS/cm) to the east of Long Plain Fault across the plateau area and marginal (780 µS/cm) west of the fault, within the Ravine Beds and the soils assessment area. Concentrations of most dissolved metals are typically low for most samples collected from each groundwater system, with many measurements below detection limits. This is typical of groundwater with reasonably neutral pH and in alpine areas where the groundwater is readily recharged via rainfall and snow melt.

3.6 Regional soils information

3.6.1 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 soils assessment area can be classed within the current Australian soil classification (Isbell 2016).

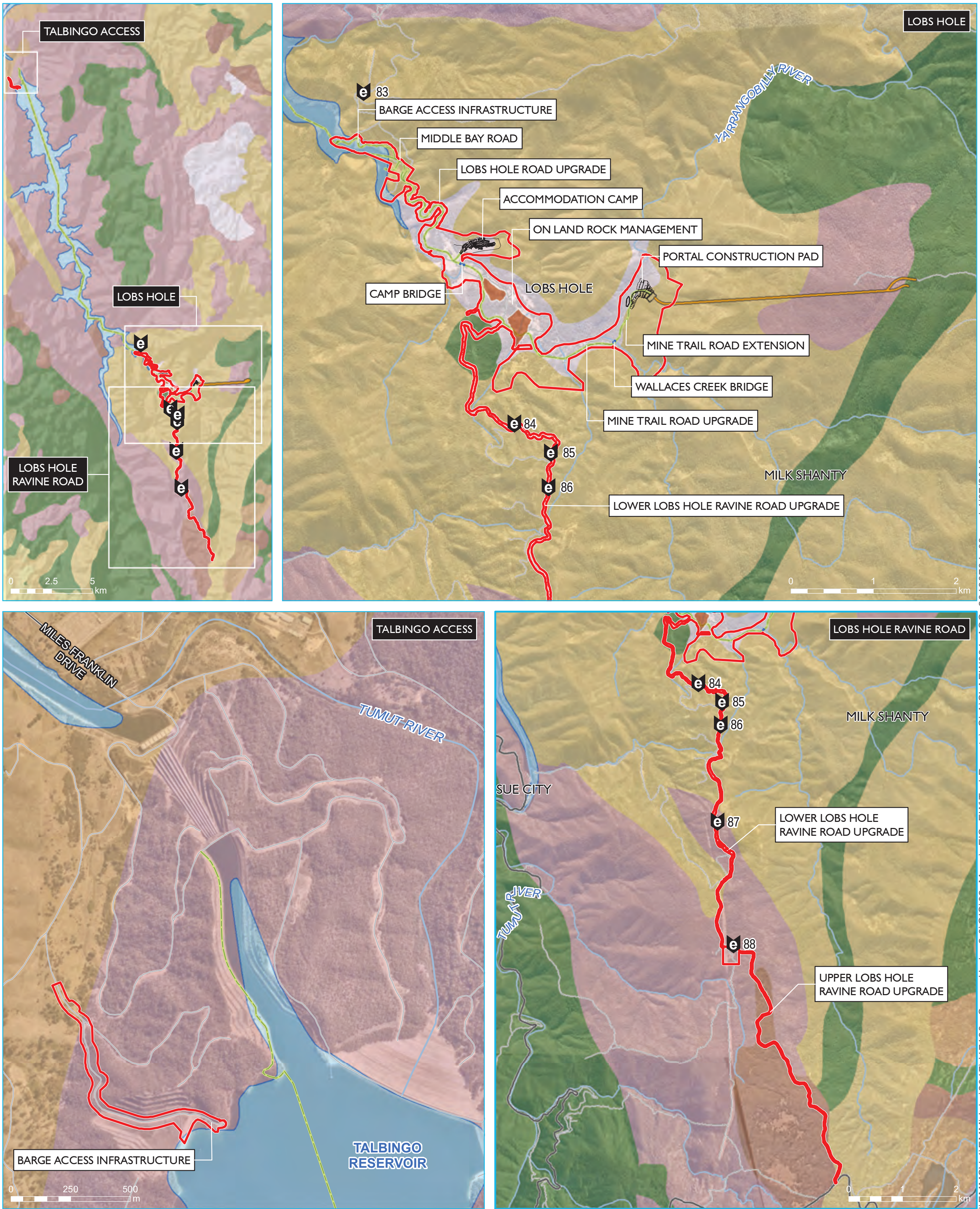
The Australian soil resource information system (ASRIS) mapping indicated that five soil types are present in the soils assessment area. Tenosols and Rudosols are associated with high exposed ridges and elevated stony slopes. Dermosols are found on the upper slopes with subsoil clay content increasing at down slope. Kurosols are found on the lower slopes and tableland areas adjacent to the mountains. Organosols are found in basins and depressions in valley floors where water collects all year round. The agricultural potential of the soils is also referenced. Soils across 98.3% of the soils assessment area were classified as having very low agricultural potential. The regional scale map is shown in Figure 3.4.

Table 3.2 Summary of regional ASC soil mapping

Soil type	Description	Agricultural potential[2]	Area (ha)[1]
Rudosols and Tenosols	Weakly structured throughout the profile with the exception of the A horizon. Often shallow ie. bedrock is located near surface.	Very low with low chemical fertility, poor structure and low water-holding capacity.	27
Dermosols	Structured B horizons and lacking strong texture contrast between A and B horizons.	High with good structure and moderate to high chemical fertility and water-holding capacity with few problems.	5.1
Kurosols	Strong texture contrast with strongly acid B horizons (pH < 5.5).	Very low with high acidity (pH<5.5), low chemical fertility and low water-holding capacity.	123.7
Kurosols (natric)	Strong texture contrast with strongly acid B horizons (pH < 5.5) and a sodic upper B2 horizon.	Very low with high acidity (pH<5.5), low chemical fertility, low water-holding capacity and sodic.	0.8
Organosols	Dominated by organic materials (>0.4 m in the upper 0.8 m of the profile or extending to a minimum of 0.1 m depth that overlies parent material).	Very low due to water logging and acidic conditions.	11.3

Notes: 1.Totals not exact due to rounding.

2. Based on Gray and Murphy (2002).



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Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); Robert Bird (2018); DFSI (2017); OEH (2012, 2018); LPMA (2011)

GDA 1994 MGA Zone 55

N

KEY

- Soils assessment area
- Permanent bridge
- Portal construction pad and accommodation camp conceptual layout
- Exploration tunnel
- On land rock management
- Communications cable
- Main road
- Local road or track
- Watercourse
- eSPADE survey point

Dominant Australian Soil Classification (ASC) - Order

- Dermosols
- Ferrosols
- Kandosols
- Kurosols
- Kurosols, Natric
- Organosols
- Rudosols and Tenosols
- Tenosols
- Water

Regional soil mapping - ASC

Snowy 2.0
Soil and Land Assessment
Exploratory Works
Figure 3.4

3.6.2 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 2018b) for the soils assessment area comprise Lithosols, Soloths, Alpine Humus Soils, Brown Podzolic Soils, Red Podzolic Soils – more fertile (volcanic and granodiorites), Red Podozloic Soils – less fertile (granites and metasediment) and Neutral to Alkaline Peats.

Table 3.3 Regional soil mapping – GSG distribution (%) in the soils assessment area

GSG	ASC equivalent	%
Lithosols	Rudosols/Tenosols	8.9
Soloths	Kurosols	0.3
Alpine Humus soils	Tenosols	42.2
Brown Podzolic Soils	Kurosols	39.9
Red Podzolic Soils – more fertile (volcanic and granodiorites)	Dermosols	1.8
Red Podzolic Soils – less fertile (granites and metasediment)	Kurosols	2.7
Neutral to Alkaline Peats	Organosols	3.9

3.6.3 Hydrologic soil group

The hydrologic soils group (OEH 2018c) present in the soils assessment area is comprised predominantly group B and C – moderate and slow infiltration respectively. There are small pockets of D associated with the organic rich soils (some Tenosols and Organosols) and Kurosols (natric). These are defined as follows:

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

3.6.4 Inherent soil fertility

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

A majority of the soils assessment area was mapped as moderate (associated with Kurosols) and low fertility land (associated with Rudosols, Tenosols and Organosols), being 98% of the soils assessment area. Small pockets of moderately high (associated with Dermosols, 1.8%) and moderately low (associated with Natric Kurosols, 0.26%) fertility land make up the remainder. Figure 3.5 shows the inherent soil fertility mapping for the soils assessment area.

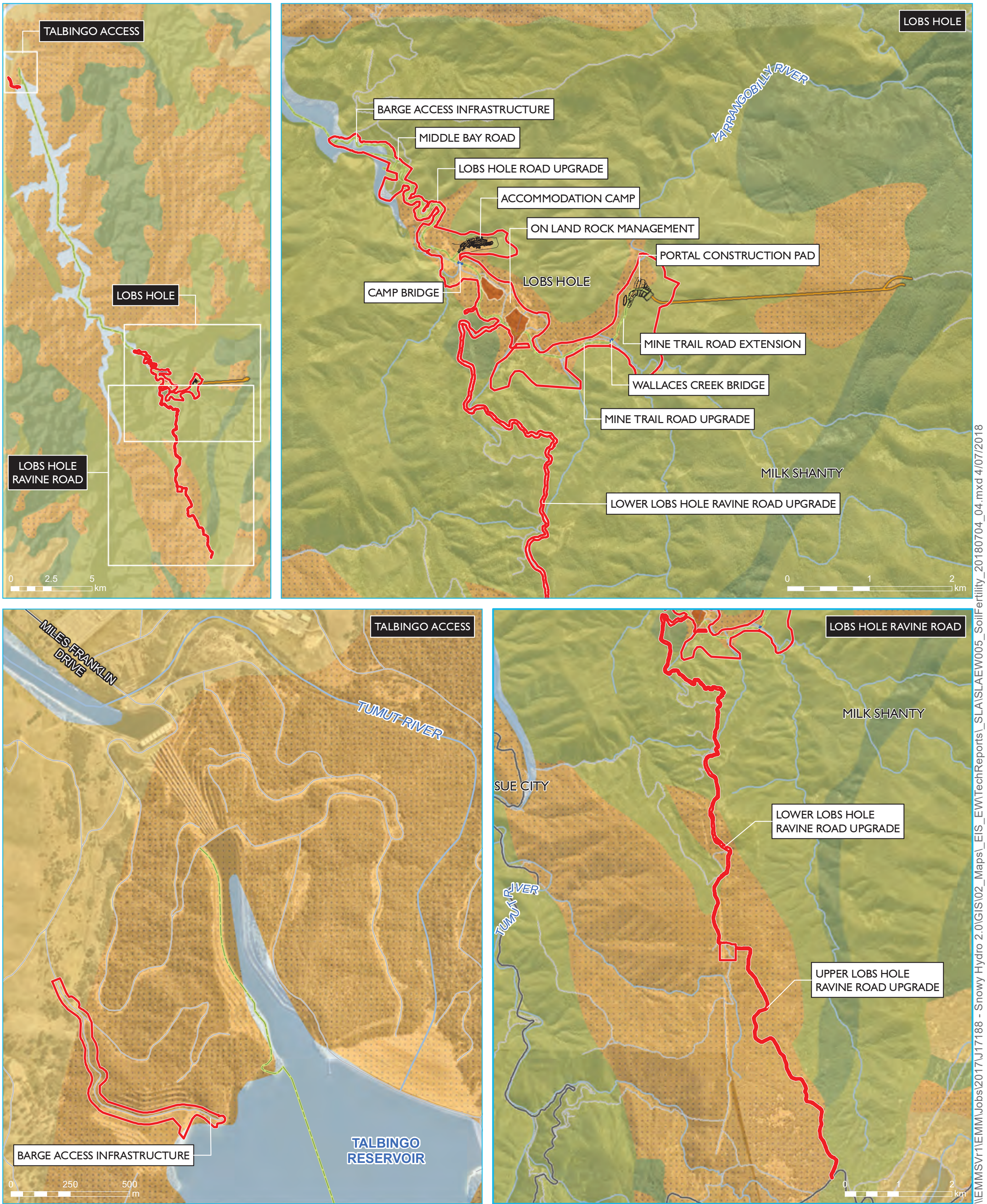
The fertility rankings are defined by OEH (2018d) as (Table 3.4):

- **Moderately high (4):** includes soils with high fertility in their virgin state but fertility can be significantly reduced after a few years of cultivation and amendments and fertilisers are required.
- **Moderate (3):** soils have low to moderate fertilities and usually require fertiliser and/or have some physical restriction for arable use.
- **Moderately low (2):** Includes soils with low fertilities, such that, generally, only plants suited to grazing can be supported. Large inputs of fertiliser are required to make the soils useable for arable purposes.
- **Low (1):** Includes soils which, due to their poor physical and/or chemical status only support plant growth. The maximum agricultural use of these soils is low intensity grazing.

Table 3.4 Summary of regional soil mapping by eSPADE within the soils assessment area

eSPADE ASC soil type	Area (ha)[1]	eSPADE inherent soil fertility	eSPADE hydrologic soil group
Rudosols and Tenosols	27	Low	Group B and Group 4 (Organic rich Tenosols)
Dermosols	5.1	Moderately high	Group C
Kurosols	123.7	Moderate	Group C
Kurosols (natric)	0.8	Moderately low	Group D
Organosols	11.3	Low	Group D

Notes: 1.Totals not exact due to rounding.



Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); Robert Bird (2018); DFSI (2017); OEH (2012, 2018); LPMA (2011)

GDA 1994 MGA Zone 55

N

KEY

Soils assessment area
Permanent bridge
On land rock management
Portal construction pad and accommodation camp conceptual layout
Exploration tunnel
Communications cable

Main road
Local road or track
Watercourse

Inherent soil fertility
Low
Moderately low
Moderate
Moderately high
Water

Inherent soil fertility

Snowy 2.0
Soil and Land Assessment
Exploratory Works
Figure 3.5

snowy 2.0 EMM

3.6.5 Soils of the Australian Alps Factsheet

The Australian Alps National Parks Co-operative Management program published a factsheet which outlines soil types found in the Australian Alps as well as the characteristics of these soil types (Mason 2014). These are summarised in Table 3.5.

Table 3.5 Characteristics of soils of the Australian Alps

Soil type	Duplex	Friable gradational loams and brownish gradational loams	Alpine humus loams	Peats	Lithosols
ASC equivalents	Kurosols and Chromosols	Dermosols and Kandosols	Tenosols	Organosols	Tenosols
Description	Two distinct horizons: a sandy loam or hard-setting loam overlaying a heavy clay horizon. They are found on the lower slopes and tableland areas adjacent to the Australian Alps.	Lower Montane: loams gradually merging into clay with depth. Upper Montane: deep friable loams. Highly porous and friable, these soils are found on the steep slopes of the montane zone.	Shallow, very friable loams. The most extensive soil type found in the subalpine and alpine zones, occurring on relatively sheltered, gentle, well-drained slopes. The surface is highly organic with strong plant root development. Highly porous and friable.	Found in basins and depressions where water collects all year round. They are highly organic and contain undecomposed and partially decomposed plant remains.	Very shallow loams found in pockets on high exposed ridges and elevated stony slopes. They have a lower organic content than alpine humus loams and are highly porous.
Surface colour	Yellow to grey-brown	Brown to grey-brown	Dark brown	Black	Light brown
Organic content (A horizon)	Medium	Medium high	High	Extremely high	Medium high
Clay content	Low in A horizon. High in B horizon.	Low in A horizon. Medium in B horizon.	Low	Low	Low
Depth	Medium	Deep	Medium	Medium	Shallow
Coarse fragments	Very few	Few	Many	Many	Many
pH	6-7	5-6	4-5	4	4-5

Table 3.5 Characteristics of soils of the Australian Alps

Soil type	Duplex	Friable gradational loams and brownish gradational loams	Alpine humus loams	Peats	Lithosols
Origin	In situ weathering of parent materials with some deposition of soils above.	Weathering of bedrock, some deposition of soils from above and the breakdown of plant remains. Wetter and cooler conditions produce deeper soils and a greater accumulation of organic material.	Weathering of bedrock and intense biological cycling in the upper layers.	An accumulation of undecomposed and decomposed plant remains. Water-logged environment and low temperatures restrict decomposition of organic matter.	Weathering of bedrock under extremes of cold, heat, wind and precipitation.
Associated vegetation communities	Open woodlands, mixed eucalypt forest.	Tall open forests (wet), open forests (dry).	Tussock grasslands, alpine herbfields, Snow gum woodlands.	Sphagnum bogs.	Shrubby heathland, herbfield feldmark.

3.6.6 eSPADE soil profiles

The eSPADE soil profile database search identifies information on soil profiles surveyed in the area and submitted to the SALIS database (OEH 2018f). Six profiles occur within the soils assessment area. Table 3.6 details the historic eSPADE soil profiles within the soils assessment area. The sites are described in detail but no laboratory data is available.

Table 3.6 eSPADE historic soil profiles within the soils assessment area (100 m buffer) (OEH 2018)

ASC	GSG	Surface pH	Surface texture	ID	Easting	Northing
Tenosol	Red Earth	6.5	Sandy clay loam	83	624693	6041104
Ferrosol	Krasnozem	6	Silty clay	88	627163	6032244
Tenosol	Lithosol	6	Silty clay loam	87	626863	6034514
Tenosol	Lithosol	7	Sandy clay loam	86	626923	6036324
Rudosol	Lithosol	7	Sandy clay loam	84	626513	6037094
Rudosol	Lithosol	7	Light clay loam	85	626953	6036744

3.7 Acid sulphate soils

Acid sulfate soils, when undisturbed, do not present a risk to the environment. When disturbed, the iron sulfides they contain react with oxygen in the air to create sulfuric acid. In turn, the sulfuric acid can release metals in the soil and damage waterways, aquatic and terrestrial flora and fauna and infrastructure.

3.7.1 National Atlas of Australian Acid Sulfate Soils

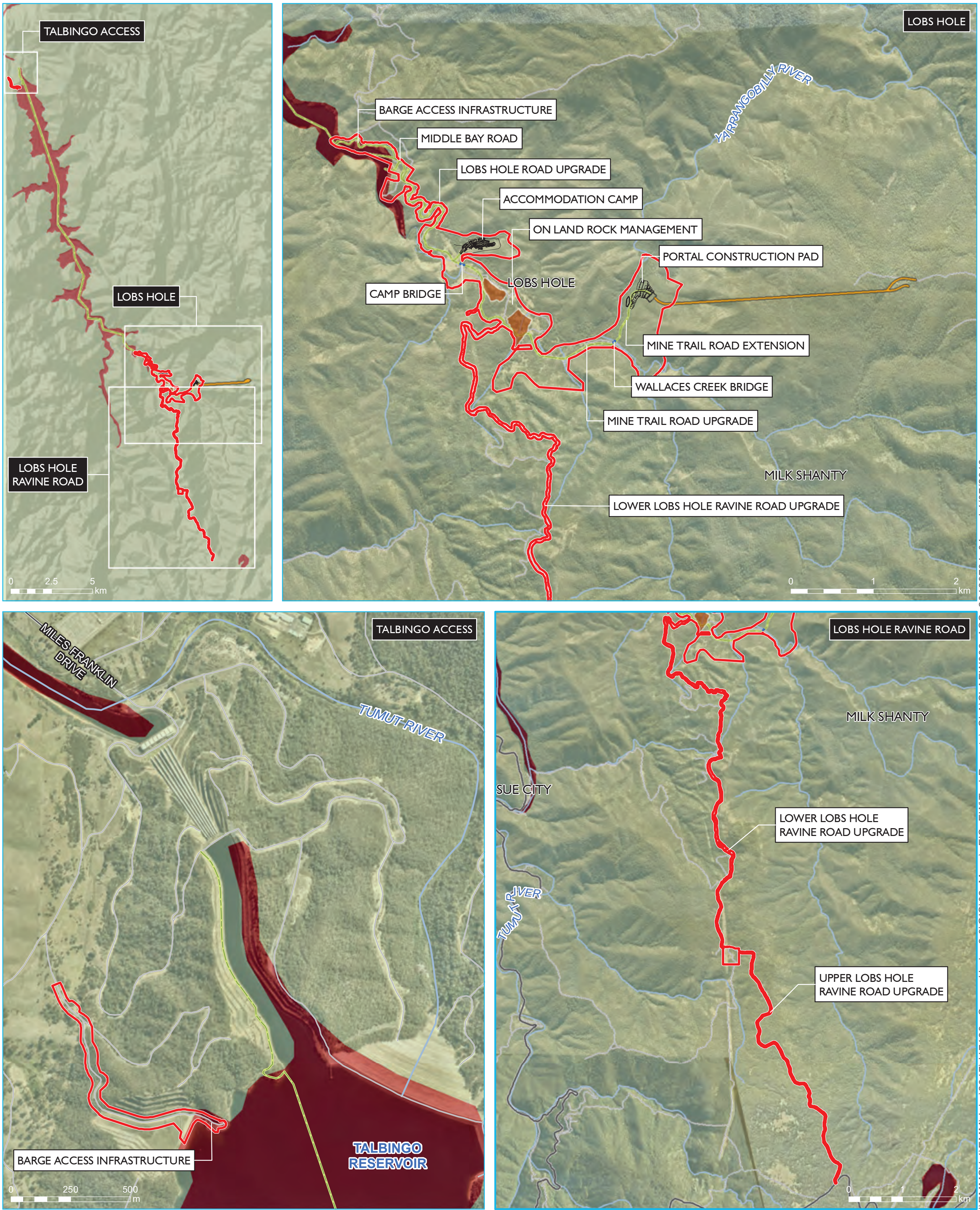
There is no local scale acid sulfate soils mapping for the soils assessment area. A review of the national Atlas of Australian Acid Sulfate Soils (Fitzpatrick et al. 2011) shows that part of the Middle Bay barge ramp is mapped as having a high probability of acid sulfate soils being present. It is worth noting that this mapping is at a broad scale (1:2,500,000) and it appears that the area mapped as 'high probability' is meant to align with the soils/sediments in the Talbingo Reservoir and not the Middle Bay barge ramp.

3.7.2 Geomorphologic factors

Due to the scale of acid sulfate soils maps and local variability, it is necessary to assess the site against geomorphic criteria. The following are listed as risk factors in the Acid Sulfate Soils Manual (Stone et al 1998):

- sediments of recent geological age (Holocene);
- soil horizons less than 5 m AHD;
- marine or estuarine sediments and tidal lakes;
- in coastal wetlands or back swamp areas; waterlogged or scalded areas; interdune swales or coastal sand dunes;
- in areas where the dominant vegetation is mangroves, reeds, rushes and other swamp-tolerant or marine vegetation;
- in areas identified in geological descriptions or in maps as bearing sulfide minerals, coal deposits or former marine shales/sediments; and
- deep older estuarine sediments > 10 metres below ground surface, Holocene or Pleistocene age.

The *Wagga Wagga 1:250,000 geological sheet* (Adamson & Loudon 1966) shows the site as having multiple geological units. These are described in Section 3.5. None of the aforementioned geomorphic criteria are present in the soils assessment area. The combination of the acid sulfate soils mapping and site geomorphic factors suggest that there is a low potential for the occurrence of acid sulfate soils.



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Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); Robert Bird (2018); DFSI (2017); LPMA (2011); CSIRO (2011)

GDA 1994 MGA Zone 55

N

KEY

- Soils assessment area
- Permanent bridge
- On land rock management
- Portal construction pad and accommodation camp conceptual layout
- Exploration tunnel
- Communications cable
- Main road
- Local road or track
- Watercourse

Potential acid sulfate soils (CSIRO, 2011)

- A - High probability of occurrence
- C - Extremely low probability of occurrence

Acid sulfate soils mapping

Snowy 2.0
Soil and Land Assessment
Exploratory Works
Figure 3.6

snowy2.0 EMM

3.8 Regional land use and land capability

3.8.1 Land use

The project is generally contained within the KNP. Local access tracks are scattered throughout, many originate from the historical use of the area and others which were constructed for access to Snowy Hydro and other infrastructure (ie transmission lines).

Lobs Hole is situated in a ravine along the Yarrangobilly River. Remnants of the former township of Ravine can be observed in the western portion of Lobs Hole, and relics of the former copper mine can be found in the eastern portion of the area. Ravine and the Lobs Hole copper mine were occupied and operational in the mid to late 1800s and abandoned in the early 1900s.

Lobs Hole is currently accessible to the public for recreational four wheel driving use and as a campground. Snowy Hydro also maintains a hydrometric and meteorological monitoring station along the river. Access to the area is made on the Lobs Hole Ravine Road to the north and south. A boat launching area into Talbingo Reservoir (near to the proposed location of the barge access infrastructure in Middle Bay) is located 1.6 km northwest of the former Ravine town site.

The barge access infrastructure would also be located at the northern end of Talbingo Reservoir (which is outside of the KNP boundary) at the Talbingo Reservoir spillway which is currently accessible to the public for day time picnic and recreational use.

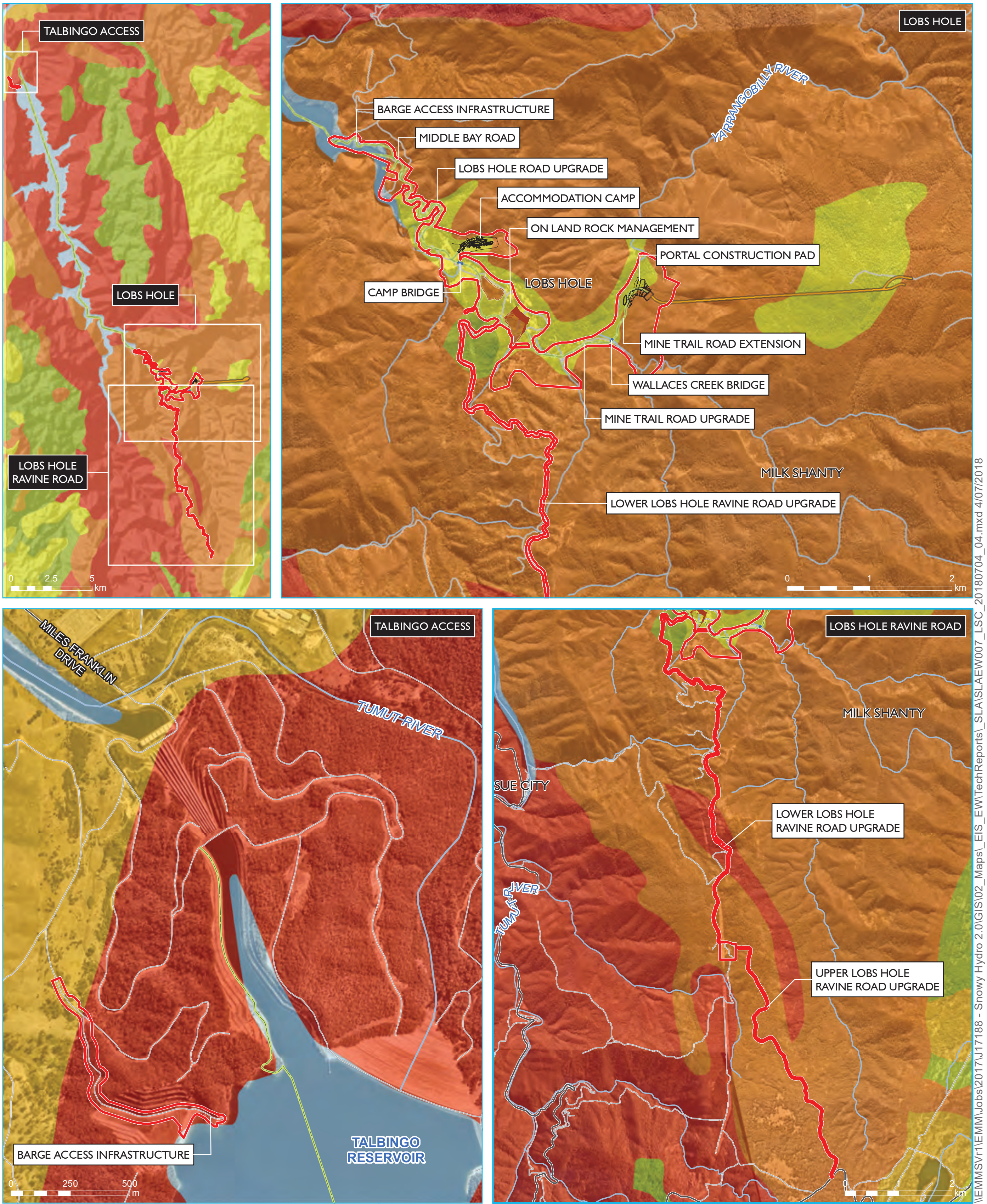
3.8.2 Land and soil capability classes

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. It is worth noting that the soils assessment area is primarily located within KNP and under conservation management. Soils and land capability is used only as a guide to the existing physical capacity of the land to supper different agricultural uses.

Most of the soils assessment area is currently mapped as Class 4 to Class 8 meaning that there are moderate to severe limitations to cropping. The majority of the soils assessment area is Class 7 and Class 8. Agricultural land uses will be restricted to grazing, forestry, and nature conservation. There are few land management practices available to overcome these limitations. The relevant LSC classes for the soils assessment area are detailed in Table 3.7. Figure 3.7 shows the current land and soil capability mapping.

Table 3.7 Relevant land and soil capability classes

LSC class	Associated ASC classes	Description	Area (Ha)	%
4	**Dermosols**	**Moderate capability land:** Moderate to high limitations for high-impact land uses. It will restrict land management options for regular high-impact land uses such as cropping, high-intensity grazing and horticulture; and the limitations can only be managed by specialised management practices with a high level of knowledge, expertise, inputs, investment and technology.	5.1	1.8
5	**Tenosols (organic rich)**	**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.	122.6	42.2
6	**Kurosols (Natric)**	**Low capability land:** Very high limitations for high-impact land uses and is generally suitable for limited land uses such as grazing, forestry and nature conservation. Careful management of limitations is required to prevent severe land and environmental degradation.	0.8	0.3
7	**Tenosols/Rudosols, Organosols, Kurosols**	**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.	150.5	51.8
8	**Tenosols/Rudosols, Organosols**	**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.	11.5	4



Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); Robert Bird (2018); DFSI (2017); OEH (2013); LPMA (2011)

GDA 1994 MGA Zone 55

N

KEY

- Soils assessment area
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- Watercourse

Land and soil capability

- 4 - Moderate to severe limitations
- 5 - Severe limitations
- 6 - Very severe limitations
- 7 - Extremely severe limitations
- 8 - Extreme limitations
- Water

Land and soil capability

Snowy 2.0
Soil and Land Assessment
Exploratory Works
Figure 3.7

4 Soil descriptions

4.1 Summary of units

The soil survey identified four major soil types within the soils assessment area (Table 4.1). The major soil orders indentified in the area Kandosols and Tenosols. Small areas of Dermosols and Vertosols were also identified. Detailed soil descriptions are provided in Sections 4.2 to 4.7. Figure 4.1 presents the spatial distribution of the soil types within the soils assessment area.

Table 4.1 Soil types in the soils assessment area

ASC order (Soil type)	Total area mapped within soils assessment area	
	(ha)	(%)
Kandosol	172.9	58.1
Dermosol	6.3	2.1
Tenosol	110.7	37.2
Vertosol	4.9	1.6
Not assessed	2.9	1
TOTAL	297.7	100

*Notes: * due to rounding.*

4.1.1 Tenosols

This soil order incorporates soils with generally weak pedologic organisation apart from the A horizons, encompassing a diverse range of soils. Tenosols generally have poor water retention, almost universal low fertility and occur in regions of low and erratic rainfall. They are mainly used for grazing based on native pastures and in better watered areas, such as the soils assessment area, may support forestry. The Tenosol described in the soils assessment area are classified as a Basic Lithic Brown-Orthic Tenosol.

4.1.2 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 soils assessment area is further classified as Haplic Mesotrophic Red Dermosol.

4.1.3 Kandosols

Kandosols are soils which lack strong texture contrast, have massive or only weakly structured B horizons, and are not calcareous throughout. The B2 horizon is generally well developed and has a maximum clay content in some part of the B2 horizon which exceeds 15%. The soils can support a wide range of land uses including cattle and sheep grazing of native pastures, cereal cropping and horticulture. The Kandosols described in the soils assessment area are classified as Haplic Red Eutrophic Kandosol, Haplic Brown Eutrophic Kandosol and Bleached or Haplic Eutrophic Grey Kandosol. These soils have been described separately due to the differences in physical and chemical characteristics, their locations in the landscape and influence of parent materials.

4.1.4 Vertosols

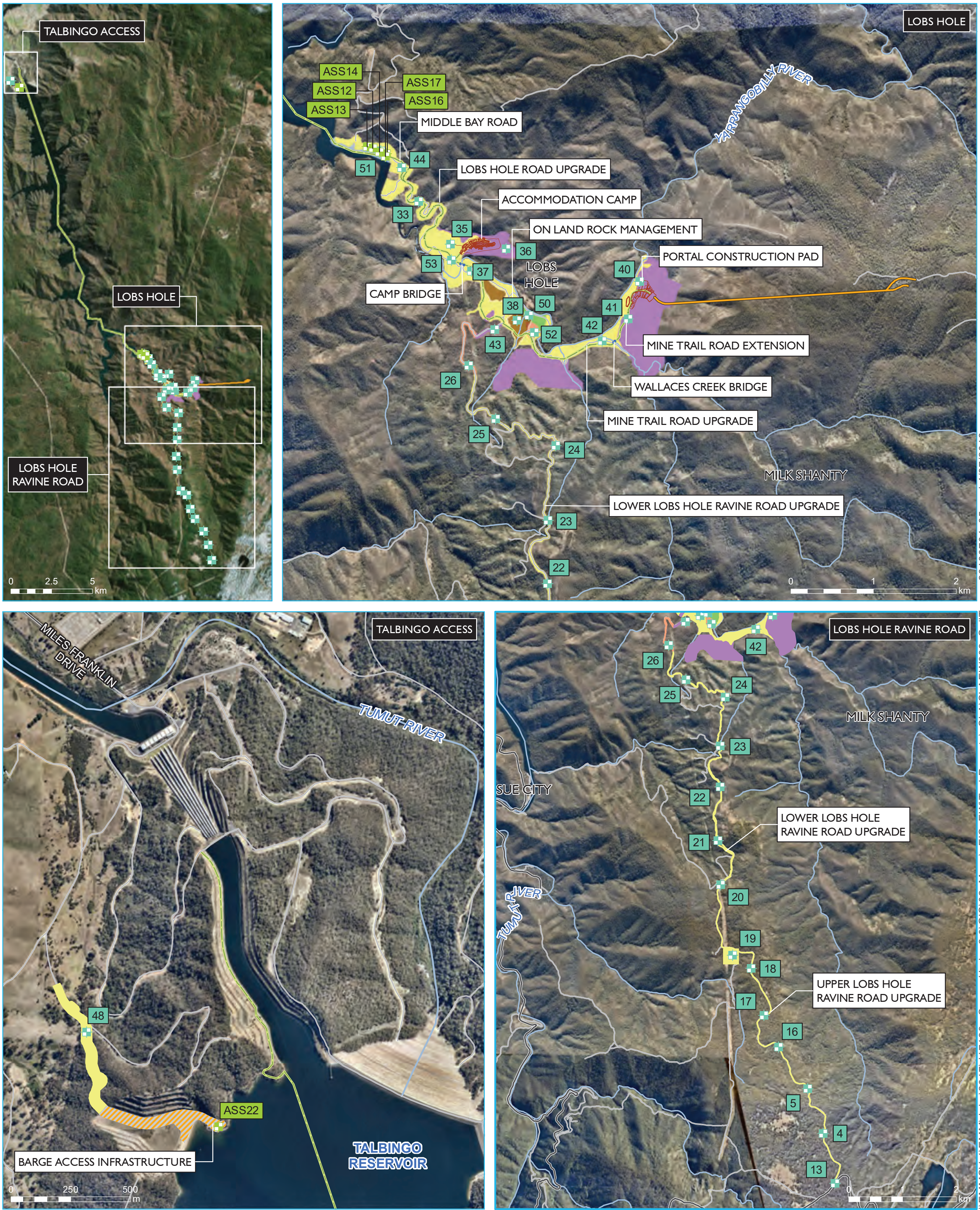
Vertosols are soils with shrink swell properties that exhibit strong cracking when dry and at depth have slickensides and/or lenticular structural aggregates. Gilgai microrelief is also common. A clay texture of 35% of more throughout the profile is present with the exception of thin, surface crusty horizons. The soils can support a wide range of land uses including irrigated and dryland cropping and grazing on native pasture in areas with low rainfall. Black vertosols in particular are some of the most productive soils in Australia. The Vertosols described in the soils assessment area are classified as a Haplic Epipedal Black Vertosol.

4.1.5 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 soils assessment area.

Table 4.2 Soil and geology relationships within the soils assessment area

Mapped geology (Wagga Wagga 1:250,000 Geological Sheet)	Surveyed soil types associated with geology
Czb: Cainozoic – Basalt	Kandosol
Dml: Palaeozoic – Limestone, shale	Kandosol
Dmr: Palaeozoic – Quartzite, siltstone	Kandosol
Dlb: Palaeozoic – Conglomerate, sandstone, tuff, siltstone, rhyolite	Kandosol Dermosol Tenosol
Sur: Palaeozoic – Conglomerate, sandstone, siltstone	Tenosol Dermosol Vertosol



\EMMSVr1\EMM\Jobs\2017\J17188 - Snowy Hydro 2.0\GIS\02_Maps_EIS_EW\TechReports_SLA\SLAEW008_SoilTypes_20180704_05.mxd 4/07/2018

Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); Robert Bird (2018); DFSI (2017); LPMA (2011)

GDA 1994 MGA Zone 55

N

KEY

- Soil sample site
- ASS sample site
- On land rock management
- Portal construction pad and accommodation camp conceptual layout
- Exploratory tunnel
- Communications cable
- Main road
- Local road or track
- Watercourse

Soils assessment area - Soil type

- Not assessed
- Dermosols
- Kandosols
- Tenosols
- Vertosols
- Water

Soil type distribution of the assessment area

Snowy 2.0
Soil and Land Assessment
Exploratory Works
Figure 4.1

4.2 Basic Lithic Brown-Orthic Tenosol

Lithic Orthic Tenosols are characterised by a weakly developed B horizon, usually in terms of colour, texture or structure or a combination of these. The B horizon directly overlies hard rock. These soils vary in texture across the soils assessment area but typically contain loamy sand to sandy clay loam in the A horizon and silty loam to clay loam in the B horizon. Coarse fragments are common on the soil surface and is of soft, organic condition. These soils have coarse fragments throughout the profile but increases with depth. There can be up to 50-70% coarse gravel and cobbles sized coarse fragments in the B horizon. Segregations and mottles are absent throughout the profile. A soil description for a typical Basic Lithic Brown-Orthic Tenosol is provided in Table 4.3 and a general landscape is shown in Photograph 4.1.

Table 4.3 Basic Lithic Brown-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 0-15cm	Dark reddish brown, 5YR 3/3 and no mottles or bleaching.	Dry, pH[2] 5.7 and rapidly rained.	Sandy clay loam, weak pedality, crumb structure.	Common surface rock, many coarse fragments, no segregations and many roots.
	B2 15-45cm	Yellowish red, 5YR 5/6 and no mottles or bleaching.	Moderately moist, pH 5.9 and moderately well drained.	Clay loam, massive.	Abundant coarse fragments, no segregations and many roots.

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

Photograph 4.1 Basic Lithic Brown-Orthic Tenosol typical landscape (Site 36)

The Basic Lithic Brown-Orthic Tenosol unit occurs on mid to upper slopes and crests of undulating hills on conglomerate, sandstone, siltstone, rhyolite and tuff surface geology. This is in agreement with existing mapping. It is expected that some Rudosol soils will occur on some upper slopes and crests of hills. Land associated with this soil consists largely of undisturbed native vegetation. A small area of Tenosols is also derived from alluvium influence (juncture of Lobs Hole Ravine Road and Lobs Hole Ravine).

The Basic Lithic Brown-Orthic Tenosols range from strongly acid to slightly acid with the A horizon sometimes being below pH 5.5. The profile tends to be gravelly with varied texture and weak pedality in the B horizon. These soils have a low water holding capacity due to their shallowness and moderate to moderately low inherent fertility (Peverill et al 2005).

4.2.1 Soil chemistry

The following soil chemistry assessment is based on sufficiency values from Apal (2017), Baker and Eldershaw (1993), DERM (2011) and Peverill, Sparrow and Reuter (1999). It is worth noting that these values apply to an agricultural setting and is thus intended as a reference only.

The soils were found to be to be slightly acid to strongly acid ranging from pH 5.2-6.2 with increasing pH observed in some profiles. One of the topsoil samples was below the soil sufficiency range which may restrict the growth of acid sensitive plants. EC was low in the whole profile ranging from 0.152-0.153 dS/m in the A1 horizon to 0.11-0.31 dS/m in the B2 horizon. This would not limit plant growth or damage infrastructure or buildings. Chloride levels are very low with all samples below detection limits (<10 mg/kg). Plant available phosphorus was below the sufficiency level of >10 mg/kg (<5-5 mg/kg). Total nitrate was very low at 0.2 mg/kg which is significantly below the sufficiency level of >15 mg/kg. Total nitrogen ranged from very low to low (440-600 mg/kg) and well below sufficiency levels. Plant available potassium was <200 mg/kg. Therefore this is inconclusive as to whether it is above the sufficiency level of >117 mg/kg. These deficiencies present fertility issues and could restrict plant growth.

Micro-nutrients were also variable. DTPA extractable zinc was low (inconclusive) down the profile. DTPA Copper was low down the profile with the exception of one B2 sample (Site 40, 20-40cm). DTPA extractable manganese was largely sufficient with the exception of one B2 sample (Site 41, 25-45cm). This is unlikely to restrict plant growth. Cation exchange capacity was low ranging from 2.7-5.5 milliequivalents per 100g (meq/100g) in the A1 horizon and 3.8-8.4 meq/100g in the B2 horizon. Exchangeable cations differ significantly between Site 40 and Site 41. Site 40 had sufficient exchangeable Ca, Mg and K throughout the profile. Exchangeable Al was below detection limits. Site 41 had very low exchangeable Ca, Mg and K in the A1 horizon and very high exchangeable aluminium (67%). Exchangeable Ca was deficient in the B2 horizon with very high exchangeable aluminium (55.2%). Exchangeable cation imbalances at Site 41 present fertility issues and could restrict plant growth. Organic carbon ranged from low to moderate in the A1 horizon (0.6-1.6%) and B2 horizon (<0.5-2.2%). Low organic carbon could present structural and fertility issues. The soil chemistry is summarised in Table 4.4.

4.2.2 Soil erosion potential

Soil erosion is the loss of soil from the landscape through water and wind leading to a reduction in land productivity and ecosystem services. Soil chemistry results (Appendix B) and the *Australian Soil Classification* indicate that the soils have low to moderate erosion potential. The erosion potential of the soil, among other physical and chemical attributes, will influence the suitability of management practices.

All of the Tenosols sent for laboratory analysis were non-sodic. Sodicity is a key factor in indicating the presence of highly dispersive soils. Site 40 has a negligible risk of dispersion in the A1 horizon (Class 8) and a low risk of dispersion (Class 4) in the B2 horizon. The B2 horizon may be prone to slaking. Calcium carbonate or gypsum is present in the B2 horizon which acts as natural flocculants. Site 41 has a moderate risk of dispersion (Class 3) throughout the profile, particularly following working of the soil. A low Ca:Mg ratio combined with the presence of high amounts of silt may be responsible for the higher dispersion risk at Site 41.

Table 4.4 Basic Lithic Brown-Orthic Tenosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.15	B2 0.1-0.45	Comments on median values (in increasing depth)
pH_{water}	pH units	6.0-7.5	5.2-6.2	6.2	Strongly acid to slightly acid (A1 horizon) to slightly acid (B2 horizon).
EC – saturated extract (EC_{se})	deciSemins per metre (dS/m)	<1.9	0.152-0.153	0.11-0.31	Low soil salinity.
Chloride (Cl^-)	Milligrams per kilogram (mg/kg)	<800	<10	<10	Not restrictive.
Macronutrients					
Nitrite + Nitrate as N (Sol.)	mg/kg	>15	0.2	-	Deficient.
Total N	mg/kg	>1500	440-600	-	Deficient.
P (Colwell)	mg/kg	>10	<5-5	-	Deficient.
K (Acid Extract)	mg/kg	>117	<200	-	Deficient (inconclusive)

Table 4.4 Basic Lithic Brown-Orthic Tenosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.15	B2 0.1-0.45	Comments on median values (in increasing depth)
Micronutrients					
Cu	mg/kg	>0.3	<1	<1-4.51	Low (inconclusive, A1 and B2 horizon) to sufficient (B2 horizon)
Zn	mg/kg	>0.5 (pH<7) >0.8 (pH>7)	<1	<1	Low (inconclusive)
Mn	mg/kg	>2	3.71-7.86	<1-11.5	Sufficient (A1 horizon). Low (inconclusive) to sufficient in the B2 horizon.
Exchangeable cations					
CEC	milliequivalents per 100 grams (meq/ 100 g)	12-25	2.7-5.5	3.8-8.4	
Ca	%	60-75	3-63	0.2-80.9	Very low to high.
Mg	%	10-20	5.4-26	15.4-23.6	Low to adequate.
Na	%	<1	<1	<0.1	Low.
K	%	3-8	3-11	3.6-7.9	Adequate.
Al	%	<1	<1-67.2	<1-55.2	Low to very high.
Emerson Aggregate	-	-	3-8	3-4	Moderate to negligible dispersion risk in the A1 horizon. Low to moderate dispersion risk in the B2 horizon.
ESP	%	<6	<1	<1	Non-sodic.
Ca:Mg ratio		>2	0.7-2.4	0.1-5.2	Unstable and stable A1 and B2 horizons.
Organic Carbon (OC)	%	>1.2	0.6-1.6	<0.5-2.2	Very low to moderate A1 and B2 horizons.

Notes: 1. Plant sufficiency sources: Apal (2017), Baker and Eldershaw (1993), DERM (2011) and Peverill, Sparrow and Reuter (1999).

** These values are an approximation based on calculations using the lowest measurable level.*

4.3 Haplic Mesotrophic Red Dermosol

Haplic Mesotrophic Red Dermosol are moderately well developed and do not have a strong texture contrast. These soils have a clay loam A horizon and a light clay B horizon. Some coarse fragments are present on the soil surface. The soil surface is of soft, organic condition. These soils have minimal coarse fragments throughout the profile with the A1 horizon having 5-10% fine gravel to gravel sized coarse fragments. The B2 horizon has <2% coarse fragments. Segregations and mottles are absent throughout the profile. A soil description for a typical Haplic Mesotrophic Red Dermosol is provided in Table 4.5 and a general landscape is provided in Photograph 4.2.

Table 4.5 Haplic Mesotrophic Red 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 0-14cm	Reddish brown, 2.5YR 5/3 and no mottles or bleaching.	Moderately moist, pH[2] 6.1 and moderately well drained.	Clay loam, strong pedality, crumb structure.	Some surface rock, Few coarse fragments, no segregations and many roots.
	B2 14-110cm	Light red, 2.5YR 6/6 and no mottles or bleaching.	Dry, pH 5.4-6.2 and moderately well drained.	Light clay, moderate pedality, subangular blocky structure.	Very few coarse fragments, no segregations and many roots.

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

Photograph 4.2 Haplic Mesotrophic Red Dermosol typical landscape (Site 26)

The Haplic Mesotrophic Red Dermosol occurs as a small pocket on Lobs Hole Ravine Road on mid slopes on conglomerate, sandstone, tuff, siltstone and rhyloite surface geology. This is in agreement with existing mapping. The landscape this soil occurs in is characterised by a reddish pink geology. Land associated with this soil consist largely of undisturbed native vegetation. A small pocket of Acidic Mesotrophic Red Dermosols occurs in Lobs Hole Ravine, adjacent to the historical mine workings. This occurs on top of a small hill and is likely as a result of a geological outcrop.

The Haplic Mesotrophic Red Dermosols range from slightly acid to strongly acid with the profile getting below pH 5.5 at the top of the B2 horizon. The profile has minimal gravel with moderate pedality in the B horizon. These soils have a moderately high water holding capacity due to the medium-strong pedality, high clay content and deep profiles. These soils have a moderately high inherent soil fertility (Peverill et al 2005).

4.3.1 Soil chemistry

The following soil chemistry assessment is based on sufficiency values from Apal (2017), Baker and Eldershaw (1993), DERM (2011) and Peverill, Sparrow and Reuter (1999). It is worth noting that these values apply to an agricultural setting and is thus intended as a reference only.

The soils were found to be slightly acid to medium acid with pH decreasing down the profile (pH 5.7-6.1). The B2 horizon was outside of the soil sufficiency range which may limit the growth of acid sensitive plants. EC was low ranging from 0.23-0.36 dS/m. This would not limit plant growth or damage infrastructure or buildings. Chloride levels are very low with all samples below detection limits (<10 mg/kg). Plant available phosphorus was below the sufficiency level (6 mg/kg). Total nitrate was very low at 0.1 mg/kg. Total nitrogen was also low at 770 mg/kg. Plant available potassium was <200 mg/kg. Therefore this is inconclusive as to whether it is above the sufficiency level of >117 mg/kg. These deficiencies present fertility issues and could restrict plant growth.

DTPA extractable Zn and Cu was low with <1 mg/kg down the profile. It is unclear as to whether they are above the sufficiency levels which of 0.3 mg/kg for Cu and 0.5 mg/kg for Zn respectively. Manganese ranged from very high to high in the A1 and B2 horizon respectively. Cu and Zn deficiencies could present fertility issues and restrict plant growth. Cation exchange capacity was very low ranging from 5.3 meq/100g in the A1 horizon compared to 2.8-3.5 meq/100g in the B2 horizon. The low CEC may present some fertility issues and restrict plant growth. Exchangeable calcium, magnesium and potassium was adequate down the profile. Mg was a little high at the bottom of the B2 horizon which may cause K deficiencies in some plants. Exchangeable cations are unlikely to present any fertility issues. Organic carbon ranged from moderate (1.4%) in the A1 horizon to <0.5% in the B2 horizon. This indicates good structural condition and fertility in the A1 horizon. The soil chemistry is summarised in Table 4.6.

4.3.2 Soil erosion potential

Soil chemistry results (Appendix B) and the *Australian Soil Classification* indicate that the soils have low to moderate erosion potential. The erosion potential of the soil, among other physical and chemical attributes, will influence the suitability of management practices.

The Dermosols sent for laboratory analysis were non-sodic. Sodicity is a key factor in indicating the presence of highly dispersive soils. There is negligible risk of dispersion in the A1 horizon (Class 8) and a low risk of dispersion (Class 4) in the majority of the B2 horizon. The B2 horizon may be prone to slaking. Calcium carbonate or gypsum is present in the B2 horizon which act as natural flocculants. The bottom 0.3 m of the B2 horizon has a moderate risk of dispersion (Class 3); particularly following working of the soil. A significantly lower Ca:Mg ratio may be responsible for this higher risk of dispersion.

Table 4.6 Haplic Mesotrophic Red Dermosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.14	B2 0.14-1.1	Comments on median values (in increasing depth)
pH_{water}	pH units	6.0-7.5	6.1	5.7 (5.4-6.2)	Strongly acid to slightly acid (A1 horizon) to slightly acid (B2 horizon).
EC – saturated extract (EC_{se})	deciSemins per metre (dS/m)	<1.9	0.36	0.25 (0.23-0.25)	Low soil salinity.
Chloride (Cl^-)	Milligrams per kilogram (mg/kg)	<800	<10	<10 (<10-<10)	Not restrictive.
Macronutrients					
Nitrite + Nitrate as N (Sol.)	mg/kg	>15	0.1	-	Deficient throughout profile.
Total N	mg/kg	>1500	770	-	Deficient.
P (Colwell)	mg/kg	>10	6	-	Deficient.
K (Acid Extract)	mg/kg	>117	<200	-	Deficient (inconclusive)
Micronutrients					
Cu	mg/kg	>0.3	<1	<1	Low (inconclusive).
Zn	mg/kg	>0.5 (pH<7) >0.8 (pH>7)	<1	<1	Low (inconclusive)
Mn	mg/kg	>2	56.3	17.8	Very high (A1 horizon) to high (B2 horizon)

Table 4.6 Haplic Mesotrophic Red Dermosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.14	B2 0.14-1.1	Comments on median values (in increasing depth)
Exchangeable cations					
CEC	milliequivalents per 100 grams (meq/ 100 g)	12-25	5.3	2.8-3.5	Very low.
Ca	%	60-75	70	57-61	Adequate.
Mg	%	10-20	22	28-34	Adequate (A horizon) to high (B horizon)
Na	%	<1	<0.1	<0.1	Very low.
K	%	3-8	8	8-10	Adequate.
Al	%	<1	<1	<2	Low.
Emerson Aggregate	-	-	8	3-4	Negligible dispersion risk in the A1 horizon. Low to moderate dispersion risk in the B2 horizon.
ESP	%	<6	<0.1	<0.1	Non-sodic.
Ca:Mg ratio		>2	3.1	1.7-2.13	Stable A horizon. Slightly unstable to stable B horizon.
Organic Carbon (OC)	%	>1.2	1.4	<0.5	Moderate (A1 horizon) to very low (B2 horizon).

Notes: 1. Plant sufficiency sources: Apal (2017), Baker and Eldershaw (1993), DERM (2011) and Peverill, Sparrow and Reuter (1999).

** These values are an approximation based on calculations using the lowest measurable level.*

4.4 Haplic Eutrophic Red Kandosol

Haplic Eutrophic Red Kandosols lack a strong texture contrast and have a well developed, weakly structured B horizon. Sandy clay loams to clay loams occur in the A horizon with clay loams to light clays in the B horizon. The soil surface is without coarse fragments with the exception of those on steeper slopes. The A horizon generally has very few coarse fragments while the B horizon has common to many coarse gravel and gravel sized coarse fragments (increases with depth). Segregations and mottles are absent throughout the profile. A soil description for a typical Haplic Eutrophic Red Kandosol is provided in Table 4.7 and a general landscape is shown in Photograph 4.3.

Table 4.7 Haplic Eutrophic Red Kandosol typical soil profile summary

ASC:	Horizon name and average depth (m)	Colour, mottles and bleach	Moisture, laboratory pH (median) and drainage	Texture and structure	Coarse fragments, segregations and roots
	A1 0-0.06 m	Brownish black, 7.5YR 3/2 and no mottles or bleaching.	Dry, pH 6 and well drained.	Clay loam, strong pedality, crumb structure.	No surface rocks, very few coarse fragments, no segregations and many roots.
	A2 0.06-0.32 m	Dull brown, 7.5YR 6/3 and no mottles or bleaching.	Dry, pH 5.9 and well drained.	Clay loam, moderate pedality, crumb structure.	Common coarse fragments, no segregations and many roots.
	B21 0.32-0.7 m	Light red, 2.5YR 6/8 and no mottles or bleaching.	Dry, pH 6.1 and moderately well drained.	Clay loam, weak pedality, subangular blocky structure.	Common coarse fragments, no segregations and many roots.
	B22 0.7-1.1 m	Strong brown, 7.5YR 5/8 and no mottles or bleaching.	Dry, pH 6.2 and moderately well drained.	Light clay, weak pedality, subangular blocky structure.	Many coarse fragments, no segregations and few roots.

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

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

Photograph 4.3 Haplic Mesotrophic Red Kandosol typical landscape (Site 37)

The Haplic Eutrophic Red Kandosol occurs on lower slopes and flats in Lobs Hole Ravine and the Middle Bay barge ramp on conglomerate, sandstone and siltstone surface geology. This differs to existing regional mapping. Land in Lobs Hole Ravine associated with this soil is largely cleared and disturbed from historical uses. The road connecting heading north-west from Lobs hole Ravine as well as the Middle Bay barge ramp area consists largely of undisturbed vegetation. The northern end of Talbingo Reservoir contains a bleached A2 horizon (Bleached Eutrophic Red Kandosol).

The Haplic Eutrophic Red Kandosols range from medium acid in the A1 horizon to medium acid to slightly acid in the B2 horizon. The profile has some gravel once below the A1 horizon with weak pedality below the A2 horizon (or below the A1 where no A2 is present). These soils have a moderate to moderately low (on steeper slopes where shallow profiles occur) water holding capacity due to the high clay content and deep profiles. These soils have a moderately low inherent soil fertility (Peverill et al. 2005).

4.4.1 Soil chemistry

The following soil chemistry assessment is based on sufficiency values from Apal (2017), Baker and Eldershaw (1993), DERM (2011) and Peverill, Sparrow and Reuter (1999). It is worth noting that these values apply to an agricultural setting and is thus intended as a reference only.

The soils were found to range from slightly acid to medium acid (pH 5.9-6.5) with a weak trend of pH increasing down the profile. This is slightly outside the soil sufficiency range but is unlikely to impact plant growth. EC ranged from very low (0.07 dS/m) to low (0.46 dS/m) with EC decreasing down the profile. This would not limit plant growth or damage infrastructure or buildings. Chloride levels were below detection limits in all samples. Plant available phosphorus was below the sufficiency level (<5-6 mg/kg). Total nitrate was very low ranging from 0.1-0.3 mg/kg. Total nitrogen was low at 780-1190 mg/kg. Plant available potassium was <200 mg/kg and is inconclusive as to whether it is above the sufficiency level of 117 mg/kg. These deficiencies present fertility issues and could restrict plant growth.

DTPA extractable Cu and Zn was low with <1 mg/kg down the profile with the exception of the A1 sample at Site 37 (1.14 mg/kg of Cu and 1.2 mg/kg of Zn). It is unclear as to whether the rest of the samples are above the sufficiency levels which of 0.3 mg/kg for Cu and 0.5 mg/kg for Zn respectively. Mn ranged from very high in the A1 horizon to low in the B22 horizon with concentrations decreasing down the profile. Cu and Zn deficiencies could present fertility issues and restrict plant growth. CEC ranged from very low (3.6-5.4 meq/100g) to low (8.9 meq/100g) with a gradual increase down the profile. The low CEC may present some fertility issues and restrict plant growth. Exchangeable Ca and Mg varied between Site 51 (Middle Bay barge ramp) and Site 37 (Lobs Hole Ravine). Calcium was sufficient throughout the profile at Site 37 and low at Site 51. Mg was sufficient at Site 37 and high at Site 51. Elevated exchangeable Mg can cause K deficiency in particular plants. Exchangeable K was sufficient for all samples tested. Elevated Mg and low Ca may present fertility issues in the soils in the Middle Bay barge ramp. Organic carbon ranged from high (2%) in the A1 horizon to low (<0.5%) in the B22 horizon with organic carbon decreasing down the profile. This indicates good structural condition and fertility in the A1 horizon. The soil chemistry is summarised in Table 4.8.

4.4.2 Soil erosion potential

Soil chemistry results (Appendix B) and the *Australian Soil Classification* indicate that the soils have low to moderate erosion potential. The erosion potential of the soil, among other physical and chemical attributes, will influence the suitability of management practices.

All of the Red Kandosols sent for laboratory analysis were non-sodic. Sodicity is a key factor in indicating the presence of highly dispersive soils. The A1 horizon has a negligible (Class 8) to low (Class 4) risk of dispersion. Class 4 soils may be prone to slaking and have carbonates or gypsum which act as natural flocculants. The A2 horizon and the top 0.2 m of the B21 horizon at Site 37 have a moderate dispersion risk (Class 3). The remainder of A2 and B horizon soils tested had a low risk of dispersion (Class 4).

Table 4.8 Haplic Eutrophic Red Kandosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.06 m	A2 0.06-0.32 m	B21 0.32-0.7 m	B22 0.7-1.1 m	Comments on median values (in increasing depth)
pH_{water}	pH units	6.0-7.5	5.9-6	5.9-6.2	6.1-6.5	6.2	Medium acid to slightly acid (A1, A2 horizon) to slightly acid (B21 horizon)
EC – saturated extract (EC_{se})	deciSemins per metre (dS/m)	<1.9	0.14-0.46	0.12-0.2	0.07-0.22	0.07	Low soil salinity.
Chloride (Cl^-)	Milligrams per kilogram (mg/kg)	<800	<10	<10	<10	<10	Not restrictive.
Macronutrients							
Nitrite + Nitrate as N (Sol.)	mg/kg	>15	0.1-0.3	-	-	-	Deficient throughout profile.
Total N	mg/kg	>1500	780-1190	-	-	-	Deficient.
P (Colwell)	mg/kg	>10	<5-6	-	-	-	Deficient.
K (Acid Extract)	mg/kg	>117	<200	-	-	-	Deficient (inconclusive)

Table 4.8 Haplic Eutrophic Red Kandosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.06 m	A2 0.06-0.32 m	B21 0.32-0.7 m	B22 0.7-1.1 m	Comments on median values (in increasing depth)
Micronutrients							
Cu	mg/kg	>0.3	<1-1.14	<1	<1	<1	Low (inconclusive) to adequate in the A1 horizon
Zn	mg/kg	>0.5 (pH<7) >0.8 (pH>7)	<1-1.2	<1	<1	<1	Low (inconclusive) to adequate in the A1 horizon.
Mn	mg/kg	>2	40.9-66.7	13-29.9	2.2-18.5	<1	High to very high in the A1 and A2 horizons. Adequate to high in the B21 horizon. Low in the B22 horizon.
Exchangeable cations							
CEC	milliequivalents per 100 grams (meq/ 100 g)	12-25	3.6-5.4	3.6-5.2	5.7 (4.3-7)	8.9	Very low to low.
Ca	%	60-75	46-66	35-69	61 (31-67)	51.7	Low to adequate (A1, A2, B21 horizon)
Mg	%	10-20	19-40	19-58	31.5 (25-58)	41.6	Adequate to very high (A1, A2 horizon). High to very high (B21 horizon)
Na	%	<1	<0.1	<0.1	<0.1	<0.1	Very low.
K	%	3-8	11-13	8-9	6-10	6.7	Adequate.
Al	%	<1	<1-<2.7	<1-<2.7	<1-<2	<1	Low.
ESP	%	<6	<0.1	<0.1	<0.1	<0.1	Non-sodic.
Emerson Aggregate	-	-	4-8	3-4	4 (3-4)	4	Low to negligible dispersion risk in the A1 horizon. Moderate to low dispersion risk in the A2 and B21 horizon. Low dispersion risk in the B22 horizon.
Ca:Mg ratio		>2	1.1-3.4	0.6-3.6	0.5-2.6	1.2	Unstable and stable A1, A2, B21 horizons. Unstable B22 horizon.
Organic Carbon (OC)	%	>1.2	2	0.6-1.2	<0.5	<0.5	Sufficient (A1 horizon), low to sufficient (A2 horizon). Very low in B21 and B22 horizons.

4.5 Haplic Eutrophic Brown Kandosol

Haplic Eutrophic Brown Kandosols lack a strong texture contrast and have a well developed, weakly structured B horizon. Silty loams (where organic matter is abundant) to clay loams occur in the A horizon with clay loams to light clays in the B horizon. The soil surface is without coarse fragments with the exception of those on steeper slopes. The A horizons generally have very few to common coarse fragments while the B horizons have common to abundant coarse gravel and gravel sized coarse fragments (increases with depth). Segregations and mottles are mostly absent throughout the profile (the exception being Site 16). A soil description for a typical Haplic Eutrophic Red Kandosol on basalt and limestone and shale are provided in Table 4.9 and Table 4.10 respectively. A general landscape is shown for these soils in Photograph 4.4 and Photograph 4.5 respectively.

Table 4.9 Haplic Eutrophic Brown Kandosol (Limestone and shale) 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 0-0.1 m	Reddish brown, 2.5YR 4/4 and no mottles or bleaching.	Dry, pH 5.4 and well drained.	Clay loam, moderate pedality, crumb structure.	No surface rocks, very few coarse fragments, no segregations and many roots.
	A2 0.1-0.32 m	Reddish grey, 2.5 YR 5/1 and no mottles or bleaching.	Dry, pH 6.1 and well drained.	Clay loam, moderate pedality, sub-angular blocky structure.	Very few coarse fragments, no segregations and many roots.
	B21 0.32-1 m	Very pale brown, 10YR 8/4 and no mottles or bleaching.	Dry, pH 5.8 and moderately well drained.	Clay loam, massive.	Common to abundant coarse fragments, no segregations and some roots.

Table 4.10 Haplic Eutrophic Brown Kandosol (Basalt) 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 0-0.11	Reddish brown, 5YR 4/6 and no mottles or bleaching.	Dry, pH 5.6 and well drained.	Silty loam, moderate pedality, crumb structure.	No surface rocks, very few coarse fragments, no segregations and many roots.
	B21 0.11-0.5	Reddish brown, 2.5YR 4/6 and no mottles or bleaching.	Moderately moist, pH 5.8 and well drained.	Clay loam, weak pedality, sub-angular blocky structure.	Very few coarse fragments, no segregations and many roots.
	B22 0.5-0.7	Dull brown, 7.5YR 4/3 and no mottles or bleaching.	Dry, pH 5.7 and moderately well drained.	Clay loam, weak pedality, sub-angular blocky structure.	Common to many coarse fragments, no segregations and no visible roots.
	B23/B3 0.7-1	Light red, 2.5YR 6/6 and no bleaching. Some yellow mottling.	Dry, pH 5.4 and moderately well drained.	Clay loam, weak pedality, sub-angular blocky structure.	Few coarse fragments, no segregations and no visible roots.

Photograph 4.4 Haplic Eutrophic Brown Kandosol (Limestone and shale) typical landscape (Site 23)

Photograph 4.5 Haplic Eutrophic Brown Kandosol (Basalt) typical landscape (Site 4)

The Haplic Eutrophic Brown Kandosols occur on the mid and upper slopes on Lobs Hole Ravine Road. There are two distinct variants of Haplic Eutrophic Brown Kandosols in the soils assessment area. The soils above Site 19 and Site 20 on Lobs Hole Ravine Road (on higher elevations) occur on Basalt surface geology. Below Site 19 and Site 20 on Lobs Hole Ravine Road (on lower elevations) these soils occur on limestone and shale. Site 19 and Site 20 appear to be a transitional profiles which occur on conglomerate, sandstone, tuff, siltstone and rhyolite. The Limestone and Shale variant tend to have an A2 horizon whereas this is largely absent in the Basalt variant. It is expected that some Rudosol and Tenosol soils will occur on the steeper upper slopes along Lobs Hole Road; particularly around Site 22 and 24 where it was too steep to survey. This differs to existing regional mapping which maps Lobs Hole Ravine Road as Organosols, Rudosols and Tenosols and Kurosols. The land which these soils exist on consists of largely undisturbed vegetation.

The Haplic Eutrophic Brown Kandosols range from strongly acid to slightly acid in the A and B horizons. The profile has some gravel below the below the A1 horizon with weak pedality below the A2 horizon (or below the A1 horizon where no A2 is present). These soils have a moderate to moderately low (on steeper slopes where shallow profiles occur) water holding capacity due to the high clay content and deep profiles. These soils have a moderately low inherent soil fertility (Peverill et al. 2005).

4.5.1 Soil chemistry

The following soil chemistry assessment is based on sufficiency values from Apal (2017), Baker and Eldershaw (1993), DERM (2011) and Peverill, Sparrow and Reuter (1999). It is worth noting that these values apply to an agricultural setting and is thus intended as a reference only.

The soils ranged from strongly acid to slightly acid (pH 5.4-6.1) with no clear trend with depth observed. EC was very low ranging from 0.06 dS/m to 0.28 dS/m with EC decreasing down the profile This would not limit plant growth or damage infrastructure or buildings. Chloride levels were very low throughout the profile (<10-30 mg/kg). Plant available phosphorus ranged from adequate to very high (17-213 mg/kg). Total nitrate and nitrites was well below sufficiency levels (<0.1-0.3 mg/kg). Total nitrogen ranged from slightly below sufficiency levels (1230 mg/kg) to high (3600 mg/kg). Plant available potassium was <200 mg/kg and is inconclusive as to whether it meets sufficiency levels. Low nitrates and nitrites and plant available potassium present fertility issues and could restrict plant growth.

DTPA extractable Cu was <1 mg/kg in all samples with the exception of the A2/B21 horizon which had a median value of 1.12 mg/kg. Zn was adequate in the A1 horizon (<1-3.99 mg/kg) and low in all other horizons (<1 mg/kg). It is unclear as to whether samples <1 mg/kg for Cu and Zn are above the sufficiency levels of 0.3 mg/kg for Cu and 0.5 mg/kg for Zn. Mn ranged from high in the A1 (28.7-101 mg/kg) and A2/B21 horizons (12.7-23.5 mg/kg) to adequate in the B21/B22 horizons (1.7-8.15 mg/kg) and low in the B23 horizon (<1 mg/kg). CEC was low in the A1 (6.5-10.8 meq/100g) and A2/B21 (5.4-11.3 meq/100g) horizons and low to moderate in the B21/22 (5.2-12 meq/100g) and B23 horizons (5.1-24.1 meq/100g). The Low CEC present in most horizons presents fertility issues and may restrict plant growth. Exchangeable Mg and K is adequate throughout the profile. Exchangeable Ca is low throughout the Basalt variant (13-35%) and the transitional profile at Site 19 (25-44%). The limestone and shale variant had adequate levels throughout the profile (61-76%). Organic carbon ranged from high in the A1 horizon and high to moderate in the A2/B21 horizon to low in the B21/22 and B23 horizons. This indicates good structural condition and fertility in the A1 and A2/B21 horizons. Soil chemistry is summarised in Table 4.11.

4.5.2 Soil erosion potential

Soil chemistry results (Appendix B) and the *Australian Soil Classification* indicate that the soils have low to moderate erosion potential. The erosion potential of the soil, among other physical and chemical attributes, will influence the suitability of management practices.

All of the Brown Kandosols sent for laboratory analysis were non-sodic. Sodicity is a key factor in indicating the presence of highly dispersive soils. There is a low (Class 4) to negligible (Class 8) risk of dispersion in the A1 horizon. The Class 4 soils may be prone to slaking. Calcium carbonate or gypsum is present in Class 4 soils which act as natural flocculants. The A2 horizon of Site 23 (the shale and limestone variant) and the B21 horizon of Site 19 (the transitional profile) has moderate risk of dispersion (Class 3); particularly following working of the soil. The rest of the B horizon soils tested were Class 4 (low dispersion risk).

Table 4.11 Haplic Eutrophic Brown Kandosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.15 m	A2/B21 0.2-0.5 m	B21/B22 0.5-0.75 m	B23 0.75-1.1 m	Comments on median values (in increasing depth)
pH_{water}	pH units	6.0-7.5	5.6 (5.4-6.2)	6 (5.7-6.1)	5.7-5.8	5.4-5.7	Slightly acid (A2 horizon) to strongly acid (B23 horizon).
EC – saturated extract (EC_{se})	deciSemins per metre (dS/m)	<1.9	0.22 (0.2-0.28)	0.11 (0.09-0.22)	0.06-0.18	0.06-0.09	Very low soil salinity.
Chloride (Cl^-)	Milligrams per kilogram (mg/kg)	<800	20 (<10-30)	<10 (<10-<10)	<10	<10	Not restrictive.
Macronutrients							
Nitrite + Nitrate as N (Sol.)	mg/kg	>15	0.2 (<0.1-0.3)	-	-	-	Deficient.
Total N	mg/kg	>1500	1500 (1230-3600)	-	-	-	Sufficient.
P (Colwell)	mg/kg	>10	54 (17-213)	-	-	-	High.
K (Acid Extract)	mg/kg	>117	<200 (<200-<200)	-	-	-	Deficient (inconclusive)
Micronutrients							
Cu	mg/kg	>0.3	<1 (<1-<1)	1.12 (<1-1.47)	<1	<1	Deficient (inconclusive, A1, B21 and B23 horizons) to adequate (A2 horizon).
Zn	mg/kg	>0.5 (pH<7) >0.8 (pH>7)	1.99 (<1-3.99)	<1 (<1-1)	<1	<1	Adequate (A1 horizon) to low (inconclusive, A2, B21 and B23 horizons)

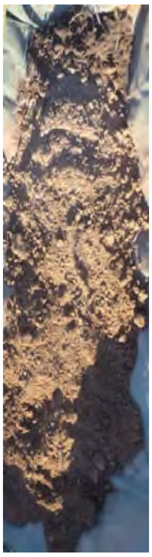
Table 4.11 Haplic Eutrophic Brown Kandosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.15 m	A2/B21 0.2-0.5 m	B21/B22 0.5-0.75 m	B23 0.75-1.1 m	Comments on median values (in increasing depth)
Mn	mg/kg	>2	31.6 (28.7-101)	16.6 (12.7-23.5)	1.7-8.15	<1	High (A1 and A2 horizons) to adequate (B21 horizon) and low (B23 horizon).
Exchangeable cations							
CEC	milliequivalents per 100 grams (meq/ 100 g)	12-25	8.1 (6.5-10.8)	5.6 (5.4-11.3)	5.2-12	5.1-24.1	Low in the A1, A2 horizons and low to moderate in the in the B21 and B23 horizons.
Ca	%	60-75	44.4 (26.1-74.1)	69.6 (40.7-76.1)	35-42.3	13.3-33.3	Low (A1, B21, B23 horizons) to adequate (A2 horizon).
Mg	%	10-20	11.1 (7.7-22.2)	16.6 (16.1-18.6)	23.1-23.2	13.7-25.5	Adequate.
Na	%	<1	<0.1 (<0.1-0.2)	<0.1 (<0.1-<0.1)	<0.1	<0.1	Low.
K	%	3-8	4 (3-9)	4.4 (3.7-14.2)	4.2-5.8	0.8-5.9	Adequate (A1, A2, B21 and B23 horizons).
Al	%	<1	29.6 (<0.9-36.9)	1.8 (<1-29.6)	23.1-23.7	29.4-36.9	High (A2 horizon) to very high (A1, B21 and B23 horizons).
ESP	%	<6	<0.1 (<0.1-0.2)	<0.1 (<0.1-<0.1)	<0.1	<0.1	Non-sodic.
Emerson Aggregate		-	4 (4-8)	4 (3-4)	4 (3-4)	4	Low to negligible dispersion risk in the A1 horizon. Low to moderate dispersion risk in the B21 and B22 horizons. Low dispersion risk in the B23 horizon.
Ca:Mg ratio		>2	3.4 (3.3-4)	4.1 (2.4-4.3)	1.5-1.8	0.97-1.3	Stable A1 and A2 horizons. Unstable B21 and B23 horizons.
Organic Carbon (OC)	%	>1.2	3.1 (1.9-8)	2.2 (0.9-3.3)	<0.5-0.8	<0.5	High in the A1 and A2 horizons. Low in the B21 and B23 horizons.

4.6 Haplic/Bleached Eutrophic Grey Kandosol

Haplic/Bleached Eutrophic Grey Kandosols lack a strong texture contrast and have a well developed, weakly structured B horizon. Silty loams (where organic matter is abundant) to clay loams occur in the A horizon with silty clay loams to light clays in the B horizon. The soil surface is without coarse fragments with the exception of those on steeper slopes. The A horizons have very few to many coarse fragments while the B horizons have very few to many coarse gravel and gravel sized coarse fragments (increases with depth). Segregations and mottles are mostly absent throughout the profile. A bleached A2 horizon may be present, particularly on the flat near Site 53. A soil description for a typical Haplic Eutrophic Grey Kandosol is provided in Table 4.9. A general landscape is shown for these soils in Photograph 4.6.

Table 4.12 Bleached Eutrophic Grey Kandosol typical soil profile summary

ASC:	Horizon name and average depth (m)	Colour, mottles and bleach	Moisture, laboratory pH (median) and drainage	Texture and structure	Coarse fragments, segregations and roots
	A1 0-0.09	Greyish brown, 5YR 5/2 and no mottles or bleaching.	Dry, pH 5.7 and well drained.	Silty loam, moderate pedality, crumb structure.	No surface rocks, very few coarse fragments, no segregations and many roots.
	A2 0.09-0.42	Very pale brown, 10YR 8/4 with no mottles. Horizon is bleached.	Moderately moist, pH 5.8 and well drained.	Clay loam, moderate pedality, sub-angular blocky structure.	Very few coarse fragments, no segregations and many roots.
	B2 0.42-1.1	Brown, 7.5YR 5/2 and no mottles or bleaching.	Dry, pH 5.7 and moderately well drained.	Clay loam, weak pedality, sub-angular blocky structure.	Common coarse fragments, no segregations and some roots.

Photograph 4.6 Bleached Eutrophic Grey Kandosol typical landscape (Site 53)

The Haplic/Bleached Eutrophic Grey Kandosols occurs on flats (the lowest part of the landscape) in Lobs Hole Ravine (Site 35 and Site 53) and as a transition profile between the lighter textured Tenosols in the Portal Construction pad area and the Vertosols in the centre of Lobs Hole Ravine (Site 42). This indicates there could be an alluvial influence from Yarrangobilly River. These soils occur on conglomerate, sandstone, tuff, siltstone and rhyolite surficial geology. Land associated with this soil is largely cleared and disturbed from historical uses. There is some undisturbed native vegetation that exists along Mine Trail Road and around the portal construction pad. A Humose Eutrophic Grey Kandosol variant occurs in the north-west of Lobs Hole Ravine (around Site 35). This is the lowest point in the landscape and has gradually accumulated clay and organic matter over time.

The Haplic/Bleached Grey Kandosols range from medium acid slightly acid in the A and B horizons. The profiles mainly have gravel below the A horizons (with the exception of Site the humose variant) with weak pedality below the A2 horizon (or below the A1 where no A2 is present). These soils have a moderate to moderately low water holding capacity due to the high clay content and deep profiles. These soils have a moderately low inherent soil fertility (Peverill et al. 2005).

4.6.1 Soil chemistry

The following soil chemistry assessment is based on sufficiency values from Apal (2017), Baker and Eldershaw (1993), DERM (2011) and Peverill, Sparrow and Reuter (1999). It is worth noting that these values apply to an agricultural setting and is thus intended as a reference only.

The soils were found to be strongly acid to neutral ranging from pH 5.4-6.8 with pH generally increasing with depth. This is unlikely to restrict plant growth. EC was very low (0.07 dS/m) to low (0.54 dS/m) and would not limit plant growth or damage infrastructure or buildings. Chloride levels were low throughout the profile ranging from <10 to 20 mg/kg. This is well below the sufficiency level of 800 mg/kg. Plant available phosphorus was above sufficiency levels in the A1 horizon (15 mg/kg). Total nitrogen was moderate and above sufficiency levels (1980 mg/kg). Nitrates and nitrite were deficient (5.6 mg/kg). This could potentially restrict plant growth.

DTPA extractable Cu was sufficient down the profile with the exception of the bottom B22 horizon sample at Site 42 which was low (inconclusive) (<1 mg/kg). Zn was adequate down the profile at Site 35. Zn was adequate in the A1 horizon at Site 42 but low (inconclusive) for the rest of the profile (<1 mg/kg). Mn ranged from adequate to very high with Site 42 having substantially higher concentrations in the A horizons. Zn deficiencies at around Site 42 could present fertility issues and restrict plant growth. CEC ranged from very low (4.5 meq/100g) to moderate (12.8 meq/100g). CEC was noticeably higher around Site 35 which can be attributed to higher clay and organic carbon contents. The low CEC, mainly around Site 42 may present some fertility issues and restrict plant growth. Exchangeable Ca, Mg and K were adequate down the profile at Site 42. The A1 horizon had high exchangeable Al (6.1%). At Site 35, exchangeable Ca is low below the A1 horizon and K below the A2 horizon. Mg is high throughout the profile. High exchangeable Al in the A1 horizon (Site 42) and elevated Mg combined with K and Ca deficiencies at Site 35 may present fertility issues. Organic carbon ranged from high (A1 horizon) to moderate (A2, B21 horizons) to low in the B22 horizon at Site 35. Site 42 had moderate organic carbon in the A1 horizon but was below detection limits (<0.5%) from the B21 horizon down. Organic carbon decreases down the profile at both sites. This indicates good fertility and structural condition down to 0.65 m (B21 horizon) at Site 35 and 0.2 m (A1 horizon) at Site 42. The soil chemistry is summarised in Table 4.13.

4.6.2 Soil erosion potential

Soil chemistry results (Appendix B) and the *Australian Soil Classification* indicate that the soils have low to moderate erosion potential. The erosion potential of the soil, among other physical and chemical attributes, will influence the suitability of management practices.

All of the Grey Kandosols sent for laboratory analysis were non-sodic. Sodicity is a key factor in indicating the presence of highly dispersive soils. There is low (Class 4) to negligible (Class 8) risk of dispersion in the A1 and A2 (where present) horizons respectively. The Class 4 soils may be prone to slaking. Calcium carbonate or gypsum is present in Class 4 soils which act as natural flocculants. The remainder of the profile at Site 42 (B21 and B22 horizons) have a moderate risk of dispersion (Class 3); particularly following working of the soil. The top of the B22 horizon at Site 35 is also a Class 3 soil. The B21 horizon and bottom of the B22 horizon have a negligible (Class 8) to low (Class 4) risk of dispersion.

Table 4.13 Haplic/Bleached Grey Kandosol soil chemistry results median (and range)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.15	A2 0.2-0.4	B21 0.4-0.8	B22 0.8-1.1	Comments on median values (in increasing depth)
pH_{water}	pH units	6.0-7.5	5.4-5.7	6.5	6.4-6.7	6.6 (6.3-6.8)	Strongly to medium acid in the A1 horizon. Slightly acid to neutral in the A2, B21 and B22 horizons.
EC – saturated extract (EC_{se})	deciSemins per metre (dS/m)	<1.9	0.13-0.54	0.15	0.17-0.2	0.12 (0.07-0.18)	Very low to low in the A1 horizon. Low in the A2, B21 and B22 horizon.
Chloride (Cl^-)	Milligrams per kilogram (mg/kg)	<800	<10-20	<10	<10	<10 (<10-<10)	Not restrictive.
Macronutrients							
Nitrite + Nitrate as N (Sol.)	mg/kg	>15	5.6	-	-	-	Deficient.
Total N	mg/kg	>1500	1980	-	-	-	Sufficient
P (Colwell)	mg/kg	>10	15	-	-	-	Adequate.
K (Acid Extract)	mg/kg	>117	<200	-	-	-	Deficient (inconclusive)
Micronutrients							
Cu	mg/kg	>0.3	1.12-2.71	2.63	1.66-3.3	2.6 (<1-4.69)	Adequate in the A1, A2 and B21 horizons. Low to adequate in the B22 horizons.
Zn	mg/kg	>0.5 (pH<7) >0.8 (pH>7)	4.03-4.33	1.36	<1-1.36	1.08 (<1-1.12)	Adequate in the A1 and A2 horizons. Low to adequate in the B21 and B22 horizons.
Mn	mg/kg	>2	14.9-135	9.24	7.18-36.9	12.1 (7.4-22.2)	Adequate to high in the A1, B21 and B22 horizons. Adequate in the A2 horizon.
Exchangeable cations							
CEC	milliequivalents per 100 grams (meq/ 100 g)	12-25	4.9-12.8	9.6	5.4-10	8.1 (4.5-11.4)	Low to moderate in the A1 and B22 horizons. Low in the A2 and B21 horizons.

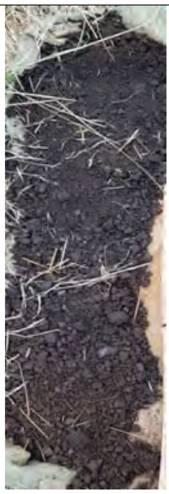
Table 4.13 Haplic/Bleached Grey Kandosol soil chemistry results median (and range)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.15	A2 0.2-0.4	B21 0.4-0.8	B22 0.8-1.1	Comments on median values (in increasing depth)
Ca	%	60-75	58-69.4	49	46-77.8	59 (43.4-75)	Adequate in the A1 horizon. Low in the A2 horizon. Low to adequate in the B horizons.
Mg	%	10-20	14.3-37.5	46.9	18.5-51	38.2 (20.8-54.9)	Adequate to high in the A1, B21 and B22 horizons. High in the A2 horizon.
Na	%	<1	<0.1	<0.1	<0.1	<0.1 (<0.1-<0.1)	Very low.
K	%	3-8	4.7-8.2	4.2	2-3.7	3 (0.9-4.4)	Adequate in the A1 and A2 horizons. Low to adequate in the B horizons.
Al	%	<1	<1-6.1	<1	<1	<1	Very low to high in the A1 horizon. Low in A2, B21 and B22 horizons.
ESP	%	<6	<0.1	<0.1	<0.1	<0.1	Non-sodic.
Emerson Aggregate		-	4	8	3-8	3 (3-4)	Low to negligible dispersion risk (A1 and A2 horizons). Low to moderate dispersion risk in the B21 and B22 horizons.
Ca:Mg ratio		>2	1.5-4.9	1	0.9-4.2	2.1 (0.79-3.6)	Unable to be calculated for A1 and B22. Very high in B21.
Organic Carbon (OC)	%	>1.2	1.4-4	1.5	<0.5-1.2	0.7 (<0.5-1)	Moderate to high in the A1 horizon. Moderate in the A2 horizon. Low to moderate in the B21 horizon. Low in the B22 horizon.

4.7 Haplic Epipedal Black Vertosol

The Haplic Epipedal Black Vertosols exhibit strong cracking when dry and at depth have slickensides and/or lenticular structural aggregates. Gilgai microrelief is not present. A clay texture of 35% or more is present throughout the profile with no thin, crusty surface horizon. The surface horizon is strongly structured and is not self-mulching. The soil surface is without coarse fragments and is of a soft, organic condition. No coarse fragments are evident in the profile. Segregations and mottles are absent in the profile. A soil description for a typical Haplic Epipedal Black Vertosol is provided in Table 4.14 and a general landscape is shown in Photograph 4.7.

Table 4.14 Haplic Epipedal Black Vertosol 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 0-0.15 m	Dark olive brown, 2.5Y 3/3 and no mottles or bleaching.	Moderately moist, pH 8.1 and mod well drained.	Light clay, strong pedality, crumb structure.	No surface rocks, very few coarse fragments, no segregations and many roots.
	B21 0.15-0.85 m	Brownish black, 2.5Y 3/1 and no mottles or bleaching.	Dry, pH 8.2 and imperfectly drained.	Medium clay, strong pedality, sub-angular blocky structure.	Very few coarse fragments, no segregations and many roots.
	B22 0.85-1.1 m	Dark olive brown, 2.5Y 3/3 and no mottles or bleaching.	Dry, pH 8.2 and imperfectly drained.	Medium clay, strong pedality, sub-angular blocky structure.	Common to abundant coarse fragments, no segregations and some roots.

Photograph 4.7 Haplic Epipedal Black Vertosol typical landscape (Site 50)

The Haplic Epipedal Black Vertosol occurs in a small area on a floodplain in the south-eastern corner of Lobs Hole Ravine. Clay alluvium has been deposited over time by the Yarrangobilly River on the inside of a meander. This differs to existing regional mapping. Land in Lobs Hole Ravine associated with this soil is largely cleared and now consists of grasses. This soil type is easily observable in the landscape due to the taller, denser grass growth compared to surrounding areas.

The Haplic Epipedal Black Vertosols are moderately alkaline in the A and B horizons. Gravel and coarse fragments are absent from the entire profile. Pedality is strong throughout the profile. These soils have a high water holding capacity due to the very high clay content and deep profiles. Vertosol soils have a high fertility and are considered some of the most fertile soils in Australia (Peverill et al. 2005).

4.7.1 Soil chemistry

The following soil chemistry assessment is based on sufficiency values from Apal (2017), Baker and Eldershaw (1993), DERM (2011) and Peverill, Sparrow and Reuter (1999). It is worth noting that these values apply to an agricultural setting and is thus intended as a reference only.

These soils were found to be moderately alkaline ranging from pH 8.1-8.2 with no obvious trend down the profile. This is slightly above the soil sufficiency range which restrict the growth of plants sensitive to alkalinity. EC was low (1.27 dS/m) in the A1 horizon and very low in the B21 and B22 horizon (0.9 and 0.85 dS/m) and would not limit plant growth or damage infrastructure or buildings. Chloride levels were low throughout the profile ranging from <10 to 20 mg/kg. This is well below the sufficiency value of <800 mg/kg. The EC is elevated compared to other soil types in the soils assessment area but it is worth noting that soluble and exchangeable calcium is high while chloride and sulfate is low; indicating that the elevated EC is due to calcium carbonates and not chloride salts (which are much more detrimental to plant growth). Plant available phosphorus was above sufficiency levels in the A1 horizon (24 mg/kg). Total nitrogen was high and well above sufficiency levels (3,500 mg/kg). Nitrates and nitrites were deficient (3.3 mg/kg). This could potentially restrict plant growth. DTPA extractable metals (Cu, Zn and Mn) were all either adequate or high with the exception of low zinc in the B22 horizon. This would not restrict plant growth.

Cation exchange capacity was moderate ranging from 13.1 to 16.3 meq/100 g. Exchangeable aluminium and acidity was below detection limits. Exchangeable Mg and K was very low throughout the profile. This could present fertility issues. Exchangeable calcium occupied >97% throughout the profile. Organic carbon ranged from high in the A1 horizon (5%) to moderate in the B22 horizon (1.8%). This indicates good structural condition and stability. The soil chemistry is summarised in Table 4.15.

4.7.2 Soil erosion potential

Soil chemistry results (Appendix B) and the *Australian Soil Classification* indicate that the soils have low erosion potential. The erosion potential of the soil, among other physical and chemical attributes, will influence the suitability of management practices.

The Vertosols sent for laboratory analysis were non-sodic. Sodicity is a key factor in indicating the presence of highly dispersive soils. There is a low risk of dispersion in throughout the entire profile (Class 4). The soil may be prone to slaking. Calcium carbonate or gypsum is present in these soils which act as natural flocculants.

Table 4.15 Haplic Epipedal Black Vertosol soil chemistry results median (and range)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.15	B21 0.15-0.85	B22 0.85-1.1	Comments on median values (in increasing depth)
pH_{water}	pH units	6.0-7.5	8.1	8.2 (8.1-8.2)	8.2	Moderately alkaline.
EC – saturated extract (EC_{se})	deciSemins per metre (dS/m)	<1.9	1.27	0.9 (0.88-0.98)	0.85	Low (A1 horizon) to very low (B21, B22 horizons) soil salinity.
Chloride (Cl^-)	Milligrams per kilogram (mg/kg)	<800	20	<10	<10	Not restrictive.
Macronutrients						
Nitrite + Nitrate as N (Sol.)	mg/kg	>15	3.3	-	-	Deficient.
Total N	mg/kg	>1500	3500	-	-	High.
P (Colwell)	mg/kg	>10	24	-	-	Adequate.
K (Acid Extract)	mg/kg	>117	<200	-	-	Deficient (inconclusive)

Table 4.15 Haplic Epipedal Black Vertosol soil chemistry results median (and range)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.15	B21 0.15-0.85	B22 0.85-1.1	Comments on median values (in increasing depth)
Micronutrients						
Cu	mg/kg	>0.3	26.2	4.96 (4.85-7.96)	3.73	High (A1 horizon) to adequate (B21, B22 horizons).
Zn	mg/kg	>0.5 (pH<7) >0.8 (pH>7)	6.54	2.16 (1.47-4.31)	<1	Adequate (A1, B21 horizons) to low (B22 horizon, inconclusive)
Mn	mg/kg	>2	24.3	23.9 (23.8-28.6)	30.6	High.
Exchangeable cations						
CEC	milliequivalents per 100 grams (meq/ 100 g)	12-25	16.3	16 (15.5-18.4)	13.1	Moderate.
Ca	%	60-75	100	100 (97.3-100)	100	Very high.
Mg	%	10-20	<1	<1 (<1-2.1)	<1	Very low.
Na	%	<1	<1	<1	<1	Very low.
K	%	3-8	<1	<1	<1	Very low.
Al	%	<1	<1	<1	<1	Very low.
ESP	%	<6	<1	<1	<1	Non-sodic.
Emerson Aggregate		-	4	4 (4-4)	4	Low dispersion risk.
Ca:Mg ratio		>2	N/A	46	N/A	Unable to be calculated for A1 and B22. Very high in B21.
Organic Carbon (OC)	%	>1.2	5	3.4 (2.4-4.5)	1.8	High (A1, B21 horizons) to moderate (B22 horizon).

4.8 Comparison with soil mapping by others

There are only limited similarities between the eSPADE existing soil mapping and the field-based soil survey results from this assessment, in terms of soil orders present and general patterns of distribution. These are summarised below.

Lobs Hole Ravine Road:

- eSPADE mapping: Mixture of Organosols and Rudosols and Tenosols in the southern end of the road and Kurosols in the northern end of the road. A small patch of Dermosols is present at the northern end of Lobs Hole Ravine Road and Lobs Hole Ravine. The juncture of Lobs Hole Ravine Road and Lobs Hole Ravine is Tenosols.

- EMM soil survey: Dominated by Kandosols with a small patch of Dermosols at the northern end of Lobs Hole Ravine Road and Lobs Hole Ravine. The juncture of Lobs Hole Ravine Road and Lobs Hole Ravine is Tenosols.

Portal construction pad and Mine Trail Road area:

- eSPADE mapping: Tenosols closer to Yarangobilly River and Kurosols in the higher elevations.

- EMM soil survey: Tenosols across the entire area with the exception of Kandosols along the road which connects the central/western Lobs Hole Ravine area to the eastern area MINE TRAIL ROAD.

Western and central area of Lobs Hole Ravine:

- eSPADE mapping: Tenosols with a small pocket of Kurosols in the north;

- EMM soil survey: Dominated by Kandosols with a pocket of Vertosols on a floodplain in the southern corner and a pocket of Dermosols just south of the Vertosols. Tenosols occur in the steeper slopes in the north.

Middle Bay barge ramp:

- eSPADE mapping: Solely Kurosols.

- EMM soil survey: Solely Kandosols.

Northern end of Talbingo Reservoir:

- eSPADE mapping: Largely Rudosols and Tenosols with a small pocket of Kurosols on the western edge.

- EMM soil survey: Solely Kandosols.

The eSPADE mapping did not identify any Kandosols within the soils assessment area. Field investigations found Kandosols and Tenosols to be the dominant soil types, in contrast with the soil mapping, with smaller areas of Dermosols and Vertosols.

Given the differences in information from the above-listed sources, and difficulty in verifying the methods or results of studies by others, the 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.

5 Acid sulfate soils assessment

A desktop review of acid sulfate soils mapping and site geomorphic factors concluded that there was a low potential for the occurrence of acid sulfate soils across the entire soils assessment area. It is important to note that this assessment applies to terrestrial areas only and that sediments within Talbingo Reservoir are addressed in the Barge Access Infrastructure Assessment (Appendix E to the EIS) and the Subaqueous Excavated Rock Placement Assessment (Appendix D to the Barge Access Infrastructure Assessment).

5.1 Geology and soils

The geology of the Middle Bay barge ramp consists of the 'Sur' unit (Upper Silurian, Ravine Beds unit) which contains conglomerate, sandstone and siltstone (described in Section 3.5). Sampling adjacent to the shoreline revealed that the original soils prior to flooding were Red Kandosols. Following the construction of the Talbingo reservoir, the profiles have become waterlogged and accumulated coarse fragments. A typical profile consists of a brown clay loam A1 horizon (0-0.1 m) underlain by a red/reddish brown clay loam B2 horizon (0.1-0.5 m). Sub-angular coarse fragments (10-50 mm) make up 20-50% of the B2 horizon. Both horizons are wet with the watertable occurring between 0.3-0.5 m bgl.

The geology of the sampling at the northern end of Talbingo Reservoir consists of the 'Dlb' unit (Middle to lower Silurian unit belonging to the Boraig Group) which contains Rhyolite and some tuff. The soils of the shoreline consist of a dark brown, loamy sand A1 horizon (0-0.07 m) underlain by a greyish brown clay loam B2 horizon (0.07-0.25 m). Large, sub-angular coarse fragments (10-50 mm) make up 40-50% of both horizons. Both horizons are wet with refusal of the auger occurring at 0.25 m. The watertable was not reached.

5.2 Field and laboratory test results

The following assessment is based on action criteria reported in *Acid Sulfate Soils: Assessment Guidelines* (Ahern et al. 1998) (Table 5.1). Works in soils that exceed these action criteria must have an acid sulfate soils management plan. The criteria for medium texture soil was utilised in the assessment.

Table 5.1 Texture-based acid sulfate soil action criteria

Type of material		***Action criteria*** **if 1 to 1000 tonnes of material is disturbed (existing + potential acidity)**		***Action criteria*** **if more than 1000 tonnes of material is disturbed (existing + potential acidity)**	
Texture range	Approximate clay content (%)	Equivalent sulfur (%S)	Equivalent acidity (mol H^+/tonne)	Equivalent sulfur (%S)	Equivalent acidity (mol H^+/tonne)
Coarse texture (sands to loamy sands)	5	0.03	18	0.03	18
Medium texture (sandy loams to light clays)	5-40	0.06	36	0.03	18
Fine texture (medium to heavy clays and silty clays)	40	0.1	62	0.03	18

The results of the field and laboratory testing are shown in Table 5.2.

Table 5.2 Field and laboratory test results

Character-istic	Unit	ASS 22	ASS 22	ASS 16	ASS 16	ASS 16	ASS 17	ASS 17	ASS 17	ASS 14	ASS 14	ASS 14	ASS 13	ASS 13	ASS 13	ASS 12	ASS 12	ASS 12
Horizon and depth		A1 0-0.07 m	B2 0.07-0.25 m	A1 0-0.1 m	B2 0.3-0.4 m	B2 0.55-0.65 m	A1 0-0.04 m	B2 0.04-0.24 m	B2 0.25-0.45 m	A1 0-0.1 m	B2 0.2-0.3 m	B2 0.6-0.7 m	A1 0-0.1 m	B2 0.2-0.3 m	B2 0.6-0.7 m	A1 0-0.1m	B21 0.3-0.4	B22 0.6-0.7
pH (1:5)	pH units	6.1	6.47	6.18	6.2	6.2	5.68	5.2	5.3	6.06	6.08	6.19	6.2	5.49	5.52	6.19	6.24	6.3
Reaction to H_2O_2[1]	-	XXX	XXX	XX	XX	XX	XXX	XXX	XXX	XX	X	X	XX	XX	XX	X	X	X
pH_{ox}		4.01	4.28	5.27	5.31	4.54	4.02	4.07	4.1	5.44	6.02	5.84	4.96	4.93	4.3	5.75	6.1	6.25
pH (1:5) - pH_{ox}	pH units	2.09	2.19	0.91	0.89	1.66	1.66	1.13	1.2	0.62	0.06	0.35	1.24	0.56	1.22	0.44	0.14	0.05
CRS	%	0.011	0.012	0.01	0.012	0.011	0.011	0.012	0.01	-	-	-	0.012	0.013	0.01	-	-	-
Total acidity	mol H^+/tonne	6.8607	7.4844	6.237	7.4844	6.8607	6.8607	7.4844	6.237	-	-	-	7.4844	8.1081	6.237	-	-	-
ANC	Kg H_2SO_4/tonne	0	0	0	0	0	0	0	0	-	-	-	0	0	0	-	-	-
Net acidity	mol H^+/tonne	6.8607	7.4844	6.237	7.4844	6.8607	6.8607	7.4844	6.237	-	-	-	7.4844	8.1081	6.237	-	-	-

Notes: 1. X = slight reaction, XX = moderate reaction, XXX = high reaction, XXXX = very rigorous reaction, gas evolution and heat generation commonly >80°C.

5.3 Discussion

The field pH (1:5) of the samples ranged from 5.2 to 6.47. A pH >4 rules out the presence of actual acid sulfate soils but does not give an indication as to the presence of potential acid sulfate soils. The pH_{ox} ranged from 4.01-6.25. The reaction of ASS 22 and ASS 17 to H_2O_2 was high resulting in a pH_{ox} of 1.13-2.19 pH units below the field pH (1:5). The reaction of ASS 16, ASS 14 (0-0.1 m) and ASS 13 was moderate resulting in a pH_{ox} of 0.56-1.66 pH units below the field pH (1:5). The reaction of ASS 14 (0.2-0.3 m, 0.6-0.7 m) and ASS 12 to H_2O_2 was low resulting in a pH_{ox} of 0.05-0.44 pH units below the field pH (1:5).

The *Acid Sulfate Soils: Assessment Guidelines* (Ahern et al. 1998) indicate that one or more of the following will occur when H_2O_2 reacts with acid sulfate soils:

- a change in colour of the soil from grey tones to brown tones
- effervescence;
- the release of sulfur smelling gases such as sulfur dioxide or hydrogen sulfide;
- a lowering of the soil pH by at least one unit; and
- a final pH <3.5 and preferably pH <3.

Effervescence and a lowering of the soil pH by at least one unit was observed in several samples.

Laboratory analysis for chromium reducible sulfur (CRS) shows that all samples analysed are well below the action criteria in Table 5.1 regardless of soil texture or potential disturbance mass. The effervescence observed when H_2O_2 was added is likely due to reactions with organic matter resulting in the production of organic acids; not a result of the oxidation of sulfides. It can therefore be concluded that the likelihood of acid sulfate soils being present in the Middle Bay barge ramp and the northern end of Talbingo reservoir is low.

6 Impact assessment

6.1 General risks to soil resources

6.1.1 Soil degradation

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

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

Structural decline: Structural decline of the soil refers to the breakdown of the aggregates (or peds), resulting in soil particles becoming more randomly and closely packed together with little pore space compared to the original structure (Keipert NL 2005). Structural decline is caused by compaction by heavy vehicles and machinery during the removal, stockpiling and re-spreading process. Soil permeability, water-holding capacity, aeration and microfauna presence decreases and the affected soils are less favourable for plant growth. Therefore, management practices need to minimise the risk of compaction wherever practicable.

Acidification: A gradual increase in acidity of the soil could lead to a decline in plant 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 (Keipert NL 2005). The pH of large areas of soil in the assessment area is currently slightly to strongly acidic and will need soil amendments (ie lime) to increase the pH and assist plant growth for rehabilitation activities.

6.1.2 Loss of soil resource

The soil will be stripped from the Exploratory Works disturbance footprint, 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.

6.1.3 Soil erosion and sediment transport

The Exploratory Works covers varying topography, soil types and plant communities. Construction of the proposed infrastructure will require vegetation clearing which destabilises soils and leaves them exposed to erosion. Follow-on effects can include stream bank erosion, downstream sedimentation, decline in fertility through loss of soil structure, and increased dust generation.

Increased slope can also contribute to the erosion potential of the soil, especially when disturbed. The slopes of the region are generally moderate to steep, with the ravine area having a lower grade. These slopes and landscape conversion zones are associated with a much higher erosion potential.

6.1.4 Soil contamination

Soil contamination may occur due to spills or unplanned releases of materials that are considered contaminants. This can include fuels or hazardous chemicals, such as hydraulic fluids or herbicides and can be sourced from storage locations or at use locations. Excavation activities can also disturb unidentified sites of contamination, for example historic cattle dips or unreported spills. These impacts can be managed through implementation of certain measures which are detailed in Section 7.1.3.

6.1.5 Acid sulfate soils

The desktop review and field survey revealed that the assessment area is unlikely to contain acid sulfate soils.

6.2 Land subject to potential impacts

The potential impacts on soil resources associated with Exploratory Works are temporary loss of land due to Exploratory Works, and disturbance during any rehabilitation activities. Land disturbance for Exploratory Works will be mainly associated with the development and use of surface infrastructure (ie access road upgrades, soil stockpiles, rock emplacement areas, portal construction pad, accommodation camp and Middle Bay barge ramp), and will have a direct disturbance footprint of approximately 105.1 ha.

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

Should the Snowy 2.0 Main Works not proceed following the commencement or completion of Exploratory Works, elements constructed are able to be decommissioned and areas rehabilitated. Given works are within KNP, Snowy Hydro will liaise closely with NPWS to determine the extent of decommissioning and type of rehabilitation to be undertaken. This approach will be taken to ensure that decommissioning allows for integration with future planned recreational use of these areas and to maintain the values of the KNP. These activities would be documented in a Decommissioning Plan, prepared in consultation with NPWS, and be implemented should Snowy 2.0 not proceed.

Likely rehabilitation and decommissioning activities for Exploratory Works are shown in Table 6.1.

Table 6.1 Summary of likely decommissioning activities by site

Exploratory Works element	Rehabilitation and decommissioning activities
Accommodation camp	• removal of all accommodation facilities; • some re-shaping of landform including fill to near pre-construction landform; • rehabilitation of slopes through placement of organic matter and revegetation; and • fencing and tree guards of revegetation areas to protect from grazing fauna.
Portal construction pad	• removal of all construction infrastructure; • re-shaping of batters by site-sourced fill material, with batters at 3H:1V with berms (4 m minimum), between each batter and to reshape to near pre-construction landform; • rehabilitation of fill and cleared areas through addition of organic matter and revegetation; • planted swales and sediment basins at the base of slope to assist in ongoing water quality treatment; and • fencing and tree guards of revegetation areas to protect from grazing fauna.
Excavated rock emplacement areas	• removal of all construction infrastructure; • final shaping of emplacement areas including finishing stockpiles surfaces; • rehabilitation of spoil stockpiles through placement of jute mesh (where required), organic matter and revegetation; • fencing and tree guards of revegetation areas to protect from grazing fauna; and • planted swales and sediment basins at the base of the stockpile to assist in ongoing water quality treatment.

During decommissioning works, soils may be disturbed temporarily while infrastructure is dismantled, and access and internal roads and other supporting infrastructure are removed. All disturbed land will be rehabilitated and returned to the agreed land use.

6.2.1 Soil types disturbed

The majority of the Exploratory Works disturbance area is positioned over two soil types; Kandosols and Tenosols.

Kandosols are associated with the lower slopes and flats of Lobs Hole as well as being a transitional soil (between Tenosols and Vertosols) along Mine Trail Road and the portal construction pad area. Large areas of these landscapes have been cleared. Tenosols are associated with mid to upper slopes and crests of undulating hills which contain largely undisturbed native vegetation. Small areas of Vertosols, mapped along a flood plain adjacent to Yarrangobilly River, and a small area of Dermosols have also been identified in the disturbance footprint.

The Grey Kandosol, in particular the humose variant, will be the most useful for rehabilitation purposes due to its high organic matter content, fertility and stability. The Red and Brown (Basalt variant) Kandosols will also be useful for rehabilitation purposes. The Tenosols and Brown Kandosols (Shale and limestone variant) are not expected to provide a significant volume of useable soil due to their shallow and rocky nature. The Dermosols and Vertosols are useful; however are not expected to provide a large volume of material. The Acidic Mesotrophic Red Dermosols will provide no suitable material for rehabilitation and should be avoided due to their very strongly acidic nature. The area of disturbance for each soil type is shown in Table 6.2.

Table 6.2 Soil types to be disturbed

Soil type	Disturbance area*	
	Ha	%
Haplic Eutrophic Brown/Red/Grey Kandosol	79.2	75.4
Haplic Mesotrophic Red Dermosol (including acidic variant)	2.7	2.6
Basic Lithic Brown-Orthic Tenosol	18.9	18
Haplic Epipedal Black Vertosol	1.3	1.3
Not assessed	2.8	2.7
TOTAL	**104.9**	**100**

*Notes: 1. Based on EMM assessment. *Numbers have been rounded.*

6.3 Land capability post rehabilitation

A general land and soil capability assessment has not completed using the scheme as a guide on the physical capacity of the land to support different agricultural land uses. It is worth noting that the soils assessment area is primarily located within KNP and under conservation management. Soils and land capability is used only as a guide to the existing physical capacity of the land to supper different agricultural uses. The overall impact to soil and land capability of the disturbance footprint is expected to be low.

Key rehabilitation principles are being established to rehabilitate the Exploratory Works disturbance area and minimise impacts and changes to the character and habitats within KNP. Steep slopes, a relatively low fertility, presence of coarse fragments, low pH and often shallow profiles are the main restrictions to intensive use of the soils in the disturbance area. The steep sloped areas within the disturbance area are only suited to minor land uses such as selective forestry, passive tourism and state and national parks. The gentler landscapes in Lobs Hole Ravine have a higher capability and may be capable of some grazing as well as the aforementioned uses. The area occupied by Haplic Mesotrophic Red Dermosols and Haplic Epipedal Black Vertosols are the exception to this and would have a higher land capability which could potentially support some forms of cultivation. It is worth noting that many of these potential land uses are inconsistent with the area's status as a national park and are for reference only.

The land capability of the areas around Mine Trail Road, Middle Bay Road, Lobs Hole Road and Lobs Hole Ravine Road will be permanently removed through the planned upgrades and extensions. Construction of the Middle Bay barge ramp will also permanently remove land capability. The accommodation camp, portal construction pad and associated infrastructure, western rock emplacement area and soil stockpiles will temporarily lower the capability of the underlying land. It is expected that this will largely be reversed and that the land capability will return to that of pre-disturbance through the reinstatement of stockpiled soil.

The eastern rock emplacement area will remain in situ and be rehabilitated. This constitutes the greatest soil and land capability impact. Soil depth will be shallower on the rehabilitated rock emplacement area benches as the stockpiled topsoil and subsoil will be placed directly onto emplaced material. The slopes between benches will not be soiled at all and will thus have a lower land capability. Table 7.3 is taken from the LSC assessment scheme guideline, and shows how the depth of soil influences LSC class. LSC Class 2 land is suited to a wide range of land uses including cultivation whereas LSC Class 7 has severe limitations for most land uses (limited to selective forestry, camping/recreation areas, passive tourism and national parks). Engagement with NPWS has identified that the future land use of the Lobs Hole area should be consistent with its current use as a remote recreational campground, and this influenced the design of the final landform of the eastern emplacement area which will be a permanent feature in the landscape.

Table 6.3 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

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

6.4 Detailed impacts to soil resources

In addition to the general impacts listed in Section 6.1, impacts specific to each of the elements of the Exploratory Works is presented in Table 6.4. Mitigation measures for these impacts are presented in Section 7.

Table 6.4 Potential impacts to soils of each of the Exploratory Works elements

Exploratory Works element	Soil types	Soil characteristics	Constraints	Potential impacts
Portal construction pad	Haplic Eutrophic Grey Kandosols	• no acid sulfate soils • moderate dispersion potential below the A1 horizon • medium acid A1 horizon (high exchangeable aluminium) to slightly acid below	• moderate erosion potential below the A1 horizon. • some horizons with unsuitable pH	• erosion and sedimentation particularly below the A1 horizon • failed rehabilitation using the A1 horizon • temporary removal of land capability • temporary removal of land capability associated with the portal construction pad

Table 6.4 Potential impacts to soils of each of the Exploratory Works elements

Exploratory Works element	Soil types	Soil characteristics	Constraints	Potential impacts
	Basic Lithic Brown-Orthic Tenosol	• moderate dispersion potential • shallow and rocky • medium acid to strongly acid with high exchangeable aluminium • no acid sulfate soils	• not suitable for stripping and rehabilitation • high erosion potential particularly due to the steep slopes	• severe erosion and sedimentation • failed rehabilitation • temporary removal of land capability associated with the portal construction pad
Accommodation camp	Basic Lithic Brown-Orthic Tenosol	• moderate dispersion potential • shallow and rocky • acidic with high exchangeable aluminium • no acid sulfate soils	• not suitable for stripping and rehabilitation • high erosion potential particularly due to the steep slopes	• severe erosion and sedimentation during construction and demobilisation • failed rehabilitation • temporary removal of land capability underneath the accommodation camp
Rock emplacement areas	Haplic Eutrophic Red Kandosol	• no acid sulfate soils • low to moderate dispersion potential • slightly acid to medium acid with some high exchangeable aluminium	• low to moderate erosion potential • A2 horizon has elevated exchangeable aluminium	• failed rehabilitation • erosion and sedimentation during construction (both rock emplacement area) and demobilisation (western emplacement area) • erosion of the rock emplacement area landform themselves • temporary removal of land capability underneath the western rock emplacement area. permanent reduction of land capability associated with the eastern rock emplacement (due to shallow profile reinstatement)

Table 6.4 Potential impacts to soils of each of the Exploratory Works elements

Exploratory Works element	Soil types	Soil characteristics	Constraints	Potential impacts
	Haplic Epipedal Black Vertosol	• no acid sulfate soils • slight to low dispersion potential • no acid sulfate soils • moderately alkaline	• none	• minimal • permanent reduction of land capability associated with the eastern rock emplacement (due to shallow profile reinstatement)
	Acidic Mesotrophic Red Dermosol	• no acid sulfate soils • extremely acidic with high exchangeable aluminium • slight to low dispersion potential	• not suitable for stripping and rehabilitation	• failed rehabilitation • permanent reduction of land capability associated with the eastern rock emplacement (due to shallow profile reinstatement)
Middle Bay barge ramp	Haplic Eutrophic Red Kandosol	• no acid sulfate soils • Medium acid to slightly acid with some high exchangeable aluminium • Slight to low dispersion potential	• some horizons with unsuitable pH	• failed rehabilitation • permanent loss of land capability of soils associated with Middle Bay barge ramp.
Access roads	Haplic Eutrophic Red Kandosol	• no acid sulfate soils • Medium acid to slightly acid with some high exchangeable aluminium • Slight to low dispersion potential	• some horizons with unsuitable pH • erosion potential in sloped areas	• failed rehabilitation • erosion and sedimentation in sloped areas (during construction) • permanent loss of land capability of soils associated with access road upgrades.
	Haplic Mesotrophic Red Dermosol	• no acid sulfate soils • slight to moderate (below 0.7 m) dispersion potential • slightly acid to strongly acid with some high exchangeable aluminium	• some horizons with unsuitable pH • low to moderate erosion potential	• failed rehabilitation • erosion and sedimentation below 0.7 m and sloped areas (during construction) • permanent loss of land capability of soils associated with access road upgrades

Table 6.4 Potential impacts to soils of each of the Exploratory Works elements

Exploratory Works element	Soil types	Soil characteristics	Constraints	Potential impacts
	Haplic Eutrophic Brown Kandosol (limestone and shale variant and transitional)	• no acid sulfate soils • low to moderate dispersion potential • slightly acid to strongly acid with high exchangeable aluminium • shallow and rocky	• unsuitable for stripping and rehabilitation below 0.3 m. • low to moderate erosion potential • some horizons with unsuitable pH	• erosion and sedimentation, particularly on sloped areas (during construction) • failed rehabilitation • permanent loss of land capability of soils associated with access road upgrades
	Haplic Eutrophic Brown Kandosol (basalt variant)	• low dispersion potential • no acid sulfate soils • strongly acid to medium acid with high exchangeable aluminium (except for B21 horizon)	• some horizons with unsuitable pH	• erosion and sedimentation in sloped areas (during construction) • permanent loss of land capability of soils associated with access road upgrades

6.4.1 Soil stripping depth

Soil stripping depths is based on laboratory testing as well as observations recorded during the soil survey. Utilising the stripping depths mentioned in Table 6.5 ensures that the most suitable growth medium is used in rehabilitation. The topsoil depth in the area of disturbance ranges between 0.1 m and 0.4 m. The subsoil depth in the area of disturbance ranges between 0 m and 0.95 m. The majority of the soils to be disturbed are Tenosols and Kandosols, but the depth varies across the soils assessment area. This is particularly relevant on Lobs Hole Ravine Road and steeper slopes in Lobs Hole Ravine where shallow soils are common.

In areas where topsoil would be stockpiled, only a shallow depth of topsoil would be required to be stripped (mainly just to remove the vegetation before creating the stockpile), as only topsoil is to be stockpiled on this land. All other areas of surface disturbance need to be stripped to at least 0.3 m depth, to allow for sufficient soil to be replaced for rehabilitation. This will be particularly important for rehabilitation of the eastern rock emplacement area. This soil will be placed over land that is comprised of excavated rock, meaning that the original soil profile has been substantially disturbed. A reinstated soil depth of 0.3 m is considered adequate to re-establish native vegetation.

In the areas where topsoil is less than 0.3 m in depth, suitable subsoil will need to be stripped. Where subsoil is not suitable, additional soil from an area with deeper, suitable subsoils should be obtained to make up the shortfall. The Vertosol and Grey Kandosol (western portion of assessment area) soils can provide additional subsoil.

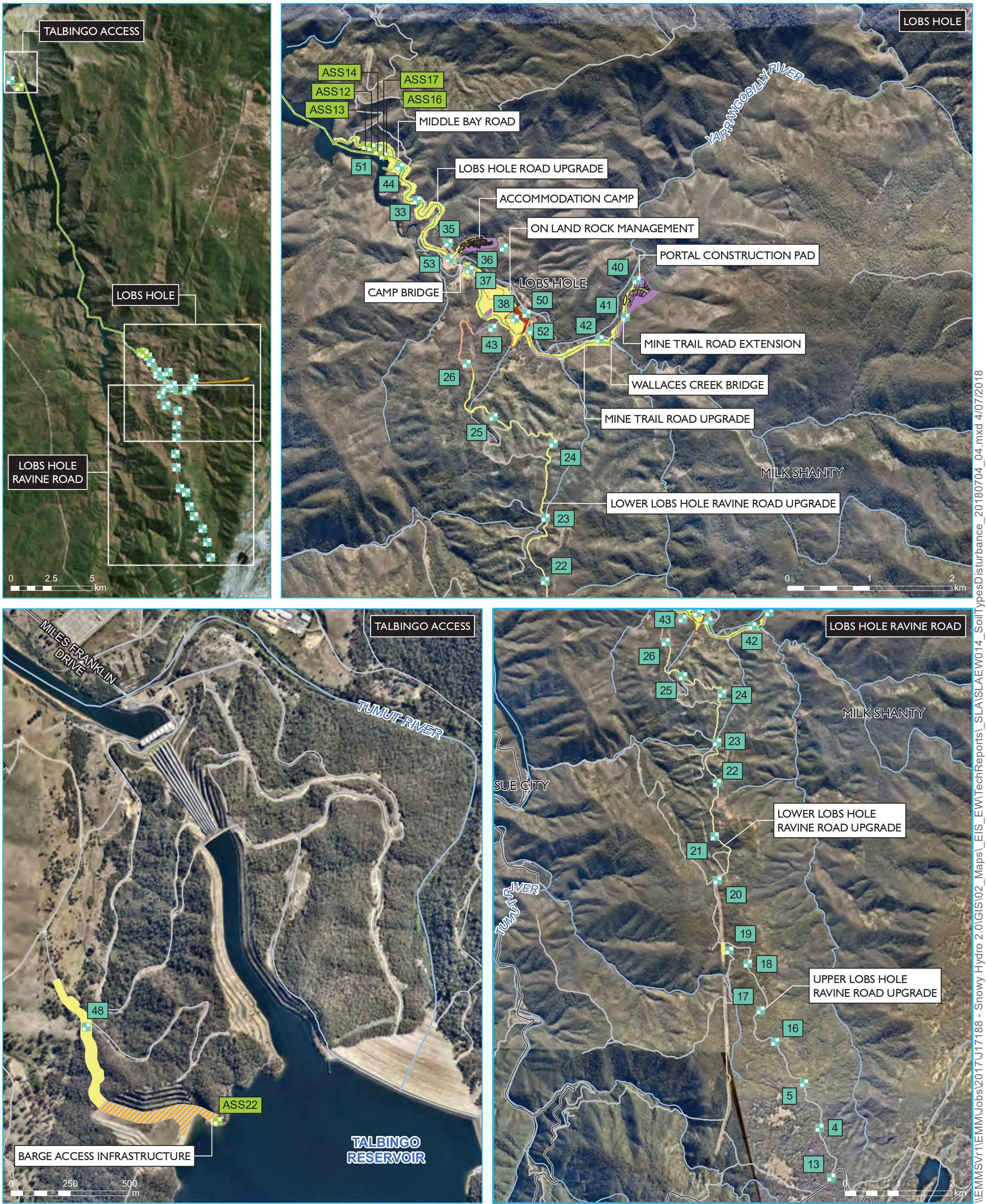
Table 6.5 presents the recommended topsoil stripping depths for each specific soil type subject to surface disturbance. It also shows the overall depth of soil (topsoil plus subsoil) which indicates areas that may be suitable for salvaging extra soil material in order to achieve a volume which would allow replacement of the profile to as close as possible to pre-disturbance conditions. It is important to note that these stripping depths are provided based on the assumption that acidic soils will be ameliorated with lime to reduce Al availability and provide a more suitable growth medium. This will also have the benefit of helping stabilise any moderately dispersive horizons through the addition of calcium to the soil exchange sites (see Section 7.1.2).

Table 6.5 Depths of topsoil and subsoil available for stripping[1]

ASC soil type	Exploratory Works element	Depth to strip		
		Topsoil (m)	Subsoil (m)	Total soil depth (m)
Basic Lithic Brown-Orthic Tenosol	Small area near juncture of Lobs Hole Ravine and Lobs Hole Road	0.1	0	0.1
Basic Lithic Brown-Orthic Tenosol	Lower end of portal construction pad	0.15	0.28	0.4
Basic Lithic Brown-Orthic Tenosol	Accommodation camp and the portal construction pad	0	0	0
Haplic Mesotrophic Red Dermosol	Lobs Hole Road	0.14	0.56	0.7
Haplic Eutrophic Red Kandosol (includes bleached variant)	Lobs Hole, Middle Bay Road, Middle Bay barge ramp, western rock emplacement area	0.3	0.68	1
Haplic Eutrophic Brown Kandosol (Basalt variant)	Lobs Hole Road	0.25	0.75	1
Haplic Eutrophic Brown Kandosol (Limestone and shale variant)	Lobs Hole Road	0.3	0	0.3
Haplic/Bleached Eutrophic Grey Kandosol	Mine Trail Road	0.2	-	0.2
Haplic/Bleached Eutrophic Grey Kandosol (includes humose variant)	Lobs Hole	0.41	0.69	1.1
Haplic Epipedal Black Vertosol	Lobs Hole, eastern rock emplacement area	0.15	0.95	1.1
Acidic Mesotrophic Red Dermosol	Lobs Hole, eastern rock emplacement area	0	0	0

Notes: 1. Estimated using soil depths recorded in EMM soil survey.

2. Excess soil available for stripping to make up any soil volume shortfall.



Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); Robert Bird (2018); DFSI (2017); LPMA (2011)

GDA 1994 MGA Zone 55

N

KEY

- Soil sample site
- ASS sample site
- Permanent bridge
- On land rock management
- Portal construction pad and accommodation camp conceptual layout
- Exploratory tunnel
- Communications cable
- Main road
- Local road or track

Soil disturbance area - Soil type

- Not assessed
- Dermosols
- Kandosols
- Tenosols
- Vertosols
- Water

Soil types within the project disturbance footprint

Snowy 2.0
Soil and Land Assessment
Exploratory Works
Figure 6.1

7 Management and mitigation measures

7.1 Management and mitigation measures

Appropriate management measures would be designed and implemented for all aspects of Exploratory Works to minimise risks. Exploratory Works will be managed through a Construction Management Plan (CMP). The guiding principles to minimise impacts to soil resources are addressed in this section, and a summary of key mitigation and management commitments is included in Table 7.1 at the end of this section.

7.1.1 Measures to prevent loss of soil resource

To mitigate the risk of not enough soil being available for use in rehabilitation works, soil requirements will be accurately determined before construction works begin. The volume of soil required for rehabilitation can be calculated using the area estimated for rehabilitation multiplied by the depth of soil required. If any alterations to the plans are made, 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 address these measures to prevent loss of soil resource.

7.1.2 Measures to manage soil erosion and sediment transport

The soil assessment area mainly sits over Kandosols and Tenosols with smaller pockets of Dermosols and Vertosols. The Vertosols have a low erosion potential while the Kandosols, Tenosols and Dermosols have a low to moderate erosion potential. Moderate erosion potentials were observed in the soil horizons directly beneath the A1 horizon in the Red and Brown Kandosols and in the bottom 0.3 m of the Dermosol profile. Grey Kandosols in the area of the portal construction pad also have moderate dispersion potential below the A1 horizon. Grey Kandosols in Lobs Hole have a moderate dispersion potential in the top of the B22 horizon. Tenosols on the slopes around the portal construction pad were moderately dispersive throughout the profile.

Erosion management will be implemented during construction activities. This will be particularly important where moderately dispersive soils are exposed. Erosion and sediment control measures will be constructed and implemented in accordance with the guideline *Managing Urban Stormwater, Volume 2A Installation of Services,* or equivalent.

To minimise the risk of loss from wind and water erosion to stockpiled topsoil, a vegetative cover will be established. Stockpiles will 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 will be considered where there could potentially be off-site impacts to waterways, as well as impacts to the rehabilitation itself.

7.1.3 Measures to prevent soil contamination

Hydrocarbon management practices will be implemented to prevent hydrocarbon spills during construction activities (eg re-fuelling, maintenance, hydrocarbon storage) and spill containment materials will be available to clean-up spills if they occurred. If any hydrocarbon spills were to occur during soil stripping, the impact will 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 will be enclosed with concrete bunds.

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

7.1.4 Methods to achieve successful rehabilitation

Topsoil and subsoil will be stripped and stockpiled. The soil stripping procedure has been designed to maximise the salvage of suitable materials so the soil profile can be reinstated to a condition that will support good ground cover. These measures will be 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.

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

Soil will be applied to provide sufficient depth for ripping and plant growth in a manner which minimises any degradation of soil characteristics. A soil balance plan will be prepared prior to spreading, which will show the depths and volume of soils to be reapplied in particular areas. Topsoil and subsoil will be applied to return the soil profile to as close as pre-disturbance conditions as possible. The soil will then be contour-ripped and seeded with a sterile cover crop, followed by native plant species. Native species will be chosen that are representative of the surrounding area.

7.1.5 Measures to minimise soil degradation

To minimise structural decline of soil, the amount of compaction of soils during stripping and stockpiling will 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, organic matter or lime application). The recommendations made in the topsoil stripping procedure and the stockpiling procedure addresses all of these risks to soil degradation.

i Topsoil management

Effective management of topsoil and subsoil also address the impacts of compaction and salinity/sodicity. The objective of topsoil management is to:

- preserve as much of the topsoil as possible;
- ensure topsoil is not degraded or compacted during construction and following reinstatement; and
- ensure topsoil is not mixed with unsuitable soil and spoil materials.

Topsoil management should be based on a risk management approach. By applying a risk based approach to topsoil stripping the level of disturbance, and therefore rehabilitation required, can be minimised. High risk activities such as trenching or creation of cut and fill batter slopes can be stripped to the largest depth while disturbance to the subsoils can be avoided on access tracks.

Topsoil depth will be observed during field surveys, recorded and mapped for the soils assessment area. Field validation of soil mapping boundaries will be based on 1,000 m intervals along linear access tracks and at a density of 1 site per 25 ha in other areas, LiDAR interpretation, aerial imagery and underlying geology. Therefore, even following field validation, due to the variability inherent in the soil mapping, stripping depths should be adjusted as necessary during works to accommodate any differences in depths encountered.

a. Topsoil stripping

The topsoil stripping procedure will be consistent with leading practice and incorporate the full range of reasonable and feasible mitigation methods for soil stripping. This will include retaining tree hollows, logs, and native seed because the soils assessment area is a national park and will be returned to the same land use.

The procedure for topsoil stripping will include the following 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.

- The area to be stripped will 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 graders, loaders and trucks, or scrapers will be used for stripping and placing soils in stockpiles. Machinery haulage circuits will be located to minimise the compaction of the stockpiled soil.
- All machinery brought onto the site for soil stripping will have to be weed-free. The site weed management plan will be prepared to guide procedures to ensure this.
- Soil stockpile locations will be identified during planning and will be stripped of topsoil before they are stockpiled.
- Any trees present will be cleared and grubbed before topsoil salvage. Any pasture grasses present will be harvested before construction work begins.
- Topsoil and subsoil will be stripped to the required depths and then stockpiled. Subsoil will 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 will be stripped and stockpiled together.
- Handling and rehandling of stripped topsoil will be minimised as far as practicable by progressively stripping vegetation and soil only as needed for development activities.
- Special care will be taken to minimise exposure of any moderately dispersive soils during the stripping procedure.

- Soil stripping in wet conditions will be avoided 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 moist, which would help in their removal and retain their structure.

- To avoid dust hazards, soil will not be stripped during particularly dry conditions. Alternatively, water trucks can be used as a control mechanism during dry conditions.

b. Topsoil stockpiling

The following techniques will be applied to topsoil stockpiles:

- stripped topsoil will be stockpiled separately from woody material and subsoil stockpiles;

- topsoil stockpile heights will not exceed 2 m, to minimise damage to the topsoil and to maintain fertility;

- topsoils to be maintained for an extended period of time (ie >4 months) should have the surface left in a rough state and may be sprayed with a bonding agent or seeded with appropriate species and monitored for weed management;

- topsoil stockpiles will be clearly signposted;

- lime will be deep ripped into the stockpile to ameliorate soil acidity and elevated exchangeable aluminium. This will also help stabilise any moderately dispersive soils by providing calcium to soil exchange sites; and

- monitoring for dispersion and erosion of topsoil stockpiles will be undertaken, particularly on moderately dispersive soils. Additional ameliorants, such as gypsum, organic matter and lime will be incorporated as required.

ii Subsoil management

Subsoil should only be disturbed during construction or trenching activities. The objective of subsoil management is to:

- prevent contamination of topsoil;

- prevent degradation of the subsoil structure;

- avoid or ameliorate subsoil constraints immediately below topsoils; and

- ensure reinstatement of soil horizons in the correct order and depths.

Subsoil will be managed using the following techniques:

- subsoil should be removed and stockpiled separately from topsoil;

- areas will be compacted to an appropriate density following backfilling with subsoil;

- excess displaced subsoil will be prevented from mixing with topsoil as the cost of extra storage space is minor compared with the rehabilitation cost of impacted topsoils;

- excess subsoil will be stockpiled separately for disposal by appropriate methods. This may include burial in voids, or, if tested and found suitable, as fill; and
- lime will be deep ripped into the stockpile to ameliorate soil acidity and elevated exchangeable aluminium. This will also help stabilise any moderately dispersive soils by providing calcium to soil exchange sites.
- monitoring for dispersion and erosion of topsoil stockpiles will be undertaken, particularly on moderately dispersive soils. Additional ameliorants, such as gypsum, organic matter and lime will be incorporated as required.

iii Topsoil application procedure

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.

Soils will be spread at a thickness that is as close to pre-disturbance conditions as possible. A minimum replaced soil thickness of approximately 0.3 m is required to provide sufficient depth for ripping and plant growth. If subsoil is stripped separately to the topsoil, the subsoil will need to be spread at approximately 0.15 m depth and then topsoil spread over the top at approximately 0.15m depth to create an overall depth of 0.1 – 0.3 m.

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

- A soil balance plan will be prepared before the topsoil is spread, which shows 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 will be respread in even layers at a thickness appropriate for the land capability of the area to be rehabilitated.
- Soils will be lightly scarified on the contour to encourage rainfall infiltration and minimise run-off.
- As soon as practicable after respreading, a sterile cover crop should be established to limit erosion and soil loss. This will also provide good mulch for native plant establishment.
- Native plant species will be established using methods outlined in the Rehabilitation Strategy (Appendix I to the EIS).
- Erosion and sediment controls will be implemented where deemed necessary prior to vegetation.

7.1.6 Summary of mitigation and management measures

A summary of the mitigation and management measures that would be implemented for Exploratory Works to minimise and avoid impacts to soil resources and land capability is provided in Table 7.1. These measures will incorporated into the CMP for Exploratory Works.

Table 7.1 Summary of mitigation and management measures

Impact/risk	REF#	Measures
Impacts on soil resources	SOIL01	Soil management procedures (including stripping, stockpiling and application) will be implemented. The objectives of soil management will be to: • preserve as much of the topsoil and subsoil as possible; • prevent contamination; • ensure soil is not degraded or compacted during construction and following reinstatement; • avoid or ameliorate subsoil constraints immediately below topsoils; • ensure topsoil is not mixed with unsuitable soil and spoil materials; and • ensure reinstatement of soil horizons in the correct order and depths.
Erosion and sediment transport	SOIL02	Erosion and sedimentation controls will be implemented to minimise erosion potential , in particular in areas of dispersive soils, in accordance with the guideline *Managing Urban Stormwater, Volume 2A Installation of Services,* or equivalent.
Soil contamination	CON01	A contaminated land management plan would be developed and prepared as part of the CMP for the areas within the construction areas which are identified as potentially contaminated, or from any land contamination which is caused by the Exploratory Works.
Changes to landform and land use	SOIL03	A Landscape Management Plan will be prepared for the rehabilitation of disturbed areas: the plan will include: • objectives for landform rehabilitation at each site; • measures to ensure successful rehabilitation and stabilisation of soils; and • a soil balance to identify the depths and volume of soils to be reapplied in particular areas during rehabilitation.
Compatibility of land use post-Exploratory Works	SOIL04	A final rehabilitation strategy will be prepared to guide the long term rehabilitation of the site. Rehabilitation goals and objectives for the domains of the soils assessment area will be determined through the final land use chosen. The strategy will be developed in consultation with NPWS and other relevant government agencies.

7.2 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, with amelioration, rather than returned as subsoil under the topsoil; and
- additional 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 take longer.

7.3 Residual impacts

Minimal residual erosion and sedimentation, contamination, rehabilitation issues, loss of soil resource and soil degradation is expected if the management and mitigation measures listed above are implemented. The biggest impact will be the loss of land capability associated with permanent infrastructure (ie Mine Trail Road, Middle Bay Road and Lobs Hole Road upgrades and Middle Bay barge ramp). There will also be a permanent reduction of land capability associated with the eastern rock emplacement area. This is due to the planned reinstatement of a shallow soil profile in rehabilitation. The temporary loss of land capability associated with the accommodation camp, portal construction pad and associated infrastructure, western waste rock emplacement area and soil stockpiles is temporary and will be reversed during rehabilitation.

8 Conclusions

The impacts to land and soil resources as a result of the project will be restricted to the disturbance footprint, covering approximately 105 ha within the 297.7 ha soils assessment area. The main soil types identified in the soils assessment area are Basic Lithic Brown-Orthic Tenosols and Haplic Eutrophic Brown/Grey/Red Kandosols. The Tenosols occur on mid to upper slopes and crests of undulating hills on conglomereate, sandstone, siltstone, rhyolite and surface geology. They can also be derived from alluvium influence (juncture of Lobs Hole Ravine Road and Lobs Hole Ravine). The Kandosols occur along the gentler mid to upper slopes on Lobs Hole Ravine Road (Brown) as well as the lower slopes and flats of Lobs Hole Ravone (Red and Grey) on varying geology. Haplic Mesotrophic Red Dermosols and Haplic Epipedal Black Vertosols were also identified in the soils assessment area. The Vertosols occur on a floodplain adjacent to Yarrangobilly River and are derived from alluvial influence. Only a small area of Vertosols is expected to be disturbed. The Dermosols occurs as a small pocket on mid slopes on Lobs Hole Ravine Road and is associated with a reddish pink landscape on conglomerate, sandstone, tuff, siltstone and rhyloite surface geology. A small pocket of Acidic Mesotrophic Red Dermosols also occurs in Lobs Hole Ravine, adjacent to the historical mine workings. This occurs on top of a small hill and is likely as a result of a geological outcrop. No acid sulfate soils were identified in the soils assessment area.

The topsoils and subsoils of the disturbance area will be stripped prior to construction and stockpiled for use in later rehabilitation. Potential impacts to land capability and soil resources from Exploratory Works will be managed through appropriate mitigation techniques aimed at returning the majority of the site to a land use similar to the pre-existing land use and in accordance with the agreed rehabilitation principles.

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Appendix A

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).

Appendix B

Laboratory results

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **ES1811372**	Page	: 1 of 16
Client	: **EMM CONSULTING PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: MS KYLIE DRAPALA	Contact	: Customer Services ES
Address	: Ground Floor Suite 1 20 Chandos Street St Leonards NSW NSW 2065	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: 07 3839 1800	Telephone	: +61-2-8784 8555
Project	: Snowy Hydro 2.0 Early Works - subsoil	Date Samples Received	: 20-Apr-2018 14:20
Order number	:	Date Analysis Commenced	: 24-Apr-2018
C-O-C number	: ----	Issue Date	: 09-May-2018 09:46
Sampler	: NICK JAMSON		
Site	: ----		
Quote number	: EN/222/17		
No. of samples received	: 36		
No. of samples analysed	: 35		

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*
Ankit Joshi	Inorganic Chemist	Sydney Inorganics, Smithfield, NSW
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Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Wisam Marassa	Inorganics Coordinator	Sydney Inorganics, Smithfield, NSW

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.

- EG005: Poor precision was obtained for Lead, Chromium and Zinc on sample ES1811365-66 due to sample heterogeneity. Results have been confirmed by re-extraction and reanalysis.
- 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	Barge LSC - 10-30cm	Barge LSC - 40-60cm	4 - 50-70cm	4 - 80-100cm	19 - 20-40cm
			Client sampling date / time	19-Apr-2018 00:00	19-Apr-2018 00:00	14-Apr-2018 00:00	14-Apr-2018 00:00	14-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	ES1811372-001	ES1811372-002	ES1811372-003	ES1811372-004	ES1811372-005
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	6.2	6.5	5.7	5.4	5.7
EA008: Calcium Carbonate Equivalent								
CaCO3 Equivalent	----	0.01	%	2.18	2.23	2.13	0.96	1.87
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	14	9	7	7	13
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	8.9	10.1	26.2	29.8	7.0
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Strong Brown	Yellowish Red	Brown	Reddish Brown	Strong Brown
Texture	----	-	-	Loamy Sand	Loamy Sand	Loam	Clay Loam	Loamy Sand
Emerson Class Number	EC/TC	-	-	4	4	4	4	3
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	----	----	3.9	8.5	2.0
Exchangeable Aluminium	----	0.1	meq/100g	----	----	3.2	6.5	1.6
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	1.8	2.2	4.2	3.2	2.2
Exchangeable Magnesium	----	0.1	meq/100g	2.9	4.1	2.8	3.3	0.9
Exchangeable Potassium	----	0.1	meq/100g	0.5	0.7	0.5	0.2	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	5.2	7.0	8.1	15.6	3.4
Exchangeable Aluminium	----	0.1	meq/100g	<0.1	<0.1	0.6	8.9	<0.1
Exchangeable Sodium Percent	----	0.1	%	<0.1	0.4	<0.1	<0.1	<0.1
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
ø Iron	7439-89-6	1.00	mg/kg	32.7	23.5	13.8	4.21	61.3
ø Manganese	7439-96-5	1.00	mg/kg	29.9	18.5	1.70	<1.00	12.7
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

Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

Compound	CAS Number	LOR	Unit	Barge LSC - 10-30cm	Barge LSC - 40-60cm	4 - 50-70cm	4 - 80-100cm	19 - 20-40cm
Client sampling date / time				19-Apr-2018 00:00	19-Apr-2018 00:00	14-Apr-2018 00:00	14-Apr-2018 00:00	14-Apr-2018 00:00
				ES1811372-001	ES1811372-002	ES1811372-003	ES1811372-004	ES1811372-005
				Result	Result	Result	Result	Result
ED093S: Soluble Major Cations - Continued								
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	**20**	**20**	<10	<10	<10
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**23100**	**26600**	**73700**	**71800**	**13700**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
EP004: Organic Matter								
Organic Matter	----	0.5	%	**1.1**	**0.7**	**1.4**	**0.8**	**1.5**
Total Organic Carbon	----	0.5	%	**0.6**	<0.5	**0.8**	<0.5	**0.9**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	19 - 50-75cm	19 - 75-95cm	19 - 95-110cm	26 - 20-40cm	26 - 40-60cm
			Client sampling date / time	14-Apr-2018 00:00	14-Apr-2018 00:00	14-Apr-2018 00:00	16-Apr-2018 00:00	16-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	ES1811372-006	ES1811372-007	ES1811372-008	ES1811372-009	ES1811372-010
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	5.8	5.7	5.6	5.4	6.2
EA008: Calcium Carbonate Equivalent								
CaCO3 Equivalent	----	0.01	%	2.03	1.12	0.05	0.76	0.56
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	22	11	8	29	27
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	10.3	11.3	11.0	6.0	5.0
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Strong Brown	Strong Brown	Strong Brown	Dark Reddish Brown	Dark Reddish Brown
Texture	----	-	-	Loamy Sand	Loamy Sand	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam
Emerson Class Number	EC/TC	-	-	4	4	4	4	4
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	1.5	1.9	2.6	1.6	----
Exchangeable Aluminium	----	0.1	meq/100g	1.2	1.5	2.1	1.3	----
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	2.2	1.7	1.4	1.7	2.0
Exchangeable Magnesium	----	0.1	meq/100g	1.2	1.3	1.3	0.8	1.2
Exchangeable Potassium	----	0.1	meq/100g	0.3	0.3	0.3	0.3	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	3.7	3.2	3.0	2.8	3.5
Exchangeable Aluminium	----	0.1	meq/100g	<0.1	<0.1	<0.1	<0.1	<0.1
Exchangeable Sodium Percent	----	0.1	%	<0.1	<0.1	<0.1	<0.1	<0.1
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
ø Iron	7439-89-6	1.00	mg/kg	33.3	17.7	17.2	42.6	21.7
ø Manganese	7439-96-5	1.00	mg/kg	8.15	<1.00	<1.00	54.6	24.9
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

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	19 - 50-75cm	19 - 75-95cm	19 - 95-110cm	26 - 20-40cm	26 - 40-60cm
			Client sampling date / time	14-Apr-2018 00:00	14-Apr-2018 00:00	14-Apr-2018 00:00	16-Apr-2018 00:00	16-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	ES1811372-006	ES1811372-007	ES1811372-008	ES1811372-009	ES1811372-010
				Result	Result	Result	Result	Result
ED093S: Soluble Major Cations - Continued								
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	**30**	**20**
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**14200**	**15200**	**15500**	**7220**	**7750**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
EP004: Organic Matter								
Organic Matter	----	0.5	%	<0.5	<0.5	<0.5	<0.5	<0.5
Total Organic Carbon	----	0.5	%	<0.5	<0.5	<0.5	<0.5	<0.5

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	42 - 0-20cm	42 - 40-60cm	42 - 60-80cm	42 - 80-100cm	Contam 10 - 20-40cm
			Client sampling date / time	17-Apr-2018 00:00	17-Apr-2018 00:00	17-Apr-2018 00:00	17-Apr-2018 00:00	17-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	ES1811372-011	ES1811372-012	ES1811372-013	ES1811372-014	ES1811372-015
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	5.7	6.4	6.3	6.4	4.8
EA008: Calcium Carbonate Equivalent								
CaCO3 Equivalent	----	0.01	%	0.76	4.86	1.77	1.72	<0.01
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	15	20	8	17	37
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	15.0	6.3	5.6	5.5	11.9
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Dark Brown	Brown	Brown	Yellowish Brown	Yellowish Red
Texture	----	-	-	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam
Emerson Class Number	EC/TC	-	-	4	3	3	3	4
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	0.5	----	----	----	5.0
Exchangeable Aluminium	----	0.1	meq/100g	0.3	----	----	----	4.5
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	3.4	4.2	3.6	3.3	1.6
Exchangeable Magnesium	----	0.1	meq/100g	0.7	1.0	1.0	1.0	0.8
Exchangeable Potassium	----	0.1	meq/100g	0.4	0.2	0.2	0.2	0.6
Exchangeable Sodium	----	0.1	meq/100g	<0.1	<0.1	<0.1	<0.1	<0.1
Cation Exchange Capacity	----	0.1	meq/100g	4.4	5.4	4.8	4.5	4.7
Exchangeable Aluminium	----	0.1	meq/100g	<0.1	<0.1	<0.1	<0.1	1.7
Exchangeable Sodium Percent	----	0.1	%	<0.1	<0.1	<0.1	<0.1	<0.1
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	<10
ED092: DTPA Extractable Metals								
ø Copper	7440-50-8	1.00	mg/kg	1.12	1.66	1.17	<1.00	126
ø Iron	7439-89-6	1.00	mg/kg	112	61.7	51.6	42.4	152
ø Manganese	7439-96-5	1.00	mg/kg	135	36.9	22.2	7.40	2.27
ø Zinc	7440-66-6	1.00	mg/kg	4.33	<1.00	<1.00	<1.00	4.22
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	<10	<10	<10	<10	<10

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	42 - 0-20cm	42 - 40-60cm	42 - 60-80cm	42 - 80-100cm	Contam 10 - 20-40cm
			Client sampling date / time	17-Apr-2018 00:00	17-Apr-2018 00:00	17-Apr-2018 00:00	17-Apr-2018 00:00	17-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	ES1811372-011	ES1811372-012	ES1811372-013	ES1811372-014	ES1811372-015
				Result	Result	Result	Result	Result
ED093S: Soluble Major Cations - Continued								
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	**40**	**40**	**40**	**40**	**40**
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**7720**	**10200**	**10900**	**12100**	**19100**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
EP004: Organic Matter								
Organic Matter	----	0.5	%	**2.4**	<0.5	**0.5**	**0.6**	**2.1**
Total Organic Carbon	----	0.5	%	**1.4**	<0.5	<0.5	<0.5	**1.2**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	Contam 10 - 50-70cm	Unknown -20-40cm	Unknown - 40-60cm	Unknown - 60-85cm	Unknown - 90-110cm
			Client sampling date / time	17-Apr-2018 00:00	19-Apr-2018 00:00	16-Apr-2018 00:00	16-Apr-2018 00:00	16-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	ES1811372-016	ES1811372-017	ES1811372-018	ES1811372-019	ES1811372-020
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	4.8	8.1	8.2	8.2	8.2
EA008: Calcium Carbonate Equivalent								
CaCO3 Equivalent	----	0.01	%	0.36	7.24	2.03	2.94	2.38
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	35	140	129	125	122
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	7.3	19.1	17.5	16.9	14.9
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Yellowish Red	Black	Black	Black	Very Dark Grey
Texture	----	-	-	Loamy Sand	Sandy Clay Loam	Clay Loam	Clay Loam	Clay Loam
Emerson Class Number	EC/TC	-	-	4	4	4	4	4
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	4.6	----	----	----	----
Exchangeable Aluminium	----	0.1	meq/100g	4.0	----	----	----	----
ED006: Exchangeable Cations on Alkaline Soils								
Exchangeable Calcium	----	0.2	meq/100g	----	18.4	15.5	16.0	13.1
Exchangeable Magnesium	----	0.2	meq/100g	----	0.4	<0.2	<0.2	<0.2
Exchangeable Potassium	----	0.2	meq/100g	----	<0.2	<0.2	<0.2	<0.2
Exchangeable Sodium	----	0.2	meq/100g	----	<0.2	<0.2	<0.2	<0.2
Cation Exchange Capacity	----	0.2	meq/100g	----	18.9	15.5	16.0	13.1
Exchangeable Aluminium	----	0.2	meq/100g	----	<0.2	<0.2	<0.2	<0.2
Exchangeable Sodium Percent	----	0.2	%	----	<0.2	<0.2	<0.2	<0.2
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	1.1	----	----	----	----
Exchangeable Magnesium	----	0.1	meq/100g	0.4	----	----	----	----
Exchangeable Potassium	----	0.1	meq/100g	0.4	----	----	----	----
Exchangeable Sodium	----	0.1	meq/100g	<0.1	----	----	----	----
Cation Exchange Capacity	----	0.1	meq/100g	3.0	----	----	----	----
Exchangeable Aluminium	----	0.1	meq/100g	1.0	----	----	----	----
Exchangeable Sodium Percent	----	0.1	%	<0.1	----	----	----	----
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	20	20	20	20	20
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	<10	<10	<10	<10	<10

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	Contam 10 - 50-70cm	Unknown -20-40cm	Unknown - 40-60cm	Unknown - 60-85cm	Unknown - 90-110cm
			Client sampling date / time	17-Apr-2018 00:00	19-Apr-2018 00:00	16-Apr-2018 00:00	16-Apr-2018 00:00	16-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	ES1811372-016	ES1811372-017	ES1811372-018	ES1811372-019	ES1811372-020
				Result	Result	Result	Result	Result
ED092: DTPA Extractable Metals								
ø Copper	7440-50-8	1.00	mg/kg	17.8	7.96	4.96	4.85	3.73
ø Iron	7439-89-6	1.00	mg/kg	38.5	52.2	33.8	31.6	24.6
ø Manganese	7439-96-5	1.00	mg/kg	<1.00	28.6	23.9	23.8	30.6
ø Zinc	7440-66-6	1.00	mg/kg	1.82	4.31	2.16	1.47	<1.00
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	<10	140	120	110	100
Magnesium	7439-95-4	10	mg/kg	<10	20	20	10	20
Sodium	7440-23-5	10	mg/kg	<10	10	10	<10	10
Potassium	7440-09-7	10	mg/kg	<10	50	50	50	70
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	13400	14600	16000	16400	14300
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
EP004: Organic Matter								
Organic Matter	----	0.5	%	0.6	7.7	5.9	4.1	3.2
Total Organic Carbon	----	0.5	%	<0.5	4.5	3.4	2.4	1.8

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	35 - 20-40cm	35 - 45-65cm	35 - 70-90cm	35 - 90-100cm	37 - 15-32cm
			Client sampling date / time	16-Apr-2018 00:00	16-Apr-2018 00:00	16-Apr-2018 00:00	16-Apr-2018 00:00	16-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	ES1811372-021	ES1811372-022	ES1811372-023	ES1811372-024	ES1811372-025
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	6.5	6.7	6.8	6.8	5.9
EA008: Calcium Carbonate Equivalent								
CaCO3 Equivalent	----	0.01	%	2.99	2.38	2.18	1.92	0.61
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	17	23	21	10	23
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	6.2	6.3	10.3	12.8	7.6
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Very Dark Greyish Brown	Very Dark Greyish Brown	Very Dark Greyish Brown	Very Dark Greyish Brown	Brown
Texture	----	-	-	Gravelly Sand	Gravelly Sand	Sandy Clay Loam	Sandy Clay Loam	Sandy Loam
Emerson Class Number	EC/TC	-	-	8	8	3	4	3
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	----	----	----	----	0.8
Exchangeable Aluminium	----	0.1	meq/100g	----	----	----	----	0.5
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	4.7	4.6	5.0	4.9	2.5
Exchangeable Magnesium	----	0.1	meq/100g	4.5	5.1	6.2	6.2	0.7
Exchangeable Potassium	----	0.1	meq/100g	0.4	0.2	0.2	0.1	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	9.6	10.0	11.4	11.3	3.6
Exchangeable Aluminium	----	0.1	meq/100g	<0.1	<0.1	<0.1	<0.1	<0.1
Exchangeable Sodium Percent	----	0.1	%	<0.1	<0.1	<0.1	<0.1	<0.1
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	2.63	3.30	3.94	4.69	<1.00
ø Iron	7439-89-6	1.00	mg/kg	99.0	103	92.1	89.1	45.1
ø Manganese	7439-96-5	1.00	mg/kg	9.24	7.18	5.64	16.8	13.0
ø Zinc	7440-66-6	1.00	mg/kg	1.95	1.36	1.12	1.08	<1.00
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	<10	<10	<10	10	<10

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	35 - 20-40cm	35 - 45-65cm	35 - 70-90cm	35 - 90-100cm	37 - 15-32cm
			Client sampling date / time	16-Apr-2018 00:00	16-Apr-2018 00:00	16-Apr-2018 00:00	16-Apr-2018 00:00	16-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	ES1811372-021	ES1811372-022	ES1811372-023	ES1811372-024	ES1811372-025
				Result	Result	Result	Result	Result
ED093S: Soluble Major Cations - Continued								
Magnesium	7439-95-4	10	mg/kg	<10	20	40	50	<10
Sodium	7440-23-5	10	mg/kg	<10	<10	<10	<10	<10
Potassium	7440-09-7	10	mg/kg	20	20	50	60	10
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	21000	19800	21200	20400	9240
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
EP004: Organic Matter								
Organic Matter	----	0.5	%	2.6	2.0	1.6	1.6	2.1
Total Organic Carbon	----	0.5	%	1.5	1.2	0.9	1.0	1.2

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	37 - 32-52cm	37 - 52-70cm	37 - 80-100cm	23 - 10-32cm	23 - 40-60cm
			Client sampling date / time	16-Apr-2018 00:00	16-Apr-2018 00:00	16-Apr-2018 00:00	16-Apr-2018 00:00	16-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	ES1811372-026	ES1811372-027	ES1811372-028	ES1811372-029	ES1811372-030
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	6.1	6.2	6.2	6.1	5.8
EA008: Calcium Carbonate Equivalent								
CaCO3 Equivalent	----	0.01	%	0.51	0.25	0.41	1.67	1.62
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	26	13	8	26	15
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	5.9	6.3	12.5	10.8	8.6
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Yellowish Red	Yellowish Red	Yellowish Red	Brown	Brown
Texture	----	-	-	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam	Loamy Sand
Emerson Class Number	EC/TC	-	-	3	4	4	4	3
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	----	----	----	----	0.8
Exchangeable Aluminium	----	0.1	meq/100g	----	----	----	----	0.6
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	2.9	3.5	4.6	8.6	4.6
Exchangeable Magnesium	----	0.1	meq/100g	1.1	1.8	3.7	2.1	1.3
Exchangeable Potassium	----	0.1	meq/100g	0.3	0.4	0.6	0.5	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	4.3	5.7	8.9	11.3	6.3
Exchangeable Aluminium	----	0.1	meq/100g	<0.1	<0.1	<0.1	<0.1	<0.1
Exchangeable Sodium Percent	----	0.1	%	<0.1	<0.1	<0.1	0.2	0.2
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	1.47	<1.00
ø Iron	7439-89-6	1.00	mg/kg	16.7	25.8	8.40	126	42.7
ø Manganese	7439-96-5	1.00	mg/kg	2.23	2.21	<1.00	23.5	12.9
ø Zinc	7440-66-6	1.00	mg/kg	<1.00	<1.00	<1.00	1.97	<1.00
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	<10	<10	<10	<10	<10

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	37 - 32-52cm	37 - 52-70cm	37 - 80-100cm	23 - 10-32cm	23 - 40-60cm
			Client sampling date / time	16-Apr-2018 00:00	16-Apr-2018 00:00	16-Apr-2018 00:00	16-Apr-2018 00:00	16-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	ES1811372-026	ES1811372-027	ES1811372-028	ES1811372-029	ES1811372-030
				Result	Result	Result	Result	Result
ED093S: Soluble Major Cations - Continued								
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	**30**	**50**
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**11500**	**13400**	**25200**	**11000**	**10800**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
EP004: Organic Matter								
Organic Matter	----	0.5	%	**0.6**	**0.6**	<0.5	**3.9**	<0.5
Total Organic Carbon	----	0.5	%	<0.5	<0.5	<0.5	**2.2**	<0.5

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	23 - 80-100cm	41 - 25-45cm	4 - 20-40cm	26 - 70-90cm	40 - 20-40cm
			Client sampling date / time	16-Apr-2018 00:00	16-Apr-2018 00:00	19-Apr-2018 00:00	16-Apr-2018 00:00	17-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	ES1811372-031	ES1811372-032	ES1811372-033	ES1811372-034	ES1811372-036
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	5.8	5.6	6.0	5.7	6.1
EA008: Calcium Carbonate Equivalent								
$CaCO_3$ Equivalent	----	0.01	%	0.91	0.51	1.37	0.25	0.81
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	38	36	11	29	12
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	8.9	6.3	31.2	4.4	7.8
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Brown	Brown	Very Dark Brown	Dark Reddish Brown	Very Dark Brown
Texture	----	-	-	Loamy Sand	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam
Emerson Class Number	EC/TC	-	-	3	3	4	3	4
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	0.8	2.5	----	1.8	----
Exchangeable Aluminium	----	0.1	meq/100g	0.5	2.1	----	1.5	----
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	4.3	<0.1	3.9	1.0	6.8
Exchangeable Magnesium	----	0.1	meq/100g	1.6	0.9	0.9	1.4	1.3
Exchangeable Potassium	----	0.1	meq/100g	0.3	0.3	0.8	0.3	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	6.2	1.3	5.6	2.7	8.4
Exchangeable Aluminium	----	0.1	meq/100g	<0.1	<0.1	<0.1	<0.1	<0.1
Exchangeable Sodium Percent	----	0.1	%	0.2	1.6	<0.1	<0.1	<0.1
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO_4^{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	1.12	<1.00	4.51
ø Iron	7439-89-6	1.00	mg/kg	30.0	30.0	72.7	18.7	108
ø Manganese	7439-96-5	1.00	mg/kg	13.2	<1.00	16.6	17.8	11.5
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

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	23 - 80-100cm	41 - 25-45cm	4 - 20-40cm	26 - 70-90cm	40 - 20-40cm
			Client sampling date / time	16-Apr-2018 00:00	16-Apr-2018 00:00	19-Apr-2018 00:00	16-Apr-2018 00:00	17-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	ES1811372-031	ES1811372-032	ES1811372-033	ES1811372-034	ES1811372-036
				Result	Result	Result	Result	Result
ED093S: Soluble Major Cations - Continued								
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	**80**	**20**	<10	**20**	**20**
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**10600**	**7720**	**54600**	**5270**	**6790**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
EP004: Organic Matter								
Organic Matter	----	0.5	%	<0.5	**0.6**	**5.7**	<0.5	**3.9**
Total Organic Carbon	----	0.5	%	<0.5	<0.5	**3.3**	<0.5	**2.2**

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **ES1811521**	Page	: 1 of 9
Client	: **EMM CONSULTING PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: MS KYLIE DRAPALA	Contact	: Customer Services ES
Address	: Ground Floor Suite 1 20 Chandos Street St Leonards NSW NSW 2065	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: 07 3839 1800	Telephone	: +61-2-8784 8555
Project	: Snowy Hydro 2.0 Early Works - Topsoil	Date Samples Received	: 20-Apr-2018 14:20
Order number	:	Date Analysis Commenced	: 23-Apr-2018
C-O-C number	: ----	Issue Date	: 04-May-2018 16:16
Sampler	: NICK JAMSON		
Site	: ----		
Quote number	: EN/222/17		
No. of samples received	: 14		
No. of samples analysed	: 12		

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 Inorganics, Stafford, QLD
Ankit Joshi	Inorganic Chemist	Sydney Inorganics, Smithfield, NSW
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Dian Dao		Sydney Inorganics, Smithfield, NSW
Ivan Taylor	Analyst	Sydney Inorganics, Smithfield, NSW
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Wisam Marassa	Inorganics Coordinator	Sydney Inorganics, Smithfield, NSW

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.

- 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	Barge LSC 0-10cm	4 - 0-10cm	19 - 0-25cm	26 - 0-14cm	40 - 0-15cm
			Client sampling date / time	19-Apr-2018 00:00	14-Apr-2018 00:00	14-Apr-2018 00:00	16-Apr-2018 00:00	17-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	ES1811521-001	ES1811521-002	ES1811521-003	ES1811521-004	ES1811521-005
				Result	Result	Result	Result	Result
EA001: pH in soil using 0.01M CaCl extract								
pH (CaCl2)	----	0.1	pH Unit	4.7	4.6	4.2	4.9	5.0
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	5.9	5.6	5.4	6.1	6.2
EA008: Calcium Carbonate Equivalent								
CaCO3 Equivalent	----	0.01	%	1.52	0.66	0.51	0.86	0.71
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	16	29	24	42	9
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	12.4	29.8	8.1	9.6	6.7
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Strong Brown	Very Dark Brown	Dark Brown	Dark Reddish Brown	Very Dark Brown
Texture	----	-	-	Gravelly Sand	Sandy Loam	Gravelly Sand	Gravelly Sand	Gravelly Sand
Emerson Class Number	EC/TC	-	-	8	4	8	8	8
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	0.9	2.7	3.1	----	----
Exchangeable Aluminium	----	0.1	meq/100g	0.6	2.4	2.4	----	----
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	2.5	1.7	3.6	3.7	1.7
Exchangeable Magnesium	----	0.1	meq/100g	2.2	0.5	0.9	1.2	0.7
Exchangeable Potassium	----	0.1	meq/100g	0.6	0.6	0.2	0.4	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	5.4	3.8	5.0	5.3	2.7
Exchangeable Aluminium	----	0.1	meq/100g	<0.1	1.1	0.3	<0.1	<0.1
Exchangeable Sodium Percent	----	0.1	%	<0.1	<0.1	<0.1	<0.1	<0.1
Calcium/Magnesium Ratio	----	0.1	-	1.1	3.4	4.0	3.1	2.4
ED021: Bicarbonate Extractable Potassium (Colwell)								
Bicarbonate Extractable K (Colwell)	----	10	mg/kg	<200	<200	<200	<200	<200
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	30	<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	Barge LSC 0-10cm	4 - 0-10cm	19 - 0-25cm	26 - 0-14cm	40 - 0-15cm
			Client sampling date / time	19-Apr-2018 00:00	14-Apr-2018 00:00	14-Apr-2018 00:00	16-Apr-2018 00:00	17-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	ES1811521-001	ES1811521-002	ES1811521-003	ES1811521-004	ES1811521-005
				Result	Result	Result	Result	Result
ED092: DTPA Extractable Metals - Continued								
ø Iron	7439-89-6	1.00	mg/kg	55.9	65.8	162	41.2	18.3
ø Manganese	7439-96-5	1.00	mg/kg	66.6	28.7	101	56.3	7.86
ø Zinc	7440-66-6	1.00	mg/kg	<1.00	<1.00	3.23	<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	30	10	10	60	20
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	14600	52700	7910	4230	4890
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	0.3	<0.1	0.3	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	0.3	0.1	0.2
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	780	3600	1500	770	440
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	780	3600	1500	770	440
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	437	3370	699	146	205
EK080: Bicarbonate Extractable Phosphorus (Colwell)								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	6	213	54	6	5
EP004: Organic Matter								
Organic Matter	----	0.5	%	3.5	13.8	5.3	2.4	1.1
Total Organic Carbon	----	0.5	%	2.0	8.0	3.1	1.4	0.6

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	Contam 10 - 0-5cm	Unknown - 0-15cm	35 - 0-20cm	37 - 0-15cm	23 - 0-10cm
			Client sampling date / time	17-Apr-2018 00:00	16-Apr-2018 00:00	16-Apr-2018 00:00	16-Apr-2018 00:00	16-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	ES1811521-006	ES1811521-007	ES1811521-008	ES1811521-009	ES1811521-010
				Result	Result	Result	Result	Result
EA001: pH in soil using 0.01M CaCl extract								
pH (CaCl2)	----	0.1	pH Unit	3.9	7.4	5.4	4.6	5.2
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	4.7	8.1	6.5	6.0	6.2
EA008: Calcium Carbonate Equivalent								
CaCO3 Equivalent	----	0.01	%	0.46	13.0	1.87	0.56	0.25
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	67	147	63	54	24
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	16.8	26.2	15.2	13.2	11.5
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Yellowish Red	Very Dark Grey	Very Dark Brown	Brown	Very Dark Greyish Brown
Texture	----	-	-	Gravelly Sand	Clay Loam	Loamy Sand	Sandy Clay Loam	Sandy Clay Loam
Emerson Class Number	EC/TC	-	-	8	4	4	4	4
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	4.1	----	----	----	----
Exchangeable Aluminium	----	0.1	meq/100g	3.2	----	----	----	----
ED006: Exchangeable Cations on Alkaline Soils								
Exchangeable Calcium	----	0.2	meq/100g	----	16.3	----	----	----
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	----	16.3	----	----	----
Exchangeable Calcium Percent	----	0.2	%	----	100	----	----	----
Calcium/Magnesium Ratio	----	0.2	-	----	N/A	----	----	----
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	1.9	----	7.4	2.4	8.0
Exchangeable Magnesium	----	0.1	meq/100g	0.7	----	4.8	0.7	2.4
Exchangeable Potassium	----	0.1	meq/100g	0.7	----	0.6	0.5	0.4
Exchangeable Sodium	----	0.1	meq/100g	<0.1	----	<0.1	<0.1	<0.1
Cation Exchange Capacity	----	0.1	meq/100g	4.1	----	12.8	3.6	10.8
Exchangeable Aluminium	----	0.1	meq/100g	0.7	----	<0.1	<0.1	<0.1
Exchangeable Sodium Percent	----	0.1	%	<0.1	----	<0.1	<0.1	0.2
Calcium/Magnesium Ratio	----	0.1	-	2.7	----	1.5	3.4	3.3

Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

Compound	CAS Number	LOR	Unit	Contam 10 - 0-5cm	Unknown - 0-15cm	35 - 0-20cm	37 - 0-15cm	23 - 0-10cm
			Client sampling date / time	17-Apr-2018 00:00	16-Apr-2018 00:00	16-Apr-2018 00:00	16-Apr-2018 00:00	16-Apr-2018 00:00
				ES1811521-006	ES1811521-007	ES1811521-008	ES1811521-009	ES1811521-010
				Result	Result	Result	Result	Result
ED021: Bicarbonate Extractable Potassium (Colwell)								
Bicarbonate Extractable K (Colwell)	----	10	mg/kg	<200	<200	<200	<200	<200
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	**30**	**20**	<10	<10	<10
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	<10	**20**	**20**	<10	**20**
ED092: DTPA Extractable Metals								
ø Copper	7440-50-8	1.00	mg/kg	**241**	**26.2**	**2.71**	**1.14**	<1.00
ø Iron	7439-89-6	1.00	mg/kg	**207**	**102**	**113**	**68.0**	**66.8**
ø Manganese	7439-96-5	1.00	mg/kg	**14.0**	**24.3**	**14.9**	**40.9**	**31.6**
ø Zinc	7440-66-6	1.00	mg/kg	**7.81**	**6.54**	**4.03**	**1.20**	**1.99**
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	**10**	**150**	<10	<10	**10**
Magnesium	7439-95-4	10	mg/kg	<10	**10**	**20**	<10	**10**
Sodium	7440-23-5	10	mg/kg	<10	<10	<10	<10	<10
Potassium	7440-09-7	10	mg/kg	**50**	**60**	**40**	**20**	**50**
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**8210**	**9170**	**14800**	**5950**	**9030**
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**	**0.2**	<0.1	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	**17.1**	**3.2**	**5.4**	**0.1**	**0.2**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	**17.1**	**3.3**	**5.6**	**0.1**	**0.2**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**2430**	**3500**	**1980**	**1190**	**1230**
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	**2450**	**3500**	**1980**	**1190**	**1230**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**1120**	**810**	**540**	**322**	**460**
EK080: Bicarbonate Extractable Phosphorus (Colwell)								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	Contam 10 - 0-5cm	Unknown - 0-15cm	35 - 0-20cm	37 - 0-15cm	23 - 0-10cm
			Client sampling date / time	17-Apr-2018 00:00	16-Apr-2018 00:00	16-Apr-2018 00:00	16-Apr-2018 00:00	16-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	ES1811521-006	ES1811521-007	ES1811521-008	ES1811521-009	ES1811521-010
				Result	Result	Result	Result	Result
EK080: Bicarbonate Extractable Phosphorus (Colwell) - Continued								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	403	24	15	<5	17
EP004: Organic Matter								
Organic Matter	----	0.5	%	8.4	8.6	6.8	3.5	3.3
Total Organic Carbon	----	0.5	%	4.9	5.0	4.0	2.0	1.9

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	41 - 0-20cm	13- 0-5cm	----	----	----
			Client sampling date / time	17-Apr-2018 00:00	16-Apr-2018 00:00	----	----	----
Compound	CAS Number	LOR	Unit	ES1811521-011	ES1811521-014	--------	--------	--------
				Result	Result	----	----	----
EA001: pH in soil using 0.01M CaCl extract								
pH (CaCl2)	----	0.1	pH Unit	**4.0**	**4.7**	----	----	----
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	**5.2**	**5.7**	----	----	----
EA008: Calcium Carbonate Equivalent								
CaCO3 Equivalent	----	0.01	%	**0.20**	**0.10**	----	----	----
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	**16**	**29**	----	----	----
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	**6.3**	**13.1**	----	----	----
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	**Brown**	**Very Dark Brown**	----	----	----
Texture	----	-	-	**Loamy Sand**	**Sandy Loam**	----	----	----
Emerson Class Number	EC/TC	-	-	**3**	**4**	----	----	----
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	**4.3**	**1.0**	----	----	----
Exchangeable Aluminium	----	0.1	meq/100g	**3.7**	**0.8**	----	----	----
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	**0.2**	**5.0**	----	----	----
Exchangeable Magnesium	----	0.1	meq/100g	**0.3**	**1.0**	----	----	----
Exchangeable Potassium	----	0.1	meq/100g	**0.2**	**0.6**	----	----	----
Exchangeable Sodium	----	0.1	meq/100g	<0.1	<0.1	----	----	----
Cation Exchange Capacity	----	0.1	meq/100g	**1.2**	**6.8**	----	----	----
Exchangeable Aluminium	----	0.1	meq/100g	**0.4**	<0.1	----	----	----
Exchangeable Sodium Percent	----	0.1	%	**3.1**	**0.5**	----	----	----
Calcium/Magnesium Ratio	----	0.1	-	**0.7**	**5.0**	----	----	----
ED021: Bicarbonate Extractable Potassium (Colwell)								
Bicarbonate Extractable K (Colwell)	----	10	mg/kg	<200	<200	----	----	----
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	<10	**10**	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	<10	**20**	----	----	----
ED092: DTPA Extractable Metals								
ø Copper	7440-50-8	1.00	mg/kg	<1.00	**1.20**	----	----	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	41 - 0-20cm	13- 0-5cm	----	----	----
			Client sampling date / time	17-Apr-2018 00:00	16-Apr-2018 00:00	----	----	----
Compound	CAS Number	LOR	Unit	ES1811521-011	ES1811521-014	--------	--------	--------
				Result	Result	----	----	----
ED092: DTPA Extractable Metals - Continued								
ø Iron	7439-89-6	1.00	mg/kg	**106**	**258**	----	----	----
ø Manganese	7439-96-5	1.00	mg/kg	**3.71**	**45.1**	----	----	----
ø Zinc	7440-66-6	1.00	mg/kg	<1.00	**3.00**	----	----	----
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	<10	<10	----	----	----
Magnesium	7439-95-4	10	mg/kg	<10	<10	----	----	----
Sodium	7440-23-5	10	mg/kg	<10	<10	----	----	----
Potassium	7440-09-7	10	mg/kg	**20**	**20**	----	----	----
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**5170**	**11900**	----	----	----
Molybdenum	7439-98-7	2	mg/kg	<2	<2	----	----	----
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	----	----	----
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	<0.1	----	----	----
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	**0.2**	**0.2**	----	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	**0.2**	**0.2**	----	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**600**	**2860**	----	----	----
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	**600**	**2860**	----	----	----
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**268**	**954**	----	----	----
EK080: Bicarbonate Extractable Phosphorus (Colwell)								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	<5	**59**	----	----	----
EP004: Organic Matter								
Organic Matter	----	0.5	%	**2.7**	**5.8**	----	----	----
Total Organic Carbon	----	0.5	%	**1.6**	**3.4**	----	----	----

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **ES1811374**	Page	: 1 of 5
Client	: **EMM CONSULTING PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: MS KYLIE DRAPALA	Contact	: Customer Services ES
Address	: 1/4 87 WICKHAM TERRACE SPRING HILL QLD 4000	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: 07 3839 1800	Telephone	: +61-2-8784 8555
Project	: Snowy Hydro 2.0 Early Works - ASS	Date Samples Received	: 20-Apr-2018 14:20
Order number	:	Date Analysis Commenced	: 27-Apr-2018
C-O-C number	: ----	Issue Date	: 27-Apr-2018 17:35
Sampler	: Nicholas Jamson		
Site	: ----		
Quote number	: EN/222/17		
No. of samples received	: 11		
No. of samples analysed	: 11		

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*
Satishkumar Trivedi	Senior Acid Sulfate Soil Chemist	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.

- ASS: EA033 (CRS Suite):Retained Acidity not required because pH KCl greater than or equal to 4.5
- ASS: EA033 (CRS Suite): ANC not required because pH KCl less than 6.5
- ASS: EA033 (CRS Suite): Liming rate is calculated and reported on a dry weight basis assuming use of fine agricultural lime ($CaCO_3$) and using a safety factor of 1.5 to allow for non-homogeneous mixing and poor reactivity of lime. For conversion of Liming Rate from 'kg/t dry weight' to 'kg/m3 in-situ soil', multiply 'reported results' x 'wet bulk density of soil in t/m3'.

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	ASS 22 0-7cm	ASS 22 7-25cm	ASS 16 0-25cm	ASS 16 20-40cm	ASS 16 45-65cm
			Client sampling date / time	18-Apr-2018 00:00	18-Apr-2018 00:00	19-Apr-2018 00:00	19-Apr-2018 00:00	19-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	ES1811374-001	ES1811374-002	ES1811374-003	ES1811374-004	ES1811374-005
				Result	Result	Result	Result	Result
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**6.2**	**6.1**	**5.5**	**5.6**	**5.7**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	**8**	**5**	**4**
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	**0.011**	**0.012**	**0.010**	**0.012**	**0.011**
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	<10	<10	<10
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	**0.02**	**0.02**	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	**14**	**13**	**11**
Liming Rate	----	1	kg CaCO3/t	<1	<1	**1**	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	**0.02**	**0.02**	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	<10	**14**	**13**	**11**
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	**1**	<1	<1

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	ASS 13 0-10cm	ASS 13 50-70cm	ASS 13 20-40cm	ASS 17 25-45	ASS 17 4-24cm
			Client sampling date / time	19-Apr-2018 00:00	19-Apr-2018 00:00	19-Apr-2018 00:00	19-Apr-2018 00:00	19-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	ES1811374-006	ES1811374-007	ES1811374-008	ES1811374-009	ES1811374-010
				Result	Result	Result	Result	Result
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	5.1	5.0	5.0	4.7	4.8
Titratable Actual Acidity (23F)	----	2	mole H+ / t	13	11	13	30	32
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	0.02	<0.02	0.02	0.05	0.05
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	0.012	0.010	0.013	0.010	0.012
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	<10	<10	<10
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	1.5	1.5	1.5	1.5	1.5
Net Acidity (sulfur units)	----	0.02	% S	0.03	0.03	0.03	0.06	0.06
Net Acidity (acidity units)	----	10	mole H+ / t	20	17	21	37	40
Liming Rate	----	1	kg CaCO3/t	2	1	2	3	3
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	0.03	0.03	0.03	0.06	0.06
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	20	17	21	37	40
Liming Rate excluding ANC	----	1	kg CaCO3/t	2	1	2	3	3

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	ASS 0-4cm	----	----	----	----
			Client sampling date / time	19-Apr-2018 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	ES1811374-011	--------	--------	--------	--------
				Result	----	----	----	----
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**5.8**	----	----	----	----
Titratable Actual Acidity (23F)	----	2	mole H+ / t	**3**	----	----	----	----
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	----	----	----	----
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	**0.011**	----	----	----	----
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	----	----	----	----
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	----	----	----	----
Net Acidity (sulfur units)	----	0.02	% S	<0.02	----	----	----	----
Net Acidity (acidity units)	----	10	mole H+ / t	**10**	----	----	----	----
Liming Rate	----	1	kg CaCO3/t	<1	----	----	----	----
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	----	----	----	----
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	**10**	----	----	----	----
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	----	----	----	----

Appendix C

Representative survey site photographs

Site	Landscape	Profile
Red Kandosol		
37		
48 (bleached)		

38

Brown Kandosol

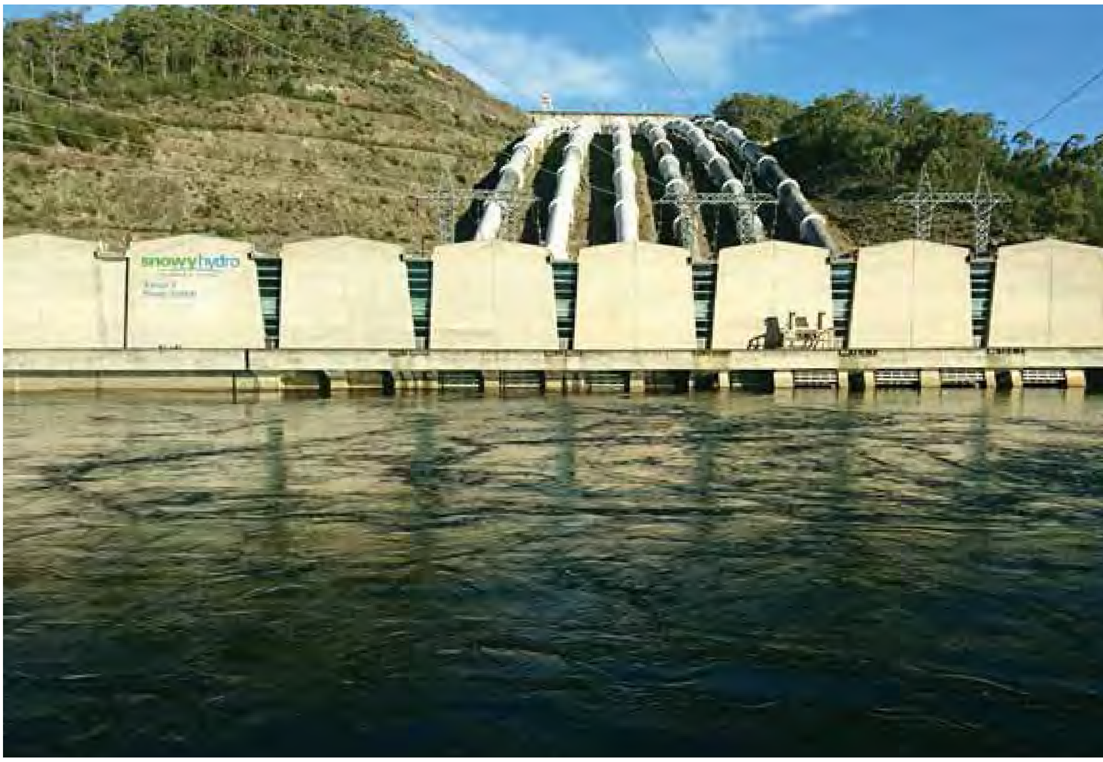
4 (Basalt)

17 (Basalt)		
21 (Limestone and shale)		

23 (Limestone and shale)		
Grey Kandosol		
35 (humose)		

53 (bleached)		
Vertosol		
50		

Tenosol		
36		
43		


snowyhydro