MUSWELLBROOK BESS

Land & Soil Capability Assessment

Prepared for:

Firm Power

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PREPARED BY

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BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Firm Power (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

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DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
630.30343 MWB	June 2022	Murray Fraser	Rod Masters	Murray Fraser

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1 Introduction

SLR has been commissioned by Firm Power to complete a Land & Soil Capability (LSC) Assessment for the Muswellbrook Battery Energy Storage System (BESS) Project (the Project). The purpose of this LSC Assessment is to form part of the site due diligence and ultimately inform any Environmental Impact Statement (EIS) for the Project in support of a development application, to be submitted under Part 4 of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) (NSW Department of Planning and Environment (DP&E), 1979).

This report has been prepared to meet the Department Planning, Industry and Environment (DPIE) Secretary's Environmental Assessment Requirements (SEARs) for the Project.

1.1 Background

Firm Power (the Applicant) is proposing to develop a BESS with a delivery capacity of 150 Megawatt (MW) and a useable energy storage of 300 Megawatt hours (MWh) on land adjacent to the Ausgrid Muswellbrook substation. The proposal is located in the Muswellbrook Shire Council (MSC) Local Government Area (LGA), within the Hunter region of NSW, approximately 2.5 km north-east of the town of Muswellbrook (**Figure 1**). The project is to be known as the Muswellbrook BESS.

The subject site is known as 20-24 Sandy Creek Road, Muswellbrook (Lots 11 and 12 DP839233 and Lot 15 DP 905479, hereafter referred to as 'the site' or 'Project Area'), and would have an area of 4.94 hectares. The Project Area, that is the area on which the BESS and associated infrastructure would be located, occupies the entirety of the site, as shown **in Figure 2.**

The Muswellbrook BESS includes the following key infrastructure:

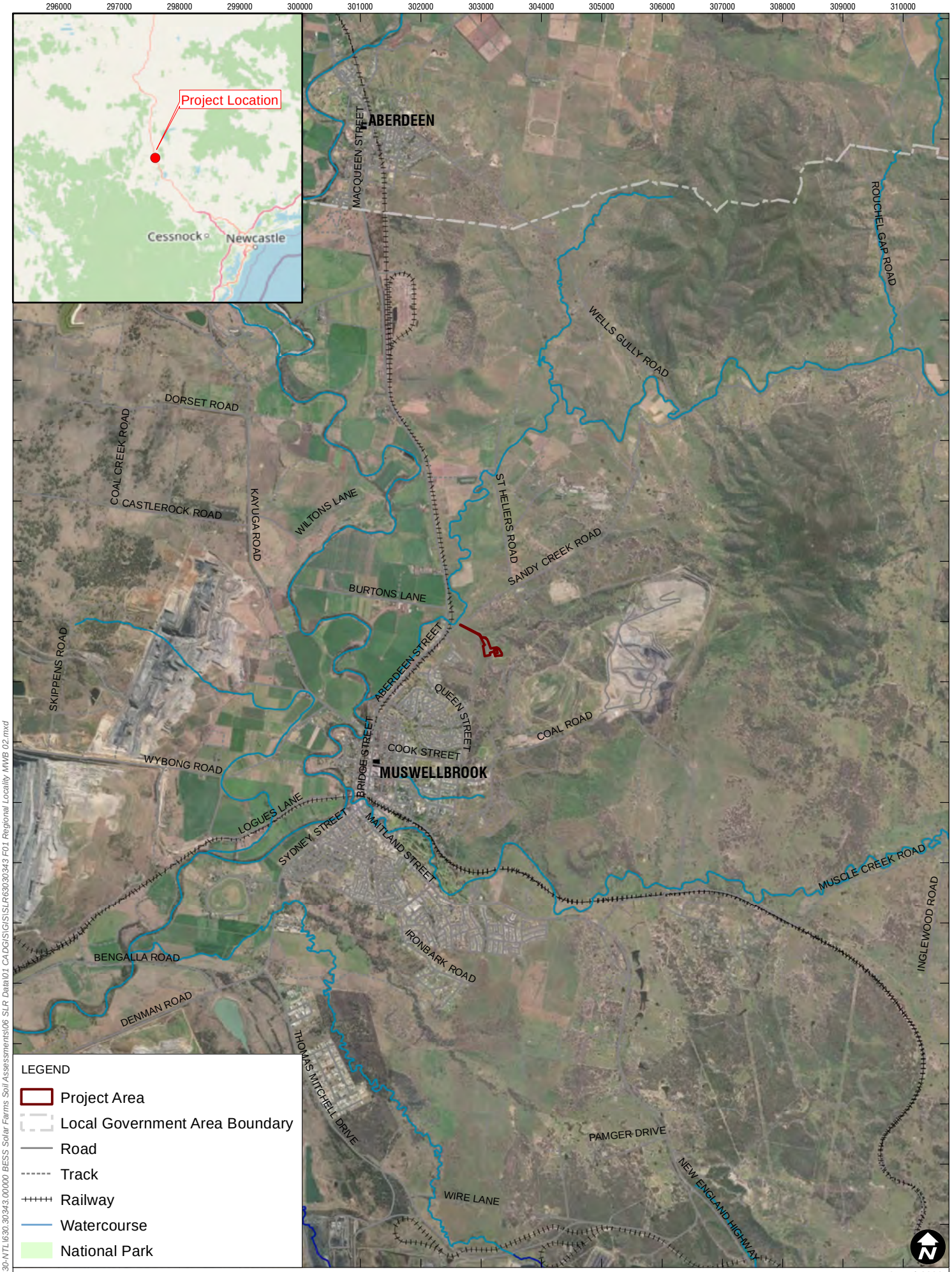
- Enclosed lithium-ion batteries;
- Power conversion systems including associated switchgear, protection and control equipment, transformers and enclosures for housing equipment;
- Underground power and fibre optic cabling interconnecting the equipment;
- Grid connection equipment including main power transformer, switchgear, protection and control equipment, metering, reactive power equipment, filtering equipment, auxiliary/earthing transformers and enclosures/buildings for housing equipment;
- Underground or overhead 132kV sub-transmission lines to connect the BESS to the Muswellbrook substation;
- Earthing and lightning protection systems;
- Site office, storage area/enclosure, internal access tracks, on-site parking, security fencing, CCTV, lighting and temporary construction laydown area;
- Noise bunds and vegetation screening; and
- Utilisation of existing site access arrangements.

The primary components associated with the installation of the BESS are as follows:

- Site investigations, vegetation clearing, levelling, bench and access way construction, drainage system installation and installation of foundations/supports to install equipment on;
- Transport to site and installation of equipment;
- Testing and commissioning of the equipment;
- Operation and maintenance.

The site is largely cleared land, owned and managed by Ausgrid. It includes an existing unsealed site access road connecting the existing substation to Sandy Creek Road. Existing 132 kV and 33 kV powerlines traverse the site, extending from the eastern and western sides of the substation and following an east-west and north-south alignment.

It is expected that augmentation work within the Ausgrid substation site would be required to facilitate connection of the BESS. The project is State Significant Development (SSD) under the *State Environmental Planning Policy (State and Regional Development)* 2011 and the applicable consent authority for the proposal is the NSW Minister for Planning or the Minister's delegate.



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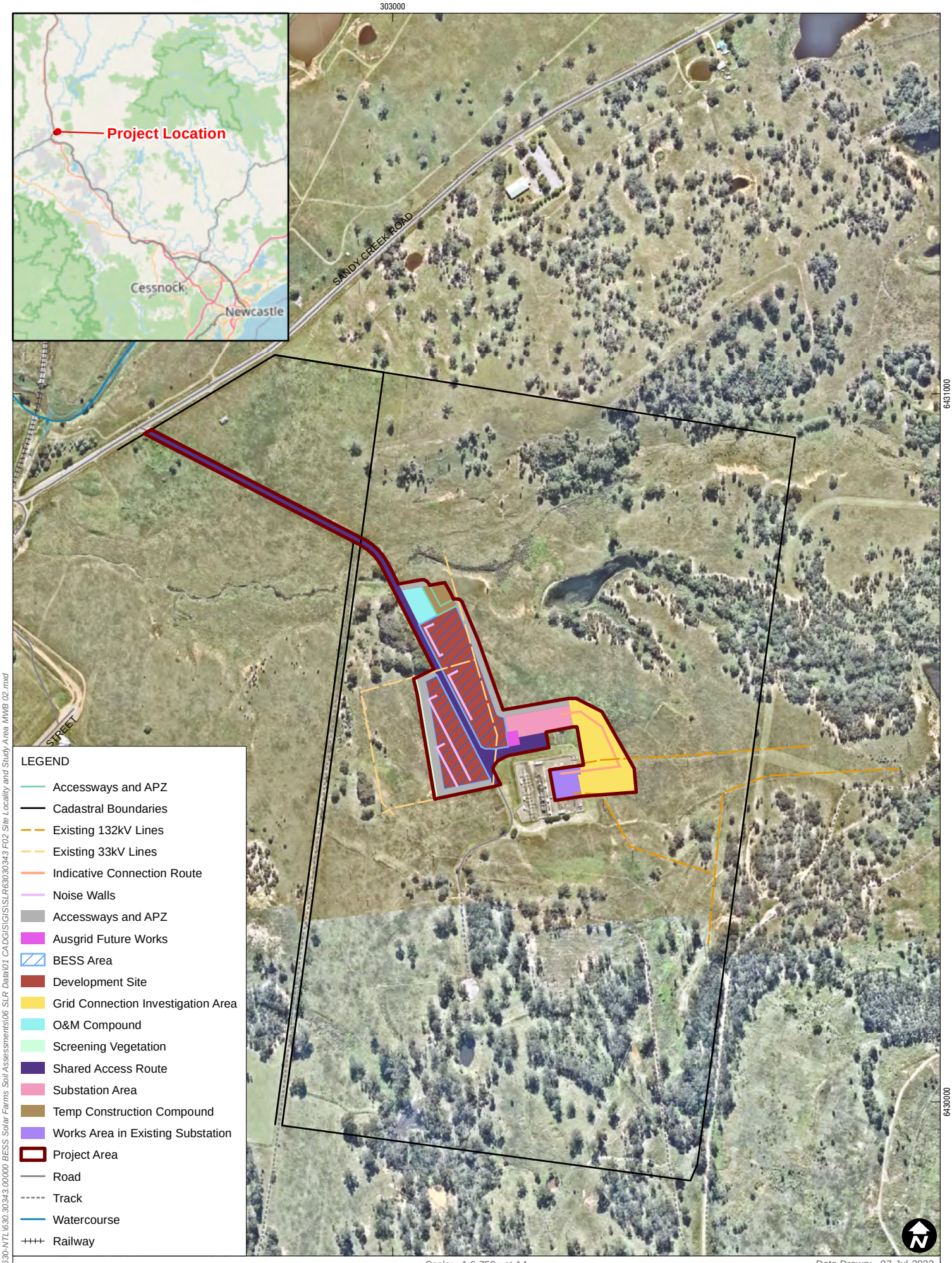
Regional Locality & Project Area

FIGURE 1



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H:\Projects-SLR\630-SrvNTL\630-NTL\630.30343.00000 BESS Solar Farms Soil Assessments\06 SLR Data\01 CADGIS\GIS\SLR630303343 F02 Site Locality and Study Area MWB 02.mxd

SLR

Site Locality and Study Area

FIGURE 2

1.2 Objective

The objective was to conduct an LSC Assessment for an area of land proposed for the Project to support the EIS/Development Application for the project.

1.3 Scope of Work

The LSC Assessment includes:

- Determination of Australian Soil Classification (ASC) (Isbell, 2002) soil types across the Project Area.
- Detailed assessment of the site and soil characteristics as per the requirements of *The Land and Soil Capability Assessment Scheme; Second Approximation* (OEH, 2012).
- Completion of field work to obtain required level of field samples in accordance with any relevant guidelines.
- Documentation of the results of the detailed assessment comprising of a written report and associated mapping to address specific items in *The Land and Soil Capability Assessment Scheme; Second Approximation* (OEH, 2012).
- Determination of preliminary BSAL status according to the *Interim Protocol for Site Verification and Mapping of Biophysical Strategic Agricultural Land* (OEH, 2013).
- Determination of erosive potential for soil types within development footprint.

1.4 Project Area

Firm Power requires an LSC Assessment for the Area of Interest (the Project Area) to support an EIS for the Project. **Table 1** shows the areas requiring soil survey for the LSC Assessment Area.

Table 1 Project Area

Assessment Component	Hectares
BESS Development Footprint / Project Area	4.94
Total LSC Assessment Area	**4.94**

1.5 Legislation and Standards

The Large-Scale Solar Energy Guideline (LSSEG) for State Significant Development was issued in December 2018 by the NSW Government (NSW Government, 2018). As there are no specific guidelines for standalone BESS projects, the LSSEG was used to guide this assessment. The guideline provides the community, industry, applicants and regulators with general guidance on the planning framework for the assessment and determination of State Significant large-scale energy projects under the *Environmental Planning and Assessment Act 1979*. Under Section 4 of the LSSEG one of the key site constraints identified for site selection is agriculture including Land and Soil Capability and BSAL.

The appropriate guideline for assessment of Land and Soil Capability is *The Land and Soil Capability Assessment Scheme; Second Approximation* (OEH, 2012).

1.5.1 Secretary's Environmental Assessment Requirements

Firm Power received the Planning Secretary's Environmental Assessment Requirements (SEARs) (**Table 2**) on the 10th December, 2021 which noted:

The EIS must address the following specific matters:

Land – including:

- *a consideration of the project's location in a mine subsidence district, flood prone land, acid sulphate soils, Crown lands, Travelling Stock Reserve (TSR 70196 Lot 15 DP 905479), mining, quarries, mineral or petroleum rights; and*
- *a soil survey to determine the soil characteristics and consider the potential for erosion to occur.*

Matters relating to land required by the SEARs which are not addressed in this report are assessed in the main EIS and the Surface Water Impact Assessment (SLR, 2022)

Table 2 SEARs Register

DPI General Comments	SLR Response	Specific Section Where Addressed
A consideration of the project's location in acid sulphate soils.	None of the soil types mapped within the Project Area have acid sulfate soil potential.	3.2.1
A soil survey to determine the soil characteristics and consider the potential for erosion to occur.	ASC soil type Subnatric Brown Sodosol of LSC Classes 4 & 5 with moderate potential for erosion to occur when subsoil is exposed to rainfall or water movement	3 & 4

2 LSC Assessment Methodology

The LSC classification applied to the Project Area was in accordance with the OEH guideline *The Land and Soil Capability Assessment Scheme; Second Approximation* (OEH, 2012). This scheme uses the biophysical features of the land and soil to derive detailed rating tables for a range of land and soil hazards. The scheme consists of eight classes, which classify the land based on the severity of long-term limitations. The LSC Classes are described in **Table 3** and their definition has been based on two considerations:

- The biophysical features of the land to derive the LSC classes associated with various hazards.
- The management of the hazards including the level of inputs, expertise and investment required to manage the land sustainably.

Table 3 Land & Soil Capability Assessment Classification

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

2.1.1 Calculating LSC Classes

The biophysical features of the land that are associated with various hazards are broadly soil, climate and landform and more specifically: slope, landform position, acidity, salinity, drainage, rockiness; and climate.

The eight hazards associated with these biophysical features that are assessed by the scheme are:

1. Water erosion
2. Wind erosion
3. Soil structure decline
4. Soil acidification
5. Salinity
6. Water logging
7. Shallow soils and rockiness
8. Mass movement

Each hazard is assessed against set criteria tables, as described in the LSC Guideline; each hazard for the land is ranked from 1 through to 8 with the overall ranking of the land determined by its most significant limitation.

Hazard 1: Water Erosion

The Project Area lies within the Eastern NSW Division, and the appropriate criteria for this division were used in the assessment. Assessment of water erosion hazard is almost solely dependent on the slope percentage of the land, based on each Soil Landscape Unit. The only exception is land which falls within the slope range of 10 to 20%, which may be designated LSC Class 4 or LSC Class 5 depending on the presence of gully erosion and/or sodic/dispersible soils. A slope analysis for the Project Area is shown on **Figure 3** while the slope analysis methodology is shown in **Appendix A**.

Hazard 2: Wind Erosion

There are four factors used to assess wind erosion hazard for each soil type. Three criteria were assessed to be consistent for each soil type:

- Average rainfall determines the capacity of the land to maintain vegetative cover and keep soil wet. The average rainfall for the region is 630 millimetres (BOM, 2022), and therefore the Project Area lies within the “greater than 500 millimetres rainfall” category for the purpose of assessing wind erosion hazard.
- Wind erosive power for the Project Area has been mapped as “Moderate” (NSW Department of Trade and Investment); and

- Exposure of the land to wind was also determined to be “Moderate” throughout the Project Area.

The determining factor with regard to wind erosion hazard was therefore the erodibility of each soil type as determined by soil texture according the LSC Guideline.

Hazard 3: Soil Structure Decline

Soil structure decline is assessed on soil characteristics, including surface soil texture, sodicity (laboratory tested) and degree of self-mulching (field tested). These parameters assess the soil structure, stability and resilience of the soil.

Hazard 4: Soil Acidification

The soil acidification hazard is assessed using three criteria, being soil buffering capacity, pH and mean annual rainfall. In this assessment, soil buffering capacity was based on soil Great Soil Group; surface soil pH and a regional mean annual rainfall range of 550 – 700 millimetres.

Hazard 5: Salinity

The salinity hazard is determined through a range of data and criteria. The recharge potential for the site was determined based on an average annual rainfall of 630 millimetres, with annual evaporation of 1,400 to 1,600 millimetres (BOM, 2022). This would suggest a low recharge potential.

Based on the annual rainfall data (630 millimetres) and an average annual evapotranspiration of 600 to 700 millimetres, a low discharge potential exists for the site due to a likely balanced rate of water flow. The Project Area according to the Salt Store Map of NSW, is located in an area of low salt store. However, due to the current available scale of this mapping, laboratory tested EC values were used to determine salt store, all of which were non-saline.

Hazard 6: Water Logging

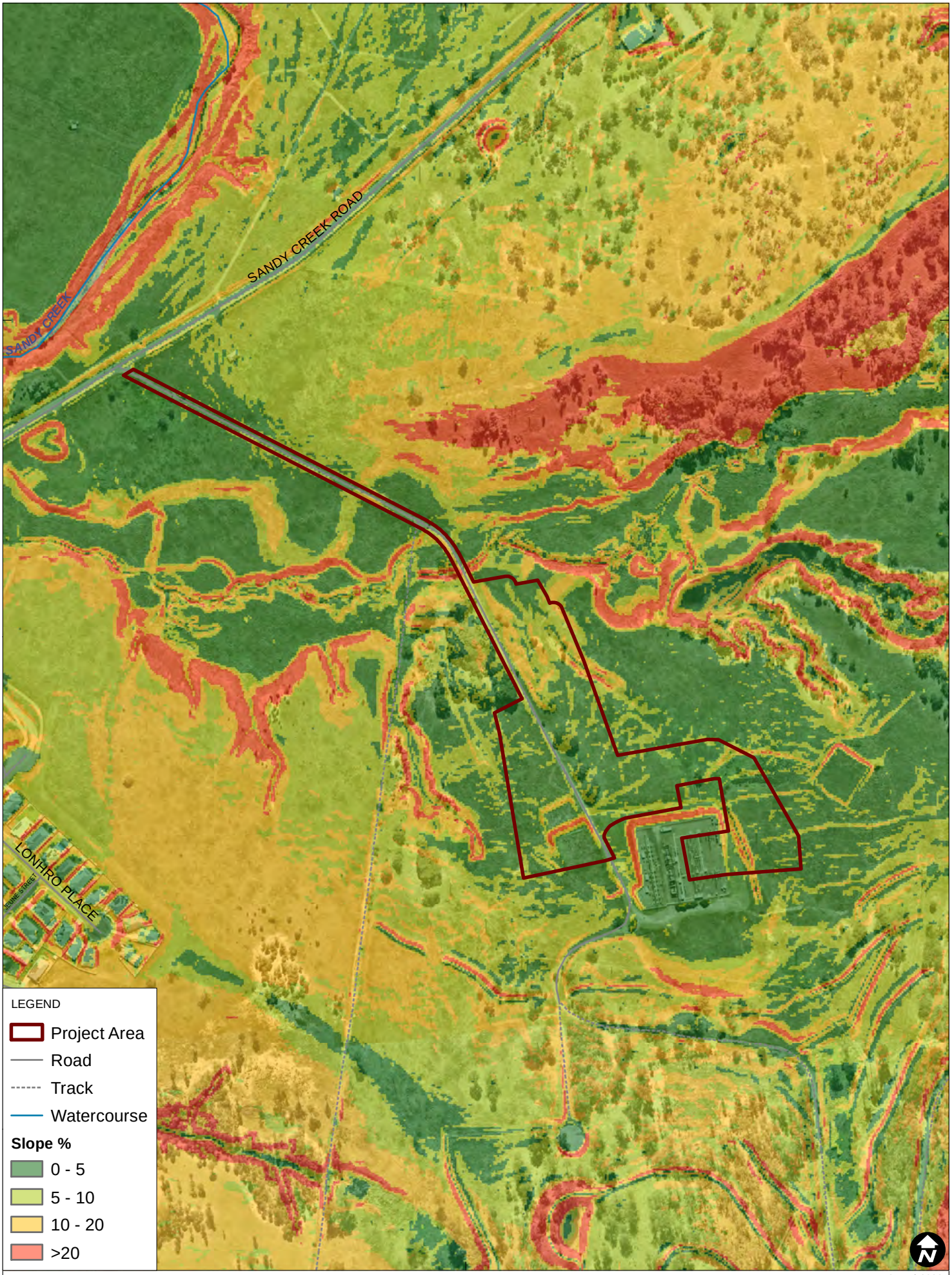
Water logging was determined by the soils drainage characteristics, specifically field sample evidence of mottling, soil texture attributes as well as slope and climate. Seasonal water logging, as indicated by strong mottling, was one of the major limitations for the Subnatric Brown Sodosol.

Hazard 7: Shallow Soils and Rockiness

The shallow soils and rockiness hazard is determined by an estimated exposure of rocky outcrops and average soil depth.

Hazard 8: Mass Movement

The mass movement hazard is assessed through a combination of three criteria; mean annual rainfall, presence of mass movement and slope class.



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SLR

Slope

FIGURE 3

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2.1.2 Risk Assessment

The soil survey was originally designed to meet the requirements for BSAL Verification and the *Interim Protocol*, a risk assessment was undertaken to determine the required survey density. The *Interim Protocol* states *"the proponent should undertake a risk assessment as this will influence the density of soil sampling required as explained in Section 9.6.1. The proposed activity on parts or all of the project area may be of low risk to agriculture and so may only require a sampling density of 1:100,000. Alternatively other areas may be at higher risk of impact and so should have a sampling density of 1:25,000."*

To identify the potential for a project to impact on agricultural resources and the appropriate level of soil survey required, an evaluation of risk to agricultural resources and enterprises has been undertaken. The risk assessment is based on the probability of occurrence and the consequence of the impact as described in the *Interim Protocol*. The potential impacts were assessed as:

- Level 5 – Very minor damage and minor impact to agricultural resources or industries. Probability: B – Likely, known to occur or it has happened. The risk matrix result was B5 which is considered a low risk. The Project Area requires an inspection density of 1:100,000.

Based on the Project only being temporary with an expected lifespan of 20 years, and having no permanent impact on the intrinsic properties of the soil, an inspection density of 1:100,000 was adopted across the Project Area.

2.1.3 Field Soil Survey

The field survey for the LSC Assessment was undertaken during April 2022 by SLR's Principal Agronomist Murray Fraser and overseen by SLR's Regional Sector Leader Rod Masters (CPSS-3).

To satisfy soil mapping requirements, although only a minimum of one site was required, the field soil survey program comprised three detailed sites in total, as shown on **Figure 4**. A breakdown of the required soil survey density, as per *Interim Protocol* requirements, is provided in **Table 4**, which exceeds the requirements for an LSC Assessment.

Table 4 Assessment of Soil Survey Density

Category	LSC Assessment Area
Total Project Area Hectares	4.94
1:100,000 Survey Density Target	Minimum 1 Required Site
Detailed Sites	3
Check Sites	0
Total Number Sites	**3**
Laboratory Analysed Sites	**2**

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SLR

Site Inspection Points

FIGURE 4

2.1.4 Soil Survey Observation Types

Soil profiles were assessed at three sites in accordance with the *Australian Soil and Land Survey Field Handbook* (NCST, 2009). Each soil-profile exposure was sampled with a hydraulic soil corer, either a depth of 1.2 metres, to equipment refusal, or to bedrock. Detailed soil profile morphological descriptions were prepared at all sites to record the information specified in *The Land and Soil Capability Assessment Scheme; Second Approximation* (OEH, 2012) Information was recorded for the major parameters specified in **Table 5**.

Global Positioning System (GPS) readings was taken for all sites where soil descriptions are recorded. Vegetation type, landform and aspect were also noted. Soil exposures from pits were photographed during field operations.

Table 5 Field Assessment Parameters

Descriptor	Application
Horizon depth	Weathering characteristics, soil development
Field colour	Permeability, susceptibility to dispersion/erosion
Field texture grade	Erodibility, hydraulic conductivity, moisture retention, root penetration
Boundary distinctness and shape	Erosional/dispositional status, textural grade
Consistence force	Structural stability, dispersion, ped formation
Structure pedality grade	Soil structure, root penetration, permeability, aeration
Structure ped and size	Soil structure, root penetration, permeability, aeration
Stones – amount and size	Water holding capacity, weathering status, erosional/depositional character
Roots – amount and size	Effective rooting depth, vegetative sustainability
Ants, termites, worms etc.	Biological mixing depth

A total of three detailed sites were evaluated, with soil collected from each major soil horizon (soil layer).

Soil samples from three detailed sites were utilised in the LSC Assessment laboratory testing program. Samples were analysed in order to classify Australian Soil Classification (ASC) (Isbell, 2002) soil taxonomic class and enable LSC classification.

Soil collected from each major soil horizon (soil layer) was sent to a National Association of Testing Authorities Australia (NATA) accredited laboratory (EAL Laboratories) for analysis. The selected physical and chemical laboratory analysis properties and their relevant application are listed in **Table 6**.

Table 6 Laboratory Analysis Parameters

Property	Application
Coarse Fragments (>2mm)	Soil workability; root development
Particle-Size Distribution (<2mm)	Determine fraction of clay, silt, fine sand and coarse sand; nutrient retention; exchange properties; erodibility; workability; permeability; sealing; drainage; interpretation of most other physical and chemical properties and soil qualities
Soil Reaction (pH)	Nutrient availability; nutrient fixation; toxicities (especially aluminium and manganese); liming; Sodicity; correlation with other soil properties
Electrical Conductivity (EC)	Appraisal of salinity hazard in soil substrates or groundwater; total soluble salts
Cation Exchange Capacity (CEC) & Exchangeable Cations	Nutrient status; calculation of exchangeable cations including sodium, calcium, magnesium, potassium and exchangeable sodium percentage (ESP); assessment of other physical and chemical properties, especially dispersivity, shrink – swell, water movement, aeration
Munsell Colour Chart (Munsell)	Drainage, oxidation, fertility, correlation with other physical, chemical and biological properties

Soil salinity in the samples from the detailed sites was determined through measurement of the electrical conductivity (EC) of soil:water (1:5) suspensions. These values were converted to the EC of a saturated extract (EC_e) based on soil texture in accordance with the *Interim Protocol*.

3 Soil Assessment

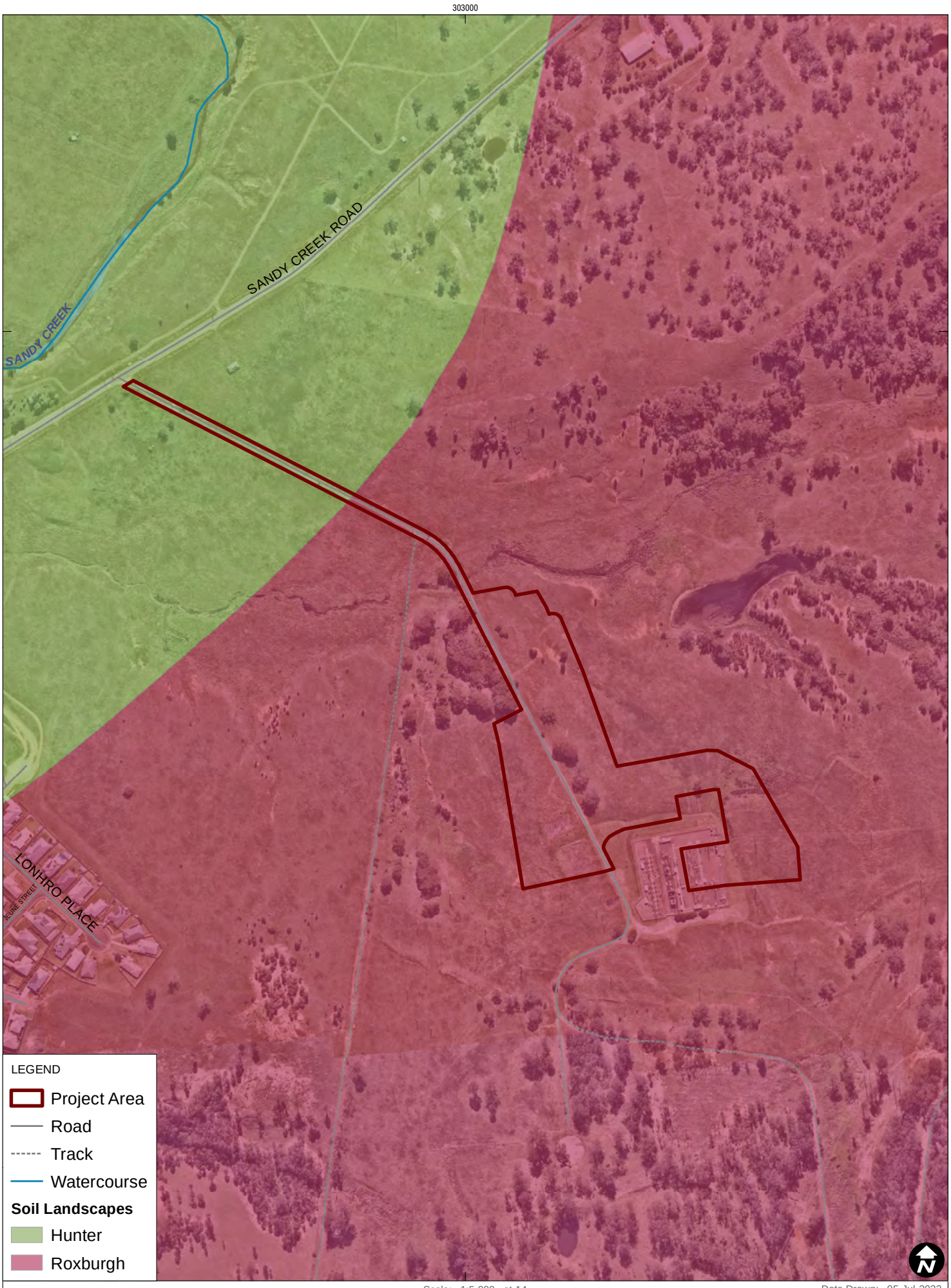
3.1 Soil Landscape Units

Soil Landscapes Units (SLU's) within the Project Area have been mapped by the former NSW Department of Land and Water Conservation, incorporating the NSW Soil Conservation Service (now part of NSW Department of Primary Industries (DPI)), on the *Soil Landscapes of the Singleton 1:250,000 Sheet* (Kovac and Lawrie, 1991) as shown on **Figure 5**. Two SLU's occur within the Project Area and are summarised in **Table 7**. Below is a summary of the key agricultural features of each SLU.

- The Roxburgh SLU is associated with Sodosols as is best suited to grazing, having moderate limitations for cultivation.
- The Hunter SLU is associated with Vertosols and is best suited for cultivation and grazing, having low limitations for both activities.

Table 7 Soil Landscape Units

Soil Landscape	Project Area		Agricultural Limitation Rating	
Unit	Hectares	%	Grazing	Cultivation
Roxburgh	4.68	95	Low	Moderate
Hunter	0.26	5	Low	Low
Total	**4.94**	**100**		



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Soil Landscape Units

FIGURE 5

3.2 Australian Soil Classification

One soil map unit was identified within the Project Area, a Subnatric Brown Sodosol, and was mapped according to this dominant ASC soil type (**Figure 6**) using a combination of the soil survey and laboratory analysis results. This soil unit and the associated observation sites are shown below in **Table 8**.

Sodosols are soils with a strong texture contrast between the A horizons and a sodic B horizon which are not strongly acidic (pH is greater than 5.5). The strongly sodic nature of the B horizon in Sodosols leave them prone to dispersion and tunnel erosion if left exposed for prolonged periods to water movement or rainfall.

A description of the three detailed sites from the mapped soil unit follows **Table 8**. Laboratory certificates of analysis are shown in **Appendix B**.

Table 8 Soil Units within Project Area

SMU	ASC Soil Type	Soil Type Group	Detailed Site	Check Site	Hectares
1	Subnatric Brown Sodosol	Dominant	M1, M2, M3	Nil	4.94

3.2.1 Acid Sulfate Soils

The likelihood of acid sulfate soils occurring within the Project Area is very low due to its position away from the coast and potential acid sulfate landform type. Furthermore, none of the soil types mapped within the Project Area have acid sulfate soil potential.

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ASC Soil Types

FIGURE 6

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3.2.2 Soil Unit 1: Subnatric Brown Sodosol

Table 9 Summary: Brown Sodosol (Site M1)

Overview	
Landscape Site M1 	
ASC Name	Brown Sodosol
Representative Site	M1
Survey Type	Detailed
Dominant Topography	Mid slope
Vegetation	Grass pasture, eucalypt
Inherent Soil Fertility	Moderately low
Slope (%)	3
Aspect	South-west
Verified	Non-BSAL (fertility & drainage)

Table 10 Profile: Brown Sodosol (Site M1)

Profile	Horizon / Depth (m)	Description
	A1 0.0 – 0.10	Greyish brown (10YR 5/2) loamy sand, weak structure of 5-10 mm crumb peds with a rough fabric and weak consistence. Nil mottling; 10% gravel content <10 mm; nil segregations; well drained with a gradual and even boundary. Sampled 0.0 – 0.10.
	A2 0.10 – 0.30	Dark yellowish brown (10YR 4/4) bleached loam, weak structure of <10 mm crumb peds with a rough fabric and weak consistence. Nil mottling; 20% gravel content <10 mm; nil segregations; moderately drained with a clear and even boundary. Sampled 0.20 – 0.30.
	B2 +0.30	Yellowish brown (10YR 5/4) medium clay, strong structure of 20-40 mm blocky peds with a rough fabric and moderate consistence. 40% distinct yellow mottling; 10% gravel content 5-10 mm; nil segregations; poorly drained. Sampled 0.30 – 0.40. Layer continues beyond sampling depth.

Table 11 Field Parameters: Brown Sodosol (Site M1)

Layer	Field pH		Field Dispersion	Field Effervescence
	Unit	Rating	Rating	Rating
A1	6.0	Moderately Acidic	Nil	Nil
A2	6.0	Slightly Acidic	Nil	Nil
B2	8.0	Moderately Alkaline	Moderate	Nil

Soil Unit 1: Subnatric Brown Sodosol

Table 12 Summary: Subnatric Brown Sodosol (Site M2)

Overview	
Landscape Site M2	
	
ASC Name	Subnatric Brown Sodosol
Representative Site	M2
Survey Type	Detailed Lab
Dominant Topography	Mid slope
Vegetation	Grass pasture
Inherent Soil Fertility	Moderately low
Slope (%)	6
Aspect	East
Verified	Non-BSAL (fertility & drainage)

Table 13 Profile: Subnatric Brown Sodosol (Site M2)

Profile	Horizon / Depth (m)	Description
	A1 0.0 – 0.10	Very dark grey (10YR 3/1) loamy sand, weak structure of 5-10 mm crumb peds with a rough fabric and weak consistence. Nil mottling; 10% gravel content 5-10 mm; nil segregations; well drained with a clear and even boundary. Sampled 0.0- 0.10.
	A2 0.10 – 0.20	Brown (7.5YR 4/2) bleached loam, weak structure of 5-15 mm crumb peds with a rough fabric and weak consistence. Nil mottling; <5% gravel content 5-10 mm; nil segregations; well drained with an clear and even boundary. Sampled 0.10 – 0.20.
	A3 0.20- -0.40	Dark yellowish brown (10YR 4/4) loam, weak structure of 5-20 mm crumb peds with a rough fabric and weak consistence Nil mottling; <5% gravel content 5-10 mm; nil segregations; well drained with an abrupt and even boundary. Sampled 0.10 – 0.20.
	B2 +0.40	Strong brown (7.5YR 5/6) light-medium clay, strong structure of 10-30 mm blocky peds with a rough fabric and weak consistence. 20% distinct brown mottling; <5% gravel content 5-10 mm; nil segregations; poorly drained. Sampled 0.65 – 0.75. Layer continues beyond sampling depth.

Table 14 Chemical Parameters: Subnatric Brown Sodosol (Site M2)

Layer	pH (1:5 water)		ESP		ECe		Ca:Mg	
	Unit	Rating	%	Rating	dS/m	Rating	Ratio	Rating
A1	5.9	Moderately Acidic	2.7	Non Sodic	2.8	Slightly Saline	3.1	Ca Low
A2	5.8	Moderately Acidic	5.3	Non Sodic	0.4	Non-Saline	1.4	Ca Low
A3	6.2	Slightly Acidic	6.2	Marginally Sodic	0.3	Non-Saline	1.5	Ca Low
B2	7.8	Mildly Alkaline	9.1	Marginally Sodic	1.1	Non-Saline	0.9	Ca Deficient

Soil Unit 1: Subnatric Brown Sodosol

Table 15 Summary: Subnatric Brown Sodosol (Site M3)

Overview	
Landscape Site M3	
	
ASC Name	Subnatric Brown Sodosol
Representative Site	M3
Survey Type	Detailed lab
Dominant Topography	Lower slope
Vegetation	Grass pasture
Inherent Soil Fertility	Moderately low
Slope (%)	17
Aspect	North-west
Verified	Non-BSAL (fertility & drainage)

Table 16 Profile: Subnatric Brown Sodosol (Site M3)

Profile	Horizon / Depth (m)	Description
	A1 0.0 – 0.10	Dark yellowish brown (10YR 4/4) loamy sand, weak structure of 5-10 mm crumb peds with a rough fabric and weak consistence. Nil mottling; 50% gravel content 5-15 mm; nil segregations; well drained with a gradual and wavy boundary. Sampled 0.0 – 0.10.
	A2 0.10 – 0.20	Brown (7.5YR 5/3) bleached loamy sand, weak structure of 5-10 mm crumb peds with a rough fabric and weak consistence. Nil mottling; 10% gravel content 5-10 mm; nil segregations; well drained with a clear and wavy boundary. Sampled 0.10 – 0.20.
	B2 +0.20	Strong brown (7.5YR 5/6) light clay, strong structure of 10-40 mm blocky peds with a rough fabric and strong consistence. 30% distinct yellow mottling; 10% gravel content 5-10 mm; nil segregations; poorly drained. Sampled 0.30 – 0.40. Layer continues beyond sampling depth.

Table 17 Chemical Parameters: Subnatric Brown Sodosol (Site M3)

Layer	pH (1:5 water)		ESP		ECe		Ca:Mg	
	Unit	Rating	%	Rating	dS/m	Rating	Ratio	Rating
A1	6.3	Slightly Acidic	5.6	Non Sodic	0.8	Non-Saline	2.1	Ca Low
A2	6.3	Slightly Acidic	5.3	Non Sodic	0.4	Non-Saline	2.0	Ca Low
B2	6.5	Neutral	10.6	Sodic	0.7	Non-Saline	0.8	Ca Deficient

4 LSC Assessment

All sites within the Project Area were classified as LSC Class 4, as listed in **Table 18**. The exception to these are all areas of greater than or equal to 10% slope which are classified as LSC Class 5, due to the presence of sodic subsoils (Hazard 1: Water Erosion).

Table 18 Land & Soil Capability Assessment

Site	Soil Type	Hazard Criteria								LSC
	ASC Great Group	1	2	3	4	5	6	7	8	
M1	Brown Sodosol	3	4	3	4	2	4	3	1	**4**
M2	Subnatric Brown Sodosol	3	4	3	4	2	4	3	1	**4**
M3	Subnatric Brown Sodosol	5	4	3	4	2	4	3	1	**5**

Two LSC Classes were identified, dominated by 4.46 hectares of LSC Class 4 with the remaining 0.49 hectares LSC Class 5 (areas greater than or equal to 10% slope), and are summarised in **Table 19** and shown on **Figure 7**. The major assessment points are listed below.

LSC Class 4 is considered to have moderate agricultural capability with moderate to high limitations for high-impact land uses which restrict land management options for regular high-impact land uses such as cropping, high-intensity grazing and horticulture. LSC Class 4 is associated with Sodosols and comprises 90% of the Project Area.

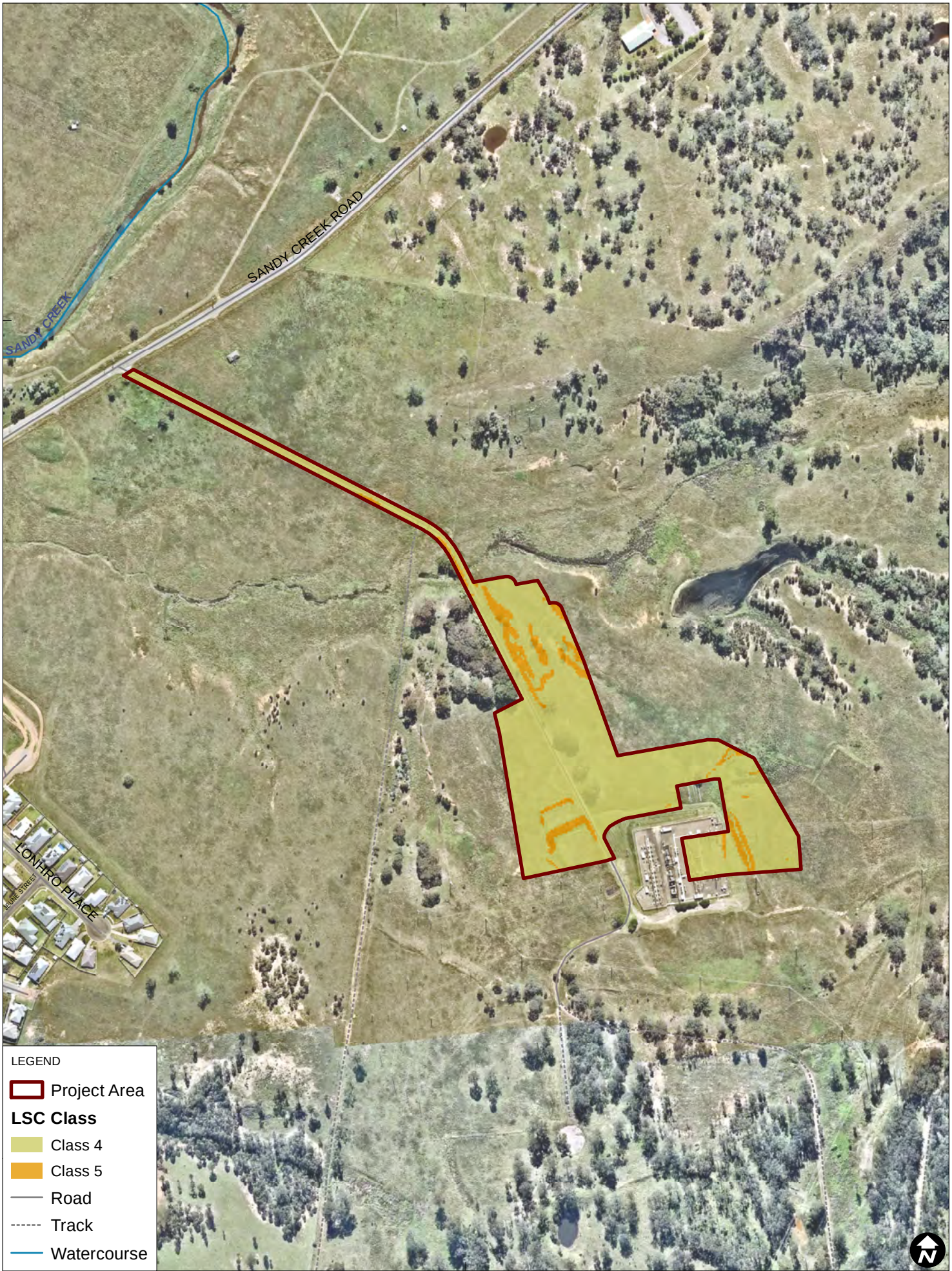
LSC Class 5 is considered to have moderate-low agricultural capability and has severe limitations for high impact land management uses such as cropping. This land is generally more suitable for grazing with some limitations or very occasional cultivation for pasture establishment. LSC Class 5 is associated with the Sodosols found on areas of greater than or equal to 10% slope and comprises 10% of the Project Area.

It should be noted that during the LSC Assessment the entire Project Area could have been classified as LSC Class 5 due to *Hazard 6: Water Logging*, however a conservative estimate was taken that the return period for waterlogging was “every 2 to 3 years” (LSC Class 4) rather than “every year” (LSC Class 5).

The entire Project Area is considered to have moderate to moderately low agricultural capability according to definitions given in *The Land and Soil Capability Assessment Scheme: Second Approximation* (OEH, 2012).

Table 19 Land and Soil Capability Class

LSC	Site	Soil Type	Limitation	Agricultural Capability Rating	Hectares
4	M1, M2	Sodosol	Water Logging	Moderate	4.46
5	M3	Sodosol	Water Logging & Water Erosion	Moderately Low	0.49
Total					**4.94**



Scale: 1:5,000 at A4
Coordinate System: GDA 1994 MGA Zone 56

Date Drawn: 07-Jul-2022
Project Number: 630.30343

SLR

Land & Soil Capability

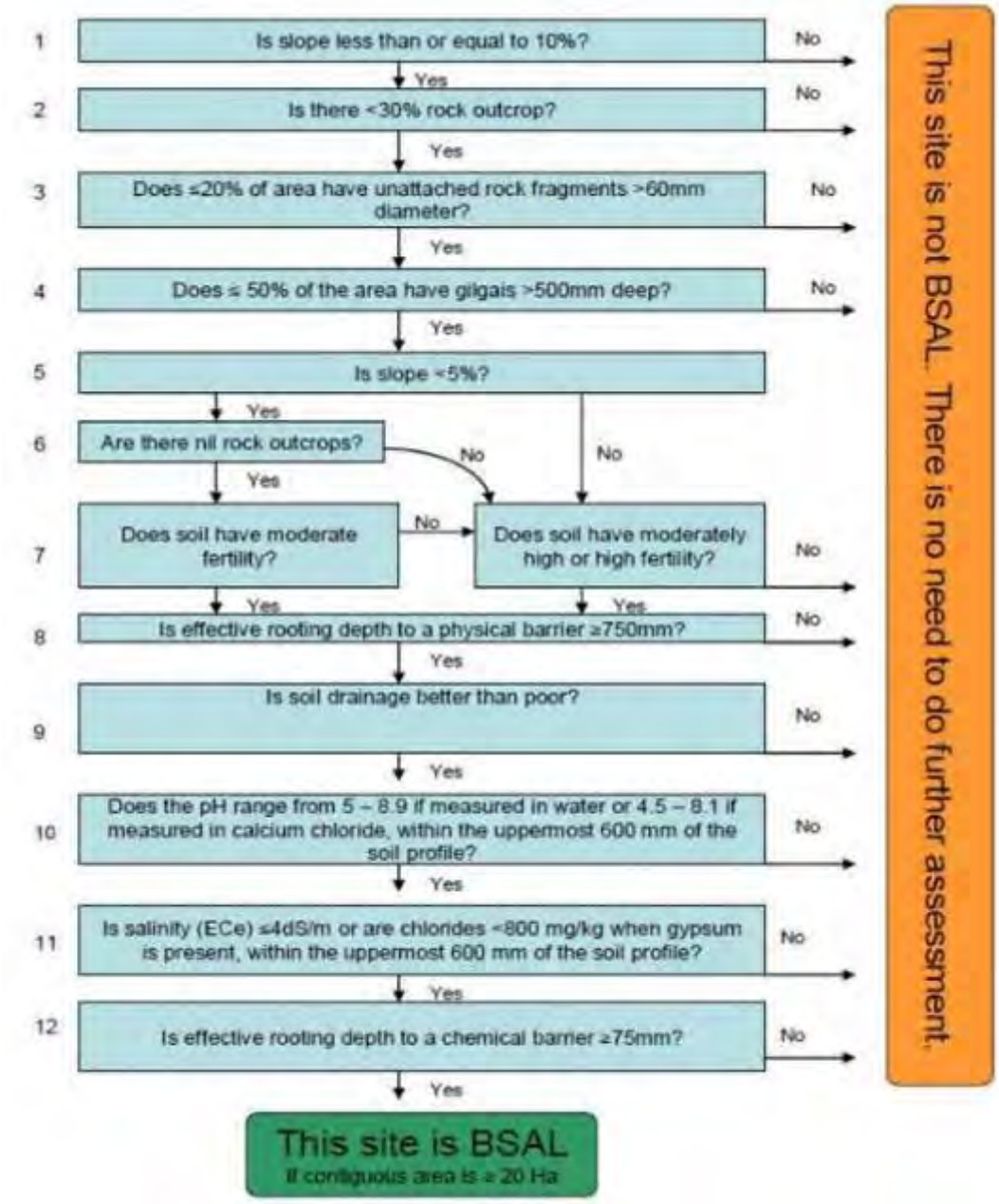
FIGURE 7

H:\Projects-SLR\630-SrvNTL\630-NTL\630.30343.00000 BESS Solar Farms Soil Assessments\06 SLR Data\01 CADGIS\GIS\SLR630303343 F07 LSC Class MWB 02.mxd

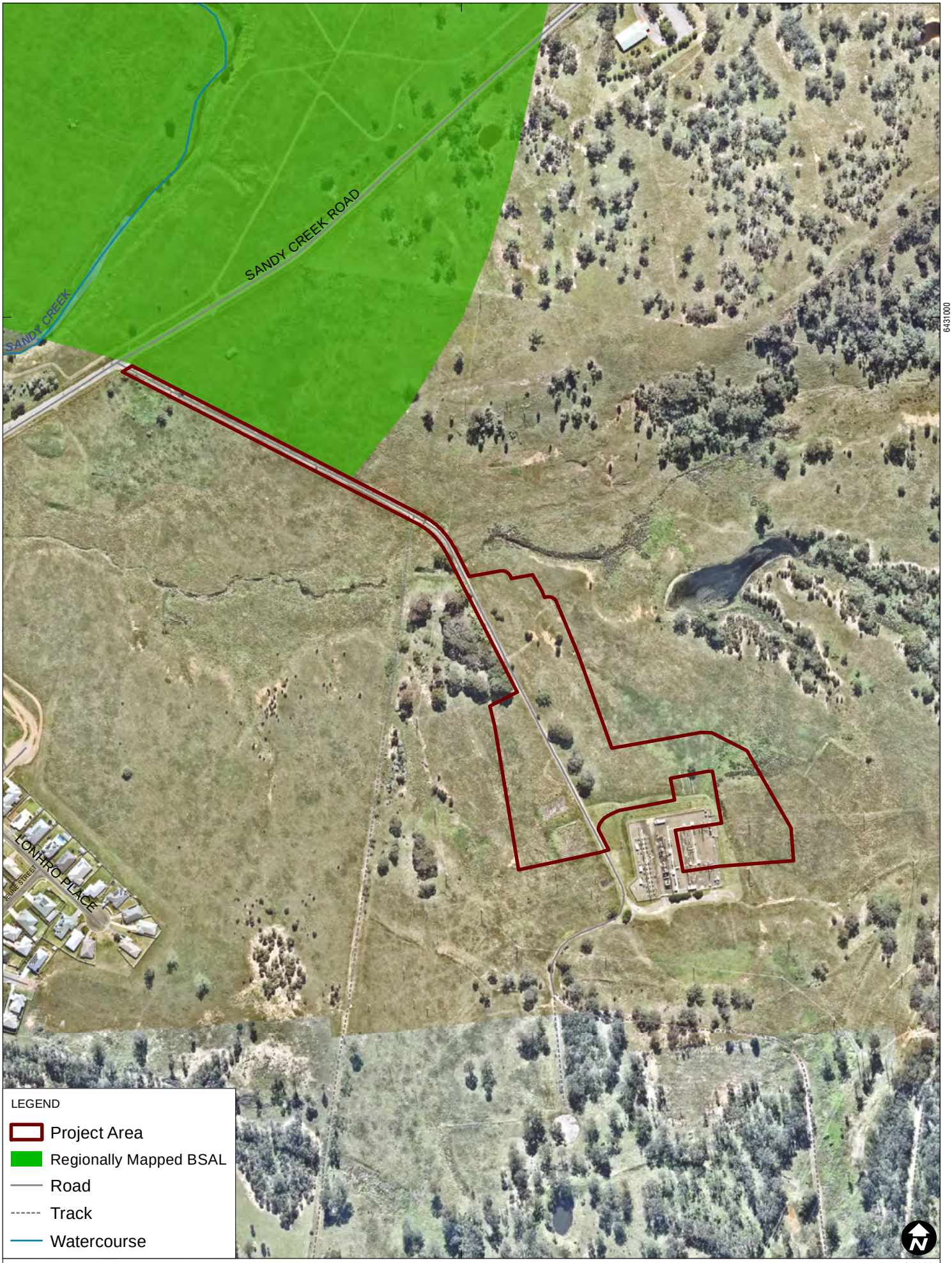
5 Preliminary BSAL Verification

According to the *Interim protocol for site verification and mapping of biophysical strategic agricultural land* (the Interim Protocol) (NSW Government, 2013), the Project Area cannot be considered biophysical strategic agricultural land (BSAL) due to failing Step 7 (moderately low inherent fertility) and Step 9 (poor drainage) on the Interim Protocol BSAL Criteria Flow Diagram shown below. There is an area of mapped BSAL outside of the development footprint (**Figure 8**).

Diagram 1 Interim Protocol BSAL Criteria Flow Diagram



Note: In applying step 12 it was assumed that the effective rooting depth to a chemical barrier of ≥75 mm was incorrect as stated in Diagram 1, and instead a value of ≥750 mm was adopted as stated in Section 6.10 of the Interim Protocol. Where soil profiles fail BSAL criteria they are shown in red font in the detailed description.


303000
6431000
SANDY CREEK ROAD
SANDY CREEK
LONHRO PLACE
JUNE STREET
LEGEND
Project Area
Regionally Mapped BSAL
Road
Track
Watercourse
0
100
200
Meters
Scale: 1:5,000 at A4
Coordinate System: GDA 1994 MGA Zone 56
Date Drawn: 05-Jul-2022
Project Number: 630.30343
Data Source:
NSW Gov
NSW Govt Mapped BSAL
FIGURE 8
H:\Projects-SLR\630-SrvNTL\630-NTL\630.30343.00000 BESS Solar Farms Soil Assessments\06 SLR Data\01 CADGIS\GIS\SLR630303343 F08 NSW Govt BSAL MWB 02.mxd

6 Soil Erosive Potential

The dispersion class and erosive potential of soils within the Project Area were determined using the Emmerson Aggregate Test (EAT), shown in **Table 20**. All soil horizons within the Project Area are classed as slightly to moderately dispersive and appropriate erosion and sediment control measures should be undertaken during construction, including the application of gypsum.

Table 20 EAT Results

Horizon	Sample Depth (cm)	EAT Score	EAT Rating	Gypsum Application
M2	0-10	4	Non-Dispersive	10 tonnes/hectare
M2	20-30	3	Slightly Dispersive	
M2	40-50	3	Slightly Dispersive	
M2	65-75	2	Moderately Dispersive	
M3	0-10	3	Slightly Dispersive	10 tonnes/hectare
M3	10-20	2	Moderately Dispersive	
M3	30-40	2	Moderately Dispersive	

7 Conclusion

SLR Consulting has completed an LSC Assessment according to *The Land and Soil Capability Assessment Scheme; Second Approximation* (OEH, 2012) encompassing the proposed Muswellbrook BESS, comprising five hectares. The LSC Assessment found 4.46 hectares of LSC Class 4 (moderate capability land) and 0.49 hectares of LSC Class 5 (moderately low capability land) within the Project Area.

A preliminary BSAL assessment found the entire Project Area is non-BSAL, and was verified as non-BSAL due to poor drainage and moderately low inherent fertility. There is no mapped BSAL within the Project Area.

The Project Area is suited to grazing and improved pastures. It is not considered highly productive agricultural land as defined in *The Land and Soil Capability Assessment Scheme; Second Approximation* (OEH 2012).

The Subnatric Brown Sodosol is classed as slightly to moderately dispersive and appropriate erosion and sediment control measures should be undertaken during construction, including the application of gypsum.

8 References

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SLR (2022) Muswellbrook BESS Surface Water Impact Assessment

State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) Amendment. (2013). NSW Government.

APPENDIX A

Slope Analysis Methodology

1st May 2022

Firm Power
BESS
LSC Assessment
SLR Slope Analysis Methodology

1. Acquire appropriate elevation information.

2. Load Contours into ArcMap 10.3

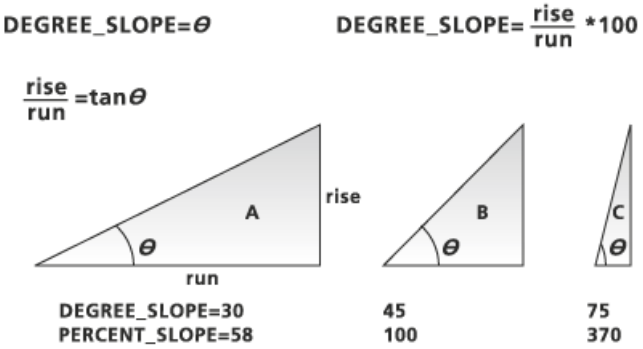
3. Using 3D Analyst Extension - Create a TIN Surface based on the contours (http://resources.arcgis.com/en/help/main/10.1/index.html#/Create_TIN/00q90000001v000000/)

4. Using 3D Analyst Extension – Run the Surface Slope Tool (http://resources.arcgis.com/en/help/main/10.1/index.html#//00q900000076000000) using a custom Break File (attached).

5. Using a Spatial Join, correlate the Surface Slope at the Soil Survey coordinates.

The Surface Slope Tool

Surface Slope creates an output polygon feature class containing polygons that classify an input TIN or terrain dataset by slope. The slope is the angle of inclination between the surface and a horizontal plane, which may be analysed in degrees or percent. Slope in degrees is given by calculating the arctangent of the ratio of the change in height (dZ) to the change in horizontal distance (dS), or slope = Arctan (dZ/dS). Percent slope is equal to the change in height divided by the change in horizontal distance multiplied by 100, or (dZ/dX) * 100.



The {**slope_field**} is the name of attribute field used to record the polygon aspect codes. Its default value is SlopeCode.

Each triangle is classified into a slope class. Contiguous triangles belonging to the same class are merged during the formation of output polygons. The {units} parameter can be set to use PERCENT or DEGREES. The default is PERCENT. The default percent slope class breaks are 1.00, 2.15, 4.64, 10.00, 21.50, 46.40, 100.00, 1000.00. Optionally, DEGREES may be used to classify slope. The default degree slope class breaks are 0.57, 1.43, 2.66, 5.71, 12.13, 24.89, 45.0, 90.0.

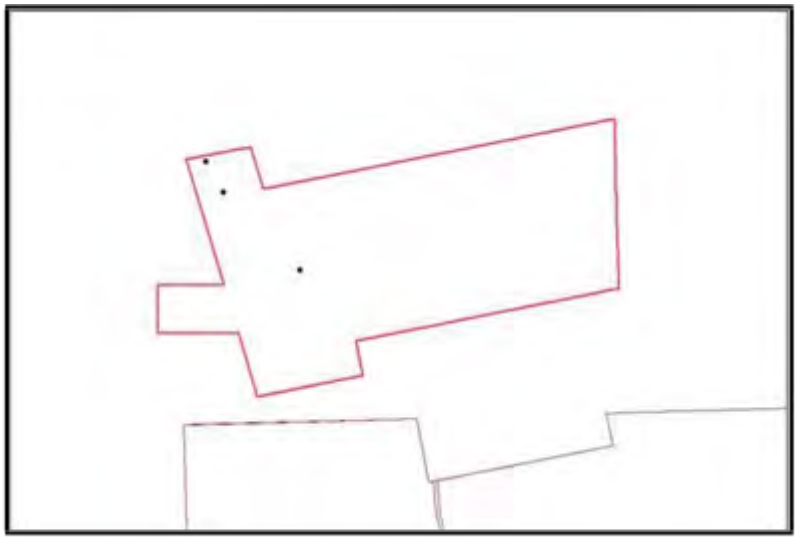
The {**class_breaks_table**} is used to define custom slope classes. The table can be either a TXT or DBF file for a Windows environment, and a DBF file in a UNIX environment. Each record in the table needs to contain two values that are used to represent the slope range of the class and its corresponding class code.

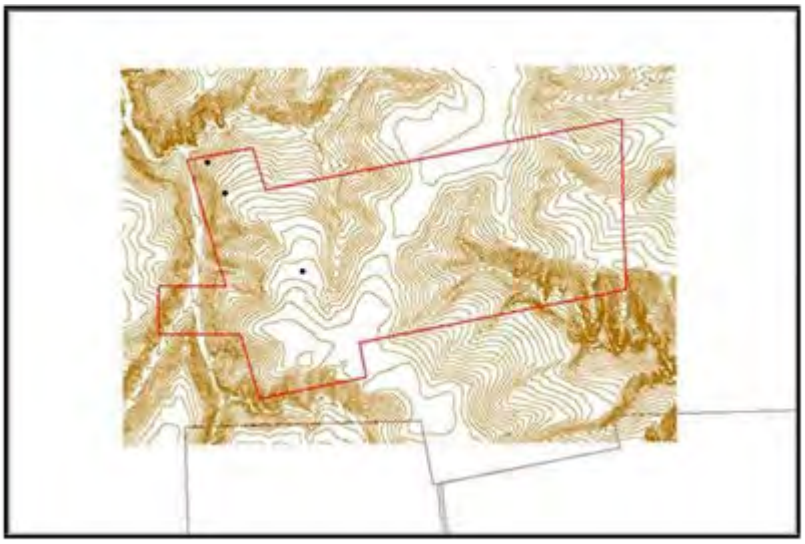
Table example:

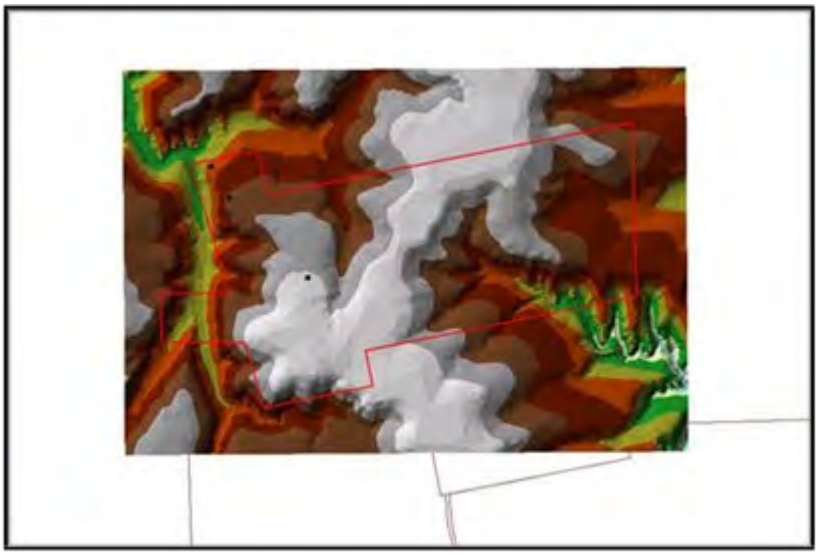
```
break, code

    10.0, 11

    25.0, 22

    40.0, 33

    70.0, 44
```

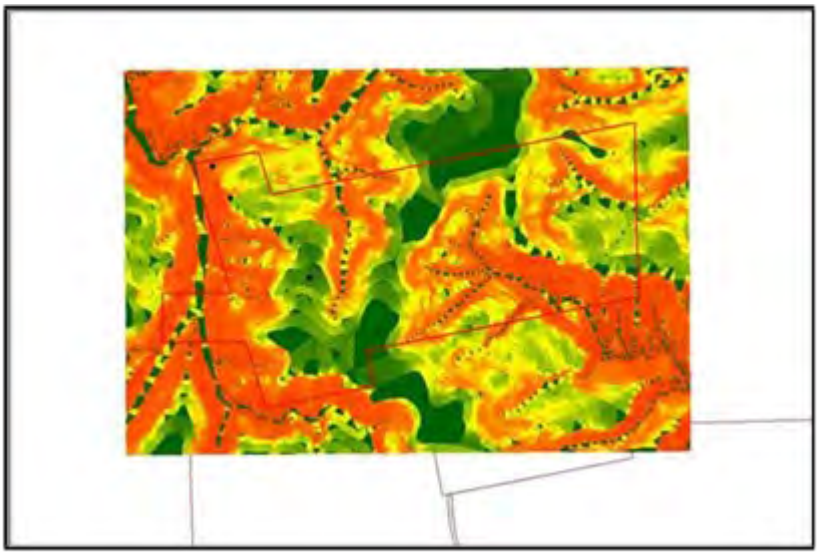
Note the comma delineation and use of decimals in the first field. Field names are needed but are ignored. The first field represents the breaks and values need to be decimal, the second field represents codes and values need to be integer. The units of the slope range are defined by the {units}. When this argument is not specified, the default classification is used.

And here is how we do it pictographically (example study shown):









APPENDIX B

Laboratory Certificate of Analysis

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AGRICULTURAL SOIL ANALYSIS REPORT

17 samples supplied by SLR Consulting Australia Pty Ltd on 12/04/2022. Lab Job No.M7681
Analysis requested by Murray Fraser. Your Job: Job Ref SLR 630.30343
10 Kings Road NEW LAMBTON NSW 2305

			Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
		Sample ID:	A1 0-10	A1 20-30	A1 40-50	A1 65-75	M2 0-10	M2 20-30
		Crop:	Soil	Soil	Soil	Soil	Soil	Soil
		Client:	Firm Power	Firm Power	Firm Power	Firm Power	Firm Power	Firm Power
	Parameter		Method reference	M7681/1	M7681/2	M7681/3	M7681/4	M7681/5	M7681/6
	pH		Rayment & Lyons 2011 - 4A1 (1:5 Water)	6.25	7.82	8.06	6.17	5.93	5.75
	Electrical Conductivity (dS/m)		Rayment & Lyons 2011 - 3A1 (1:5 Water)	0.068	0.057	0.067	0.084	0.121	0.041
	Exchangeable Calcium	(cmol$_+$/kg)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	8.5	8.0	7.7	4.3	11	4.2
		(kg/ha)		3,807	3,588	3,440	1,939	4,792	1,870
		(mg/kg)		1,700	1,602	1,536	866	2,140	835
	Exchangeable Magnesium	(cmol$_+$/kg)		3.2	1.7	1.4	2.2	3.5	2.9
		(kg/ha)		865	461	376	604	949	801
		(mg/kg)		386	206	168	270	424	358
	Exchangeable Potassium	(cmol$_+$/kg)		0.43	0.17	0.12	0.12	0.80	0.75
		(kg/ha)		377	147	<112	<112	697	656
		(mg/kg)		168	66	<50	<50	311	293
	Exchangeable Sodium	(cmol$_+$/kg)		0.33	0.19	0.17	0.15	0.42	0.46
		(kg/ha)		168	96	90	75	216	238
		(mg/kg)		75	43	40	34	96	106
	Exchangeable Aluminium	(cmol$_+$/kg)	**Inhouse S37 (KCl)	0.01	<0.01	<0.01	<0.01	0.02	0.19
		(kg/ha)		2.5	1.6	<1	<1	3.6	38
		(mg/kg)		1.1	<1	<1	<1	1.6	17
	Exchangeable Hydrogen	(cmol$_+$/kg)	**Rayment & Lyons 2011 - 15G1 (Acidity Titration)	0.10	<0.01	<0.01	0.03	0.06	0.15
		(kg/ha)		2.2	<1	<1	<1	1.4	3.3
		(mg/kg)		<1	<1	<1	<1	<1	1.5
	Effective Cation Exchange Capacity (ECEC) (cmol$_+$/kg)		**Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol$_+$/kg)	13	10	9.3	6.8	15	8.7
	Calcium (%)		**Base Saturation Calculations - Cation cmol$_+$/kg / ECEC x 100	68	80	82	63	69	48
	Magnesium (%)			25	17	15	32	23	34
	Potassium (%)			3.4	1.7	1.3	1.8	5.2	8.7
	Sodium - ESP (%)			2.6	1.9	1.9	2.1	2.7	5.3
	Aluminium (%)			0.10	0.08	0.05	0.07	0.11	2.2
	Hydrogen (%)			0.78	0.00	0.00	0.50	0.39	1.7
	Calcium/Magnesium Ratio		**Calculation: Calcium / Magnesium (cmol$_+$/kg)	2.7	4.7	5.5	1.9	3.1	1.4
	Labile Carbon (%)		**Blair 1995 - 0.333 M Potassium Permanganate	0.9	0.2	0.2	0.1	1.4	0.1
	pH		**Rayment & Lyons 2011 - 4B4 ($CaCl_2$)	5.44	7.22	7.55	5.99	5.40	4.76

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AGRICULTURAL SOIL ANALYSIS REPORT

17 samples supplied by SLR Consulting Australia Pty Ltd on 12/04/2022. Lab Job No.M7681
Analysis requested by Murray Fraser. Your Job: Job Ref SLR 630.30343
10 Kings Road NEW LAMBTON NSW 2305

			Sample 7	Sample 8	Sample 9	Sample 10	Sample 11
		Sample ID:	M2 40-50	M2 65-75	M3 0-10	M3 10-20	M3 30-40
		Crop:	Soil	Soil	Soil	Soil	Soil
		Client:	Firm Power	Firm Power	Firm Power	Firm Power	Firm Power
	Parameter	Method reference	M7681/7	M7681/8	M7681/9	M7681/10	M7681/11
	pH	Rayment & Lyons 2011 - 4A1 (1:5 Water)	6.16	7.76	6.26	6.30	6.51
	Electrical Conductivity (dS/m)	Rayment & Lyons 2011 - 3A1 (1:5 Water)	0.034	0.133	0.036	0.015	0.083
	Exchangeable Calcium (cmol$_+$/kg)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	3.2	8.3	3.0	1.5	6.8
	Exchangeable Calcium (kg/ha)		1,454	3,748	1,357	661	3,040
	Exchangeable Calcium (mg/kg)		649	1,673	606	295	1,357
	Exchangeable Magnesium (cmol$_+$/kg)		2.1	9.0	1.4	0.73	8.3
	Exchangeable Magnesium (kg/ha)		580	2,463	392	198	2,251
	Exchangeable Magnesium (mg/kg)		259	1,100	175	88	1,005
	Exchangeable Potassium (cmol$_+$/kg)		0.59	0.37	0.52	0.40	0.59
	Exchangeable Potassium (kg/ha)		513	327	455	348	517
	Exchangeable Potassium (mg/kg)		229	146	203	155	231
	Exchangeable Sodium (cmol$_+$/kg)		0.40	1.8	0.30	0.15	1.9
	Exchangeable Sodium (kg/ha)		207	922	156	79	958
	Exchangeable Sodium (mg/kg)		92	412	69	35	428
	Exchangeable Aluminium (cmol$_+$/kg)	**Inhouse S37 (KCl)	0.04	0.01	0.02	0.07	0.06
	Exchangeable Aluminium (kg/ha)		8.3	2.8	5.0	14	12
	Exchangeable Aluminium (mg/kg)		3.7	1.3	2.2	6.3	5.2
	Exchangeable Hydrogen (cmol$_+$/kg)	**Rayment & Lyons 2011 - 15G1 (Acidity Titration)	0.04	<0.01	0.04	0.05	<0.01
	Exchangeable Hydrogen (kg/ha)		<1	<1	<1	1.1	<1
	Exchangeable Hydrogen (mg/kg)		<1	<1	<1	<1	<1
	Effective Cation Exchange Capacity (ECEC) (cmol$_+$/kg)	**Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol$_+$/kg)	6.4	20	5.3	2.9	18
	Calcium (%)	**Base Saturation Calculations - Cation cmol$_+$/kg / ECEC x 100	50	43	57	51	39
	Magnesium (%)		33	46	27	25	47
	Potassium (%)		9.1	1.9	9.7	14	3.4
	Sodium - ESP (%)		6.2	9.1	5.6	5.3	11
	Aluminium (%)		0.64	0.07	0.46	2.4	0.33
	Hydrogen (%)		0.58	0.00	0.71	1.7	0.00
	Calcium/Magnesium Ratio	**Calculation: Calcium / Magnesium (cmol$_+$/kg)	1.5	0.92	2.1	2.0	0.82
	Labile Carbon (%)	**Blair 1995 - 0.333 M Potassium Permanganate	0.1	0.2	0.4	0.2	0.1
	pH	**Rayment & Lyons 2011 - 4B4 ($CaCl_2$)	5.06	7.13	5.43	5.37	5.55

GRAIN SIZE ANALYSIS (hydrometer and sieving techniques)

11 soil samples supplied by SLR Consulting Australia Pty Ltd on 12 April, 2022 - Lab Job No. M7681
Analysis requested by Murray Fraser. Your Job: Job Ref SLR 630.30343
10 Kings Road NEW LAMBTON NSW 2305

SAMPLE ID	Lab Code	EMERSON DISPERSION CLASS	MOISTURE CONTENT (% of water in sample)	TOTAL GRAVEL > 2 mm (% of total oven-dry equivalent)	GRAVEL > 4.75 mm (% of total oven-dry equivalent)	GRAVEL 2.00-4.75 mm (% of total oven-dry equivalent)	COARSE SAND 200-2000 µm (0.2-2.0 mm) (% of total oven-dry equivalent)	FINE SAND 20-200 µm (0.02-0.2 mm) (% of total oven-dry equivalent)	SILT 2-20 µm ISSS (% of total oven-dry equivalent)	CLAY < 2 µm (% of total oven-dry equivalent)
A1 0-10	M7681/1	4	23.3%	3.3%	2.0%	1.3%	35.8%	29.6%	11.6%	19.7%
A1 20-30	M7681/2	4	15.7%	23.4%	15.4%	8.0%	25.9%	31.0%	6.7%	13.0%
A1 40-50	M7681/3	4	14.0%	25.7%	23.0%	2.7%	16.0%	36.4%	9.9%	12.0%
A1 65-75	M7681/4	4	12.6%	1.9%	0.0%	1.9%	22.1%	30.8%	10.6%	34.6%
M2 0-10	M7681/5	4	29.1%	10.1%	2.9%	7.2%	28.9%	34.0%	19.6%	7.4%
M2 20-30	M7681/6	3	11.2%	1.3%	0.0%	1.3%	17.9%	44.6%	15.4%	20.8%
M2 40-50	M7681/7	3	10.9%	1.3%	0.0%	1.3%	19.6%	48.4%	15.9%	14.8%
M2 65-75	M7681/8	2	16.0%	0.7%	0.0%	0.7%	12.9%	32.3%	12.0%	42.2%
M3 0-10	M7681/9	3	12.9%	48.7%	46.0%	2.7%	6.5%	38.2%	2.8%	3.9%
M3 10-20	M7681/10	2	15.0%	10.3%	5.9%	4.4%	20.9%	57.2%	5.4%	6.2%
M3 30-40	M7681/11	2	17.2%	0.6%	0.0%	0.6%	8.8%	34.3%	18.1%	38.1%

Note:

1: The Hydrometer Analysis method was used to determine the percentage sand, silt and clay,
modified from SOP meth004 (California Dept of Pesticide Regulation), using method of Gee & Bauder (1986),
in *Methods of Soil Analysis. Part 1* Agron. Monogr. 9 (2nd Ed). Klute, A., American Soc. of Agronomy Inc., Soil Sci. Soc. America Inc., Madison WI: 383-411.

2: Australian Standard 1289.3.8.1-1997 (see attached)

3. Analysis conducted between sample arrival date and reporting date.

4. This report is not to be reproduced except in full. Results only relate to the item tested.

5. All services undertaken by EAL are covered by the EAL Laboratory Services Terms and Conditions (refer scu.edu.au/eal).

6. This report was issued on 04/05/2022.

checked: .....
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