C.2 Soil Impact Assessment

Oxley Solar Farm

Soil Impact Assessment

Oxley Solar Farm

October 2022

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Acronyms and abbreviations

µS/cm	Micro Siemens per centimetre
AC	Alternating Current
AHD	Australian Height Datum
BGL	Below Ground Level
BSAL	Biophysical Strategic Agricultural Land
CEC	Cation Exchange Capacity
DPI	Department of Primary Industries
dS/m	Deci Siemens per metre
EAT	Emerson Aggregate Test
EC	Electrical Conductivity
EIS	Environmental Impact Statement
ESCP	Erosion and Sediment Control Plan
Ha	Hectares
KM	Kilometres
kV	Kilovolt
LGA	Local Government Area
meq/100g	milliequivalents per 100 grams
m	Metres
mm	Millimetres
MW	Megawatts
MWh	Megawatt hour
NATA	National Association of Testing Authorities
PBI	Phosphorous Buffering Index
PCU	Power Conversion Units
PSA	Particle Size Analysis
PV	Photovoltaic
SIA	Soil Impact Assessment
TOC	Total Organic Carbon

1. Introduction

NGH Pty Ltd (NGH) have been engaged by Oxley Solar Development Pty Ltd (the Client) to prepare a Soil Impact Assessment (SIA) for the proposed 215 Megawatts (MW) Oxley Solar Farm (the proposal). The proposal involves the construction, operation and decommissioning of a ground-mounted photovoltaic (PV) solar array and is located on the southern side of Waterfall Way (Grafton Road), approximately 14 kilometres (km) south-east of Armidale in the New England region of NSW, refer to Figure 1-1.

This SIA describes the soil characteristics at the site of the proposal. It assesses the potential for erosion during construction, operation and decommissioning and provide a benchmark for soil condition for rehabilitation.

1.1. Purpose

The purpose of this assessment is to determine the soil characteristics and consider the potential for erosion to occur as a consequence of the development of the Oxley Solar Farm. Soil and water impacts were a key issue raised during the public exhibition of the Environmental Impact Statement (EIS; NGH 2021). The SIA has been prepared to address the agency and community concerns regarding the potential soil impacts for the proposal.

This SIA focuses on areas that are proposed to be disturbed by the construction, operation and decommissioning of the proposal. The results of this assessment would also be used as a benchmark for rehabilitation activities, during construction but also as required during operation and decommissioning of the project. Recommended mitigation measures to minimise the erosion and sedimentation risks are also included.

1.2. Key Components of the Proposal

Table 1-1 Site identification

Site identification	Details
Address	914 Gara Road, Metz 2350 NSW 972 Gara Road, Metz 2350 NSW 1352 Gara Road, Metz 2350 NSW
Affected Lot and Deposited Plan numbers	Lot 5 DP253346 Lot 2 DP1206469 Lot 6 DP625427 Lot 1 DP1206469 Lot 7003 DP1060201 Lot 7004 DP1060201
Centre co-ordinate	385586, 6616725 GDA2020 MGA56
Proposal site area	1048 hectares (ha)
Development footprint (maximum	268ha

Site identification	Details
soil disturbance area)	
Local Government Area (LGA)	Armidale Regional LGA
Current land use	Agriculture, zoned RU1 Primary Production.

Of the 1048 ha proposal site, the development footprint would represent approximately 268ha, which would be developed for the solar farm and associated infrastructure. Two existing TransGrid 132 kilovolt (kV) transmission lines run parallel to each other within the northern section of the proposal site and would be used to connect the solar farm to the national electricity grid. The primary access point during the construction and operational phases for light and heavy vehicles would be off Waterfall Way (Grafton Road), north of the site.

The indicative site layout assumes maximum development impact and includes the following key infrastructure:

- Approximately 385,280 PV solar panels mounted on either fixed or tracking systems, both of which are considered feasible:
- Fixed-tilted structures in a north orientation; or east-west horizontal tracking systems.
- Approximately 43 Power Conversion Units (PCU) composed of two inverters, a transformer and associated control equipment to convert DC energy generated by the solar panels to 33 kV alternating current (AC) energy.
- An onsite 132kV substation containing up to two transformers and associated switchgear to facilitate connection to the national electricity grid via the existing 132kV transmission lines onsite.
- Steel mounting frames with driven or screwed pile foundations.
- Underground power cabling to connect solar panels, combiner boxes and PCUs.
- Underground auxiliary cabling for power supplies, data services and communications.
- Buildings to accommodate a site office, indoor 33kV switchgear, protection and control facilities, maintenance facilities and staff amenities.
- About 1km of access track off Waterfall Way (Grafton Road) to the site which would require construction to the proposed onsite substation.
- Internal access tracks for construction and maintenance activities.
- An energy storage facility with a capacity of up to 50 megawatt hour (MWh) (i.e. 50MW power output for one hour) and comprising of lithium ion batteries with inverters.
- Perimeter security fencing up to 2.3 metres (m) high.
- Native vegetation planting to provide visual screening onsite and for specific receivers.

The construction phase of the proposal would take about 12 – 18 months. The peak construction period would be a shorter period of about six months. Approximately 300 workers would be required during the peak construction period.

The proposal is anticipated to be operational for about 30 years. Around five fulltime equivalent operations and maintenance staff and service contractors would operate the facility.

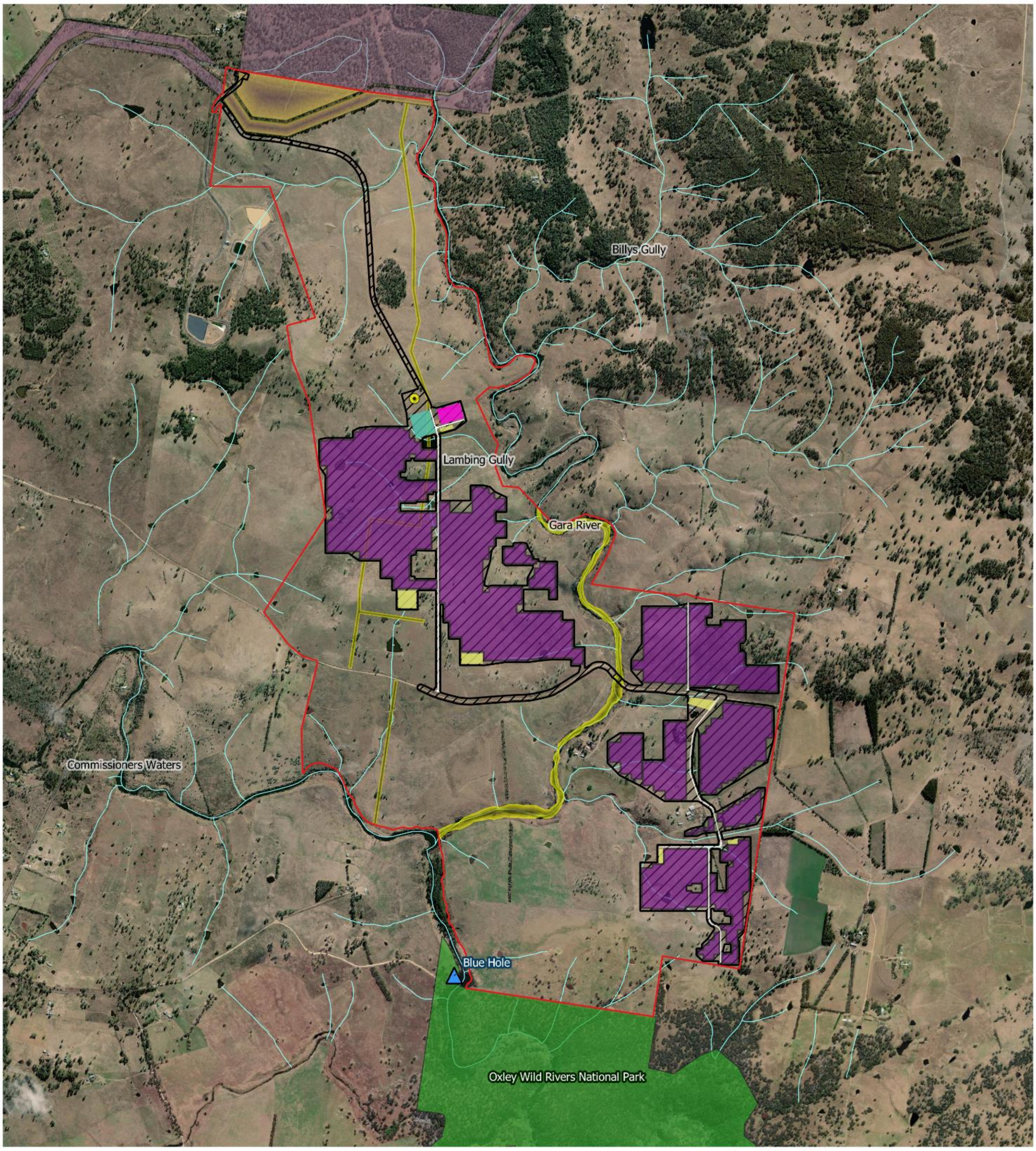
When the solar farm is no longer considered viable, the site will be returned to existing or improved land capability. All above ground infrastructure, with the possible exception of the onsite substation, would be removed. Any cabling more than 500 millimetres (mm) underground may also be left in place (as this would not impact future agricultural activities following rehabilitation of the site). Similarly, access tracks may be left in place and dependent on the future use of the site.

1.2.1. Design and Construction

Factors of the design and construction that may contribute to the erosion potential are presented in Table 1-2.

Table 1-2 Design and construction elements that contribute to the erosion potential

Factor	Input
Duration of disturbance	12 to 18 months. With a peak construction period of six months for the duration of earthworks including cable installation.
Area of disturbance	The area of construction disturbance has been estimated as 268ha. Depending on the construction methodology implemented by the construction contractor the disturbance of existing ground cover may be more or less.
Slopes	The solar arrays would be located on areas with slopes up to 23%. The greatest slopes are those on the topographic highs, to the north eastern and south western corner of the proposal site. However, slopes where solar panels would be installed are only average 3.13%. The power lines would be located along similar slopes.



Development Footprint

Legend
- Proposal site
- Development Footprint
- Waterways
- National Park
- Travelling Stock Reserves
- Crown Land within Proposal site
- Blue Hole Picnic Area

Infrastructure layout
- Array area
- BATTERY STORAGE
- CONTROL ROOM
- PV-PCU
- Shed
- Site road
- Laydown areas
- Substation
- Transmission connection point

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Ref: 21-393 Submissions and Amendment workspace 20220523 \ Development Footprint
Author: kyle.m
Date created: 19.09.2022
Datum: GDA94 / MGA zone 56

Figure 1-1 Proposal site layout

2. Soil Survey

2.1. Desktop Assessment

2.1.1. Existing Environment

The proposal site is located within the Northern Tablelands of NSW, approximately 13km east of the regional city of Armidale. The topography of the proposal site typically falls from north to south with an elevation ranging from 1015m Australian Height Datum (AHD) to 905m AHD.

The proposal site has been extensively cleared of woody vegetation and has been highly modified by historical farming practices.

Two major watercourses transect the proposal site, the Gara River in the north to south direction and Commissioners Waters in the west to east direction. Both major watercourses are 6th order streams, classified as Key Fish Habitat. These two major watercourses form a confluence on the southwestern boundary of the proposal site before entering the Gara Gorge within the Oxley Wild Rivers National Park which is located adjacent the southern boundary of the proposal site.

2.1.2. Soils and Geology

The Dorrigo-Coffs Harbour 1:250,000 geological map (Minview, 2021) indicates that the geology underlying the proposal site consists of Carboniferous sedimentary rocks for the majority of the proposal site. Within the southernmost section of the proposal site the geology consists of Permian S-type granites formed by the heating of sedimentary rocks.

The majority of the proposal site is within the New England Orogen rock unit and is comprised of Permian sedimentary and volcanic rocks. More specifically, the proposal site belongs to the following:

- Coffs Harbour Association at the northern and central section of the proposal site, which is a thick turbidite sequence dominated by siltstone that has been deformed and regionally metamorphosed to biotite grade.
- Gara Monzogranite at the southern section of the proposal site, which is Biotite monzogranite-granodiorite, amphibole, orthopyroxene and garnet bearing variants.

Seven soil landscapes occur across the proposal site and are described in Table 2-1, shown in Figure 2-1 and attached in Appendix A. Soil types are shown in Figure 2-2.

Table 2-1 Soil landscape data (eSPADE, 2021)

Soil landscape	Qualities and limitations	Typical soil erosion	Geology	Soil
Argyle (ar) Erosional	Rock outcrop (localised), steep slopes (localised), sheet erosion risk, gully erosion risk, shallow soils (localised), low general fertility (localised), dieback (localised), engineering hazard (localised).	Minor gully erosion mainly on lower slope drainage lines (gully depth <1.5m, partially stable to active). Some slopes have evidence of sheet erosion especially where overgrazing has occurred, and a protective groundcover is minimal.	Permian to Late Carboniferous Coffs Harbour Association (the Girrakool Beds) and some Devono-Carboniferous Sandon Association metasediments. In the vicinity of Argyle, greywacke is the most commonly occurring rock type with numerous outcropsand adjacent hillslopes. The greywacke/chert and related rocks are seldom deeply weathered, forming resistant outcrops which rise above the surrounding less resistant countryside. Some metamorphosed rocks, e.g., slates, phyllites, schists.	Very shallow to shallow (<50 cm), well-drained Basic Lithic Leptic Rudosols (Lithosols) and other shallow soils on crests, ridges and upper slopes. Shallow to moderately deep (40–80 cm) moderately well-drained Haplic Eutrophic Yellow Kandosols/Tenosols (Yellow Earths) on midslopes and occasionally extending onto crests. Shallow to moderately deep (<80 cm) moderately well-drained Yellow/Red and Grey Chromosols (Yellow and Red Podzolic Soils) on midslopes, footslopes and drainage lines. Mottled-Subnatric Eutrophic Brown and Yellow Sodosols (Soloths) occur along some drainage depressions.
Castledoyle (cd) Erosional	Rock outcrop, severe gully erosion risk, shallow soils (localised), sheet erosion risk, non-cohesive soils (localised), dieback, dryland salinity (localised), poor moisture availability, groundwater pollution hazard (localised).	Severe, active, slightly branched gully erosion exceeding 1.5 m in depth occurs along some drainage lines. Some incipient tunnel erosion is also evident at these sites. Elsewhere sheet erosion is commonplace. Tracks built on these soils are often degraded with sheet and rill/gully erosion evident.	Gara Adamellite comprised of biotite monzogranite.	Moderately deep (60–100 cm), moderately well-drained Haplic and Mottled Eutrophic Yellow Chromosols (Yellow Podzolic Soils) are the main soils on most slopes. Some crests, upper slopes and areas with rock outcrop have shallow, well-drained soils (<60 cm) such as Orthic Paralithic Basic Tenosols (Siliceous Sands/Earthy Sands) and Rudosols (Lithosols). Exposed gullied drainage depressions and some lower slopes have deep (>120 cm), moderately well-drained Mottled-Subnatric Eutrophic Brown and Yellow Sodosols/Haplic, Bleached-Mottled Sodic and Bleached-Mottled Eutrophic Brown and Yellow Chromosols (Soloth/Yellow Podzolic Soil intergrades). Some minor loose river sands,

Soil landscape	Qualities and limitations	Typical soil erosion	Geology	Soil
				Rudosols, occur on some drainage lines.
Commissioners Waters (cm) Alluvial	Gully erosion risk, permanently high water-tables, engineering hazard, flood hazard (localised), poor moisture availability, groundwater pollution hazard, dieback (localised), non-cohesive soils (localised).	Streambank and gully erosion on streams and depressions on parts of this landscape.	Quaternary alluvium derived primarily from metasediments (the Sandon Beds). Also some granite source rock, the Gara Adamellite and Hillgrove Adamellite, and more rarely basalt source rock (giving rise to slightly darker coloured soils).	Variable soils showing a relationship with the source rocks from which they are derived. Shallow to moderately deep (40–100 cm), well-drained Alluvial Sands and Alluvial Loams (Yellow/Brown and Grey Earths) occur in areas derived from coarse-grained parent materials. Moderately deep to deep (>80 cm), moderately well-drained Mottled Eutrophic Grey Chromosols/Grey Sodosols (Gleyed Podzolic Soils/Grey Brown Podzolic Soils/Lateritic Podzolic Soils) are fairly common. Some Haplic Eutrophic Brown Dermosols/Kandosols (Prairie Soils) are encountered along parts of Burying Ground Creek.
Ironstone (ir) Erosional/transferral	Rock outcrop (localised), high run-on, sheet erosion risk, gully erosion risk, shallow soils (localised), engineering hazard (localised), dieback.	Sheet erosion is a problem on unprotected slopes and minor gully erosion is evident along some drainage depressions.	Tertiary ferricrete/ironstone or sometimes referred to as laterite. The deposits are suggested to be either post basaltic or contemporaneous, formed from the mobilisation and concentration of iron minerals in Tertiary basaltic soil profiles. Outcrops (10–20%) comprise scattered surface strewn or surface lag deposits with a distinctly nodular or vesicular appearance which distinguish them from the adjoining basalt/chert/greywacke terrain with more massive rock outcrop (where present). The deposits are orange, red, brown or black in colour.	Shallow to very shallow (<50 cm), well-drained Rudosols (Lithosols/Structured Loams) and other shallow soils (Red Podzolic Soils) occur on crests and upper slopes. Mid to lower slopes and footslopes have moderately deep to deep (>60 cm), moderately well-drained Bleached-Sodic and Manganic Eutrophic Yellow and Brown Dermosols (Yellow and Brown Podzolic Soils) and Manganic Eutrophic Grey and Yellow Chromosols (Lateritic Podzolic Soils). Some broader footslopes and basalt-influenced footslopes have deep (>100 cm), moderately well-drained Vertosols (affinity with Black Earths) and Black Chromosols (Chocolate Soils). Some Eutrophic Yellow Dermosols (Structured Yellow Earths) and

Soil landscape	Qualities and limitations	Typical soil erosion	Geology	Soil
				Mesonatric Eutrophic Brown Sodosols (Soloths) also occur.
Long Point (variant b) (lp) Residual	Shallow soils (localised), sheet erosion risk (localised), engineering hazard (localised).	Sheet erosion (minor) is evident on exposed crests and side slopes.	Remnant basalt cappings/flows of Tertiary age. Some minor associated ferruginous sandstone/ferricrete occurs in places, e.g., Silverton and Glenross.	Moderately deep (50–100 cm), moderately well-drained Ferrosols/Dermosols (Krasnozems/Prairie Soils/Red Podzolic Soils) on crests and sideslopes. Some Black and Brown Dermosols (Chocolate Soils) near Metz/Silverton. Minor shallow (<40 cm) well-drained Rudosols (Structured Loams/Lithosols) in association with rock outcrop. Moderately deep (>70 cm), moderately well-drained Haplic, Epipedal, Black Vertosols (Chernozems/Black Earths) on some lower slopes and drainage lines (variant lpb).
Middle Earth (me) Erosional/Transferal	Groundwater pollution hazard (localised), low general fertility (localised), severe gully erosion risk (localised, lower slopes/depressions), rock outcrop (localised), sheet erosion risk, shallow soils (localised), dieback.	Severe, often branched, gully erosion is evident on some lands. Some minor tunnel erosion is occasionally associated with the gully erosion. Sheet erosion occurs especially on disturbed areas with the removal of the A1 horizon.	Sandon Beds. Greywacke is the main rock type with chert, slate and ferricrete. Some Girrakool Beds with a similar lithology underlie parts of this landscape. The soil colour at any given site reflected the bedrock from which the soil was derived, with rusty brown coloured soils associated with chert and a dusty yellow colour associated with the greywacke lithologies.	Moderately deep to deep (>70 cm), moderately well-drained Bleached-Mottled Haplic Eutrophic Yellow Kurosols and Chromosols (Yellow Podzolic Soils) are widespread. Deep (>100 cm), poorly drained Yellow Chromosols and Mottled-Mesonatric and Mottled-Subnatric Eutrophic Yellow Sodosols (Soloths) and Bleached-Manganic and Bleached-Ferric Eutrophic Yellow Chromosols (Lateritic Podzolic Soils/Grey Brown Podzolic Soils) occupy drainage depressions and poorly drained areas. Occasional shallow (<40 cm), well-drained Bleached Eutrophic Yellow Kandosols (Yellow Earths) on slopes with bedrock close to the surface.
Silverton (si)	Steep slopes, rock outcrop,	Sheet erosion occurs on	Gara Adamellite comprised of biotite	Shallow (<40 cm), well-drained Rudosols

Soil landscape	Qualities and limitations	Typical soil erosion	Geology	Soil
Erosional	rockfall hazard (localised), high run-on, sheet erosion risk, gully erosion risk, shallow soils (localised), low general fertility (localised).	most slopes. Some severe gully erosion occurs, e.g., in some of the tributaries of Herders Gully.	monzogranite.	(Lithosols/Siliceous Sands) adjacent to granite tors and on some upper to mid slopes. Shallow to moderately deep (20–60 cm), well-drained Haplic Eutrophic Yellow and Brown Kandosols (Yellow and Brown Earths) on steep slopes. Lower slopes and narrow drainage lines have moderately deep to deep (>80 cm), imperfectly drained Subnatric Eutrophic and Mesotrophic Yellow Kurosols/Chromosols/Sodosols (Yellow Podzolic Soils/Yellow Solodic Soils/Soloths).

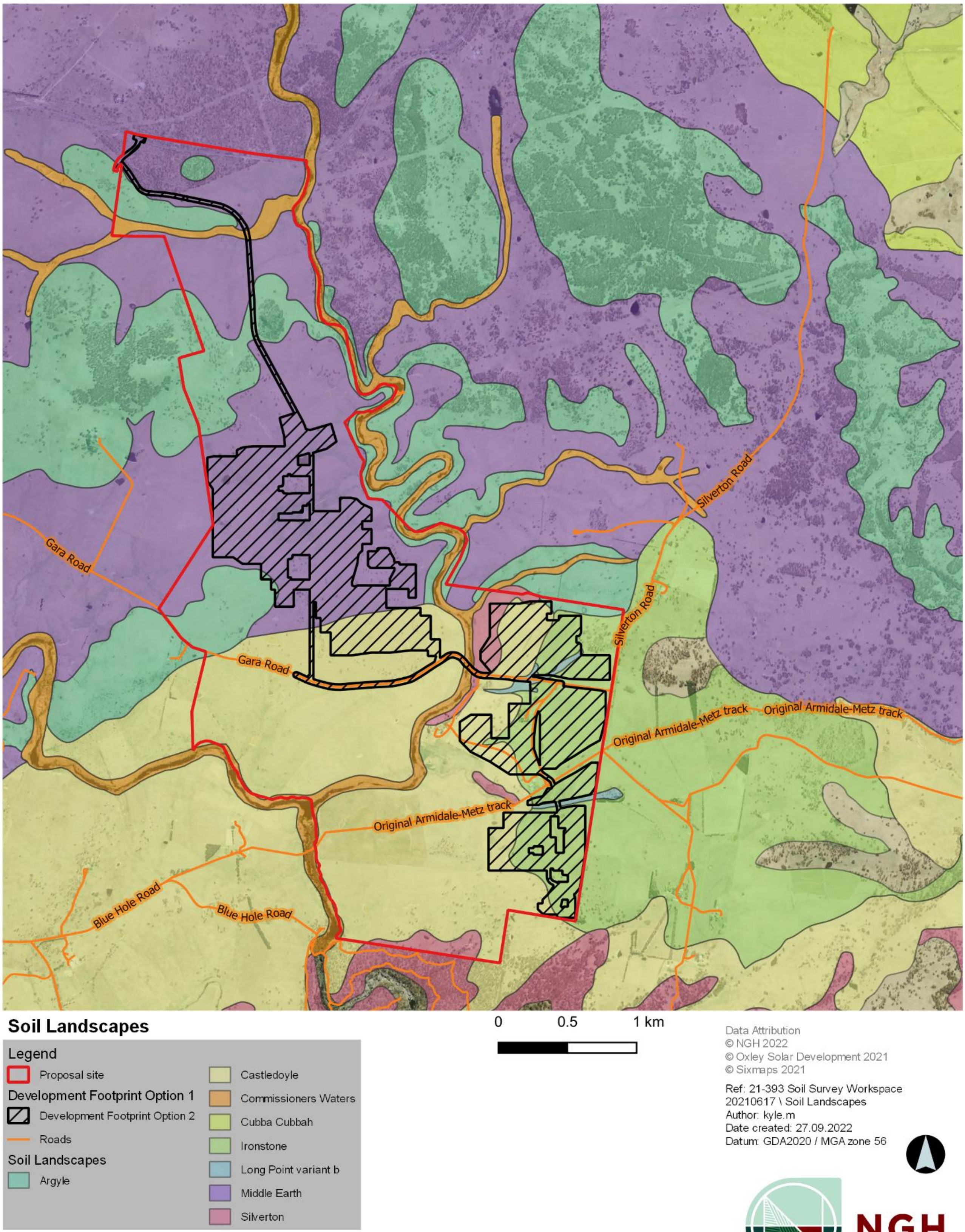

Figure 2-1 Soil Landscapes within the proposal site

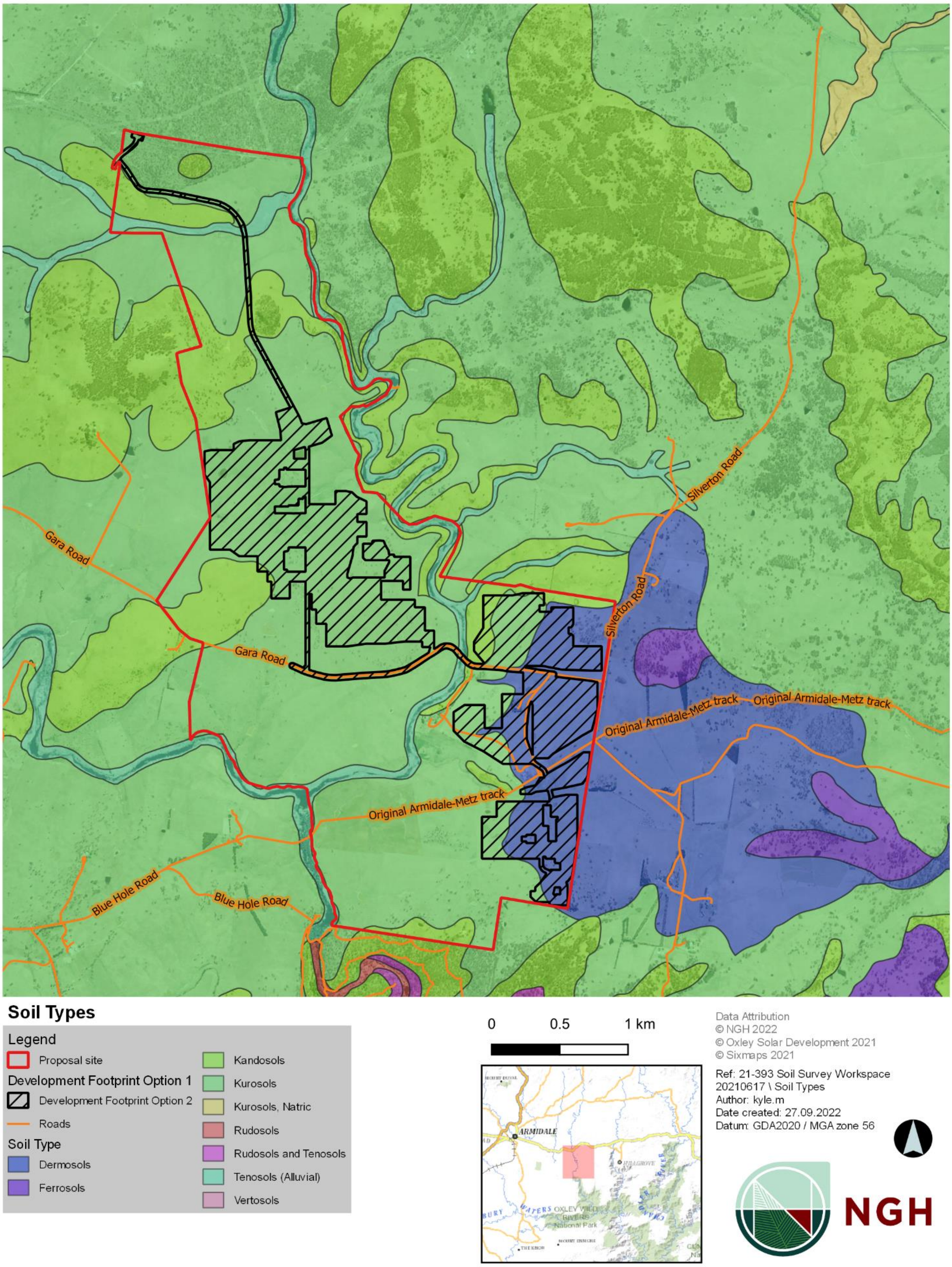

Figure 2-2 Soil Types within the proposal site

2.1.3. Land and Soil Capability Mapping

Land and soil capability (LSC) is 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 (OEH 2012). The NSW land and soil capability assessment scheme (OEH 2012) describes and maps eight land and soil capability classes. The classes range from 1 (best, highest capability land) and 8 (worst, lowest capability land). The classification is based on the biophysical features of the land and soil (including landform position, slope gradient, drainage, climate, soil type and soil characteristics) and susceptibility to hazards. Hazards include water erosion, wind erosion, soil structure decline, soil acidification, salinity, waterlogging, shallow soils and mass movement.

The proposal is located on land mapped in Capability Class 4 (moderate capability land) on the eastern portion of the proposal site, Class 5 (moderate to low capability) across the central and western portion of the proposal site, and Class 6 (low capability) within the centre of the proposal site, east of Gara River. Class 4 is defined as moderate to severe limitations for some land uses that require conscious management to prevent soil and land degradation. Class 5 is defined as having high to severe limitations for high impact land management uses. Class 6 is defined as having very severe limitations for a wide range of land uses and few management practices are available to overcome these limitations.

Table 2-2 provides an overview of Class 4, Class 5 and Class 6 under the *Land and Soil Capability Assessment Scheme* (OEH 2012). Land capability across the site is mapped in Figure 2-3.

Table 2-2 LSC class within the proposal site (OEH 2012).

Class	Broad category	Description
Class 4	Moderate capability land	Land has moderate to high limitations for high-impact land uses. Would 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.
Class 5	Low to moderate capability land	Land has high to severe limitations for high impact land management uses such as cropping. Very few land management practices can overcome this severe limitation. Land is generally more suitable for grazing and very occasional cultivation for pasture management.
Class 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.

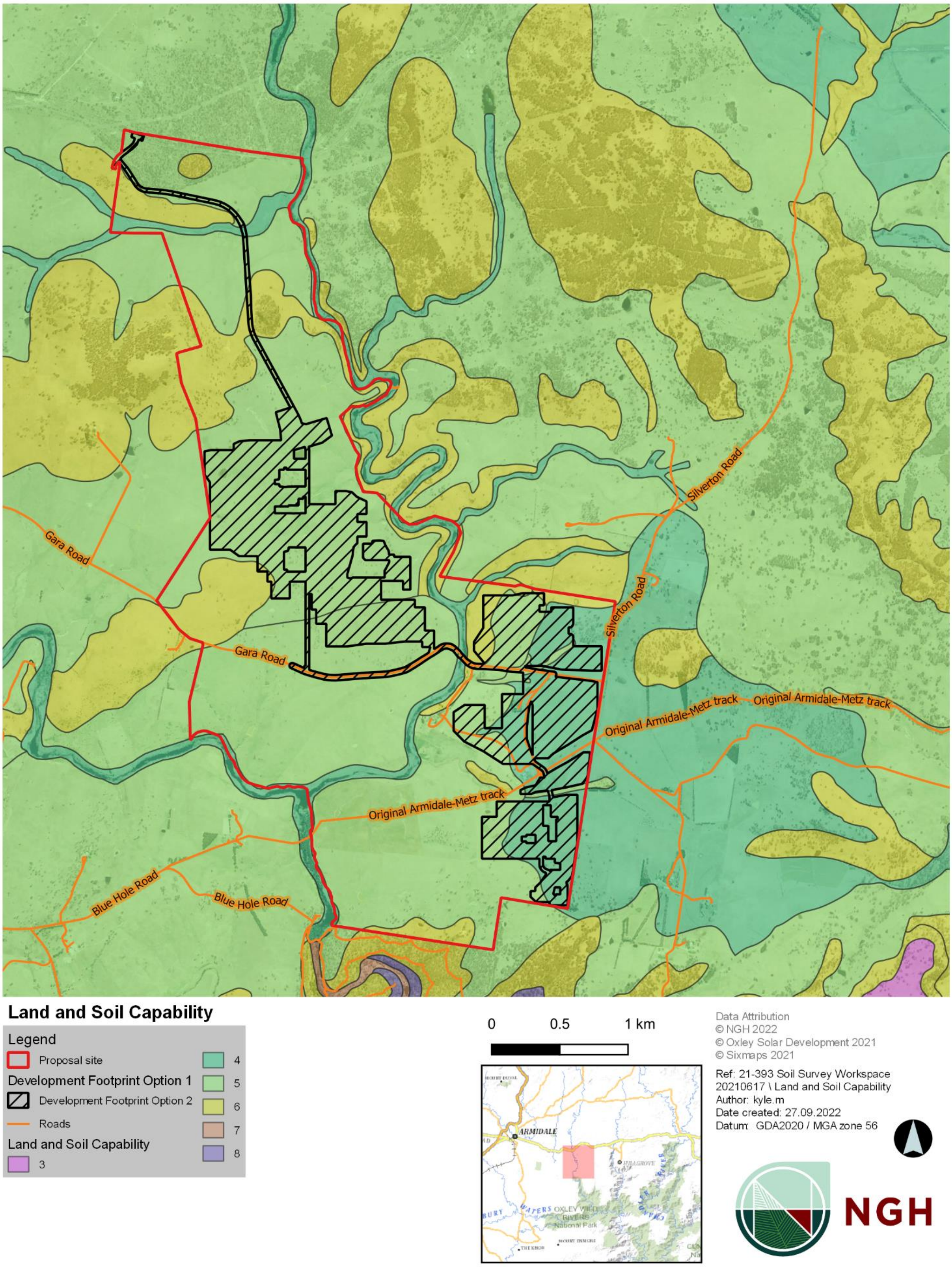

Figure 2-3 LSC within the proposal site

2.1.4. Biophysical Strategic Agricultural Land

Land mapped as Biophysical Strategic Agricultural Land (BSAL) is to ensure competing land use proposals on this category of land are managed effectively. Proposals for state significant coal seam gas or mining sites that occur on BSAL land are subject to an independent Gateway assessment of land and water impacts prior to lodgement of a Development Application. This Gateway assessment does not apply to solar farms.

The proposal site is not mapped as BSAL. The closest mapped BSAL is located 2km east of the proposal site. BSAL land is managed under the Strategic Regional Land Use Plan – New England Northwest (DPI, 2012). BSAL land features quality soil and water resources that can sustain high levels of agricultural productivity (NSW Government 2013).

No further investigation is therefore required for BSAL.

2.1.5. Acid Sulfate Soils

A search of the NSW Government eSPADE database on the 23 June 2021 (eSPADE, 2021) indicated that the proposal site is mapped with a low probability of acid sulphate soils. No further investigation is required.

2.2. Soil Sampling and Analysis

2.2.1. Sampling

The soil investigation included a drilling program completed using a four-wheel drive mounted auger. The soil sampling and classification of in situ soils was undertaken in accordance with the *Australian Soil and Land Survey Field Handbook* (CSIRO, 2009) and the *Australian Soil Classification* (Isbell, 2021). The density for number of boreholes completed was undertaken in accordance with the *Guidelines for Surveying Soil and Land Resources* (CSIRO, 2008) for a moderately high (detailed) intensity level (Table 2-3).

Table 2-3 Recommended soil survey intensity.

Intensity level	Inspection density	Publication scale	Objectives
Moderately (semi-detailed)	1 to 5 per km^2 i.e. 1 per 20 ha to 100 ha	1:50 000	Moderately intensive uses at farm level, semi-detailed project planning, district level planning

The total number of boreholes required is provided in Table 2-4.

Table 2-4 Number of boreholes required.

Description	Area/length	Survey density	No. of boreholes
Soil disturbance area	228.77 ha[1]	1 site per 20 ha	12

The location of the 12 boreholes (BH01 to BH12) are presented in Figure 2-4. The boreholes were located within the development footprint of the proposal site. They were excluded from the buffer around underground services, the archaeological sensitivity area around Gara River and identified Aboriginal Cultural Heritage places and objects.

Note: Since the SIA field work was completed, the site layout has since been reduced and BH01 no longer is located within the development footprint.

Soil logs were recorded during the soil investigation and are included in Appendix B. Photos from the soil survey are attached as Appendix C.

The maximum borehole sampling depth was to 1.0 m Below Ground Level (BGL). Shallow bedrock (sandstone/siltstone) was encountered in borehole locations located in areas higher in the landscape. In some instances, borehole depth was terminated as shallow as 0.4mBGL (BH04).

Field soil moisture was predominantly moist to wet, and gravels were not uncommon through the soil profiles across the proposal site. Field texture of topsoil was generally clay or silty clay with some sandy clays towards the south-eastern portion of the proposal site. Field texture of the subsoils was generally clay, increasing in stiffness with depth. Soil colour was assessed on site with reference to a Munsell colour chart.

The depth of each borehole and the material descriptions are included in the soil survey logs (Appendix B).

2.2.2. Site Observations

The following site observations were recorded for each Lot:

- Lot 5 DP253346 (BH01, BH03, BH04, BH05, BH09, BH10, BH11, BH12): Bedrock was encountered at shallow depths, ranging from 0.4mBGL in BH04 and 0.5mBGL in BH01. Silty/sandy clay, loose with low plasticity was observed in both boreholes on top of bedrock. Hard clay with low plasticity and gravels were observed in BH05. BH09 observed sandy clays with high plasticity, whereas BH10 and BH11 observed loose sandy clays on top of a gravelly clay with high plasticity. BH12 observed a water layer at 0.1mBGL within a soft clayey sand layer trapped on top of a hard gravel band layer at 0.7mBGL.
- Lot 2 DP1206469 (BH02): Lower lying areas (trapping moisture and soil) were observed to have a deeper soil profile with a high moisture content. Secondary layers were observed to be predominately clay with a high plasticity. No bedrock was encountered.
- Lot 6 DP625427 (BH06, BH07, BH08): Observed sandy clays with high plasticity in all boreholes, with no topsoil encountered in BH08 which was located nearby the creek. Gravelly clay was observed at 0.9mBGL in BH07.

[1] Survey area excludes roads

Refer to Image 1 to Image 22 in Appendix C for the site investigation photos.

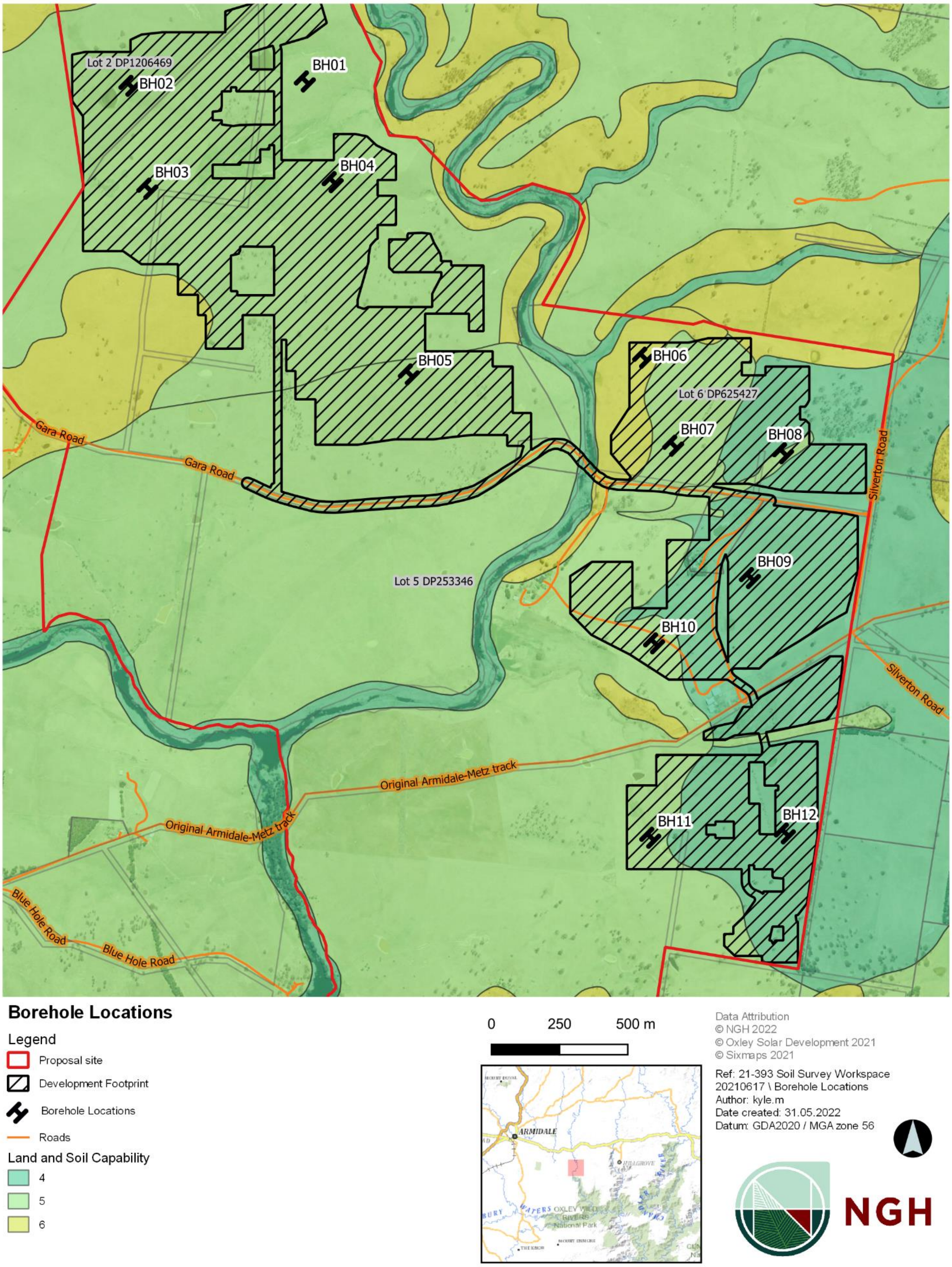

Figure 2-4 Borehole locations

2.2.3. Laboratory Analysis

Topsoil

Six topsoil samples were analysed by ALS, a National Association of Testing Authorities (NATA) accredited laboratory. The suite of analytes included:

- pH (1:5 water).
- Electrical conductivity (EC) (1:5 water).
- Chloride.
- Exchangeable Cations (Calcium, Magnesium, Sodium, Potassium) plus effective cation exchange capacity (CEC)
- Exchangeable Sodium Percentage (ESP)
- Nitrogen - Total Nitrogen as N.
- Phosphorous - Total Phosphorus as P.
- Sulfur - Total Sulfur as S.
- Total Organic Carbon (TOC).
- Phosphorous Buffering Index (PBI), analysed at Envirolab, also a NATA accredited laboratory.

Three topsoil samples were analysed for:

- Sizing - Particle Sizing to 75µm (sieve).
- Emerson Aggregate Test (EAT).

The laboratory results are included as Appendix D. A summary of the topsoil analysis is presented in Table 2-5 and Table 2-6.

Subsoil

Eleven subsoil samples were analysed by ALS, a NATA accredited laboratory. The suite of analytes included:

- pH plus EC (1:5).
- Chloride (requires 1:5 soil water leach).
- Exchangeable Cations (Ca, Mg, Na, K) plus CEC

Six subsoil samples were analysed for:

- Particle Size Analysis (PSA) to 75µm (sieve).
- EAT.

The laboratory results are included as Appendix D. A summary of the subsoil analysis is presented in Table 2-7 and Table 2-8.

Table 2-5 Topsoil sample analysis results.

Sample ID	Sample Date	pH	EC	Exchangeable Calcium	Exchangeable Magnesium	Exchangeable Potassium	Exchangeable Sodium	CEC	ESP	Total Sulfur	Chloride	Nitrate	Total Kjeldahl Nitrogen	Total Nitrogen	Total phosphorus	TOC	PBI
		-	µS/cm	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	-
BH01 0.0-0.1	30/06/2021	6	32	5.6	1.2	0.5	<0.1	7.5	1.0	<0.01	<10	3.8	1930	1930	370	0.66	46
BH02 0.0-0.1	30/06/2021	6.4	18	0.9	0.5	<0.1	0.2	1.7	10.1	0.01	<10	0.1	350	350	215	0.67	23
BH03 0.0-0.1	30/06/2021	7.5	76	5.8	3.9	0.2	0.7	10.6	6.8	0.01	630	31.3	790	820	103	0.80	42
BH04 0.0-0.1	30/06/2021	6	20	5.0	1.2	0.2	0.1	6.5	1.7	<0.1	<10	1.4	770	770	211	0.69	36
BH08-0.0-0.1	30/06/2021	7	34	31.8	21.6	0.5	0.4	54.5	0.8	0.02	<50	3.4	2000	2000	460	3.10	120
BH10 0.2-0.3	30/06/2021	6.2	22	1.3	0.5	0.2	<0.1	2.0	2.8	0.02	<10	0.9	330	330	124	0.94	7.0

Table 2-6 Topsoil sample analysis for EAT, PSA, texture and Munsell colour.

Sample ID	Sample date	EAT (class)	PSA (% fines (0.75µm))	Texture	Colour (Munsell)
BH02 0.0-0.1	30/06/2021	3	46	Light medium clay	Grayish brown (10YR 5/2)
BH08 0.0-0.1	30/06/2021	3	12	Light medium clay	Very dark brown (10YR 2/2)
BH10 0.2-0.3	30/06/2021	3	67	Silty loam	Very dark grayish brown (10YR 3/2)

Table 2-7 Subsoil sample analysis results.

Sample ID	Sample Date	pH	EC	Exchangeable Calcium	Exchangeable Magnesium	Exchangeable Potassium	Exchangeable Sodium	CEC	ESP	Chloride
		-	µS/cm	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	%	mg/kg
BH01 0.4-0.5	30/06/2021	6.8	22	9.4	2.5	0.2	0.2	12.4	1.6	20
BH02 0.5-0.6	30/06/2021	7.1	35	2.4	4.5	0.1	1.2	8.2	14.0	240
BH03 0.5-0.6	30/06/2021	7.7	161	8.6	6.4	<0.2	2.0	17.1	11.7	530
BH05 0.5-0.6	30/06/2021	6.6	14	3.6	2.7	0.4	<0.1	6.8	1.2	10
BH06 0.5-0.6	30/06/2021	6.1	32	5.9	5.8	0.2	0.7	12.6	5.4	70
BH07 0.5-0.6	30/06/2021	6.7	25	11.8	10.7	0.4	0.4	23.2	1.7	80
BH08 0.9-1.0	30/06/2021	7.6	46	29.0	20.8	0.3	0.5	50.6	0.9	<10
BH09 0.5-0.6	30/06/2021	6.2	26	9.2	11.1	0.3	0.6	21.2	3.1	620
BH10 0.5-0.6	30/06/2021	7.4	93	2.8	3.0	0.3	0.5	6.6	7.4	340
BH11 0.5-0.6	30/06/2021	7.0	21	2.0	1.4	0.2	0.1	3.8	3.9	10
BH12 0.5-0.6	30/06/2021	6.1	11	0.6	0.2	<0.1	<0.1	0.9	2.1	<10

Table 2-8 Subsoil sample analysis for EAT, PSA, texture and Munsell colour.

Sample ID	Sample date	EAT (class)	PSA (% fines (0.75µm))	Texture	Colour (Munsell)
BH03 0.5-0.6	30/06/2021	2	22	Sandy clay loam	Dark grayish brown (2.5Y 4/2)
BH05 0.5-0.6	30/06/2021	3	39	Clay loam	Strong brown (7.5YR 5/6)
BH06 0.5-0.6	30/06/2021	3	4	Light clay	Strong brown (7.5YR 5/6)
BH09 0.5-0.6	30/06/2021	3	29	Medium clay	Very dark grayish brown (10YR 3/2)
BH10 0.5-0.6	30/06/2021	3	43	Medium heavy clay	Light olive brown (2.5Y 5/3)
BH12 0.5-0.6	30/06/2021	2	68	Sandy loam	Gray (7.5YR 6/1)

3. Discussion of Results

3.1. Desktop assessment

The desktop assessment indicates that the topsoil and subsoil of the proposed development footprint is a combination of one or seven soil landscapes (refer to section 2.1.2). Soil landscapes include:

- Argyle
- Castledoyle
- Commissioners Waters
- Ironstone
- Long point
- Middle Earth
- Silverton

Streambank, gully, and sheet erosion hazards are associated with the soils in most of these soil landscapes, particularly on drainage depressions, exposed crests and side slopes. Suitable erosion and sediment control measures would be required to mitigate the potential for widespread erosion.

3.2. Laboratory assessment

The results of topsoil laboratory analysis indicate:

- Topsoil pH values ranged from slightly acidic (6.0 to 7.0) to slightly alkaline (7.0 to 8.0). Increasing soil alkalinity leads to some plant nutrients becoming unavailable. Soils may need to be treated prior to groundcover rehabilitation according to advice from an agronomist (DPI, Result Interpretation, 2004)[2].
- EC ranged 18 to 76 µS/cm, indicating low conductivity, which is consistent for the topsoil across the site. A productive soil's conductivity should be below 150 µS/cm and is a measure of salts in the soil (DPI, 2004).
- ECe has been calculated using the EC and ranged from 0.1892 to 0.6536 dS/m, indicating low salinity, which is consistent for the topsoil across the site. Increased salinity above 2 dS/m can adversely affect the growth of most plants, land use and increase soil erosion (Hazelton & Muphey, 2016).
- The CEC ranged from 1.7 to 54.5 meq/100g. CEC is the capacity of the soil to hold and exchange cations by electrical attraction and is a useful indicator of soil fertility. It demonstrates the ability of the soil to supply three important plant nutrients: Calcium, Magnesium and Potassium. The CEC is rated generally low to high for all topsoil samples analysed, with a preferred level of 10 meg/100g or above (DPI, Result Interpretation, 2004).
- Cation analysis indicates that the topsoil in some locations is within the suggest quantity for Sodium (<1.0 meq/100g), above the suggest quantity for Calcium (>5 meq/100g), and

[2] Note the source referenced uses a pH ($CaCl_2$) test rather than of pH (1:5 water) test that this report uses. When soil pH is measured in a solution of $CaCl_2$, the pH is 0.5–0.8 lower than if measured in water. The Preferable pH ($CaCl_2$) range of 5.0-5.5 would be equivalent to pH (1:5 water) 5.5-6.0 (low range) or 5.8-6.3 (high range)

below the suggest quantity generally for Magnesium (>1.6 meq/100g) and Potassium (>0.5 meq/100g) (DPI, 2004).

- Nitrate values in the topsoil range from 0.1 to 31.3 mg/kg. Generally, the soils are deficient in plant available nitrogen. These soils would likely respond well to nitrogen-based fertiliser to assist with site revegetation (Soilquality.org.au, 2021).
- PBI is the capacity of the soil to asorb Phosphorus. The values of PBI in the topsoil ranged from 7.0 to 120, which are generally rated extremely low (<7) to low (71-140).
- Topsoil in BH02 recorded 46% of particles passing through a 0.75µm sieve, and topsoil in BH08 recorded 12% of particles passing through a 0.75µm sieve. Both BH02 and BH08 had a light medium clay texture. Topsoil in BH10 recorded 67% of particles passing through a 0.75µm sieve, with a texture of silty loam. Generally, sandy and silty soils are more susceptible to soil erosion by water.
- The ESP of the topsoils generally ranged from 0.8 to 2.8%, indicating non-sodic topsoil. Highly sodic topsoils at BH02 and BH03 had an ESP result of 6.8 to 10.1% respectively. Sodic soils are dispersive and have a high susceptibility to erosion, structural problems, low infiltration and low hydraulic conductivity and hard-setting surfaces (Hazelton and Murphy 2016).
- Emerson aggregate test results indicate all topsoil samples are slightly dispersive with an EAT class of 3. The Emerson aggregate test classifies the behaviour of soil aggregates when immersed in water. The results are categorised 1 (extremely dispersive) to 8 (non-dispersive).
- The topsoil TOC content generally ranged from 0.66 to 0.94% which is extremely low to low across the site, except for BH08 which had a result of 3.10%. Total organic carbon is a measure of the carbon contained within soil organic matter. Total organic carbon above 2% is a good indicator of topsoil quality (DPI, Result Interpretation, 2004).

The results of subsoil laboratory analysis indicate:

- Subsoil pH values ranged from slightly acidic (6.0 to 7.0) to slightly alkaline (7.0 to 8.0). Increasing soil alkalinity leads to some plant nutrients becoming unavailable. Soils may need to be treated prior to groundcover rehabilitation according to advice from an agronomist (DPI, Result Interpretation, 2004)[3].
- EC ranged 11 to 161 µS/cm, indicating low conductivity, which is consistent for the subsoil across the site. A productive soil's conductivity should be below 150 µS/cm and is a measure of salts in the soil (DPI, 2004).
- ECe has been calculated using the EC and ranged from 0.0946 to 0.9338 dS/m, indicating low salinity, which is consistent for the subsoil across the site. Increased salinity above 2 dS/m can adversely affect the growth of most plants, land use and increase soil erosion (Hazelton & Muphey, 2016).
- The CEC ranged from 0.9 to 50.6 meq/100g. CEC is the capacity of the soil to hold and exchange cations by electrical attraction and is a useful indicator of soil fertility. It demonstrates the ability of the soil to supply three important plant nutrients: Calcium, Magnesium and Potassium. The CEC is rated generally low to high for subsoil samples

[3] Note the source referenced uses a pH ($CaCl_2$) test rather than of pH (1:5 water) test that this report uses. When soil pH is measured in a solution of $CaCl_2$, the pH is 0.5–0.8 lower than if measured in water. The Preferable pH ($CaCl_2$) range of 5.0-5.5 would be equivalent to pH (1:5 water) 5.5-6.0 (low range) or 5.8-6.3 (high range)

analysed, with a preferred level of 10 meg/100g or above (DPI, Result Interpretation, 2004).

- Cation analysis indicates that the topsoil in some locations is within the suggested quantity for Sodium (<1.0 meq/100g), and above the suggest quantity for Calcium (>5 meq/100g), Magnesium (>1.6 meq/100g) and below the suggest quantity for Potassium (>0.5 meq/100g).
- Subsoils ranged from 4 to 68% of particles passing through a 0.75µm sieve, with a texture ranging from sandy clay/sand/clay loams to light/medium heavy clays. Generally, sandy and silty soils are more susceptible to soil erosion by water.
- The ESP of the topsoils generally ranged from 0.9 to 3.9% in six of the subsoil samples, indicating non-sodic topsoil. Marginally sodic subsoils were recorded for BH06 and BH10 with ESP results of 5.4 to 7.4% respectively. Highly sodic subsoils were recorded at BH03 and BH02 with ESP results of 11.7 to 14.0% respectively. Sodic soils are dispersive and can lead to high susceptibility to erosion, structural problems, low infiltration and low hydraulic conductivity and hard-setting surfaces (Hazelton and Murphy 2016).
- The EAT results indicate all subsoils samples are dispersive to slightly dispersive with an EAT class of 2 and 3. The EAT classifies the behaviour of soil aggregates when immersed in water. The results are categorised 1 (extremely dispersive) to 8 (non-dispersive).

4. Conclusion and Recommendations

The results of the laboratory analysis indicate:

- The topsoil and subsoil in the north-western portion of the proposal site are consistent with the Middle Earth soil landscape. Soils include Kurosols and Sodosols. Laboratory results indicate highly sodic topsoil and subsoils in BH02 and BH03. These soils are dispersive and are highly susceptible to erosion.
- The topsoil and subsoil in the central portion of the proposal site are consistent with the Castledoyle soil landscape. Soils include Chromosols. Laboratory results indicate non sodic topsoils and subsoils. These soils non-dispersive and have a reduced likelihood of erosion.
- The topsoil and subsoil in the very central portion of the proposal site east of Gara River are consistent with the Commissioners Waters soil landscape. Soils include Kandosols and Sodosols Laboratory results indicate moderate sodic topsoils and subsoils. These soils are dispersive and are susceptible to erosion.
- The topsoil and subsoil in the eastern portion of the proposal site are consistent with the Ironstone soil landscape. Soils include brown Dermosols. Laboratory results indicate non sodic topsoils and subsoils. These soils non-dispersive and have a reduced likelihood of erosion.
- The topsoil and subsoil in the eastern portion of the proposal site are consistent with the Long Point variant b soil landscape. Soils include brown Dermosols. Laboratory results indicate non sodic topsoils and subsoils. These soils are non-dispersive and have a reduced likelihood of erosion.

As a result of the desktop assessment and the laboratory analysis the topsoil is considered to have a low to high erosion potential and the subsoil a low to high erosion potential if not stabilised. However, it is noted that the actual area of soil impacts due to excavation for solar farms is relatively low. Most of the area of impact is actually due to shading and changed run off patterns, not to excavation risks. However, with the implementation of mitigation measures recommended in section 4 the potential risk of erosion and sedimentation would be minimised. Table 4-1 summarises the potential landscape limitations for Dermosols, Kandosols, Kurosols, Sodosols, and Chromosols.

Table 4-1 Potential soil landscape limitations.

Soil type	Erosion hazard	Salinity risk	Acid Soil	Waterlogging risk	Acid Soils	Sulfate	Infrastructure stability
Dermosols	Non-dispersive, however suspectable to rill and sheet erosion when left exposed to heavy rainfall and or stream bank erosion	Low	No	Moderate	No		Little to no expansive clays, potentially at depth.

Soil type	Erosion hazard	Salinity risk	Acid Soil	Waterlogging risk	Acid Sulfate Soils	Infrastructure stability
Kandosols	Generally not dispersive, however sandy soils are susceptible to rill, sheet and stream bank erosion	Low	No	Low to moderate	No	Little to no expansive clays.
Kurosols	Tunnel and gully erosion risk, dispersive subsoils	Moderate	High	Low	No	No expansive clays.
Sodosols	Subsoils are often dispersive and/or salty.	High	Low	Poor to imperfectly drained	No	Little to no expansive clays.
Chromosols	The subsoil is non-sodic and as a result is generally not dispersive.	High	Low	Poor to imperfectly drained	No	Little to no expansive clays.

Erosion risk of construction activities would be considered low to moderate, dependent on their location within the landscape and the level of groundcover. Factors that indicate a low erosion risk are the predominantly low sodicity and salinity levels of the of the soil profiles. Moderate to high erosion risks would occur in areas where there are sodic subsoils.

5. Safeguards and Mitigation Measures

Without the implementation of erosion and sediment control measures, projects with a similar duration and area of disturbance would be considered high risk. With the implementation of the mitigation measures recommended in Table 5-1 the potential risk of erosion and sedimentation would be minimised and is considered low risk.

Table 5-1 Safeguard and mitigation measures.

Safeguard and mitigation measures	Timing
A construction Erosion and Sediment Control Plan (ESCP) should be prepared for the Proposal in accordance with Landcom Soils and Construction: Managing Urban Stormwater (2004).	Construction; Operation; Decommissioning
The design, construction and decommissioning of the proposal should minimise the extent and duration of ground disturbance and avoid disturbing steep slopes and waterways.	Construction; Decommissioning
Where ground disturbance is required the vegetation (organic matter) should be retained and reused during rehabilitation.	Construction; Decommissioning
Handling of topsoil should be undertaken when the topsoil is moist (not wet or dry) to avoid structural decline and avoid stockpiles greater than 2 m in height to prevent structural decline. It should be stripped and stockpiled separately. Stockpiles should be stabilised with a groundcover (i.e. geo-textile or similar) if stockpiling is required for more than 6 weeks.	Construction; Decommissioning
A revegetation plan (operation) and rehabilitation plan (decommissioning) should be prepared and include stabilisation and topsoil amelioration (e.g. incorporation of organic matter to improve soil structure or gypsum to improve structure, reduce hard-setting surfaces and reduce soil dispersion).	Operation; Decommissioning
Subsoils disturbed during construction and with an exchangeable sodium percentage above 6% should be treated with gypsum to increase the levels of calcium and magnesium, and thus lowering the exchangeable sodium percentage and the dispersiveness of the soil.	Construction; Decommissioning
Avoid altering the groundwater and surface water regime to prevent mobilisation of any salt stores, however low, in the soil.	Construction
Maintain at least 70% groundcover throughout the site during operation to reduce the risk of erosion.	Operation
Reference the soil survey results (this document), *Australian Soil and Land Survey Handbook* (CSIRO 2009), *Guidelines for Surveying Soil and Land Resources* (CSIRO 2008) and the *Land and Soil Capability Assessment Scheme: second approximation* (OEH 2012) when returning the site to the pre-solar farm land capability.	Decommissioning

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Appendix A Soil Landscape Data Sheets

Appendix B Soil Survey Logs

Appendix C Soil Investigation Photos

Image 1 BH01

Image 2 BH02

Image 3 BH03

Image 4 BH03

Image 5 BH04

Image 6 BH05

Image 7 BH05

Image 8 BH06

Image 9 BH07

Image 10 BH07

Image 11 BH07

Image 12 BH08

Image 13 BH09

Image 14 BH10

Image 15 BH11

Image 16 BH11

Image 17 BH12

Image 18 BH12

Image 19 Gara River - road crossing

Image 20 Rocky outcrop on Gara Road

Image 21 Centre of proposal site, facing north west

Image 22 Gara River, facing west

Appendix D Soil Laboratory Results