Appendix J

Rehabilitation and landscape management strategy

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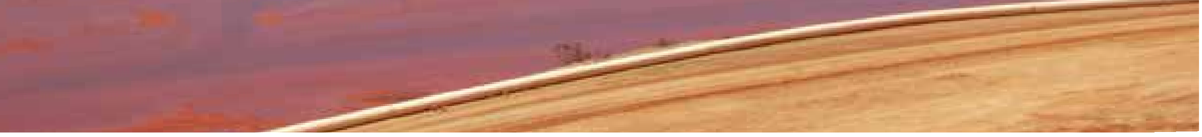


Rehabilitation and Landscape Management Strategy

Dubbo Quarry Continuation Project

Prepared for Holcim (Australia) Pty Ltd
January 2021




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Rehabilitation and Landscape Management Strategy

Dubbo Quarry Continuation Project

Report Number

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Client

Holcim (Australia) Pty Ltd

Date

14 January 2021

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v1 Final

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14 January 2021	14 January 2021

Executive Summary

This Rehabilitation and Landscape Management Strategy (the strategy) forms part of the Environmental Impact Statement to support a development application for the Dubbo Quarry; for which approval is sought under Part 4, Division 4.1 of the *NSW Environmental Planning and Assessment Act 1979*.

The Dubbo Quarry Continuation Project (the project) comprises two key components; the existing quarry where basalt rock is being quarried, processed and distributed to the market, and two proposed resource areas – the Southern Extension Area and the Western Extension Area. This report presents a rehabilitation strategy for the entire project.

The existing quarry is approximately 1.9 km west of Dubbo, within the Dubbo Regional Council local government area.

The overarching rehabilitation objective of the project is to restore the land as much as possible to its pre-quarrying land use at the end of its operational life; that is, primarily an agricultural land use comprising grazing on improved pasture while improving the biodiversity values of the area by re-establishing endemic woodland communities as part of the rehabilitation program.

There will be opportunities for progressive rehabilitation of all available disturbed areas as the quarry is developed. Wherever possible during operations, disturbed areas no longer required for quarrying activities will be progressively rehabilitated.

The project area has been divided into a series of primary and secondary domains, in accordance with ESG3 Mining Operations Plan (MOP) Guidelines (NSW Department of Trade and Investment – Division of Resources and Energy 2013). The primary domains form the basis of conceptual rehabilitation and project closure planning for this strategy. The primary domains identified across the project area are infrastructure areas, water management areas, soil stockpiles and the quarry pits. A secondary domain (ie final land use) of pasture/grazing has been assigned to all of the primary domains as well as a secondary domain of biodiversity for the pit walls and the north-eastern bank of Eulomogo Creek, and Pond 1 which will remain as a water storage.

Preliminary completion criteria have been developed for each of the domains as part of this strategy. Rehabilitation monitoring will be undertaken throughout the quarry life once rehabilitation commences and post-closure to assess progress towards meeting the criteria. Whether rehabilitation criteria have been met depends on the trending of measurements over time compared to analogue site conditions. The criteria will be refined and confirmed in a rehabilitation management plan to be prepared following approval of the project, and a detailed closure plan to be prepared as the project progresses towards closure.

Once extraction has completed, closure of the quarry will likely involve rehabilitation of the remaining unrehabilitated sections of the pits, decommissioning and removal of infrastructure and services; soil testing of potentially contaminated areas such as hydrocarbon storage areas and bitumen coating areas; and remediation or removal of any contaminated soil if required. Soil will also be tested for erosion and agronomic aspects and ameliorated as required to suit the agreed post-quarrying land use. Reshaping will be undertaken where required to blend disturbed surfaces into surrounding topography, contours scarified, and stockpiled soil applied to promote the establishment of species appropriate for the agreed post-quarrying land use.

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1 Introduction

1.1 Overview

Holcim (Australia) Pty Limited (Holcim) are the owners and operators of Dubbo Quarry (the quarry) located on Sheraton Road, Dubbo (refer Figure 1.1). The quarry has operated since 1980 under a development consent granted by Dubbo Regional Council (DRC). Accessible basalt resources within the existing quarry boundary (refer Figure 1.2) are close to exhaustion and planning approval is required to allow the quarry to continue operating. Holcim is, therefore, seeking approval for the Dubbo Quarry Continuation Project (henceforth referred to as 'the project') which involves the continued operation of the quarry through the development of two new resource areas to the south and west of the existing quarry boundary (refer Figure 1.2).

The project is classified as State significant development (SSD) under Part 4, Division 4.1 of the NSW *Environmental Planning Assessment Act 1979* (EP&A Act). This report will accompany the environmental impact statement (EIS) prepared for the project.

1.2 The site

The quarry is located within Dubbo Regional Local Government Area (LGA) approximately 1.9 kilometres (km) west of the city of Dubbo. The quarry is accessed via Sheraton Road which connects to the Mitchell Highway approximately 2 km north-west of the quarry.

The project area relates to the following land as shown on Figure 1.2:

- Lot 222 DP 1247780, owned by Holcim; and
- Part Lot 100 DP 628628, for which Holcim propose to enter into an Access Licence with the landowners.

Development consent for Dubbo Quarry was originally granted by Talbragar Shire Council on 18 March 1980 under SPR79/22 (the existing consent). This consent related to the establishment of a basalt quarry on former Portions 208 and 211, Parish Dubbo (the existing site) and contains eight conditions with no restrictions on production rates or operating hours. Holcim also holds Environment Protection Licence (EPL) No. 2212 for land-based extraction activities between 100,000 and 500,000 tonnes per annum (tpa).

The quarry produces high quality aggregates for use in the construction industry, such as concrete and asphalt production, and for use as road base. Precoated sealing aggregates from crushed basalt are produced at the quarry. The quarry produces many types of road base, both specification and non-specification, such as the premium road base product Heavy Duty DGB20 which is frequently used by local councils and Roads and Maritime Services (RMS) for the construction and upgrade of roads.

1.3 Project overview

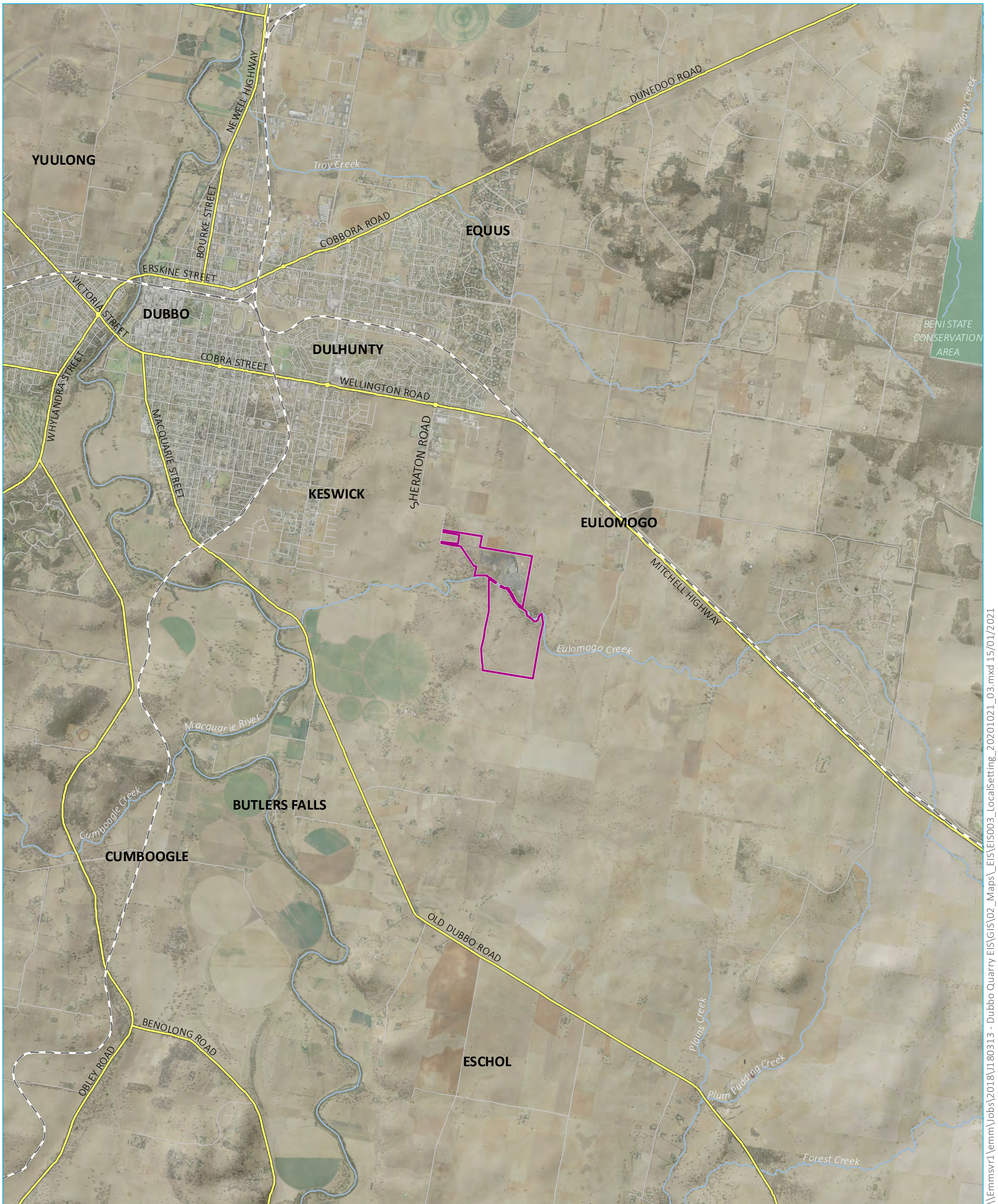
The project involves continued operations within the existing site and into two new resource areas as described below (refer Figure 1.2):

- the existing approved disturbance boundary within Lot 222 DP 1247780 which is approximately 32.5 ha in size and contains approximately 960,000 t of remaining resource;
- the Western Extension Area (WEA) which is west and north-west of the existing quarry boundary, located within Lot 222 DP 1247780 (north and south of Sheraton Road), is approximately 6.5 ha in size and contains approximately 2.24 Million tonnes (Mt) of resource; and

- the Southern Extension Area (SEA) which is south of the existing quarry boundary on the southern side of Eulomogo Creek, located within part Lot 100 DP 628628, is approximately 13.6 ha in size and contains approximately 5.17 Mt of resource.

A new haul road and crossing over Eulomogo Creek would also be constructed as part of the project to connect the existing site with the SEA. The quarry's access road, which connects to Sheraton Road, is to be relocated around the boundary of the WEA.

The existing consent for quarry operations places no restriction on production, with the existing infrastructure having the capacity to produce a maximum of 500,000 tpa. The two proposed extension areas provide sufficient resource for quarry operations to continue for approximately 20–25 years.



DFSI (2017); DFSI (2020); EMM (2020)

0 1 2 km
GDA 1994 MGA Zone 55
N

KEY

- Project area
- Rail line
- Major road
- Minor road
- Named watercourse
- NPWS reserve

Local setting

Dubbo Quarry Continuation Project
Rehabilitation and Landscape Management Strategy
Figure 1.1

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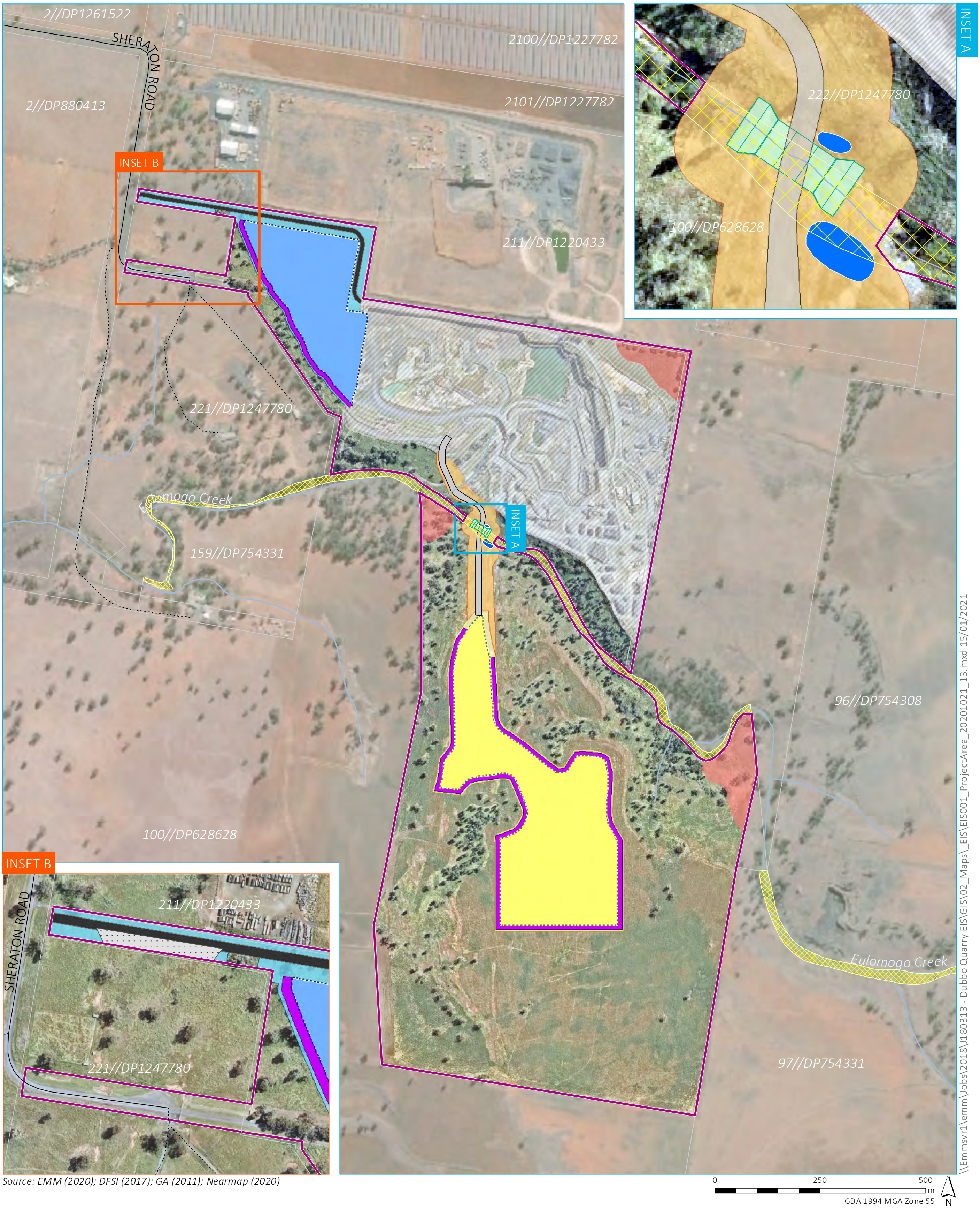

Source: EMM (2020); DFSI (2017); GA (2011); Nearmap (2020)

KEY

- Project area
- Sediment pond
- Aboriginal protection zone
- Indicative existing disturbance area
- Proposed haul road
- Indicative proposed water crossing
- Bund wall
- Proposed access road
- Truck tarping area
- Western extension area
- Western disturbance area
- Haul road disturbance area
- Southern extension area
- Southern disturbance area
- Minor road
- Vehicular track
- Watercourse/drainage line
- Waterbody
- Cadastral boundary (data does not align with surveyed site boundary)
- Crown land

Project area

Dubbo Quarry Continuation Project
Rehabilitation and Landscape
Management Strategy
Figure 1.2

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1.4 Report objectives

This Rehabilitation and Landscape Strategy has been prepared by EMM Consulting Pty Limited (EMM) to assess the potential land resources, rehabilitation and closure impacts associated with the project.

This assessment addresses the relevant Secretary's Environmental Assessment Requirement (SEARs) (refer to Section 1.5).

1.5 Secretary's Environmental Assessment Requirements

The SEARs for the project were issued on 3 April 2020. The SEARs related to land resources, rehabilitation and closure are provided in Table 1.1.

Table 1.1 SEARs land resources, rehabilitation and closure requirements

SEARs	Report section
Land Resources – including a detailed assessment of:	
• potential impacts on soils and land capability (including potential erosion and land contamination) and any proposed mitigation, management and remedial measures (as appropriate);	s. 3.3.2
• potential impacts on landforms (topography), paying particular attention to the long term geotechnical stability of any new landforms (such as overburden dumps, bunds etc); and	s.3.2.1
• the compatibility of the development with other land uses in the vicinity of the development in accordance with the requirements in Clause 12 of *State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries)* 2007, paying particular attention to the adjacent quarry and agricultural land use in the region.	Addressed in chapter 6 of the EIS
Rehabilitation – including the proposed rehabilitation strategy for the site having regard to the key principles in the *Strategic Framework for Mine Closure*, including:	
• rehabilitation objectives, methodology, monitoring programs, performance standards and proposed completion criteria;	s. 4, s.5 and s.6
• nominated final land use, having regard to any relevant strategic land use planning or resource management plans or policies; and	s.4 and s.5
• the potential for integrating this strategy with any other rehabilitation and/or offset strategies in the region	All relevant regional strategies are addressed in Chapter 3 of the EIS.

1.6 Other legislation, guidelines and leading practice

1.6.1 Legislation and environmental planning instruments

i Protection of the Environment Operations Act 1997

The *Protection of the Environment Operations Act 1997* (POEO Act) establishes the State's environmental regulatory framework and includes licensing requirements for certain activities. The objectives of the POEO Act that relate to decommissioning and rehabilitation include:

> to protect, restore and enhance the environment, to reduce risks to human health and prevent degradation of the environment.

The POEO Act objectives have been used in the preparation of this strategy and are principally reflected in one of the overarching goals of the strategy; to minimise the risk of pollution occurring from the quarry during and following closure, decommissioning and rehabilitation.

ii Dubbo Local Environment Plan 2011

The project area is zoned IN3 Heavy Industrial, RE2 Private Recreation, and RU1 Primary Production under the Dubbo Local Environment Plan (Dubbo LEP). Extractive industries are permissible with consent within the IN3 and RU1 zones. Extractive industries are prohibited within the RE2 zone. However, Section 4.38(3) of the EP&A Act states, in relation to SSD, that:

> (3) Development consent may be granted despite the development being partly prohibited by an environmental planning instrument.

The objectives of the zoning from the Dubbo LEP and applicability to this strategy are detailed in Table 1.2.

Table 1.2 Dubbo LEP 2011 objectives

Zone	Objectives	Applicability to project
IN3 Heavy industrial (current project area)	To provide suitable areas for those industries that need to be separated from other land uses	The current approved quarry is located in this zone. The objectives allow consideration of other industrial land uses within the zone.
	To encourage employment opportunities	
	To minimise any adverse effect of heavy industry on other land uses.	
	To support and protect industrial land for industrial uses	
RE2 Private recreation (western extension area)	To enable land to be used for private open space or recreational purposes	The western extension area is currently used for horse grazing. Rehabilitation of this area will not preclude private recreation.
	To provide a range of recreational settings and activities and compatible land uses.	As above
	To protect and enhance the natural environment for recreational purposes.	Woodland communities will be established on the recontoured walls of the final landform to enhance the biodiversity values consistent with this objective.

Table 1.2 Dubbo LEP 2011 objectives

Zone	Objectives	Applicability to project
RU1 Primary production (southern extension area)	To encourage sustainable primary industry production by maintaining and enhancing the natural resource base.	Quarrying of the SEA will preclude grazing at this location for approximately 25 years however the pre-quarrying LSC will be re-established.
	To encourage diversity in primary industry enterprises and systems appropriate for the area.	As above
	To minimise the fragmentation and alienation of resource lands	The proposed quarry operation and planned post-quarrying landform will not result in fragmentation or alienation of resource lands.
	To minimise conflict between land uses within this zone and land uses within adjoining zones.	There is potential for short-term conflict between grazing land-uses but the land will be rehabilitated to its pre-quarrying LSC class.
	To enable uses of an appropriate scale to facilitate the economic sustainability of primary production.	As above
	To enable function centres, restaurants and appropriate forms of tourist and visitor accommodation to be developed in conjunction with agricultural uses.	There are no agritourism based businesses or facilities within the immediate bounds of the quarry.

1.6.2 Guidelines

There are currently no recognised rehabilitation and closure guidelines for extractive industries. The nature and scale of hard rock extractive industries is similar to hard rock mining as are the phases of planning, design, operation, rehabilitation and closure. For these reasons, the following mine rehabilitation and closure planning guidelines have been considered for the preparation of this rehabilitation and landscape management strategy.

i Strategic Framework for Mine Closure

The *Strategic Framework for Mine Closure* (Australian and New Zealand Minerals and Energy Council and Minerals Council of Australia, 2000) (SFMC) was developed to promote nationally consistent mine closure management. The SFMC provides guidelines for the development of a mine closure plan to make sure that all stages of mine closure are conducted appropriately, including stakeholder engagement, development of mine closure methodology, financial planning, and implementation of mine closure. The SFMC also describes the expected standards for mine closure and relinquishment of the mine to a responsible authority. Whilst the objectives generally relate to mine closure, there are key elements that are relevant to rehabilitation of the project, in particular the allocation of appropriate resources and the establishment of rehabilitation criteria, which have been included in this strategy.

The main objectives of the SFMC that apply to the quarry are:

- to enable all stakeholders to have their interests considered during the closure process;
- to ensure the process of closure occurs in an orderly, cost-effective and timely manner;
- to ensure the cost of closure is adequately represented in company accounts and that the community is not left with a liability;

- to ensure there is clear accountability, and adequate resources, for the implementation of the closure plan;
- to establish a set of indicators which will demonstrate the successful completion of the closure process; and
- to reach a point where the company has met agreed rehabilitation criteria to the satisfaction of the Responsible Authority.

ii Mining Operations Plan Guidelines

The ESG3 – Mining Operations Plan (MOP) Guidelines, September 2013 (the MOP guidelines) (NSW Department of Trade and Investment – Division of Resources and Energy 2013) provide a process for managing and monitoring progression towards successful rehabilitation of a mine site. The guidelines provide content and formatting requirements for MOPs and Annual Reviews. The purpose of these documents is to '*ensure that all mining operations are safe, the resources are efficiently extracted, the environment is protected and rehabilitation achieves a stable and satisfactory outcome.'*

As the project will not require a mining lease, the requirements for a MOP are not triggered, this strategy has been prepared to address the various requirements of the closure and rehabilitation aspects of the MOP guidelines. In particular, rehabilitation domains have been identified as per the guidelines, as well as objectives and completion criteria for these domains.

iii Mine Rehabilitation - Leading Practice Sustainable Development Program for the Mining Industry

The aim of Mine Rehabilitation – Leading Practice Sustainable Development Program for the Mining Industry (NSW Department of Industry, Tourism and Resources, 2006) (MR Handbook) is to provide guidelines to promote 'leading practice' sustainable mine planning and rehabilitation design, considering environmental, economic, and social aspects to support on-going sustainability of a mining development. The MR Handbook recommends procedures and mitigation measures that should be considered during mine plan and rehabilitation design, including stakeholder consultation, material and handling, water balance, final landform design, soil (topsoil and subsoil) management, vegetation and fauna habitat re-establishment and rehabilitation, and agriculture/commercial forestry suitability. The MR Handbook also provides relevant mine development case studies supporting the recommended procedures and mitigation measures. Where relevant to the project, the above principals have been addressed in this strategy.

iv Mine Closure and Completion - Leading Practice Sustainable Development Program for the Mining Industry

The aim of Mine Closure and Completion – Leading Practice Sustainable Development Program for the Mining Industry (NSW Department of Industry, Tourism and Resources, 2006) (MCC Handbook) is to provide guidelines to promote 'leading practice' sustainable mine closure and completion, minimising any long-term environmental, economic, and social impacts and resulting in a suitable final land form for an agreed land use. Specifically, the MCC Handbook provides that a progressive rehabilitation plan, which is a key principle of this strategy, should be developed for mine closure.

v Managing Urban Stormwater – Soils and Construction Volume 1

The purpose of Managing Urban Stormwater – Soils and Construction Volume 1, 4th edition (Landcom 2004) is to help mitigate the impacts of land disturbance on soils, landforms and receiving waters by focusing on erosion and sediment control to:

- reduce pollution to downstream areas and receiving water; and

- reduce land degradation.

It is based on the premise that land degradation can be avoided or minimised, largely through appropriate planning before commencement of land disturbing activities and the application of best management practices using a 'treatment train' approach.

vi Managing Urban Stormwater – Soils and Construction Volume 2E Mines and Quarries

The purpose of Managing Urban Stormwater – Soils and Construction Volume 2E – Mines and quarries, Department of Environment and Climate Change 2008 (DECC 2008) is to provide guidelines, principles and recommended design standards for erosion and sediment control at mines and quarries. Specifically, it guides the user in the application of the principles and practices of erosion and sediment control described in Landcom 2004 to mines and quarries.

1.7 Adoption of leading practices

Holcim is committed to adopting leading practices in the planning, construction, operation, closure and rehabilitation of the project. This includes leading practice measures to avoid, minimise and/or mitigate potential environmental and social impacts. In relation to rehabilitation the leading practices adopted are:

- adoption of a pit wall rehabilitated slope design that avoids structural drainage and linear features that have potential to fail and are visually intrusive;
- use of topsoil/rock matrices on the reshaped pit wall slopes to provide critical shear protection, reduce runoff and encourage root penetration;
- establishing a biodiversity post mining land-use on the pit walls and north-eastern bank of Eulomogo Creek that will help account for previous clearing for agricultural purposes;
- using mineral based–biologically activated fertilizers to reduce nutrient run-off compared to chemical based fertilizers and promote beneficial soil biology in rehabilitation areas to increase root depth, drought tolerance and nutrient cycling; and
- re-establishing pre-mining Land and Soil Capability (LSC) classes within the quarry pits.

1.8 Purpose and objectives of this strategy

The purpose of this strategy is to address applicable regulatory requirements, standards and guidelines for the rehabilitation and landscape management of the quarry.

The objectives of this strategy are:

- to describe the proposed post-quarrying land use;
- identify potential risks and impacts which will impact on rehabilitation, landscape management and success;
- to describe the methods for establishing stable post-quarrying landforms; and
- to set rehabilitation criteria and outline the monitoring requirements that assess whether or not these criteria are being accomplished.

The rehabilitation concepts presented in this strategy should be regarded as provisional to allow for consideration of the outcomes from future rehabilitation trials and research, and other unforeseeable changes that may come about, for example via the quarry closure consultation phase. Final rehabilitation and project closure requirements will ultimately be formulated in consultation with key government agencies and other relevant stakeholders.

2 Rehabilitation domains

2.1 Overview

Holcim have adopted a domain based rehabilitation approach where the project area has been divided into a series of physically discrete rehabilitation domains that have similar rehabilitation requirements in accordance with the Department of Trade and Investment's guideline ESG3: Mining Operations Plan (MOP) Guidelines (September 2013) (the MOP guidelines).

2.2 Primary domains

Primary domains are based on land management units within the project area, with a unique operational and functional purpose during operation and, therefore, have similar characteristics for managing environmental issues. The primary domains form the basis of conceptual rehabilitation and project closure planning for this strategy. The primary domains that have been identified for the project, are:

1. Infrastructure areas;
2. Water management areas;
3. Soil stockpiles; and
4. Quarry voids.

The primary domains are illustrated in Figure 2.1, and the extent of disturbance per primary domain is presented in Table 2.1.

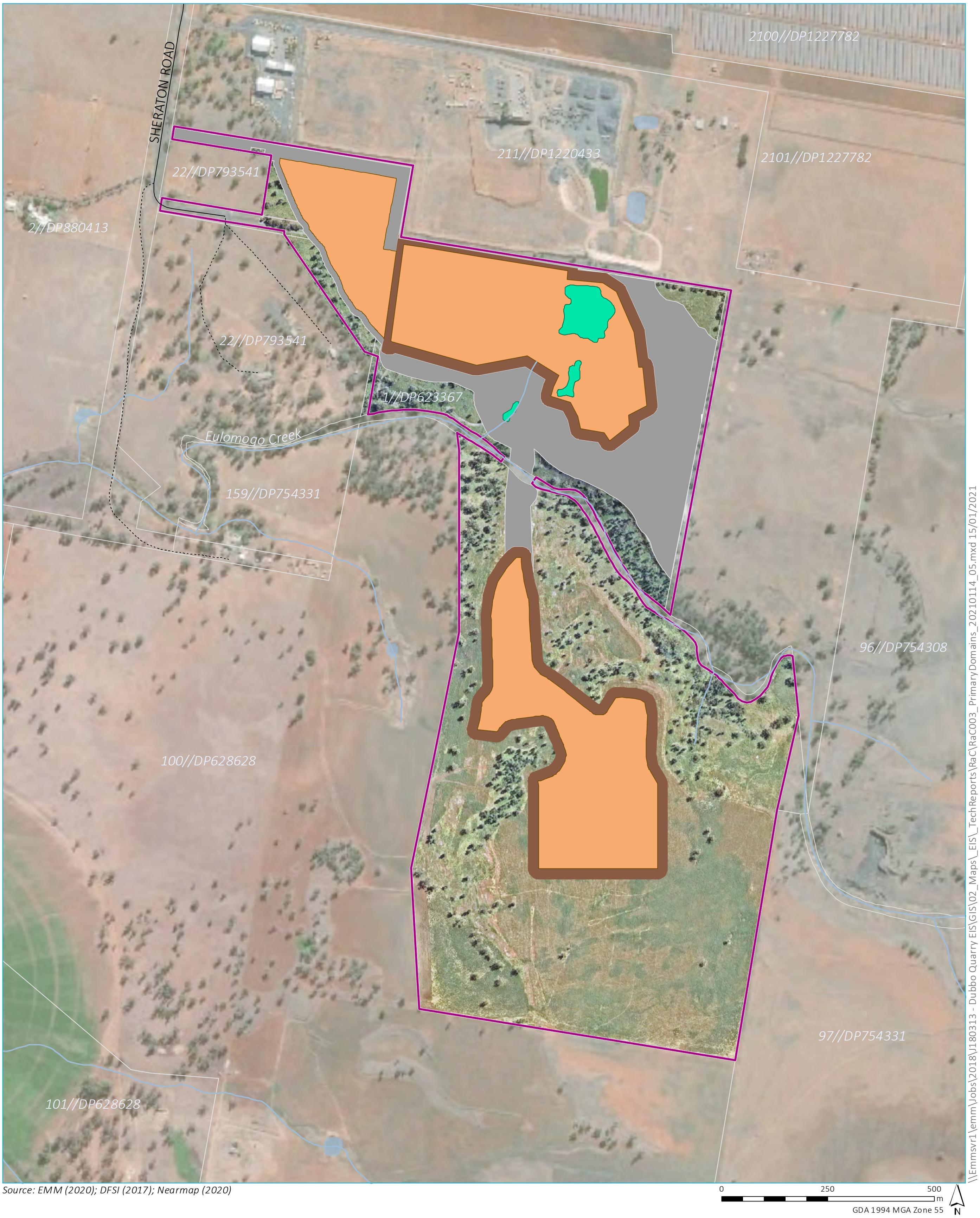
Table 2.1 Surface Infrastructure disturbance by primary domain

Primary domain	Project element	Area (ha)
1. Infrastructure areas	Crushing and screening circuits Pre-coat plant Pug mill Product stockpiles General infrastructure Access roads and haul roads Offices, carpark, workshop, stores Utilities (power line, water pipelines) Fuel storage	18.51
2. Water management areas	Pump 1 pond Pump 2 pond Settling pond Haul road sediment sumps	1.50
3. Soil stockpiles	Subsoil stockpiles for capping and amelioration to growing media Topsoil stockpiles	10.47

Table 2.1 Surface Infrastructure disturbance by primary domain

Primary domain	Project element	Area (ha)
4. Pits	West pit (existing) East pit (existing) WEA (proposed) SEA (proposed)	33.25

A description of the rehabilitation activities to be carried out in each primary domain is presented in Chapter 5.



Source: EMM (2020); DFSI (2017); Nearmap (2020)

KEY

- Project area
- Primary domains
- 1. Infrastructure area
- 2. Water management area
- 3. Soil stockpile area
- 4. Pit
- Minor road
- Vehicular track
- Watercourse/drainage line
- Waterbody
- Cadastral boundary (data does not align with surveyed site boundary)

Primary domains

Dubbo Quarry Continuation Project
Rehabilitation and Landscape Management Strategy
Figure 2.1

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3 Environmental and socio-economic risk management

3.1 Overview

Identifying environmental, social and economic risks associated with rehabilitation and closure is essential for effective closure planning.

Key risks during the rehabilitation and closure phases include:

- mineralised drainage to rock geochemistry and geotechnical instability;
- not achieving the agreed post-mining LSC classes on rehabilitated lands and post-mine land uses;
- erosion and sediment control;
- noise and dust;
- weeds;
- hydrocarbons, chemicals and wastes;
- bushfire; and
- socio-economic considerations.

3.2 Environmental risk

3.2.1 Geochemistry and geotechnical stability

Specific testing has not been undertaken for potential acid rock drainage (ARD) as the Tertiary` alkali basalt rock chemistry does not include elements that can oxidise to form ARD and mobilise heavy metals. Basalt is commonly pulverised as the basis for mineral based fertilisers for agronomic and revegetation purposes (Carson et al 2012).

Testing of a site sample by Geochempet Services (Geochempet 2019) summarised the sample to be:

- basalt (a basic volcanic rock type);
- finely crystalline and variably glassy;
- contains < 1% of vesicles;
- unweathered to slightly weathered;
- fresh to lightly altered;
- 5% green to yellow smectite clay, 1% zeolite and <1% iddingsite and calcite;
- hard (not easily scratched); and

- strong (resistant to permanent deformation by flow or fracture).

Geochempet 2019 determined that the rock is suitable for use as concrete aggregate, is predicted to be suitable for use in road base, asphalt/sealing aggregate (subject to bitumen stripping and polishing tests) and rail ballast (subject to compliance with Durability Criteria of CT147/AS2758.7).

They predicted it to be suitable for use as rip rap and marine armour rock, provided blocks of sufficient size can be obtained free of weak or permeable joint and other penetrative defects.

There has been one high wall failure that occurred at the eastern end of the west pit on 8 February 2019 via a stepped downwards slide of the rock mass. The trigger mechanism was assumed to be rainfall entering via tension cracks and reducing shear resistance along the sliding plane (GHD 2019). A Ground Control Plan prepared for the quarry in 2017 by Xstract mining consultants 2017 interpreted the eastern wall as being close to the margin of the channel into which the lava flowed to form the basalt. It was inferred that the contact between the basalt and the lithic sandstone was moderately to steeply dipping to the west (into the pit) and was a relatively narrow zone approximately 1 m thick.

Based on observations of the highwall failure, GHD 2019 confirmed that is was likely due to translational sliding along the altered basalt-sandstone contact.

Xstract 2017 stated that the rock mass exposed in the existing west pit is typically high strength (50 to 100 MPa estimate) for the fresh rock materials. To minimise geotechnical hazards, such as rock falls and slides to quarry workers in the pit, Xstract 2017 recommended a maximum batter height, minimum berm width of 10 m and maximum face angle between 70° and 80° depending on the location within the west pit and the orientation of joints and faults to:

- working benches;
- terminal benches; and
- terminal pit walls, from crest to toe over multiple benches.

During rehabilitation, completed pit faces will be blasted to form an overall slope gradient of 1(v) to 3(h) or 32° which is consistent with rehabilitation practices currently undertaken on site (Photograph 3.1).

Photograph 3.1 Existing rehabilitation west pit

There is no evidence of slope failure or erosion on the existing rehabilitation areas on site that have been in place since 2010.

3.2.2 Land and soil capability

i LSC classes

The LSC classes of the project area were determined as part of the Land and Soil Capability Assessment undertaken for the project (Landloch 2019), in accordance with the Land and Soil Capability Assessment Scheme – second approximation (LSC Assessment, OEH 2012) (refer Appendix A).

The LSC assessment classifies land into one of eight classes (Table 3.1). These classes give an indication of what the land can be used for without causing land and soil degradation.

Table 3.1 Land and soil capability classes (OEH 2012)

LSC Class	Description
Land capable of wide variety of uses (cropping, grazing, horticulture, forestry, nature conservation)	
1	Extremely high capability land: Land has no limitations. No special land management practices required. Land capable of all rural 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 limitations
Land capable of a variety of land uses (cropping with restricted cultivation, pasture cropping, grazing, some horticulture, forestry, nature conservation)	
4	Moderate land 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 will need to be carefully managed to prevent long-term degradation.
Land capable of a limited set of land uses (grazing, forestry, nature conservation and 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 agriculture land use (selective forestry, 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: Limitations are so severe that land is incapable of sustaining any land use apart from nature conservation. There should be no disturbance of native vegetation.

Five soil mapping units (SMU's) were mapped by Landloch 2019 for the project area (s.3.2.2 ii a). The ratings for individual LSC hazards and limitations relative to each SMU are provided in Table 3.2.

Table 3.2 LSC hazard assessment

Hazard/limitation	Soil Mapping Unit				
	Southern extension areas			Western extension area	
	A	B	C	D	E
Water erosion	2	3	4	2	3
Wind erosion	1	1	2	1	1
Soil structural decline	2	2	2	2	2
Soil acidification	2	2	2	2	2
Salinity	1	1	1	1	1
Waterlogging	2	2	2	2	2
Shallow soils and rockiness	5	5	6	2	3
Mass movement	1	1	1	1	1
LSC Class	5	5	6	2	3

For SMUs A and B, Landloch 2019 determined that the LSC class for shallow rock was between class 4 and 6 and was, therefore, overall assessed as class 5.

Mapping of LSC classes for the project area is provided in Figure 3.1.

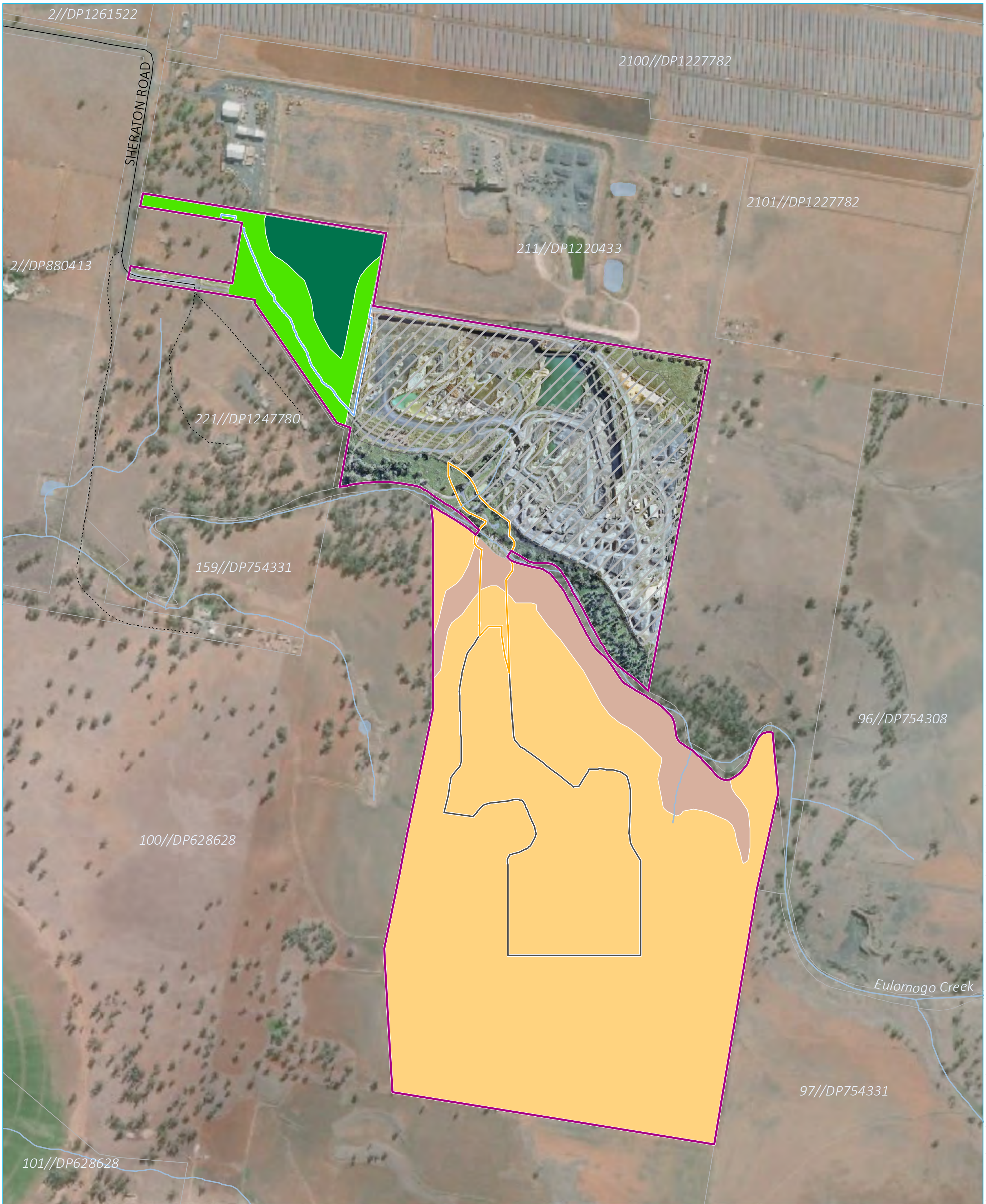
The WEA has LSC class 2 and class 3 land which is capable of most land uses including cropping with cultivation, grazing, horticulture, forestry and nature conservation. The current land-use is horse grazing.

The SEA has LSC class 5 and class 6 land. Land use is primarily limited to grazing, forestry, nature conservation, and very occasional cultivation for (dryland) pasture establishment. The current land-use for the LSC class 5 is grazing for dairy cattle which includes cultivated for irrigated improved pasture and no significant land degradation was identified by Landloch in this area.

Landloch 2019 identified that the primary limitation for the SEA is shallow soils and rockiness. The area identified as LSC class 6 (Figure 3.1) has widespread rock outcrops that cover an estimated 30-50% of this LSC class and the soil depth is 0.3-0.7m. The area identified as LSC class 5 (Figure 3.1) has localised rocky outcrops (<30% coverage) and the soil depth is 0.25–0.8m.

The key limiting factor for re-establishing the pre-mining LSC classes on rehabilitation areas will be the availability of sufficient soil resources particularly in the SEA where soils are shallow (s.3.3.3 ii).

If necessary, soil or other suitable materials with applicable waste exemptions will be imported to site to ensure sufficient depth of soil. Figure 3.2 shows the proposed post quarrying LSC classes.



\\Emmsvr1\emm\Jobs\2018\J180313 - Dubbo Quarry EIS\GIS\02_Maps_EIS_TechReports\RaC\RaC004_ LandSoilCapability_20201215_03.mxd 15/01/2021

Source: EMM (2019); DFSI (2017); Nearmap (2020)

0 250 500 m

GDA 1994 MGA Zone 55

N

KEY

- Project area
- Western disturbance area
- Haul road disturbance area
- Southern disturbance area
- Indicative existing disturbance area

Land and soil capability

- Very high capability land
- High capability land
- Moderate-low capability land
- Low capability land

- Watercourse/drainage line
- Waterbody
- Minor road
- Vehicular track
- Cadastral boundary (data does not align with surveyed site boundary)

Existing land and soil capability classes

Dubbo Quarry Continuation Project
Rehabilitation and Landscape Management Strategy
Figure 3.1

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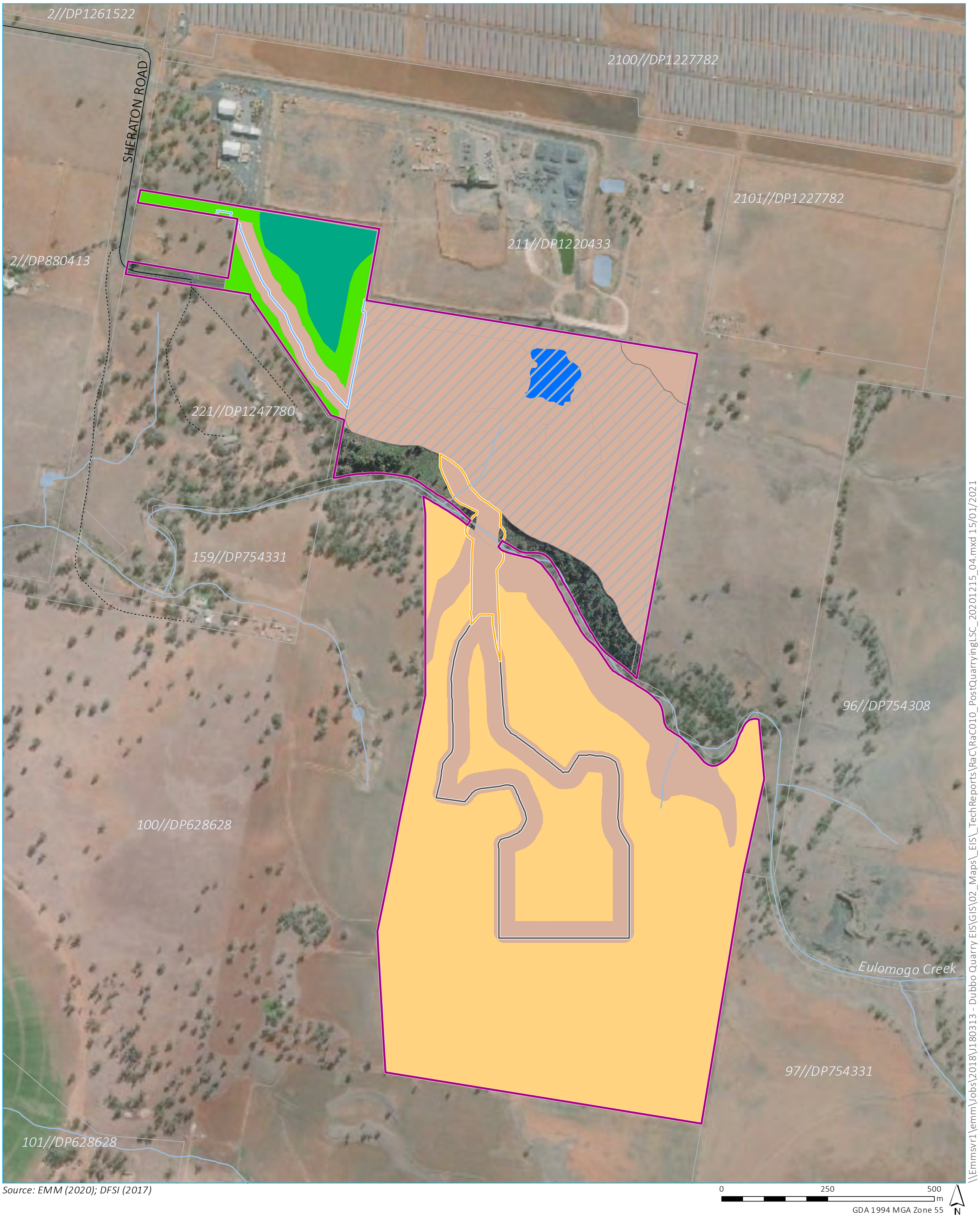


Source: EMM (2020); DFSI (2017)

KEY

Project area

Western disturbance area

Haul road disturbance area

Southern disturbance area

Indicative existing disturbance area

Land and soil capability

LSC 2 - very high capability land

LSC 3 - high capability land

LSC 5 - moderate low capability land

LSC 6 - low capability land

Water storage

Minor road

Vehicular track

Watercourse/drainage line

Waterbody

Cadastral boundary (data does not align with surveyed site boundary)

Post quarrying land and soil capability classes

Dubbo Quarry Continuation Project
Rehabilitation and landscape management strategy
Figure 3.2

EMM
creating opportunities

ii Soils

a Soil mapping units

Landloch 2019 delineated five SMU's over the project area. These are described in Table 3.3.

Table 3.3 Soil mapping units

SMU	Area (ha)	Description	Soil type(s) and sites
A	53	Landform is comprised of a crest and plateaus on basalt. Slopes are very gently inclined at <3%. Soil depth is 0.25-0.8 m being underlain by weathered basalt.	Complex mapping unit including Moderately Deep Ferrosol (25%) and Shallow Ferrosol (75%). Sites included TP5/5a and TP6/6a.
B	26	Landform consists of upper slopes on basalt. Slopes are inclined at 3-10%. Soil depth is 0.4-0.8 m being underlain by weathered basalt. Several large rock outcrops present in this SMU (approximately 1 ha).	Complex mapping unit including Moderately Deep Ferrosol (25%) and Shallow Ferrosol (75%). Sites included TP3/3a and TP4/4a.
C	8	Landform consists of simple slopes on basalt. Slopes are primarily 10-20% with some steeper slopes up to 50%. Soil depth of 0.4-0.8 m being limited by weathered basalt. Several large rock outcrops present in this SMU (approximately 1ha).	Complex mapping unit including Moderately Deep Ferrosol (25%) and Shallow Ferrosol (75%). Sites included TP1/1a and TP2/2a.
D	6	Landform consists of upper slopes on basalt. Slopes are primarily 3-10% with some steeper slopes up to 20%. Soil depth is >1.0 m. Several small rock outcrops present in this SMU (<1ha).	Simple mapping unit including Moderately Deep Ferrosol. Sites included TP8/8a.
E	5	Landform consists of upper slopes on basalt. Slopes are primarily <3%. Soil depth is 0.7->1.1 m underlain by weathered basalt. Several small rock outcrops present in this SMU (<1ha).	Simple mapping unit including Moderately Deep Ferrosol. Sites included TP7/7a.

The SMU for the project is shown in Figure 3.3.

b Soil physical and chemical limitations

The project area contains Moderately Deep Ferrosol and Shallow Ferrosol soils. Moderately Deep Ferrosol soils have the following key features:

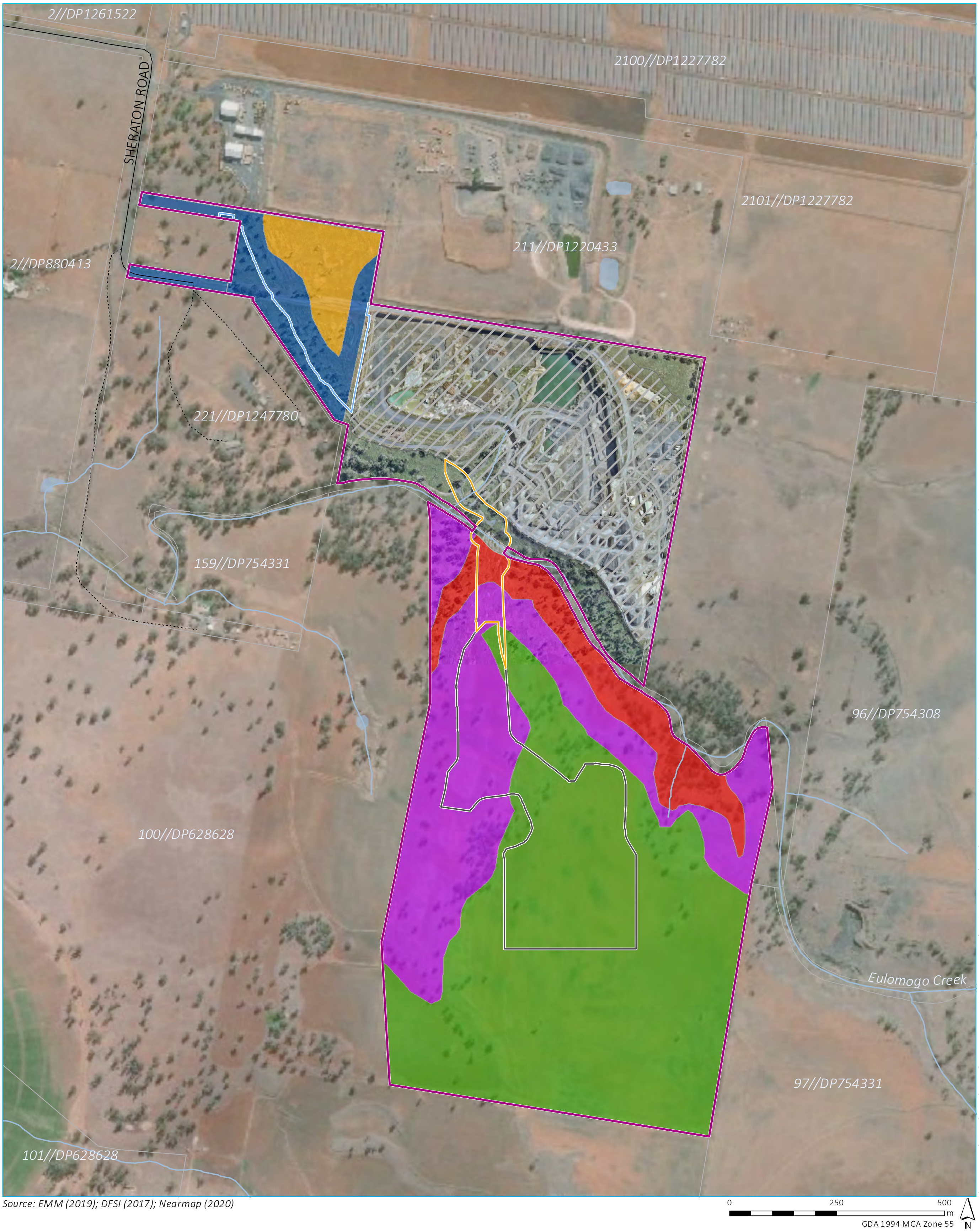
- Residual, colluvial and erosional landscapes from the Tholeiitic Alkali Basalt geological unit.
- Uniform, textured soil profiles with high cobble (round stone) content (up to 60 to 80%) with typical depths of 0.5-1.1 m.
- Topsoil fertility rating is moderate to high with moderate total nitrogen; high available phosphorous; very high available potassium and moderate organic carbon. The cation exchange capacity (CEC) indicates the topsoil has moderate potential to supply nutrients.

The Shallow Ferrosols have the key following features:

- Residual, colluvial, and erosional landscapes from the Tholeiitic Alkali Basalt geological unit.
- Uniform, textured soil profiles with high cobble (round stone) content (up to 60 to 80%) with typical depths of 0.25 to 0.5 m.
- Low to moderate nutrient supply potential.

The Moderately Deep Ferrosols are found in the WEA and the Shallow Ferrosols are found in the SEA.

The soil physical and chemical properties and associated management considerations are summarised in Table 3.4.



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Source: EMM (2019); DFSI (2017); Nearmap (2020)

KEY

- Project area
- Indicative existing disturbance area
- Western disturbance area
- Haul road disturbance area
- Southern disturbance area

Soil mapping unit

- A
- B
- C
- D
- E

- Minor road
- Vehicular track
- Watercourse/drainage line
- Waterbody
- Cadastral boundary (data does not align with surveyed site boundary)

Project soil mapping units

Dubbo Quarry Continuation Project
Rehabilitation and Landscape Management Strategy
Figure 3.3

Table 3.4 Soil physico-chemical properties

Typical depth (mm)	Texture	pH	Salinity	Sodicity/dispersion	Management considerations
0 to 50-100	Clay loam or light clay	Low to moderate acidity	Low	Non-sodic/sometimes slightly dispersive	Moderate fertility, moderate organic matter content. Negligible physico-chemical limitations to plant growth
100-500	Light to medium heavy clay	Low acidity to high alkalinity	Low to moderate salinity	Non-sodic to sometimes sodic/ potentially dispersive and slaking	Low fertility, low organic matter. Potentially sodic.
>500	Light to medium clay to medium heavy clay	Neutral to extremely alkaline	Low	Non-sodic to sometimes sodic/potentially dispersive and slaking	

The subsoil limitations are readily addressed via amelioration which will be undertaken during the stripping and rehabilitation phases. This is addressed in more detail in Section 5.1.

c Erosion and sediment control

Erosion potential of soil is determined by its physical and chemical properties and is expressed numerically as the K-factor.

Rosewell 1993 (Table 3.5) provides an estimate of soil erosion risk based on the physical properties of the soil but not the chemical properties, even though the K-Factor is increased by 20% when a dispersive soil in encountered. Soils where the dominant cations are sodium or magnesium tend to be dispersive when wet.

Table 3.5 Rosewell (1993) Soil Erosion Ranking

K factor (t ha h $ha^{-1}MJ^{-1}mm^{-1}$)	Erosion Potential
<0.02	Low
>0.02 to <0.04	Moderate
>0.04	High

Loch (1998) recommends a minimum K-factor of 0.06 for dispersive soils which does not align with the modelled K-factors for the project area which range from 0.03 to 0.04 (Figure 3.4, OEH 2016).

Yang et al 2017 used digital soil maps (DSMs) and NSW Soil and Land Information System to map and validate soil erodibility for soil depths up to 100 cm. They assessed eight empirical methods or existing maps on erodibility estimation and produced a harmonised high-resolution soil erodibility map for the entire state of NSW with improvements based on studies in NSW. The modelled erodibility values were compared with those from field measurements at soil plots for NSW soils and revealed good agreement.

The modelled K-factors are for topsoil and not subsoil which is why there is a discrepancy.

An assessment of the project's K-factors against the Rosewell (1993) soil erosion ranking (Table 3.5) demonstrates a 'high' soil erosion potential (which is fundamentally due to soil dispersion risk).

The erosion hazard for the project area has been determined using the procedure described in section 4.4.1 of Landcom 2004. The first step in the hazard assessment is a simple process using Figure 4.6 from Landcom 2004 (reproduced as Figure 3.5) that considers slope of the land and the Rainfall Erosivity or R factor.

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Source: EMM (2019); DFSI (2017); DPIE - eSPADE (2020)"

0 250 500 m

GDA 1994 MGA Zone 55 N

KEY

- Project area
- Western disturbance area
- Haul road disturbance area
- Southern disturbance area
- Indicative existing disturbance area
- Minor road
- Vehicular track
- Watercourse/drainage line
- Waterbody
- Cadastral boundary (data does not align with surveyed site boundary)

Modelled soil erosion

RUSLE K-Factor

High : 0.07

Low : 0.01

Modelled K-factors

Dubbo Quarry Continuation Project

Rehabilitation and Landscape Management Strategy

Figure 3.4

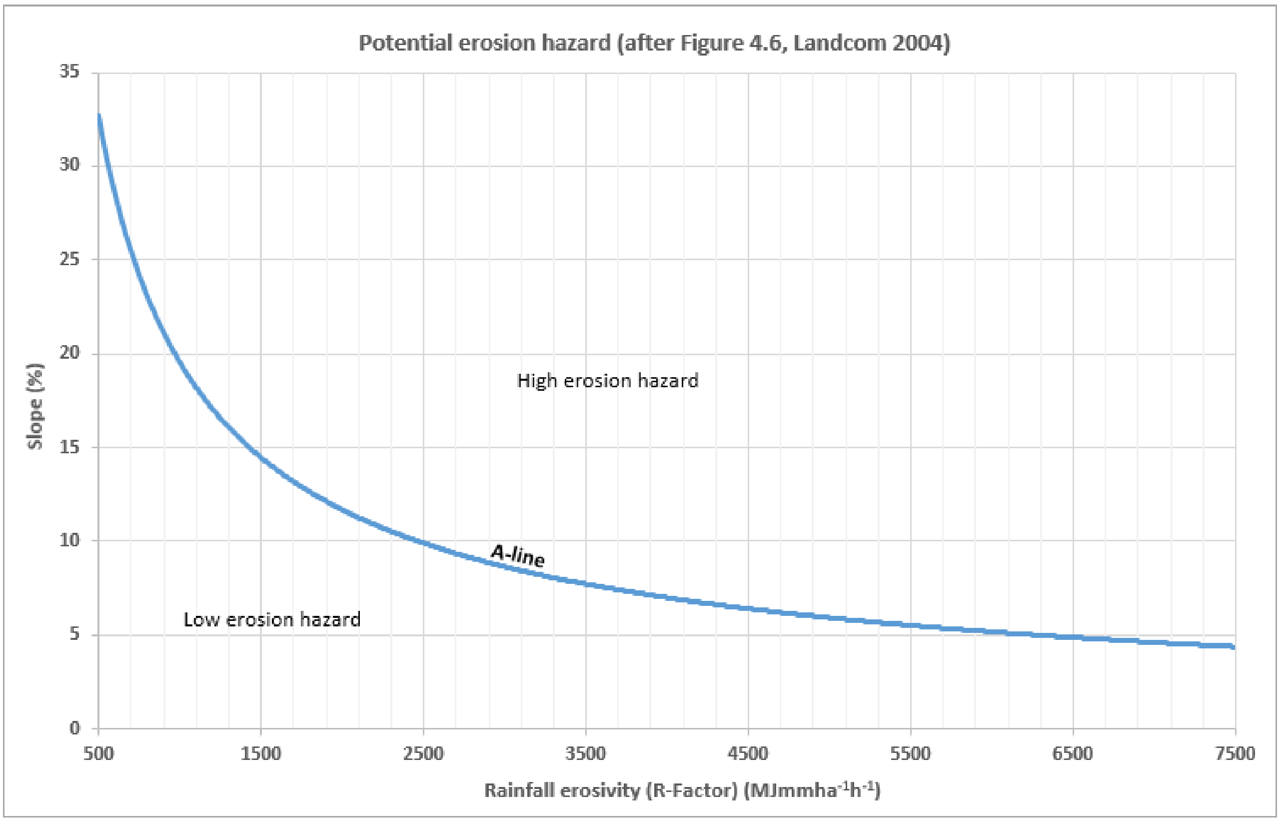


Figure 3.5 Assessment of potential erosion hazard (Figure 4.6 Landcom 2004)

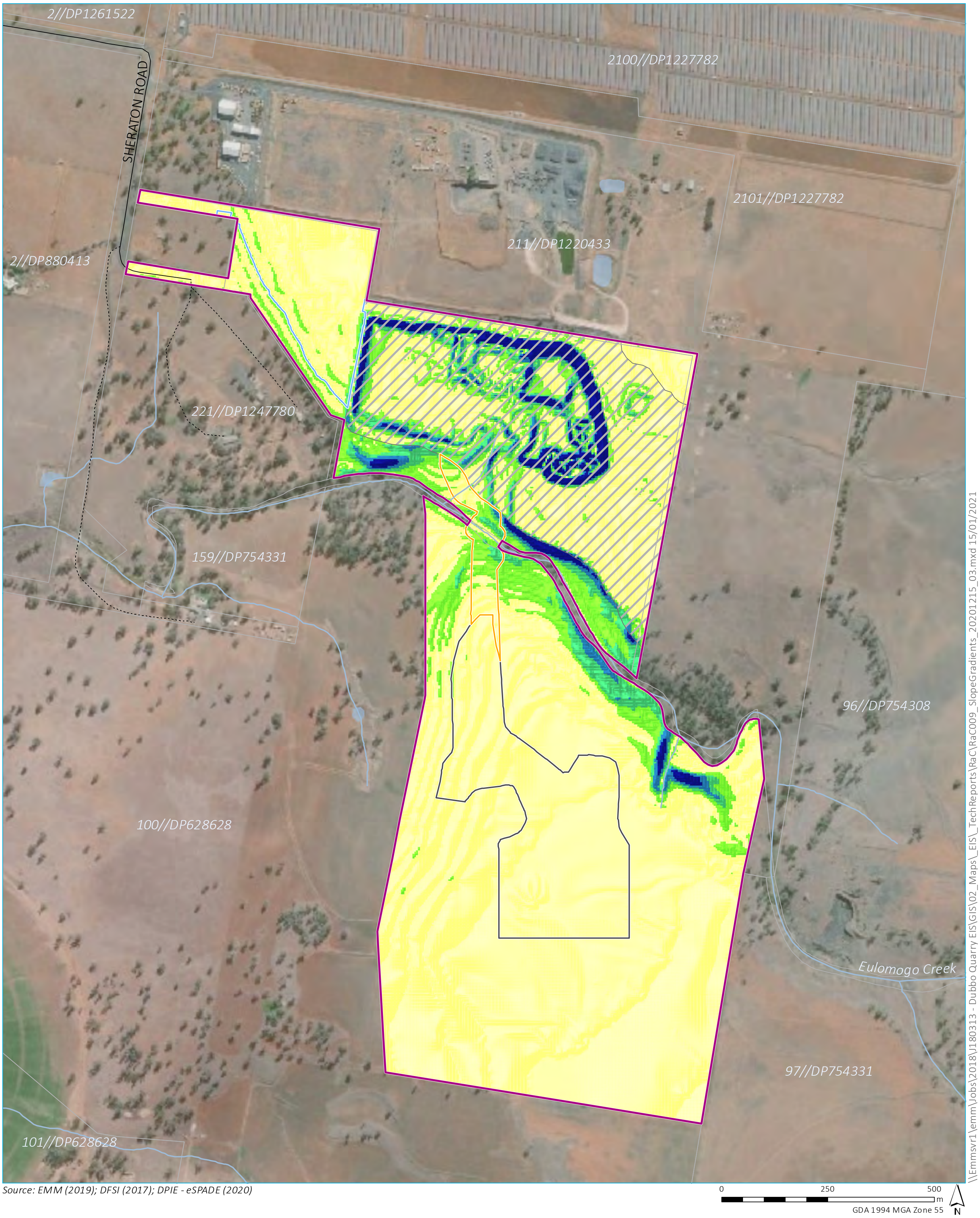
For the project, the slope gradient of planned disturbed areas ranges from less than 1% to 10% in the proposed quarry pits with isolated areas between 10 to 20% where the haul road crosses Eulomogo Creek (Figure 3.6). The rainfall erosivity factor (R factor) is 1,300 MJ.mm ha^{-1} h^{-1} (Appendix B Landcom 2004). Applying these parameters to the erosion hazard nomograph results in an erosion hazard of low for the proposed extraction areas and high where the haul road crosses over Eulomogo Creek. A high erosion hazard requires further detailed assessment in accordance with section 4.4.2 of Landcom 2004 to determine soil loss classes (3.6).

During quarrying the pit walls will have gradients of between 70° and 80° depending on the orientation of the walls with joints and faults. This will, however, have a very low erosion hazard due to the presence of the exposed basalt.

Table 3.6 Soil loss classes *(*adapted from Table 4.2 Landcom 2004)

Soil loss class	Calculated soil loss (t/ha/y)	Erosion hazard
1	0 to 150	Very low
2	151 to 225	low
3	226 to 350	Low-moderate
4	351 to 500	moderate
5	501 to 750	high
6	751 to 1,500	Very high
7	>1,500	Extremely high

Soil loss classes are determined by calculating the annual average soil loss using the Revised Universal Soil Loss Equation (RUSLE) with a nominal 80m slope length and soil surface cover factor (C-factor) of 1.



Source: EMM (2019); DFSI (2017); DPIE - eSPADE (2020)

KEY

- Project area
- Western disturbance area
- Haul road disturbance area
- Southern disturbance area
- Indicative existing disturbance area

Slope (%)

- 0 - 10
- 11 - 20
- 21 - 30
- 31- 40
- >40

- Minor road
- Vehicular track
- Watercourse/drainage line
- Waterbody
- Cadastral boundary (data does not align with surveyed site boundary)

Project slope gradients

Dubbo Quarry Continuation Project
Rehabilitation and Landscape Management Strategy
Figure 3.6

creating opportunities

RUSLE calculates the annual average erosion in tons per hectare from rill and inter-rill (sheet) erosion. It does not consider gully or tunnel erosion and does not calculate peak erosion.

Most of the project is Soil Loss Class (SLC) 1 which has a very low erosion hazard with Eulomogo Creek crossing and approaches having SLCs from SLC 2 to SLC 5 which has a low to high erosion hazard.

Landcom 2004 recommends scheduling land disturbing activities for times of low rainfall erosivity for SLC 5 and SLC 6 lands (riparian lands are considered to be SLC 6). Where it is not possible or practical to schedule disturbance for periods of low rainfall erosivity then it will be necessary to provide erosion protection to achieve C-factors of 0.1 or lower when the 3-day rainfall forecast suggests that rain is likely. Further detail will be provided in the Water Management Plan for the project.

3.2.3 Dust and noise

Air quality and noise management plans will be implemented during operations and will be updated to include the rehabilitation phase of the project prior to rehabilitation activities commencing. These management plans will be designed to achieve compliance with licence limits during decommissioning and rehabilitation activities.

The main anticipated source of dust during rehabilitation operations include:

- light and heavy vehicles travelling on unsealed roads and tracks;
- soil dumping during capping and topsoil activities; and
- land shaping.

Dust management to be used during rehabilitation and closure may include:

- sheeting roads with gravel;
- application of trafficable soil stabilising polymers to unsealed roads and tracks;
- watering areas of dust generation;
- reducing the speed of light and heavy vehicles;
- not undertaking works on exposed locations during windy conditions; and
- progressive stabilisation and rehabilitation of disturbed areas.

The main sources of noise during the rehabilitation and closure phases include:

- demolition works;
- hauling and placement of capping materials and topsoil; and
- reshaping works.

Noise control during rehabilitation and closure may include:

- undertaking demolition and rehabilitation works in daylight hours only;
- reducing heavy vehicle speeds; and

- maintenance of guarding and silencers on vehicles and machinery.

3.2.4 Weeds

The presence of weed species has the potential to have an impact on revegetation outcomes. Additionally, weed species within the surrounding land has the potential to impact on the success of rehabilitated areas. Weed management will, therefore, be a critical component of rehabilitation activities.

Weeds will be managed through a series of control measures, including:

- if machinery to be used for rehabilitation is brought to the site from another site, and if there is a risk of weed seeds having been transported on the machinery, it will be hosed down in an approved wash down area before entry to the project area;

- herbicide spraying or scalping weeds from soil stockpiles prior to re-spreading;

- rehabilitation inspections to identify potential weed infestations; and

- identifying and spraying existing weed populations together with ongoing weed spraying over the life of the project.

Weed control programs will be implemented according to industry best management practice for the weed species present, if required.

3.2.5 Hydrocarbons, chemicals and wastes

Despite designs that prevent or contain spills, there is a low residual risk that land within the surface infrastructure area could be contaminated during de-commissioning (eg from hydrocarbon spills, storage of fuel and chemicals, refuelling activities, sewage, etc).

To manage any potential contamination sources, waste management practices in accordance with the quarry's Environmental Management System will continue to be implemented during rehabilitation. For example:

- hydrocarbons will be stored in self bunded tanks or bunded areas designed in accordance with Australian Standard 1940;

- refueling will be undertaken away from Eulomogo Creek and in-pit water storages;

- waste products that are removed from the project will be appropriately disposed of at licensed facilities; and

- sewage generated post-decommissioning will be minimal (ie after the on-site sewerage treatment facility is removed). Any such waste (eg portable toilets) will be transported off-site for appropriate disposal at a licensed facility by a licensed waste contractor.

There is a low risk that hydrocarbon spills may also occur during soil spreading associated with rehabilitation (eg a burst hydraulic hose), but the impact would be isolated and spill-clean-up procedures would mitigate any potential impacts.

3.2.6 Bushfire

To prevent or manage bushfire risks, the site bushfire management plan will continue to be implemented. A hot work permit system will be used during rehabilitation works which will take into account the risk factors for bush fires. Machinery working on site will have spark arrestors fitted to their exhaust systems.

3.3 Socio-economic impacts

Community consultation has been, and will continue to be, key to project planning and understanding the project's potential impacts on the local community. Relevant stakeholders will be engaged in the rehabilitation and closure planning and implementation process, including in the development of a detailed closure plan as the project progresses towards completion. The closure plan will address post-quarrying land use and rehabilitation objectives.

4 Land use options following closure

Land uses on properties surrounding the project area primarily comprise agricultural uses, rural residential, quarrying, a solar farm, industrial and transport infrastructure (Mitchell Highway). Consideration of final land use options have taken into account the current land uses in and surrounding the project area, infrastructure that has been developed by the project, and the proximity of the project to existing agricultural land uses, the city of Dubbo, residences and general local infrastructure. The rehabilitation approach for the project is to reinstate the previous land-use as much as possible while enhancing biodiversity values lost due to past agricultural clearing.

As described in Section 3.2.2, the project area is currently LSC classes 5 and 6 in the SEA and LSC classes 2 and 3 in the WEA, which is consistent with the historic land-use of growing naturalised and improved pasture to support grazing by cattle and sheep.

All soil will be stripped and preserved prior to quarrying as having sufficient subsoil and topsoil volumes resources to ensure pre-quarrying LSCs can be established. It is intended that soils would be formed into bund walls around the perimeter of the WEA and SEA for future use in rehabilitation activities and to provide visual and acoustic treatment. However, due to low soil availability in the project area it will be necessary to import soil or other suitable materials with applicable waste exemptions to ensure sufficient depths of soil in rehabilitation activities (0.25 - 1 m).

Holcim proposes an open woodland for the pit walls to enhance the biodiversity and visual amenity of the project area.

There are some infrastructure areas associated with the project that may be able to provide an alternate beneficial post mining land use, such as:

- the quarry infrastructure areas and the pit floors that may be used for industrial purposes; and
- a workshop that may be suitable for storage of agricultural machinery or industrial enterprise.

Such alternate options will be considered, along with any other identified options by Holcim during operation of the quarry as part of detailed closure planning, and in consultation with relevant stakeholders, including the Department of Planning, Industry and Environment and Dubbo Regional Council.

Proposed post mining land uses for each domain are summarised in Table 4.1.

Table 4.1 Dubbo quarry proposed post mining land uses

Domain Number	Primary Domain (Operational)	Description	Pre-mining LSC classes	Post-mining LSC classes	Reasons
1	Infrastructure Areas	Crushing and screening circuits Pre-coat plant Pug mill Product stockpiles General infrastructure access roads and haul roads offices, carpark, workshop, stores utilities (power line, water pipelines) Fuel storage	Not part of the current project assessment	6	Infrastructure areas will have concrete foundations and slabs removed, any contamination remediated, the surface recontoured to form stable gradients and will be topsoiled. The presence of hardstand materials at depth will restrict the potential for cultivation; however, grazing will be able to be sustained at pre-mining levels.
2	Water management areas	Pump 1 pond Pump 2 pond Settling pond Haul road sediment sumps	Not part of the current project assessment	6, 7	Pond 1 pond will remain as a permanent water storage facility. Pond 2, the Settling Pond and Haul road sediment sumps will be backfilled and rehabilitated.
3	Soil stockpiles	Topsoil stockpiles, subsoil stockpiles	5, 6	5, 6	No change.
4	Pits	WEA, West Pit and East Pit SEA	2,3 5, 6	2,3 5,6	Pit walls will be recontoured via blasting and dozing to have an over slope of 18°. Open woodland will be established on the pit walls and pasture grasses and legumes on the pit floor.

4.1 Rehabilitation objectives

This rehabilitation strategy has been developed in consideration of several factors including opportunities (such as proximity to remnant native vegetation areas) and constraints (such as slope and soil quality), ecological and rural land use values, and existing strategic land use objectives. The rehabilitation objectives for the project are set out in Table 4.2.

Table 4.2 Rehabilitation objectives

Aspect	Objective
Quarry (as a whole)	• Safe, stable and non-polluting • Minimise visual impact of final landforms as far as is reasonable and feasible
Pits	• Minimise to the greatest extent practicable the safety risk to humans, stock and fauna • Re-establish pre-quarry land and soil capability while enhancing biodiversity values
In pit water storage	• Engineered to be hydraulically and geomorphologically stable
Surface infrastructure	• To be decommissioned and removed, unless agreed otherwise as part of the detailed closure planning process
Community	• Ensure public safety

Further details of specific rehabilitation methodology and rehabilitation criteria related to the establishment of these areas as outlined above are included in the following sections.

4.2 Rehabilitation by domain

4.2.1 Secondary domains

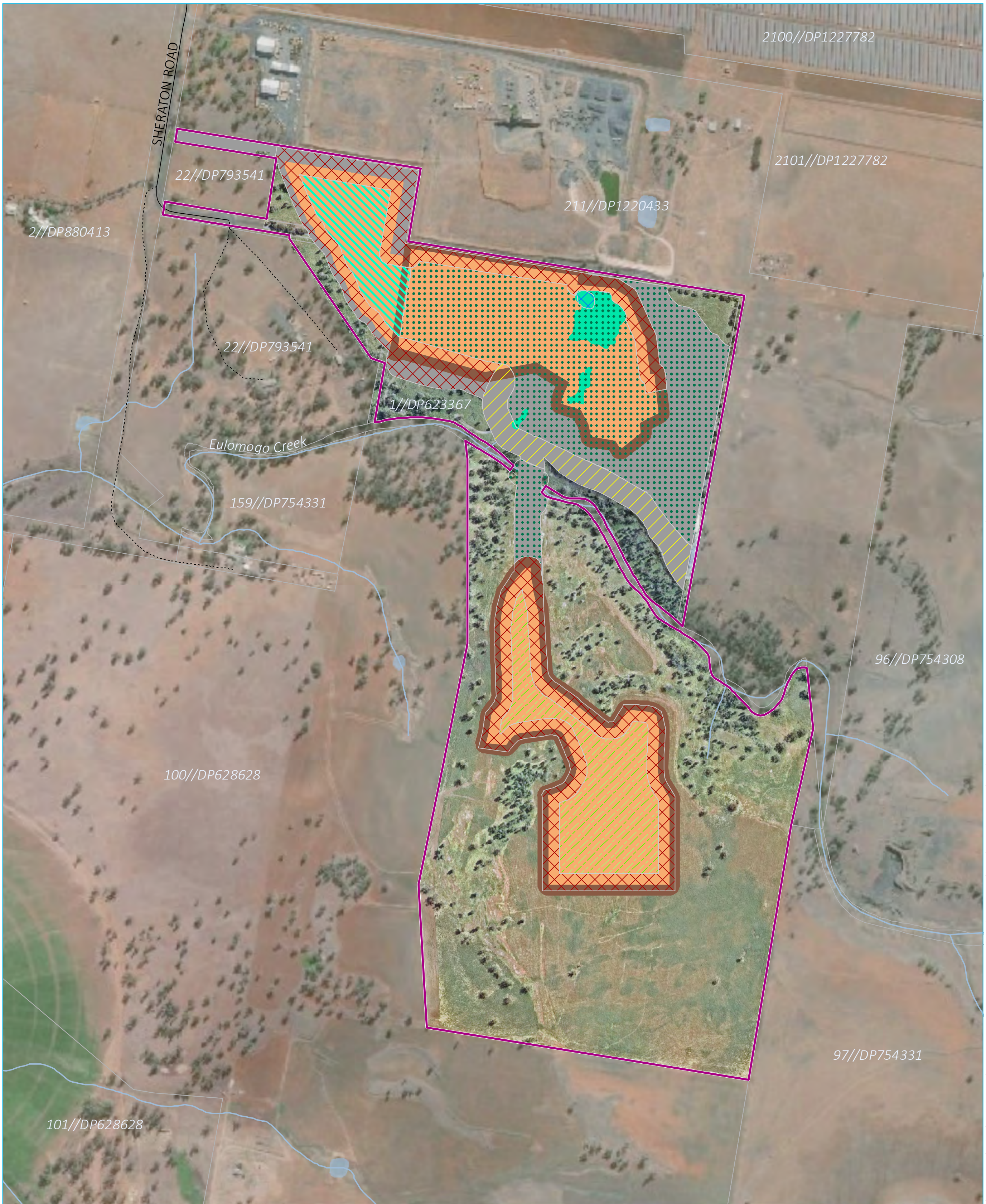
Primary and secondary domains for rehabilitation planning have been developed for the project in accordance with the requirements of ESG3. As described in Section 2.2, the primary domains are defined based on land management units within the project area with unique operational and functional purposes.

The secondary domains are the post-quarrying land-use domains and are characterised by similar post-quarrying land-uses. These domains form the basis of performance criteria used for measuring rehabilitation and closure success.

The primary domains are identified numerically, and the secondary domains are identified alphabetically. The primary and secondary domains for the project area are shown on Figure 4.1 and summarised in Table 4.3.

Table 4.3 Primary and secondary domains

Code	Primary Domain (Operational)	Mine Areas included	Code	Secondary Domains (Post Mining Land Use)
1	Quarry Infrastructure Areas	Crushing and screening circuits Pre-coat plant Pug mill Product stockpiles General infrastructure access roads and haul roads offices, carpark, workshop, stores utilities (power line, water pipelines)	B D E	Rehabilitation Pasture –LSC Class 6 Biodiversity – Blakely's Red Gum -Yellow Box grassy tall woodlands on flats and hills in the Brigalow Belt South Bioregion and Mandewar Bioregion Biodiversity – Western Grey Box – cypress pine shrub grass shrub tall woodland in the Brigalow Belt South Bioregion
2	Water management areas	Pond 1 Pond 2 Settlement Pond Haul road drive in sumps	B C	Rehabilitation Pasture –LSC Class 6 Water storage – LSC Class 8
3	Soil stockpiles	Topsoil and subsoil stockpiles	A B	Rehabilitation Pasture – LSC Class 5 Rehabilitation Pasture –LSC Class 6
4	Pits	West Pit East Pit WEA SEA	A B D F G	Rehabilitation Pasture – LSC Class 5 Rehabilitation Pasture –LSC Class 6 Biodiversity – Blakely's Red Gum -Yellow Box grassy tall woodlands on flats and hills in the Brigalow Belt South Bioregion and Mandewar Bioregion Rehabilitation Pasture –LSC Class 2 Rehabilitation Pasture –LSC Class 3



Source: EMM (2020); DFSI (2017); Nearmap (2020)

0 250 500 m
GDA 1994 MGA Zone 55
N

KEY

- Project area

Primary domains

- 1. Infrastructure area
- 2. Water management area
- 3. Soil stockpile area
- 4. Pit

Secondary domains

- A. Rehabilitation pasture - LSC Class 5
- B. Rehabilitation pasture - LSC Class 6
- C. Water storage - LSC Class 8
- D. Biodiversity - Blakely's Red Gum - Yellow Box grassy tall woodlands on flats and hills in the Brigalow Belt South Bioregion and Mandewar Bioregion (walls)
- E. Biodiversity - Western Grey Box - cypress pine shrub grass shrub tall woodland in the Brigalow Belt South Bioregion
- F. Rehabilitation pasture - LSC Class 2
- Cadastral boundary (data does not align with surveyed site boundary)
- Minor road
- Vehicular track
- Watercourse/drainage line
- Waterbody

Primary and secondary domains

Dubbo Quarry Continuation Project
Rehabilitation and Landscape Management Strategy
Figure 4.1

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4.2.2 Domain 1 Infrastructure areas

Domain 1 is situated on the north-eastern side of Eulomogo Creek as shown in Figure 2.1. An angle of repose fill embankment and dirty water diversion has been constructed as part of the current quarry on the north-eastern bank of Eulomogo Creek and generally follows the top bank of creek to the west to where it meets the northern end of the proposed haul road.

At the completion of quarrying the diversion bank will be removed and the fill batter recontoured to blend in with the profile of the existing creek bank. Any excess fill from the recontouring works will be used to back fill water management areas or used as subsoil for rehabilitation of the quarry pits.

All buildings, plant, machinery, tanks, footings, slabs, pipelines, power lines and road pavements will be removed unless required for an alternate post-quarrying land use to be determined later in the project's life.

Land contamination assessments will be undertaken, and any contaminated materials will either be bioremediated on site or transported to a suitable off-site facility.

Hardstand areas will be contour ripped and soils will be ameliorated to support improved pastures. Slopes steeper than 1(v):4(h) will be contour scarified and hydromulched. Blakely's Red Gum -Yellow Box grassy tall woodlands on flats and hills in the Brigalow Belt South Bioregion and Mandewar Bioregion and Western Grey Box – cypress pine shrub grass shrub tall woodland in the Brigalow Belt South Bioregion community species will be planted within the re-contoured fill batter on the creek bank via hydro-seeding and hydro-mulching to enhance biodiversity values.

4.2.3 Domain 2 Water management areas

All water management areas will be rehabilitated apart from Pond 1 that will remain as a water storage. All pumps, footvalves and pipelines will be removed. All other water management structures will be backfilled using embankment material and soil generated from recontouring Domain 1 and revegetated.

The highwall above Pond 1 will be recontoured via blasting and dozing in accordance with the rehabilitation practices for pit walls described in section 4.2.5.

4.2.4 Domain 3 Soil stockpiles

Soil stockpiles will be removed as progressive rehabilitation is undertaken. In-situ soils in the footprint of the stockpiles will be contour scarified, ameliorated if required and direct seeded with pasture species.

4.2.5 Domain 4 Pits

Once extraction has been completed in a pit, the pit walls will be recontoured via blasting and dozing to have an overall gradient of approximately 1(v):3(h) or 18° consistent with rehabilitation undertaken to date on the south-western wall of the west pit. The blasted rock will be mixed with soil to form a rock/soil matrix to facilitate slope stability and a suitable growing media for the Blakely's Red Gum -Yellow Box grassy tall woodlands on flats and hills in the Brigalow Belt South Bioregion and Mandewar Bioregion and Western Grey Box – cypress pine shrub grass shrub tall woodland in the Brigalow Belt South Bioregion communities. This will be direct seeded via hydro-seeding and then protected with a hydro-mulch.

Subsoil and topsoil will be respread on the pit floors at sufficient depth to re-establish the pre-quarrying LSC class. If there is a soil deficit, soil or other suitable materials with applicable waste exemptions will be imported for the purpose. During the operation of the quarry the materials will be imported and stockpiled on the west pit for this purpose.

The SEA pit floor will be re-shaped so that it is free draining to Eulomogo Creek. The floor of the west pit generally drains to Pond 1 at the eastern end of the pit. The floor of the WEA will be shaped so that it free drains to Pond 1.

A contamination assessment will be undertaken in the pits and extension areas and any contaminated materials either bioremediated on site or taken to an appropriate disposal facility.

Soils in the floor of the pits will be contour scarified, ameliorated if required, and seeded with pasture species.

5 Rehabilitation methods for closure

5.1 Soil management

Topsoil and subsoil stripping plans will be developed for each area prior to soil disturbance. As part of this process, a Land Disturbance Permit system will be implemented for operations personnel, to ensure that stripping activities are managed appropriately.

Some soils within the project area are sodic and/or magnesic. Sodium and magnesium levels typically increase with depth. Soil stripping and stockpiling will involve disturbance and mixing of soil; therefore, reduction in soil stability and fertility can be expected. Rehabilitated areas will be (initially) completely bare of vegetation, subject to increased rates of runoff and (if sloping) risk of erosion. Therefore, amelioration of the soils to ensure stability and to redress any fertility decline is likely to be required.

Where required, gypsum will be applied to the soil during stripping to reduce the potential for dispersion and reduce soil pH where high alkalinity exists.

5.1.1 Soil testing

Prior to stripping, topsoil and subsoil will be sampled to:

- identify the soil resource prior to stripping;
- assist with the preparation of a soil balance or inventory to assist with rehabilitation planning; and
- determine if the soil requires amelioration.

Soil sampling will determine if the soil requires amelioration to ensure the soils physical and chemical characteristics are within ranges necessary to address any erosion or revegetation constraints posed by the soils.

Soil exchangeable sodium levels, soil exchangeable magnesium levels and potential for clay dispersion will be assessed, with data on exchangeable cations used to calculate gypsum requirements to reduce Exchangeable Sodium Percentage (ESP) to <4% and Exchangeable Magnesium Percentage (EMP) to <20% (presence of dispersive clays will drastically increase erosion risk, and also reduce vegetation establishment and growth.)

Removal of vegetation will effectively reduce nutrient stores. Some elements such as nitrogen will be eventually replaced by growth of leguminous species, but elements (generally phosphorus) that are in extremely low levels may well become limiting to both pastures and native woodland rehabilitation.

The soil parameters to be measured are listed in Table 5.1 Physical and chemical soil testing parameters.

Table 5.1 Physical and chemical soil testing parameters

Parameter	Method
Organic carbon	Walkley and Black
pH	1:5 suspension, water
Effective cation exchange capacity and exchangeable cations	
Electrical conductivity	1:5 suspension, water

Table 5.1 Physical and chemical soil testing parameters

Parameter	Method
Total Nitrogen	Kjeldahl
Total Phosphorous	Nitric/Perchloric
Available Phosphorous	Colwell
Available Potassium	Colwell
Labile Sulfur	KCl extraction

Additional assessment of topsoil for the presence of weeds will be undertaken as part of soil sampling.

Soil sampling will be undertaken at a sampling frequency of one sample per 0.8-4 hectares (1:10,000 scale) and will include an assessment of topsoil depth and analysis of soil characteristics as detailed in Table 5.1. A soil stripping and placement plan will be incorporated into the Land Disturbance Permit for each stripping event.

5.1.2 Clearing and grubbing

During the clearing and grubbing process the following will be undertaken to minimise subsoil contamination of the topsoil:

- grub out stumps and roots ≥100 mm in diameter to a depth of 0.5 m; and
- minimise mixing of topsoil and subsoil during grubbing.

5.1.3 Soil amelioration

Soil testing as discussed previously will be undertaken to determine amelioration requirements and rates.

Some ameliorants may be mixed in with the topsoil and subsoil as part of the stripping operation, irrespective if the topsoil or subsoil is to be placed in bunds around the extraction areas or directly applied to a rehabilitation area.

Application of ameliorants as part of the soil stripping process is more cost effective and allows additional time for certain ameliorants to react and modify the soil to assist in the maintenance of soil conditions suitable for plant development.

The quarry soils will require amelioration with agricultural gypsum to treat dispersion, and improve the structure, water holding capacity.

Fertilisers will be applied following respreading to compensate for nutrients lost from the soil when stored in the extraction area bunds. Preference will be given to the use of mineral based biologically activated fertilisers over water soluble chemical fertilisers to minimise the potential for nutrient runoff into Eulomogo Creek and to encourage beneficial microbial activity in the soil.

Topsoil stockpiles will require amelioration and/or good mixing of the anaerobic and aerobic layers when returned to rehabilitated areas.

5.1.4 Soil stripping

A soil stripping and placement plan will be developed for each area that is to be stripped as part of the Land Disturbance Permit process. All staff and contractors will be required to obtain the relevant permit prior to clearing activities. The responsible environmental personnel will advise on permits required and authorise permits prior to commencement of works.

The depth of soil material suitable for recovery and re-use as a topsoil in rehabilitation will be determined using available information from Landloch 2019. Table 5.2 shows the depths and available volume of topsoil and subsoil for stripping the project area, although this has yet to be refined for the footprint of the quarry pits.

Table 5.2 Soil stripping depths and volumes

SMU	Area (ha)	Topsoil depth (m)	Topsoil volume(m^3)	Subsoil depth (m)	Minimum subsoil volume (m^3)
A	53	0.1	53,000	0.25 - 0.8	132,500
B	26	0.1	26,000	0.4 - 0.8	104,000
C	8	0.1	8,000	0.3–0.7	24,000
D	6	0.1	6,000	1	60,000
E	5	0.1	5,000	0.7 - 1.1	35,000

The process of soil stripping will also involve the continual evaluation of soil throughout the depths of the profile as areas and layers are exposed. Management of soils and stripping depths during this process is dynamic and generally require soil observations to be made on site on the day topsoil stripping is occurring. This enhances decision making and operational modifications can be adopted to best utilise the soil resources available.

The following process for stripping topsoil will be followed:

- the area to be stripped of topsoil will be clearly demarcated and surveyed;
- topsoil will not be stripped during excessively wet or dry conditions;
- as part of the planning process, temporary drainage, sediment control and structures to prevent erosion will be developed for the area, if required;
- excavated soils will be placed into bunds using dump trucks and excavators to form visual and noise amenity bunds around the extraction areas; and
- a record will be kept of the nature and quantities of salvaged bush rocks, timber etc to ensure that the salvage of these items is maximised, in accordance with protocols outlined in the Rehabilitation Management Plan.

Due to the soil volume limitations for rehabilitations, all subsoil resources will be stripped and stockpiled from the footprint of the quarry area.

5.1.5 Soil stockpiling

All stripped topsoil and subsoil will be used to form visual amenity and acoustic bunds around the extraction areas. The topsoil will be stripped first and temporarily pushed into a windrow just beyond the outer tow of the proposed bund. Soil ameliorants (most likely gypsum) will be broadcast over the exposed subsoil and will be mixed when the subsoil is pushed up to form the bund.

The bund will be compacted via track rolling with a bulldozer and then the topsoil will be spread over the bund and hydro-mulched with cover crops and appropriate grass species to minimise erosion and weed infestation.

5.1.6 Soil respreading

Subsoil will respread prior to topsoil in order to re-establish an appropriate soil profile that approximates the pre-disturbance profile.

Prior to re-spreading of stockpiled topsoil, an assessment of weed infestation will be undertaken to determine if individual stockpiles require burial due to their unsuitability as a result of weed infestation.

The following will be considered during soil respreading:

- topsoil requirements for rehabilitation areas will be balanced against stored stockpile inventories, proposed post mine land-use and proposed stripping volumes;
- during the removal of soils from the stockpiles, care will be taken to minimise structural degradation of the soils; and
- material will be spread in even layers at an appropriate thickness to meet the rehabilitation goals of the area being rehabilitated.

Required soil depths to re-establish the pre-disturbance LSC classes based on rock outcropping of <30%, as detailed in Table 15 of OEH 2012, are provided in Table 5.3.

Table 5.3 LSC class soil depths

LSC class	Soil depth (m)
2	>1
3	0.75 - <1
4	0.5 - <0.75
6	0.25 - <0.50
7	0 - <0.25

5.1.7 Monitoring

The soil management process will be monitored through each step to ensure that the health of the soil is maintained, and the rehabilitation and biodiversity objectives can be achieved.

The Rehabilitation Management Plan will detail the testing, witness, and hold points requirements for each step of the soil management process.

5.2 Establishment of vegetation

Vegetation species for rehabilitation purposes is anticipated to consist of:

- cover crop species for short term erosion protection and weed suppression;
- introduced pasture species for long-term soil stockpile protection and rehabilitation for grazing purposes; and

- species that comprise the vegetation communities currently present within the project area: Blakely's Red Gum -Yellow Box grassy tall woodlands on flats and hills in the Brigalow Belt South Bioregion and Mandewar Bioregion and Western Grey Box – cypress pine shrub grass shrub tall woodland in the Brigalow Belt South Bioregion communities for the pit wills and western side of Eulomogo Creek.

Seed for cover crop and pasture species will be obtained from commercial suppliers.

Seed will be stored in a humidity controlled and vermin free environment to maximise its viability.

A number of sowing methods will be employed at the quarry. These may include:

- hand seeding;
- broadcast seeding; and
- hydroseeding.

Hand seeding is likely to be used on small areas or where machinery access is difficult.

Broadcast seeding is likely be used for the establishment of cover crop and pasture species of flatter areas up to approximately 14°. This will be followed by harrowing using pasture harrows to lightly cover the seed with soil to ensure intimate soil contact. The rockiness of the soil generally precludes the use of drill seeding techniques.

On the pit walls and western side of Eulomogo Creek, native seed will be sowed using a hydro-seeder followed by the application of a straw-based hydro-mulch and hydro-colloid binder to protect the seed and soil from compact and erosion by rainfall and erosion from overland flow.

Cover crops will be used with all seeding activities to provide erosion protection and minimise the potential for weed invasion.

It may also be necessary to inoculate woodland rehabilitation areas with small quantities of fresh topsoil from adjacent open-woodland and open forest areas from within the project area to ensure necessary mycorrhizal fungi are present within the soil biology.

5.3 Erosion and sediment control

An assessment of soil erosion hazard was undertaken for the project in accordance with the requirements of Landcom 2004. This is described in Section 3.2.2 and ranges from very low to high. The key erosion risks for the project are:

- dispersible subsoils due to ESP and/or EMP; and
- steep gradients where the haul road crosses Eulomogo Creek and a steep fill batter associated with Domain 1 of the north-eastern side Eulomogo Creek.

Dispersive soils will be gypsum treated during the stripping process to reduce ESP and/or EMP to improve their electrochemical stability.

The greatest erosion risk during the rehabilitation phase will be the removal of the culvert in Eulomogo Creek and rehabilitation of the haul road either side of the culvert. These works should be undertaken during periods of low rainfall erosivity from April to September. An environmental work method statement including an erosion and sediment control plan will be prepared prior to undertaken these rehabilitation work to ensure risks are identified and appropriately managed and mitigated.

The floor of the WEA will drain to Pond 1 in the western pit and will ultimately be contained.

A sediment dam will be excavated south of Eulomogo Creek, adjacent to the southern haul road, at a lower elevation than the SEA to contain turbid runoff and this will be retained until approximately 60% soil surface cover has been achieved.

Based on observations of existing rehabilitation works in the west pit and the lack of rill erosion, annual average erosion rates of less than 2 tonnes per hectare per year (t/ha/y) and a peak erosion rate of less than 5t/ha/y should be achieved on the pit walls essentially reducing the erosion hazard to very low using a combination of rock/soil matrices and hydromulching.

Revegetation techniques as described in Section 5.2 will be varied to suit the erosion hazard of areas undergoing rehabilitation. For example, broadcast seeding is appropriate for the pit floors as the slope gradients are very low and significant erosion of the exposed soil awaiting grass germination is unlikely to occur, whereas it is unsuitable for the recontoured fill batter on the north-eastern side of Eulomogo Creek as the erosion and sedimentation risk is high and the costs associated with replacing the lost topsoil and seed would be very high.

Holcim will, therefore, aim to progressively rehabilitated disturbed areas as quickly as possible to minimise the risk of erosion and re-work.

A water management plan will be prepared for the project that will include an overarching erosion and sediment control plan. Progressive erosion and sediment control plans will then be prepared for discrete areas as required in accordance with the requirements of DECC 2008.

5.4 Post-closure maintenance

5.4.1 Rehabilitation monitoring

Rehabilitation monitoring will be undertaken annually once rehabilitation commences, using analogue sites and Landscape Function Analysis (LFA) to assess rehabilitation progress and success and an annual rehabilitation report will be prepared. A summary of which will be provided in the Annual Review.

Data obtained from the analogue sites will provide a range of values from replicated examples of similar vegetation communities. Rehabilitation areas are compared to reference sites that best represent the final land use, vegetation community and management conditions they will be subjected to.

This approach allows the recognition of the dynamic nature of ecosystems and, therefore, rehabilitation sites will be monitored simultaneously to the reference sites over time to account for changes in:

1. seasonal variations;
2. climatic conditions;
3. management practices; and
4. unexpected disturbance events such bushfire.

In order to demonstrate rehabilitate success, or succession toward rehabilitation success, specific indicators will be expected to equal or exceed values obtained from the reference site under the same set of conditions or demonstrate a positive trend towards target values.

All domains will have all or part grazing post-mining land use. Holcim will include grazing productivity parameters in the rehabilitation monitoring program.

Rehabilitation monitoring will inform areas requiring maintenance and identify and address deviations from the expected outcomes. Rehabilitated areas will be assessed against performance indicators (refer Section 6) and regularly (at least on an annual basis) inspected for the following aspects:

- evidence of any erosion or sedimentation;
- success of initial establishment cover;
- natural regeneration of improved pasture;
- weed infestation (primarily noxious weeds, but also where rehabilitation areas are dominated by other weeds);
- integrity of drainage, erosion and sediment control structures; and
- general stability of the rehabilitation areas.

Where rehabilitation criteria have not been met, maintenance works will be undertaken. This may include the following:

- re-seeding and, where necessary, re-soiling and/or the application of specialised treatments;
- use of materials such as composted mulch to areas with poor vegetation establishment;
- replacement of drainage controls if they are found to be inadequate for their intended purpose, or compromised by vegetation or wildlife; and
- de-silting or repair of sediment control structures.

5.4.2 Weed management

The presence of weed species has the potential to majorly impact on revegetation outcomes. Additionally, any significant weed species within the surrounding land has the potential to impact on the success of the rehabilitated areas. Therefore, weed management will be an important component of rehabilitation activities.

The spread of declared noxious weeds (and other invasive weeds that could impact revegetation success and/or plants that are undesirable to grazing stock) will be managed across the project area through a series of control measures, including:

- herbicide spraying or scalping weeds;
- post-quarrying use of rehabilitated areas as a working farm, with associated management practices; and
- rehabilitation inspections to identify potential weed infestations.

5.4.3 Access

Access tracks may be required to facilitate the revegetation and ongoing maintenance of the project. These tracks will be kept to a practical minimum and will be designated prior to the completion of the project.

5.4.4 Public safety

Controls will be implemented to minimise the potential for impacts on public safety, and may include maintenance of fencing and warning signs around areas that have the potential to cause harm and are that are accessible to the public. Permanent bunding of the quarry pits are not anticipated due to the planned regrading to a safe and stable gradient of 18° which is trafficable by farm machinery and agricultural equipment such as quad bikes.

An assessment of the regraded pit walls will be undertaken to determine if there are any large rocks present that may provide a safety risk post closure of the quarry.

5.4.5 Rehabilitation resources

The Quarry Manager will be responsible for achieving the rehabilitation criteria.

A rehabilitation management plan will be developed to provide a structured and documented process for managing and improving rehabilitation activities at the quarry. The plan will serve as a process map for interdepartmental administration of rehabilitation activities within the quarry planning and implementation process.

The rehabilitation management plan will have two focus areas.

1. The integration of rehabilitation activates between the various departments within the quarry organisational structure through all stages of the rehabilitation process. To achieve this, the rehabilitation management plan will separate the rehabilitation process into different phases and outline responsibilities at each stage with hold and witness points.

2. The second focus is on establishing effective and robust monitoring methods with clear guidelines on the process to be followed to achieve quarry rehabilitation objectives, and a means to record the process followed and results obtained.

6 Performance indicators and completion criteria

6.1 Rehabilitation criteria and reporting

Rehabilitation completion criteria will be used as the basis for assessing when rehabilitation of the project is complete. Indicators will be measured against the criteria, and are set for the six phases of rehabilitation, consistent with ESG3 as follows:

- Phase 1 – Decommissioning (ie removal of equipment and infrastructure);
- Phase 2 – Landform Establishment (ie land shaping);
- Phase 3 – Growth Medium Development (ie soil physical and chemical properties);
- Phase 4 – Ecosystem and Land Use Establishment (ie vegetation establishment);
- Phase 5 – Ecosystem and Land Use Sustainability (ie established vegetation is supporting post-mining land use); and
- Phase 6 – Land Relinquishment.

Interim rehabilitation criteria for the project have been developed with the current knowledge of rehabilitation practices and success in similar project environments. They consist of a set of objectives; rehabilitation criteria and evidence that criteria have been met using Landscape Function Analysis (LFA) and agricultural productivity measures.

Whether rehabilitation criteria have been met depends on the trending of measurements over time compared to pre-mining or reference site conditions. The criteria will be refined and confirmed in the Rehabilitation Management Plan and in the detailed closure plan as the project progresses towards closure.

The rehabilitation criteria need to demonstrate that the rehabilitation objective has been achieved. Consequently, interim rehabilitation criteria are presented in Tables 6.1, 6.2 and 6.3 that address the following outcomes:

- restoration of a safe and stable landform that is non-polluting; and
- reinstate soil profiles and function and create landforms that are compatible with surrounding topography; and reestablishment of landforms that permit grazing, improved pasture and biodiversity outcomes.

Table 6.1 provides rehabilitation criteria applicable to both grazing and biodiversity post quarrying land uses. Table 6.2 provides rehabilitation criteria applicable to grazing only and Table 6.3 provides rehabilitation criteria application to biodiversity only.

Reporting on rehabilitation activities, monitoring and progress towards achieving agreed rehabilitation criteria will occur via an annual rehabilitation report which will be summarised in Annual Reviews.

Table 6.1 Common rehabilitation performance indicators and completion criteria

Stage of Development	Aspect or Component	Completion Criteria	Performance Indicators
Landform establishment and stability	Landform slope, gradient	Landform suitable for final land use and generally compatible with surrounding topography	Slope angles consistent with design
	Landform function	Landform is functional and indicative of a landscape on a trajectory towards a self-sustaining ecosystem	LFA Stability; LFA Infiltration; LFA Nutrient Cycling; and LFA Landscape Organisation
	Active erosion	Areas of active erosion are limited	Number of rills/gullies; cross-sectional area of rills/gullies; presence/absence of sheet erosion; presence/absence of tunnel erosion
Growth medium development	Soil chemical and physical properties and amelioration	Soil properties are suitable for the establishment and maintenance of selected vegetation species	pH; Electrical Conductivity; Organic Matter; Phosphorus; Nitrate; Cation Exchange Capacity; and Exchangeable Sodium Percentage, Mg and Al
		Soil contaminant levels are suitable for post mine land use	TPH, metals, chemicals

Table 6.2 Grazing rehabilitation performance indicators and completion criteria

Stage of Development	Aspect or Component	Completion Criteria	Performance Indicators
Pasture establishment	Pastures established equivalent to analogue pastures sites	Pastures contains a diversity of species comparable to analogue pastures	Native and introduced pasture species richness;
		Number of weeds species and surface area cover ≤ analogue site	Diversity and percentage cover of weed species
Pasture development	Protective ground cover	Ground layer contains protective ground cover and structure comparable to that of the local pasture analogue	Litter cover; foliage cover; annual plants; cryptogam cover; rock; log; bare ground; perennial plant cover (0.5m); total ground cover
	Ground cover diversity	Pasture contains a diversity of species per square metre comparable to that of the local remnant vegetation	Native understorey abundance; exotic understorey abundance
		Number of weeds species and surface area cover ≤ analogue site	Diversity and percentage cover of weed species
Pasture stability	Pasture health	Pasture condition is comparable to that of analogue pastures	Live plants, healthy plants, pest infestation
	Pasture productivity	Pasture productivity equivalent to analogue pastures	Carrying capacity DSE/ha Crude protein % Digestibility % Green/dry matter content

Table 6.3 Biodiversity rehabilitation performance indicators and completion criteria

Stage of Development	Aspect or Component	Completion Criteria	Performance Indicators
Ecosystem establishment	Vegetation diversity	Vegetation contains a diversity of species comparable to that of the local remnant vegetation	Diversity of shrubs and juvenile trees; total species richness; native species richness; exotic species richness
	Vegetation density	Vegetation contains a density of species comparable to that of the local remnant vegetation	Density of shrubs and juvenile trees
	Ecosystem composition	The vegetation is comprised by a range of growth forms comparable to that of the local remnant vegetation	Trees; shrubs; sub-shrubs; herbs; grasses; reeds; ferns; aquatic
Ecosystem development and habitat complexity	Protective ground cover	Ground layer contains protective ground cover and structure comparable to that of the biodiversity analogue	Litter cover; foliage cover; annual plants; cryptogam cover; rock; log; bare ground; perennial plant cover (0.5 m); total ground cover
	Ground cover diversity	Vegetation contains a diversity of species per square metre comparable to that of the local remnant vegetation	Native understorey abundance; exotic understorey abundance
		Native ground cover abundance is comparable to that of the local remnant vegetation	Percent ground cover provided by native vegetation
	Ecosystem growth and natural recruitment	The vegetation is maturing and/or natural recruitment is occurring at rates similar to those of the local remnant vegetation	Shrubs and juvenile trees 0-0.5 m in height; Shrubs and juvenile trees 0.5-1 m in height; Shrubs and juvenile trees 1-1.5 m in height; Shrubs and juvenile trees 1.5-2 m in height; Shrubs and juvenile trees >2.0 m in height
Ecosystem stability	Ecosystem structure	The vegetation is developing in structure and complexity comparable to that of the local remnant vegetation	Foliage cover 0.5-2 m; foliage cover 2-4 m; foliage cover 4-6 m; foliage cover >6 m
	Tree diversity	Vegetation contains a diversity of maturing tree and shrub species comparable to that of the local remnant vegetation	Tree diversity
	Tree density	Vegetation contains a density of maturing tree and shrub species comparable to that of the local remnant vegetation	Tree density; average diameter at breast height
	Ecosystem health	The vegetation is in a condition comparable to that of the local remnant vegetation	Live trees; healthy trees; medium health; advanced dieback; dead trees; mistletoe; flowers/fruit (trees)

6.2 Rehabilitation monitoring and research

6.2.1 Monitoring methodology

As proposed rehabilitation works require the establishment of pastures and woodland areas, the rehabilitation monitoring methodology adopted needs to be sufficiently flexible and capable of providing meaningful information of rehabilitation trajectories and when intervention is required.

A combination of LFA and agricultural productivity analysis is an appropriate and generally accepted rehabilitation monitoring methodology for demonstrating the success of rehabilitation works and providing meaningful guidance where intervention is required. However, the specific monitoring methods applied will be determined in the rehabilitation management plan and will be flexible in consideration of advancing technologies and changes to industry best practice.

6.2.2 Frequency of monitoring

It is expected that formal rehabilitation monitoring will be undertaken annually during operations and for approximately five years following quarry closure (or less if the rehabilitation criteria have been met). At this time, a review of the monitoring frequency will be undertaken based on the performance of the revegetation and an appropriate monitoring frequency determined. The frequency will be determined by a suitably qualified person(s) and in consultation with the relevant regulatory authorities.

Informal monitoring of rehabilitation by quarry personnel will also be undertaken.

6.2.3 Analogue sites

Representative analogue sites will be established for grazing areas and woodland communities. These will be identified in the Rehabilitation Management Plan.

6.2.4 Rehabilitation monitoring

Permanent transacts and quadrats will be established for rehabilitation monitoring in analogue and rehabilitation areas over time. These will include permanent photo monitoring points.

The monitoring results will be used to assess whether rehabilitation areas are on a trajectory towards a self-sustaining landscape.

Soil samples will be taken using a core sampler within a monitoring quadrat at each rehabilitation monitoring site and soil samples will be sent to a National Association of Testing Authorities (NATA) accredited laboratory for analysis. Soil samples are analysed for the following parameters: pH, electrical conductivity, available calcium, magnesium, potassium, ammonia, sulphur, organic matter, exchangeable sodium, calcium, magnesium, potassium, hydrogen, aluminium, cation exchange capacity, available and extractable phosphorus, micronutrients (zinc, manganese, iron, copper, boron) and total carbon and nitrogen. Exchangeable sodium percentages are also calculated to determine sodicity and soil dispersion.

The parameters to be tested are likely to reduce over time as a better understanding of project soils and the key parameters are understood.

For the native woodland and riparian rehabilitation, various biodiversity components will be assessed to monitor the successional phases/changes of plant development and to identify the requirements for ameliorative measures and guide adaptive management.

Rapid ecological assessment techniques will be used to provides quantitative data that measures changes in:

- floristic diversity including species area curves and growth forms (using full floristic sampling);
- ground cover diversity and abundance;
- vegetation structure and habitat characteristics (including ground cover, cryptogams, logs, rocks, litter, projected foliage cover at various height increments);
- understorey density and growth (including established shrubs, direct seeding and tube stock plantings and tree regeneration);
- overstorey characteristics including tree density, health and survival; and
- other habitat attributes such as the presence of hollows, mistletoe and the production of buds, flowers and fruit. Permanent transects and photo-points (as described below) have been established to record changes in these attributes over time.

As large portions of the site will be returned to a grazing post-mine land use, rehabilitation monitoring will also include indicators of grazing productivity such as:

- stock carrying capacity;
- pasture crude protein levels;
- digestibility; and
- dry matter content.

6.2.5 Research and continual improvement

Knowledge of appropriate rehabilitation practices required to achieve the rehabilitation objectives is continually growing. Holcim have engaged with industry specialists in the development of rehabilitation designs and techniques through the EIS development process and will consult with various experts as required during the operational, rehabilitation and closure phases of the project to address any rehabilitation and closure knowledge gaps.

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Appendix A

Land and soil capability assesement




HOLCIM QUARRY DUBBO: LAND AND SOIL CAPABILITY ASSESSMENT

July 2019

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Project Number: 3407.19d

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EXECUTIVE SUMMARY

Landloch was engaged by EMM Consulting Pty Ltd (EMM), on behalf of Holcim Australia Pty Ltd (Holcim), to undertake a Land and Soil Capability Assessment (LSC) at its Holcim's basalt quarry near Dubbo. This LSC report forms part of an *Environmental Assessment* for the expansion of the quarry. The study area includes two (2) parcels of land referred to as 'Skinners' and 'Cameron'. Skinners is approximately 88 ha and is situated to the south of the existing quarry. Cameron is approximately 10 ha and is located to the west of the existing quarry.

The geology of the study area consists of the Tholeiitic Alkali Basalt. From this parent material two soil types have been identified and five soil mapping units have been developed that have recognisable and distinguishable properties.

The land use evaluation identifies that Skinners has LSC Class 5 (53 ha) and 6 (26 ha) land. Land use is primarily limited to grazing, forestry, nature conservation, and very occasional cultivation for (dryland) pasture establishment. The primary limitation to more intensive land use is shallow soil depth.

Cameron has LSC Class 2 (6 ha) and Class 3 (5 ha) land. This land is capable of most land uses including cropping with cultivation, grazing, horticulture, forestry and nature conservation.

Details for soil stripping are presented in *Appendix D, Soil Recover Toolbox.*

1 INTRODUCTION

Landloch was engaged by EMM Consulting Pty Ltd (EMM), on behalf of Holcim Australia Pty Ltd (Holcim), to undertake a Land and Soil Capability Assessment (LSC) at its Holcim's basalt quarry near Dubbo. This LSC report forms part of an *Environmental Assessment* for the expansion of the quarry.

1.1 Project Description

Holcim Quarry is located at 20L Sheraton Road, approximately 5 km southeast from the centre of Dubbo (Figure 1). The study area includes two (2) parcels of land referred to as 'Skinners' and 'Cameron'. Skinners is approximately 88 ha and is situated to the south of the existing quarry. Cameron is approximately 10 ha and is located to the west of the existing quarry.

Figure 1. The study area is located approximately 5 km southeast of Dubbo.

1.2 Objectives

The objectives of the LSC undertaken by Landloch were to:

- Identify, characterise, and delineate the soil types within the study area;
- Describe and delineate the land capability classes within the study area;
- Provide recommendations to mitigate soil erosion and sedimentation associated with the works; and
- Provide growth media characterisation and inventory of the soil materials that may be utilised for rehabilitation.

1.3 Scope of Works

The scope of works for this assessment included:

- Desktop assessment to review existing soils, geology and topographical information;
- Preparation of preliminary soil mapping units for further investigation during a field program;
- A field program to undertake a soil survey to describe the soil and land condition across the study area and collect samples for laboratory analysis;
- Laboratory analysis and interpretation; and
- Reporting.

2 METHODOLOGY

The methodology adopted for the Land and Soil Capability Assessment is detailed in this section.

2.1 References and Guidelines

The soil survey has been developed in reference to the following guidelines:

- *Australian Soil and Land Survey: Guidelines for Surveying Soil and Land Resources* (McKenzie, et al., 2008);
- *Australian Soil Classification* (Isbell, 2002);
- *Australian Soil Survey and Land Survey Field Handbook* (The National Committee on Soil and Terrain, 2009);
- *The Land and Soil Capability Assessment Scheme* (NSW OEH, 2012); and
- *Soil and Landscape Issues in Environmental Impact Assessment* (NSW Department of Land and Water Conservation, 2000).

2.2 Desktop Assessment

A desktop assessment was undertaken prior to commencing field works, to construct a baseline conceptual model of the soil and landscape characteristics of the study area. It identified the preliminary mapping units that would require ground observations during the fieldwork. This included:

- Reviewing the available topographic, geological, vegetation, soil mapping and associated reports for the survey area and surrounding region;

- Reviewing the aerial imagery of the study area; and
- Drafting the preliminary mapping units for validation during fieldwork.

Listed below are the information sources referred to in the desktop component of this study.

- *Dubbo 1:100,000 Geological Sheet 8633* (Raymond, 2000).
- Contour data at 1m elevations, supplied by the client.
- *Soil landscapes of the Dubbo 1:250 000 Sheet* - Department of Land & Water Conservation (Murphy B.W.; Lawrie J.W., 1998)
- Climate data downloaded from the Bureau of Meteorology (BOM) website (Bureau of Meteorology, 2019).

2.2.1 Preliminary Mapping

The drafting of preliminary mapping for the study area was based on spatial analysis and a review of existing information. Existing mapping of topography, geology and soils was analysed through the use of a geographic information system (GIS). The preliminary mapping identified tracts of land that are expected to share similar soil landscape attributes. Each mapping unit can be separated from a neighbouring tract of land due to its different pattern of similar attribute values.

2.3 Fieldwork

The field work targeted preliminary mapping units for ground observations, with the aim that every soil mapping unit produced in the resultant mapping contains at least one detailed site description.

2.3.1 Ground observation densities for the soil survey.

A field scale of 1:25,000 was adopted and ground observation densities and types were undertaken in accordance with the *Guidelines for Surveying Soil and Land Resources* (McKenzie, et al., 2008). Samples were collected at no less than one (1) sample per 20 ha which corresponds to the field scale of 1:25,000. The number of sites required and adopted for ground observation across the study area is shown in Table 1.

Table 1. Adopted ground observation intensity compared with recommended intensity (McKenzie, et al., 2008).

Name of Study Area	Area (ha)	Number of Sites	
		Minimum Required	Adopted
Cameron	10	1	4
Skinners	88	5	12
Total	98	6	16

2.3.2 Ground observation types and proportions

Details of the recommended proportions of ground observation types (McKenzie, et al., 2008) that were adopted are shown in Table 2. The aim was for every soil type assessed to have at least one full morphological description with a comprehensive laboratory analysis. The locations of all ground observation sites are included in Figure 2.

Table 2. Adopted ground observation site types compared with recommended site types (McKenzie, et al., 2008).

Site Types	Details	Recommended	Adopted
Detailed	Detailed morphological and site descriptions to characterise the main soils and landscapes in a survey area.	10–30 %	50 % (8 sites)
Check and Semi Detailed	Brief mapping observations to confirm mapping boundaries, soil type distributions or other characteristics being mapped in the survey. These were brief with only a minimal amount of information recorded to correlate the site with a soil where a 'detailed' ground observation had occurred.	< 90 %	50 % (8 sites)
Sampling	Profiles with samples analysed. Analysis was conducted to characterise reference soil profiles in regard to soil attributes such as fertility, sodicity or salinity.	1–5 %	Full: 38 % (3 sites)

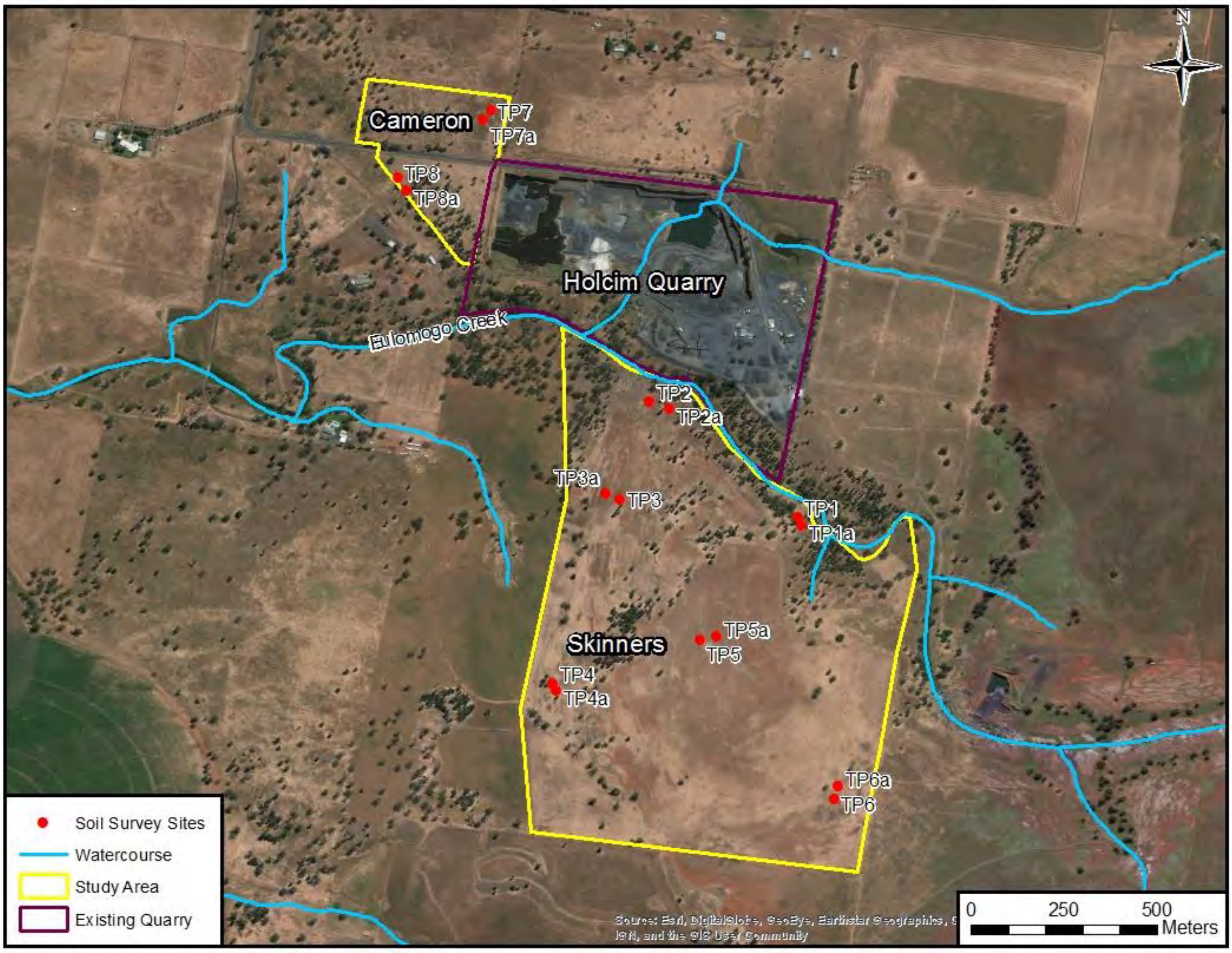

Figure 2. Locations of ground observation sites.

2.3.3 Surface descriptions

Data were collected from all ground observation sites in accordance with the *Australian Soil and Land Survey Field Handbook* (NCST, 2009). At all sites, this data included, but were not limited to:

- Geospatial location;
- Land use management;
- Landscape attributes (landform, vegetation, erosion, micro-relief, rock outcrops etc.); and
- Soil surface condition.

Refer to Appendix A for a summary of the surface descriptions collected in the field.

2.3.4 Full morphological descriptions

Full morphological descriptions included collecting and recording the following details:

- Horizon depths and designation;
- Horizon boundary type and distinctness;
- Field texture;
- Colour (Munsell chart) and mottles;
- Pedality and structure;
- Coarse fragments and segregations; and
- Slaking, 5-minute score; and dispersion, 10-minute score [based on (NSW Agriculture, 1999)].

Site descriptions were from machine excavated test pits that were advanced until refusal occurred on weathered rock (basalt). At all locations the soil was excavated and depth was recorded at duplicate locations; because soil depth was generally shallow. These duplicate test pits and recordings were within 20 m of each other. At Site TP8 and TP8a there was an existing trench that was utilised for describing the profile and collecting soil samples. The trench was approximately 1.0 m deep and 350 m long.

Detailed soil profile descriptions were observed to depths of between 0.25 to 1.1 m, depending on where refusal occurred. Refer to Appendix B for a summary of the soil profile descriptions and results of field tests.

2.3.5 Sampling protocol

Soil samples were collected in accordance with national and state protocols (Ryan & Wilson, 2008), (NSW OEH & OASFS, 2013) and (NSW DECCW, 2009). Generalised sampling depths were 0–0.1 m, 0.2–0.3 m, 0.5–0.6 m and 0.8–0.9 m with no sample interval exceeding 0.3 m in thickness. Allowances were made for horizon boundaries, with samples collected from within major soil horizons (i.e. sampling did not cross A and B horizons).

Surface soil samples were bulked by combining at least ten (10) sub-samples taken at random locations within a 10 m radius of the soil profile and on the same landform element. All samples were identified using the project name, unique profile number and depth range from which the sample was taken.

Samples for chemical analysis were placed into bags containing approximately 250 to 500 g, as required to adequately analyse samples.

2.3.6 Laboratory analysis

Laboratory analysis was undertaken by a National Association of Testing Authorities (NATA) and Australian Soil and Plant Analysis Council (ASPAC) accredited laboratory. Different analytical suites were adopted, based on site description. The typical analytical suites for reference soils are itemised below (NSW DECCW, 2009).

- Topsoil suite: pH (1:5 water), electrical conductivity (EC) (1:5 water), chloride, exchangeable cations, cation exchange capacity (CEC) and, organic carbon, total nitrogen, available phosphorus, available sulfur, and trace metals (B, Cu, Zn, Mn and Fe);
- Subsoil suite: pH, EC, chloride, exchangeable cations and CEC;
- Basic suite: pH, EC, and chloride; and
- Emerson aggregate test (EAT).

2.4 Reporting

The technical soil report describes the land and soil capability assessment, soil landscape mapping units, mapping of soil distributions, laboratory results, soil classifications, landscape details, limitations and constraints, and recommendations. Guidance on the suitability of materials for use in rehabilitation as topsoil, subsoil, marginal topsoil or subsoil (amelioration required) is provided, and an inventory was developed for the material volumes.

2.4.1 Soil classification

The soil at each site was classified using the Australian Soil Classification system (Isbell, 2002), generally to a suborder level (NSW OEH & OASFS, 2013). Soil types were determined by similarity of morphological and physico-chemical properties as well as by parent material, representative landforms and geomorphological position in the landscape (McKenzie, et al., 2008).

2.4.2 Land and soil capability assessment

A land and soil capability assessment was undertaken with reference to *The Land and Soil Capability Assessment Scheme* (NSW OEH, 2012).

2.4.3 Mapping

Mapping was completed following the fieldwork and laboratory analysis, to refine and modify the preliminary mapping units and to develop 'soil mapping units. The soil mapping units contained one or more dominant soil classes, and some contained one or more sub-dominant soil classes. Soil types are not considered to be unique, as the same soil types may be encountered more than once in different soil mapping units.

3 DESCRIPTION OF THE STUDY AREA

3.1 Climate

Dubbo is considered to have a humid subtropical climate. It borders the semi-arid climate of Western NSW and is located within Australia's hot summer and cold winter climate zone (Bureau of Meteorology, 2016).

Temperatures in the summer months tend to range between a minimum of 16–18 °C and a maximum of 32–34 °C. In the winter months, temperatures tend to be between a minimum of 3–4 °C and a maximum of 16–18 °C (Bureau of Meteorology, 2019).

The distribution of rainfall is relatively even throughout the year with no distinguishable wet or dry season (Dubbo City Council, 2019). The mean annual rainfall is approximately 570 mm with mean monthly rainfall depths of 30 to 60 mm.

Annual evaporation averages 1800 mm to 2000 mm, while annual evapotranspiration is 500mm to 600 mm per annum (Bureau of Meteorology, 2019).

The wind patterns are relatively consistent throughout the year with prevailing winds from the southeast, south, southwest and west accounting for approximately 64 % of the wind direction throughout the year (Dubbo City Council, 2019). Average monthly wind speeds range from approximately 15–20 km/hr (Bureau of Meteorology, 2019).

Table 3 summarises the climate data from Dubbo Airport (Bureau of Meteorology, 2019), which is located approximately 11 km to the northwest of the study area.

Table 3. Summary of mean monthly rainfall, temperature and wind statistics, Dubbo Airport (Bureau of Meteorology, 2019).

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max. Temp (°C)	34	32	29	25	20	16	16	18	21	25	29	32
Min. Temp (°C)	18	18	15	10	6	4	3	3	6	10	14	16
Rainfall (mm)	57	40	60	31	40	50	41	35	43	48	61	61
Wind Speed[1] (km/hr)	20	19	18	17	15	15	15	17	18	19	20	20

[1] Average of 9am and 3pm monthly wind speed values

3.2 Topography and Hydrology

The generalised topography of the local area consists of low undulating hills and rises with some stony hillocks. The elevation ranges from 280–360 m above sea level with local relief ranging from 20–60 m. The slopes are 1000–4000 m long on gentle gradients of 3–8 %. Drainage lines are 400–1500 m apart (Murphy B.W.; Lawrie J.W., 1998).

The study areas of Cameron and Skinners are dissected by Eulomogo Creek which flows west towards the Macquarie River, which is located approximately 3 km to the west of Holcim Quarry. These study areas are not within a flood hazard zone (Murphy B.W.; Lawrie J.W., 1998).

The elevation within the study area is presented in Figure 3 and the slope is presented in Figure 4. The following describes the topography within the study areas of Cameron and Skinners.

- Cameron covers an area of approximately 10 ha. The elevation ranges from 300 m at the northeast to 288 m in the southwest of the site. Runoff flows southwest towards Eulomogo Creek across the plateau on slopes of <3 %; then down slopes with gradients generally <10 % and onto the neighbouring property. The steepest terrain at Cameron has gradients of 10–20%.

- Skinners covers an area of approximately 88 ha. The elevation ranges from 309 m at the southeast to 278 m in the northwest of the site. Runoff flows across the plateau on slopes less than <3 % then down slopes generally with gradients of up to 20% and into Eulomogo Creek. The steepest terrain at Skinners has gradients of near 50%.

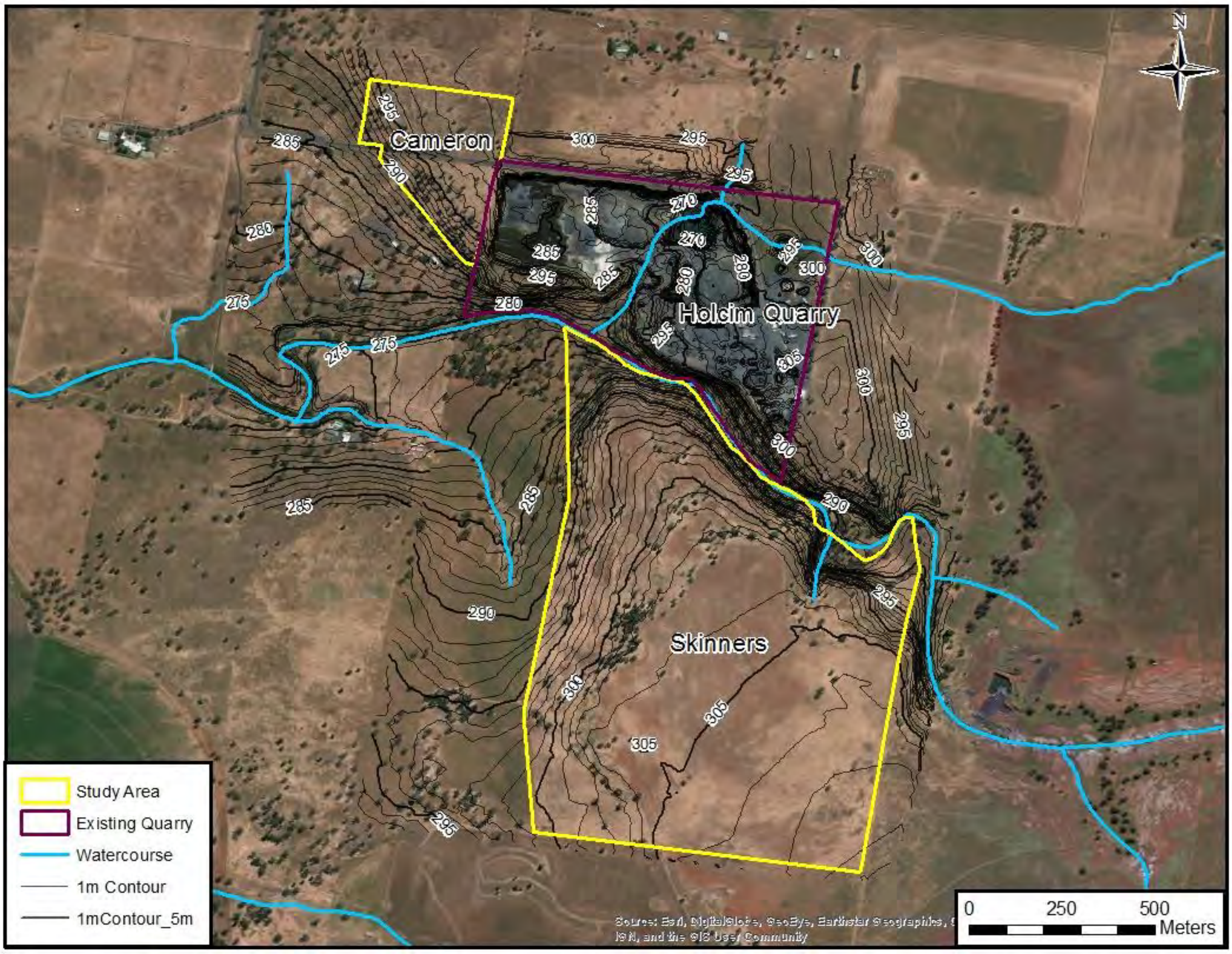

Figure 3. Topography of the study area.

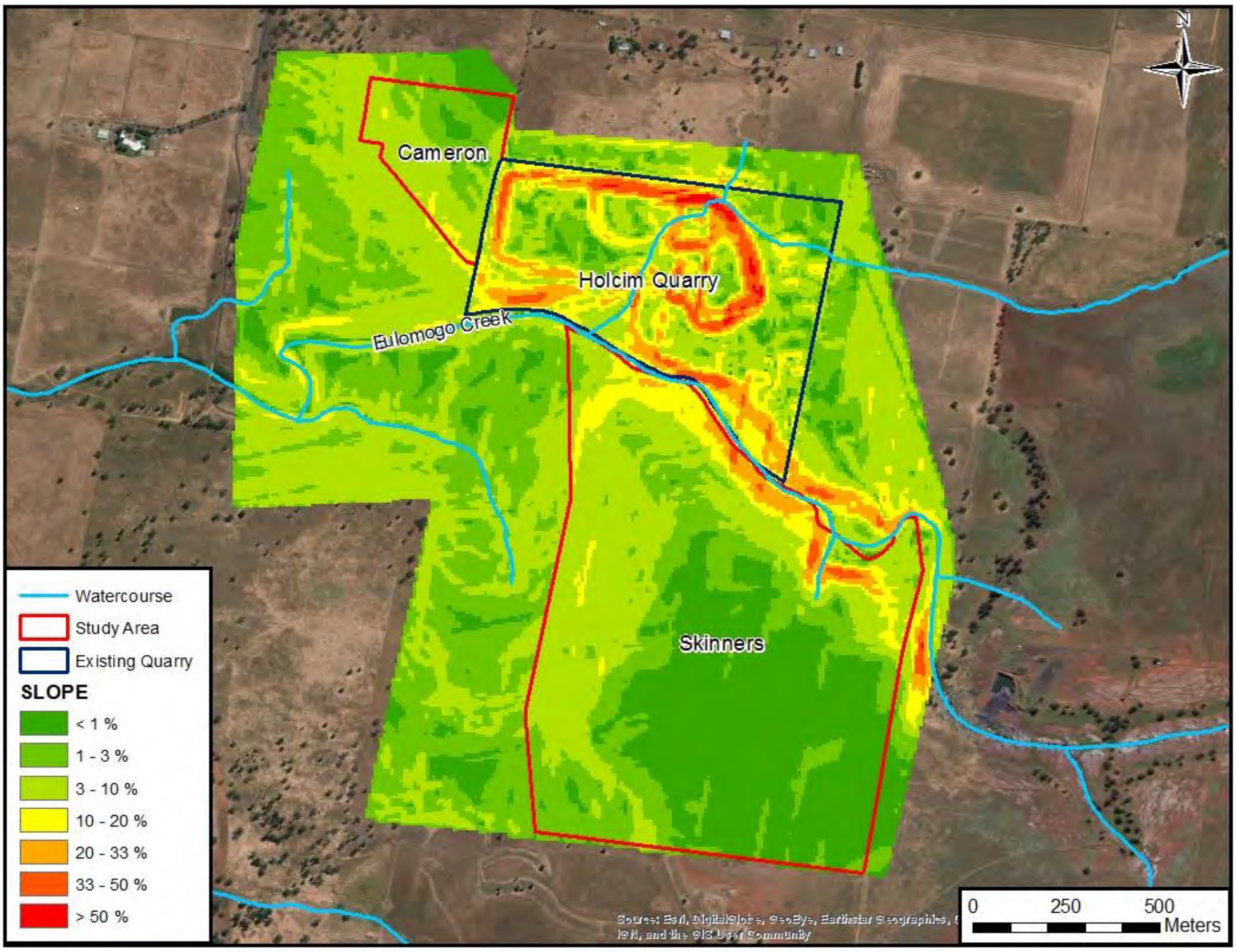

Figure 4. Slope of the study area.

3.3 Geology

The Dubbo 1:100,000 Geology Map (Raymond, 2000) shows that most of the study area falls within the Tholeiitic Alkali Basalt (Tb) geological unit (Figure 5), and there is a unit of Quaternary Alluvium (Qa) located within the northern edge of the Skinners area and within the existing Holcim Quarry.

However this mapping is considered erroneous, in that that the land represented as Quaternary Alluvium is also Tholeiitic Alkali Basalt.

In justification of this statement, the quarry is mining basalt and not alluvium. Furthermore, the field study identified basalt outcrops along Eulomogo Creek and adjacent slopes (Photographs 1a and 1b).

A description of the geological units is provided in Table 4.

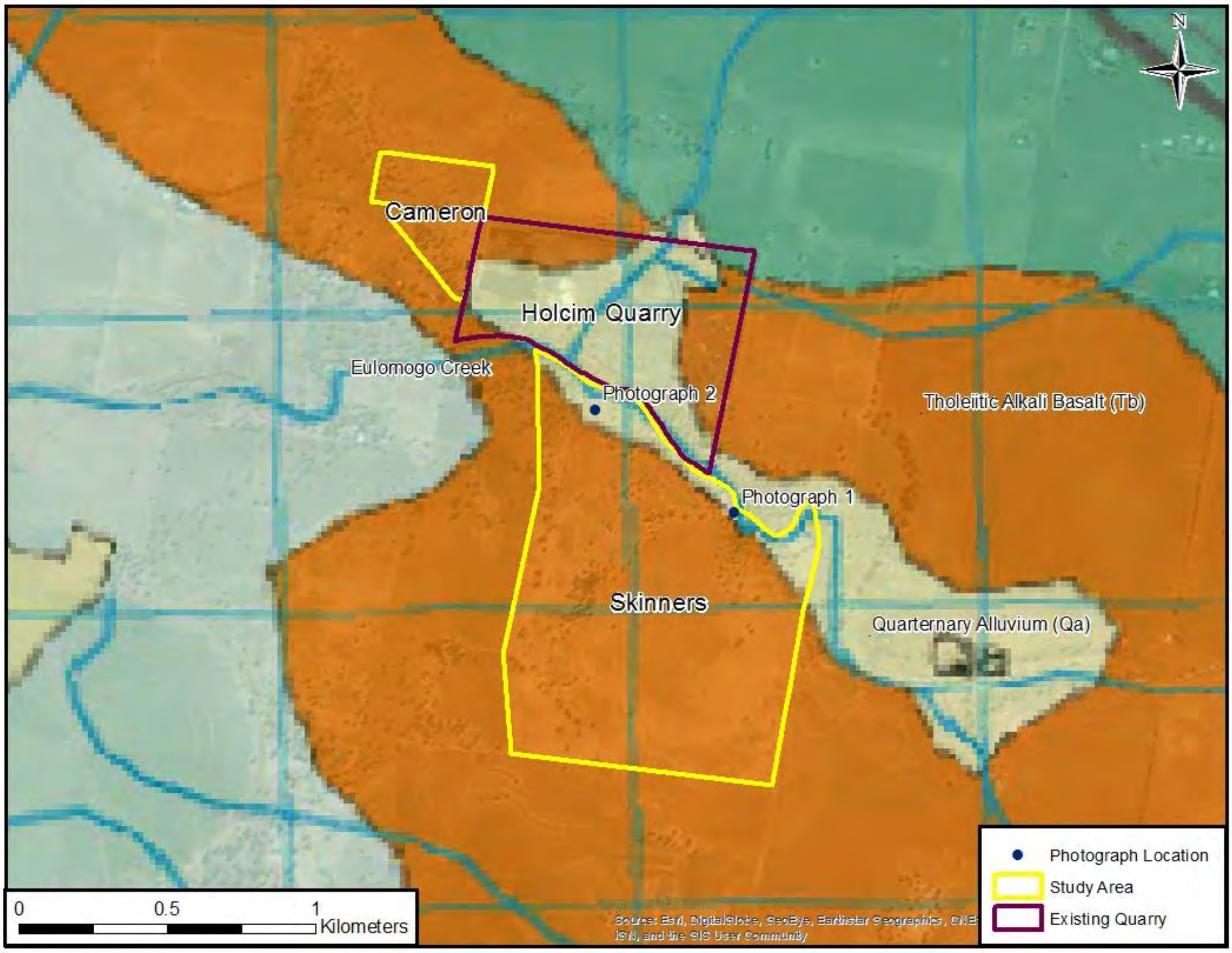

Figure 5. Geology mapping 100K of the study area (Raymond, 2000).

Photograph 1a. Basalt outcropping within the Eulomogo Creek and adjacent slopes (red arrows).

Photograph 1b. Basalt outcropping along banks of Eulomogo Creek (red arrows).

Table 4. Brief description of the geological units relevant to the study area (Raymond, 2000).

Geological unit	Map code	Description	Parent material category
Quaternary Undifferentiated Sediments (Alluvium)	Qa	Alluvial silt, clay and san, variable humic content, sporadic pebble to cobble-sized unconsolidated conglomeratic lenses	Alluvial deposits
Tholeiitic Alkali Basalt	Tb	Tholeiite, alkali basalt, basanite, nephelinite, limburgite, trachyte, rare obsidian	Cainozoic undifferentiated

3.4 Regional Soils

Cameron and Skinners are located in the Wongarbon soil landscape as described by the *Soil Landscapes of the Dubbo 1:250 000 Sheet* (Murphy B.W.; Lawrie J.W., 1998) (Figure 6). The Wongarbon Soil Landscape is considered to have the following features:

- Moderate to high fertility;
- Friable surface soils;
- High water holding capacity;
- Moderate to high erosion hazard when cultivated; and
- Moderate to high shrink-swell potential.

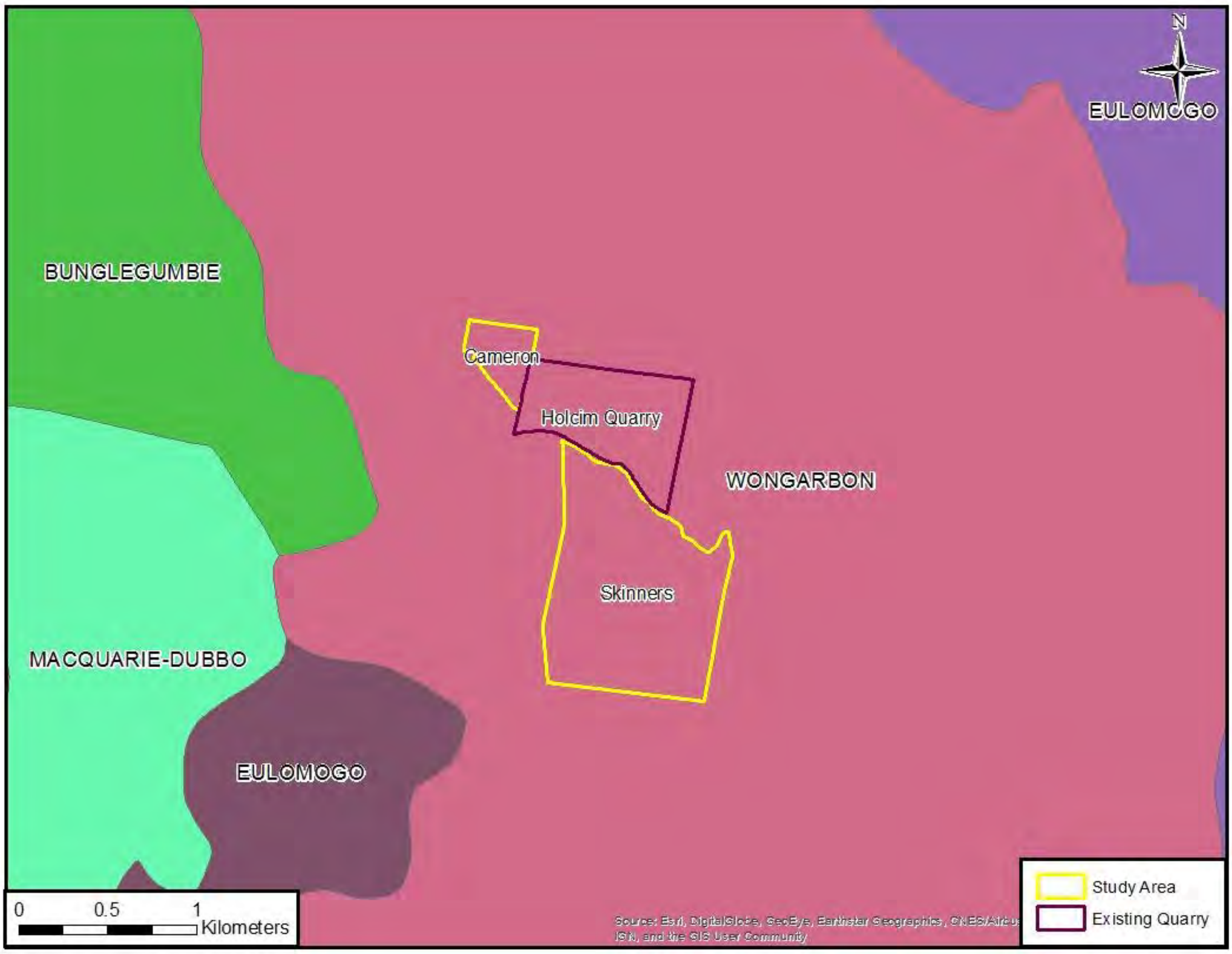

Figure 6. Soil landscapes of the study area and surrounds (NSW Goverment Spatial Services, 2019).

There are three main soil types described for the Wongarbon soil landscape (Figure 7) (Murphy B.W.; Lawrie J.W., 1998). These are detailed below:

- *Euchrozems*
  - Topsoil – Dark reddish-brown clay loam to light clay; strong structure (fine blocky to polyhedral); pH 6.0; to 15 cm depth. Gradual change to;
  - Subsoil – Strongly structured, dark reddish-brown light to medium clay; pH 6.5 - 8.0. Changing at 40 cm to reddish-brown to dark red light to medium clay; strong polyhedral to prismatic structure; pH ranges from 7.0 - 8.5. Calcium carbonate often occurs at depth (80 to 100 cm).
- *Red cracking clays*
  - Topsoil – Self-mulching, reddish-brown medium clay; strong fine blocky structure; some calcium carbonate nodules; pH 8.5; to 10 cm depth. Gradual change to;
  - Subsoil – Reddish-brown heavy clay; strong structure (coarse lenticular breaking to moderate blocky or prismatic) and soft calcium carbonate concretions; pH 8.5; to greater than 100 cm.
- *Brown cracking clays*
  - Topsoil – Self-mulching brown medium clay; strong fine polyhedral peds with small $CaCO_3$ nodules; pH 8.5. Irregular, gradual boundary at 8 cm to;
  - Subsoil – Brown heavy clay; strong prismatic structure (50 to 100mm size peds) with very shiny ped faces; soft $CaCO_3$ nodules present; grading to coarse (150 to 200 mm size peds), lenticular structure below 40 to 50 cm depth; pH is 8.5 to 100 cm.

Soils of the Wongarbon soil landscape are mainly Euchrozems (Ferrosols) on plateau tops and on mid and lower slopes. Shallow loams are often found on the steep, plateau slopes. Linear gilgai occur on slopes where red and brown cracking clays exist. Soils in the upper landscape range from dark reddish-brown clay loams and clays in the A horizon to strongly structured dark reddish-brown medium clay in the B horizon (NSW OEH, 2019).

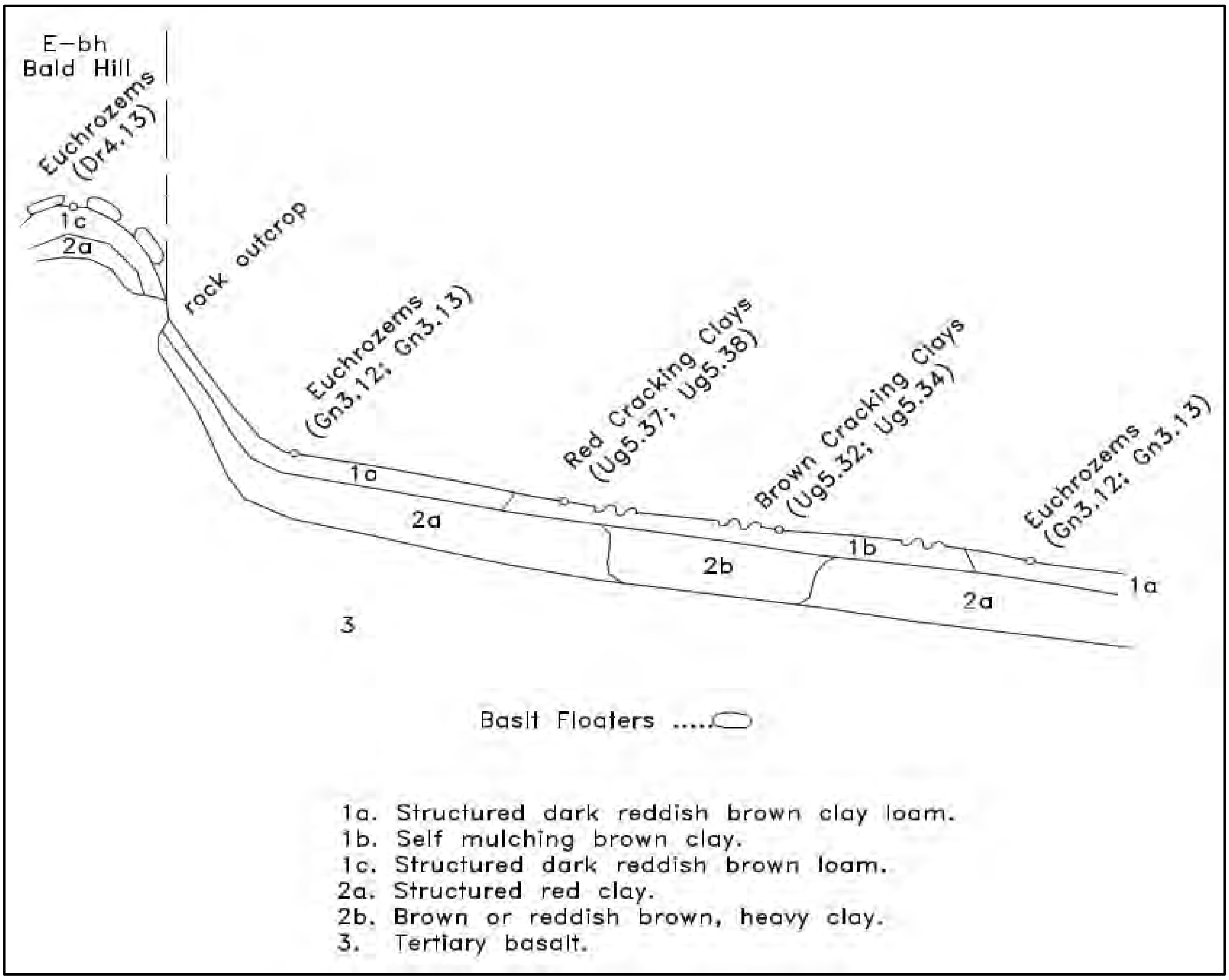

Figure 7. Soil materials of the Wongarbon soil landscape (Murphy B.W.; Lawrie J.W., 1998).

3.5 Hydrogeology and Salinity

The basalts are highly weathered and fractured. Water percolates through the dominant vertical joints and moves laterally along horizontal defects situated between lava flows and between the base of lava flows and the underlying materials. Salts concentrate where the slope changes at the contact of the basalt cap with the underlying geology, in colluvial areas and often on the valley floor. Salt sites also occur at the interflow contacts in the colluvium and where it contacts the alluvium. Salty fluids percolate laterally through these permeable sediments. Small areas of moderate to highly salt affected land are a feature of this landscape and will continue to appear (Figure 8) (NSW OEH, 2019).

The landscape has limited salt, but a relatively continuous flow through it that contributes a moderate salt load to streams. Streams typically have low electrical conductivity (EC) (<2 dS) with occasional spikes of moderate EC (2–4 dS) (NSW OEH, 2019).

The Skinners and Cameron Study Area are situated on the plateau and upper slopes that correspond as hydrological recharge zones.

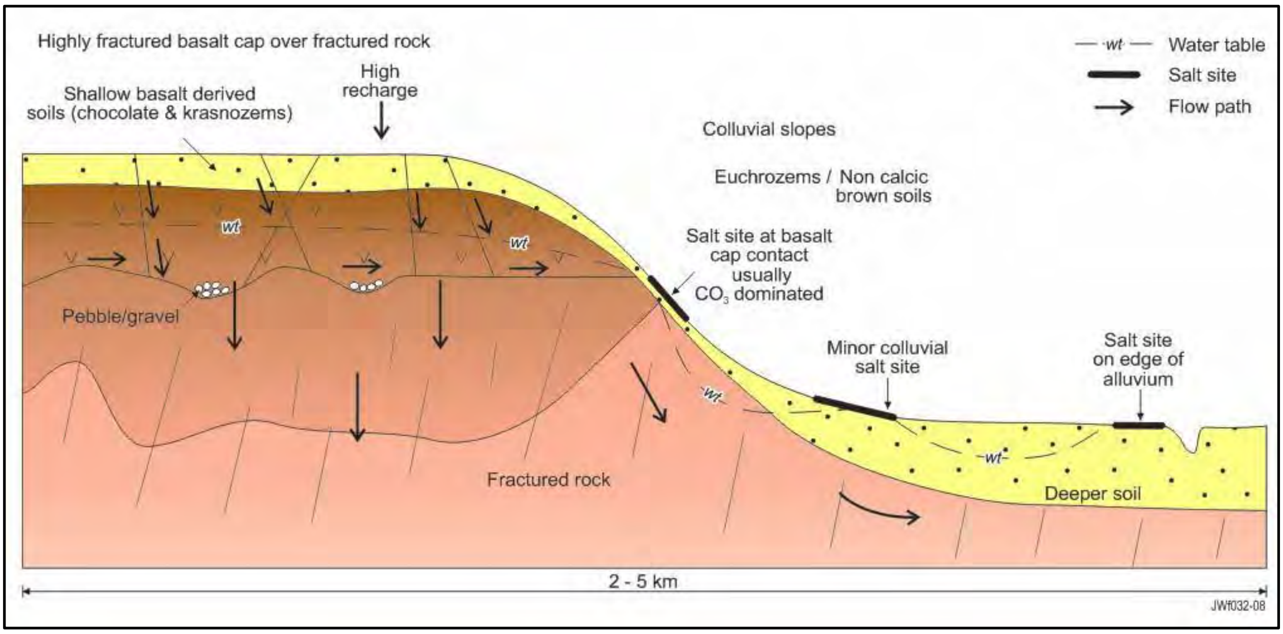

Figure 8. Conceptual Hydrogeological Landscape cross-section showing the distribution of regolith, landforms, salt sites and flow paths (NSW OEH, 2019).

3.6 Vegetation

Most of the vegetation in the study area has been cleared for cropping and grazing.

Published soil landscape mapping of the area reports that native vegetation consisted of open-woodlands that were dominated by a white-yellow box and white Cyprus pine association. White box occupies the upper slopes, with white Cyprus pine on stony, shallow ridges. The lower slopes are dominated by yellow box and fuzzy box (Murphy B.W.; Lawrie J.W., 1998).

3.7 Land Use

The primary land use in the region is dryland cropping, improved pastures and minor urban settlements. The rural capability of the Wongarbon soil landscape typically includes Class II, Class III, and Class IV cropping land (Murphy B.W.; Lawrie J.W., 1998).

4 SOILS

Soil profiles were described at sixteen locations. Records of field descriptions are provided in Appendix A (Surface Descriptions) and Appendix B (Soil Profile Descriptions). Laboratory data is present in Appendix C.

The soils from each location have been classified into two (2) soil types based on soil profile properties in common.

A total of five (5) SMU have been developed within the study area. Soil mapping units (SMU) have been developed to reflect variations in soil type, geology, landform, drainage and vegetation. All SMU have some soil variation, and generally include more than one soil type. *Simple* SMUs have predominantly one soil type, whereas *complex* SMUs have two or more soil types that are unable to be delineated at this published scale.

Details on *soil types* and *soil mapping units* follow below.

4.1 Soil Types

A total of two soil types were identified across the study area. Both of these soils are classed as *Ferrosols* according to the Australian Soil Classification (Isbell, 2002). They are differentiated from each other primarily by soil depth.

The soil types included:

- Soil Type 1: Moderately Deep Ferrosol (0.5 to <1.1 m deep); and
- Soil Type 2: Shallow Ferrosol (0.25–0.5 m deep).

In Skinners both soil types were encountered. At Cameron the only soil encountered was the *Moderately Deep Ferrosol.*

Descriptions of the two soil types are detailed below.

4.1.1 Soil Type 1: Moderately Deep Ferrosol

Brief Description	Well-structured clay soils generally 0.5 to 1.0 m deep		
Landform	Relatively flat (< 3 % slope) plateaus and gentle upper slopes (< 10 % slope) (Photograph 2a). Sometimes on steeper slopes of up to 20% (Photograph 2b).		
Geology	Tholeiitic Alkali Basalt geological unit.		
ASC	Red, Brown and Grey Ferrosols		
Microrelief	Nil	**Runoff**	Very Slow to Very Rapid (depending on slope
Permeability	Slow to moderate	**Drainage**	Moderate
Surface	Firm or soft. Cobbles cover 20–50 % of the surface in areas where not cultivated and generally < 10% in areas that are cultivated. Groundcover was generally 60–80 %.		
Observations	TP1, TP2a, TP4, TP4a, TP6, TP7, TP7a, TP8, TP8a		
Laboratory data	Full profile: TP4, TP6, TP8. Partial profile: TP1, TP7		

Photograph 2a. Site TP6 (facing north). This area is on the flat plateau and has been cleared and cultivated for pasture.

Photograph 2b. Site TP1 (facing south). Upper slopes adjacent to Eulomogo Creek.

4.1.1.1 Key features

The features listed below are characteristic of the Moderately Deep Ferrosol soils. Laboratory data for physico-chemical parameters are included in Appendix C and are summarised below as well as in Table 5 and Table 6.

- Residual, colluvial, and erosional landscapes from the Tholeiitic Alkali Basalt geological unit.
- Uniform, textured soil profiles with high cobble content (up to 60–80 %). Typical depths are 0.5–1.1 m.
- Topsoil fertility rating is *moderate–high*; total N: moderate; available P: high; available K: very high and organic carbon: moderate. The CEC indicates the topsoil has a moderate potential to supply nutrients.

Table 5. Summary of physico-chemical parameters.

Typical Depth (mm)	Texture	pH	Salinity	Sodicity/ Dispersive
0 to 50–100	Clay loam or light clay	Low to moderately acid	Low	Non-sodic / Sometimes slightly dispersive
100 to 500	Light to medium heavy clay	Low acid to highly alkaline	Low to moderate salinity	Non-sodic to sometimes sodic / Potentially dispersive and slaking
> 500	Light medium clay to medium heavy clay	Neutral to extremely alkaline	Low	Non-sodic to sometimes sodic / Potentially dispersive and slaking

Table 6. Management considerations.

Typical Depth (mm)	Growth Media Suitability	Comments
0 to 50–100	Topsoil	Moderate fertility, moderate organic matter content. Negligible physico-chemical limitations to root growth.
> 100	Subsoil	Low fertility, low organic matter. Potentially sodic

4.1.1.2 Representative profile description

Site TP6 (Photograph 3a and 3b) is classified as a Brown Ferrosol and is an example of a representative profile for a Moderately Deep Ferrosol. Its description follows:

A 0–50 mm	Reddish brown (moist 5YR 4/3) light clay. Structure moderate with polyhedral peds < 10 mm diameter. Coarse fragments 2–10 %, sub-angular cobbles < 200 mm. Laboratory pH 5.7. Roots many. Clear boundary to –
B21 50–250 mm	Reddish brown (moist 5YR 4/3) medium heavy clay. Structure strong with polyhedral peds <50 mm. Coarse fragments 2–10 %, sub-angular cobbles < 200 mm. Laboratory pH 8.3. Roots many. Gradual boundary to –

B22 250–600 mm	Brown (moist 7.5YR 4/3) medium heavy clay. Structure strong with prismatic peds <50 mm. Coarse fragments 10–20 %, sub-angular cobbles < 200 mm. Laboratory pH 9.2. Roots few. Gradual boundary to –
B3/C > 800 mm	Light clay and weathered basalt. Refusal at 800 mm.

Photograph 3a. Surface at Site TP6.

Photograph 3b. Profile at Site TP6.

4.1.2 Soil Type 2: Shallow Ferrosol

Brief Description	Well-structured clay soils generally 0.25 to 0.5 m deep.		
Landform	Relatively flat (< 3 % slope) plateaus and gentle upper slopes (< 10 % slope) (Photograph 4a). Sometimes on steeper slopes of up to 20% (Photograph 4b).		
Geology	Tholeiitic Alkali Basalt geological unit.		
ASC	Red and Brown Grey Ferrosols		
Microrelief	Nil	**Runoff**	Very Slow to Very Rapid depending on slope
Permeability	Slow to moderate	**Drainage**	Moderate
Surface	Sometimes firm and sometimes soft. Cobbles cover 20–50 % of the surface in areas where not cultivated and generally < 10% in areas that are cultivated. Groundcover was generally 60–80 %.		
Observations	TP1a, TP2, TP3, TP3a, TP5, TP5a, TP6a		
Laboratory data	Full profile: nil; Partial profile: TP2, TP3, TP5		

Photograph 4a. Site TP3 (facing north). This area is on the upper slope and has been cleared and cultivated for pasture.

Photograph 4b. Site TP2 (facing west). Upper slopes adjacent to Eulomogo Creek.

4.1.2.1 Key features

The features listed below are characteristic of the Shallow Ferrosol soils. Laboratory data for physico-chemical parameters are included in Appendix C and are summarised below as well as in Table 7 and Table 8.

- Residual, colluvial, and erosional landscapes from the Tholeiitic Alkali Basalt geological unit.
- Uniform, textured soil profiles with high cobble content (up to 60–80 %). Typical depths are 0.25–0.5 m.
- The CEC indicates the topsoil has a low to moderate potential to supply nutrients.

Table 7. Summary of physico-chemical parameters.

Typical Depth (mm)	Texture	pH	Salinity	Sodicity/ Dispersive
0 to 50–100 topsoil	Clay loam or light clay	Low to high acid	Low	Non-sodic
100 to 500 shallow subsoil	Light medium clay	Low acid	Low salinity	Non-sodic

Table 8. Management considerations.

Typical Depth (mm)	Growth Media Suitability	Comments
0 to 50–100	Topsoil	Moderate fertility, moderate organic matter content. Negligible physico-chemical limitations to root growth.
> 100	Subsoil	Low fertility, low organic matter.

4.1.2.2 Representative profile description

Site TP1 (Photograph 5a and 5b) is classified as a Brown Ferrosol and is an example of a representative profile for a Shallow Ferrosol. Its description follows:

A 0–100 mm	Dark brown (moist 7.5YR 3/4) clay loam. Structure weak with polyhedral peds < 20 mm diameter. Coarse fragments 40–60 %, sub-angular cobbles < 200 mm. Laboratory pH 6.4. Roots many. Gradual boundary to –
B 100–500 mm	Dark brown (moist 7.5YR 3/4) clay loam. Structure weak with polyhedral peds <20 mm. Coarse fragments 60–80 %, sub-angular cobbles < 200 mm. Roots many. Clear boundary to –
C > 500 mm	Weathered basalt. Refusal at 500 mm.

Photograph 5a. Surface at Site TP1.

Photograph 5b. Profile at Site TP1.

4.2 Rock Outcrops

Several areas of rock outcrop were observed during this investigation. The rock outcrops within the study area were primarily located on the crests and uppers slopes. Some of these outcrops were quite large and covered more than 1 ha. Figure 9 shows the location of rock outcrops that were confirmed during fieldworks and predicted rock outcrops identified from aerial photographs.

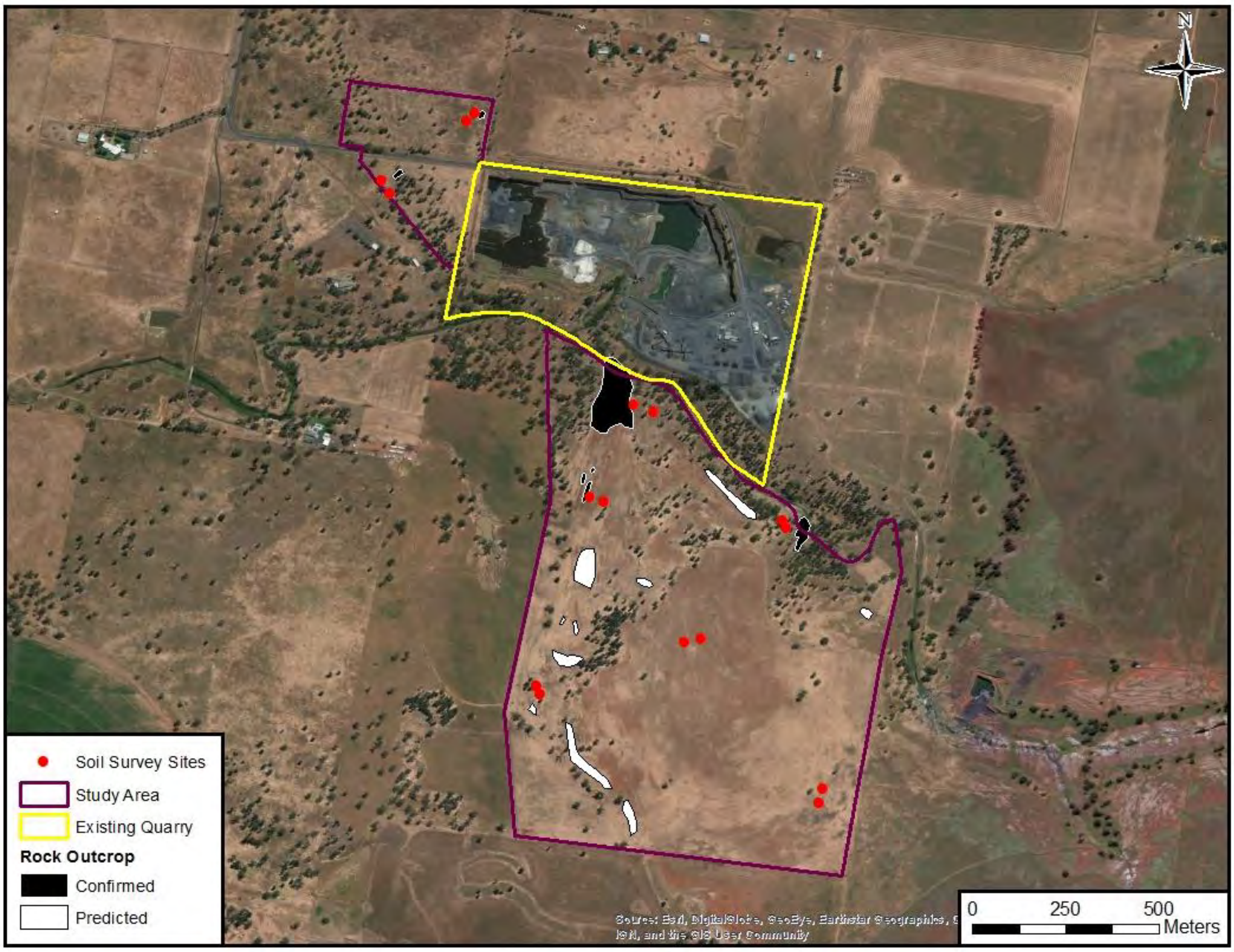

Figure 9. Location of confirmed and predicted rock outcrops.

4.3 Soil Mapping Units

A total of five (5) soil mapping units (SMU) have been developed for the study area for the purpose of LSC assessment and soil inventory/recovery (Figure 10). These are described in Table 9.

Table 9. Descriptions of the Soil Mapping Units.

SMU	Area (ha)	Description	Soil Type(s) and Sites
A	53	Landform is comprised of a crest and plateaus on basalt. Slopes are very gently inclined at < 3%. Soil depth is 0.25–0.8 m being underlain by weathered basalt.	Complex mapping unit including *Moderately Deep Ferrosol* (25 %) and *Shallow Ferrosol* (75 %). Sites included TP5/5a & TP6/6a.
B	26	Landform consists of upper slopes on basalt. Slopes are inclined at 3–10 %. Soil depth is 0.4–0.8 m being underlain by weathered basalt. Several large rock outcrops present in this SMU (approximately 1 ha in total).	Complex mapping unit including *Moderately Deep Ferrosol* (25 %) and *Shallow Ferrosol* (75 %). Sites included TP3/3a & TP4/4a
C	8	Landform consists of simple slopes on basalt. Slopes are primarily 10–20 % with some steeper slopes at up to 50 %. Soil depth is 0.4–0.8 m being limited by weathered basalt. Several large rock outcrops present in this SMU (approximately 1 ha in total).	Complex mapping unit including *Moderately Deep Ferrosol* (25 %) and *Shallow Ferrosol* (75 %). Sites included TP1/1a & TP2/2a
D	6	Landform consists of upper slopes on basalt. Slopes are primarily 3–10 % with some steeper slopes at up to 20 %. Soil depth is >1.0 m. Several small rock outcrops present in this SMU (< 1 ha in total).	Simple mapping unit including *Moderately Deep Ferrosol.* Sites included TP8/8a.
E	5	Landform consists of a plateau on basalt. Slopes are primarily <3 %. Soil depth is 0.7–>1.1 m being underlain by weathered basalt. Several small rock outcrops present in this SMU (< 1 ha in total).	Simple mapping unit including *Moderately Deep Ferrosol.* Sites included TP7/7a.

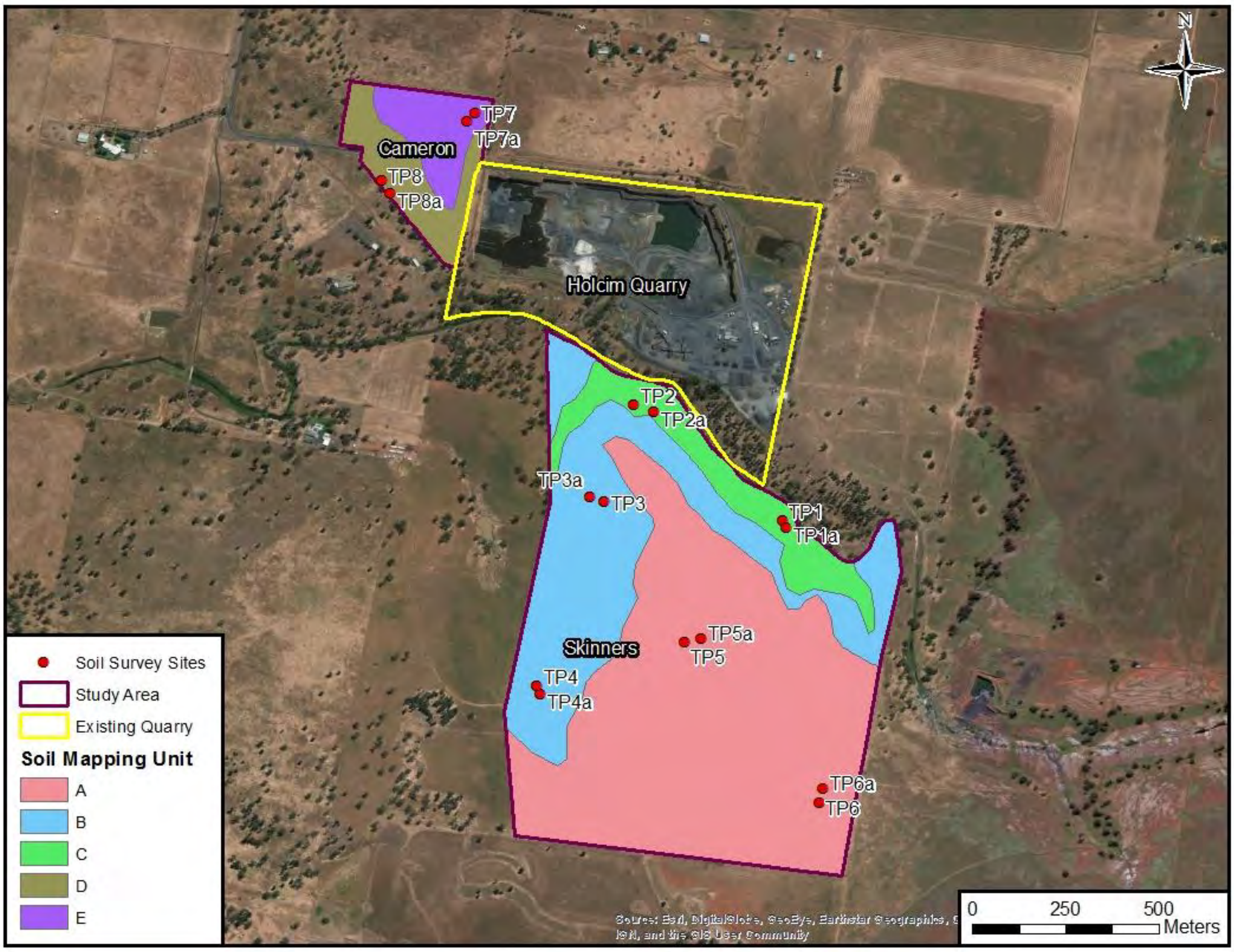

Figure 10. Soil Mapping Units of the study area.

5 LAND AND SOIL CAPABILITY ASSESSMENT

Land capability is a function of landscape features and processes and is influenced by terrain, soil and climatic attributes, as well as the interactions between these attributes. A LSC is based on the following:

- The biophysical characteristics of the land;
- The extent the biophysical characteristics will limit a particular type of land use; and
- Current technologies that are available to manage the land.

A LSC provides information on the agricultural land uses most physically suited to an area. This has regard to the requirements of the type of land use, the physical qualities of the land, and the limitations and potential hazards associated with specific uses of the site (NSW OEH, 2012).

There are eight (8) LSC classes as described in Table 10. LSC classes indicate the land management practices that can be applied to a study area without causing degradation of the land, soil and infrastructure both onsite and offsite (NSW OEH, 2012).

Table 10. General definitions of land and soil capability classes (NSW OEH, 2012).

LSC Classes	General Definition
Land capable of a wide variety of land uses (cropping, grazing, horticulture, forestry, nature conservation)	
1	**Extremely high capability land** Land has no limitations. No special land management practices required. Land capable of all rural land uses and land management practices
2	**Very high capability land** Land has slight limitations. These can be managed by readily available, easily implemented management practices. Land is capable of most land uses and land management practices, including intensive cropping with cultivation.
3	**High capability land** Land has moderate limitations and is capable of sustaining high-impact land uses, such as cropping with cultivation, using more intensive, readily available and widely accepted management practices. However, careful management of limitations is required for cropping and intensive grazing to avoid land and environmental degradation.
Land capable of a variety of land uses (cropping with restricted cultivation, pasture cropping, grazing, some horticulture, forestry, nature conservation)	
4	**Moderate capability land** Land has moderate to high limitations for high-impact land uses. Will restrict land management options for regular high-impact land uses such as cropping, high-intensity grazing and horticulture. These limitations can only be managed by specialised management practices with a high level of knowledge, expertise, inputs, investment and technology.
5	**Moderate–low capability land** Land has severe limitations for high impact land management uses such as cropping. There are few management practices generally available to overcome these limitations. However, highly specialised land management practices can overcome some limitations for high value crops or products. This land is generally more suitable for grazing with some limitations or very occasional cultivation for pasture establishment.
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

5.1 LSC Framework

The LSC assessment was undertaken with reference to *The Land and Soil Capability Assessment Scheme* (NSW OEH, 2012). The LSC framework is based on the evaluation of eight (8) main hazards and limitations for each soil mapping unit. The rating of the most limiting hazard or limitation is then used to determine the final LSC class for the land (Figure 11).

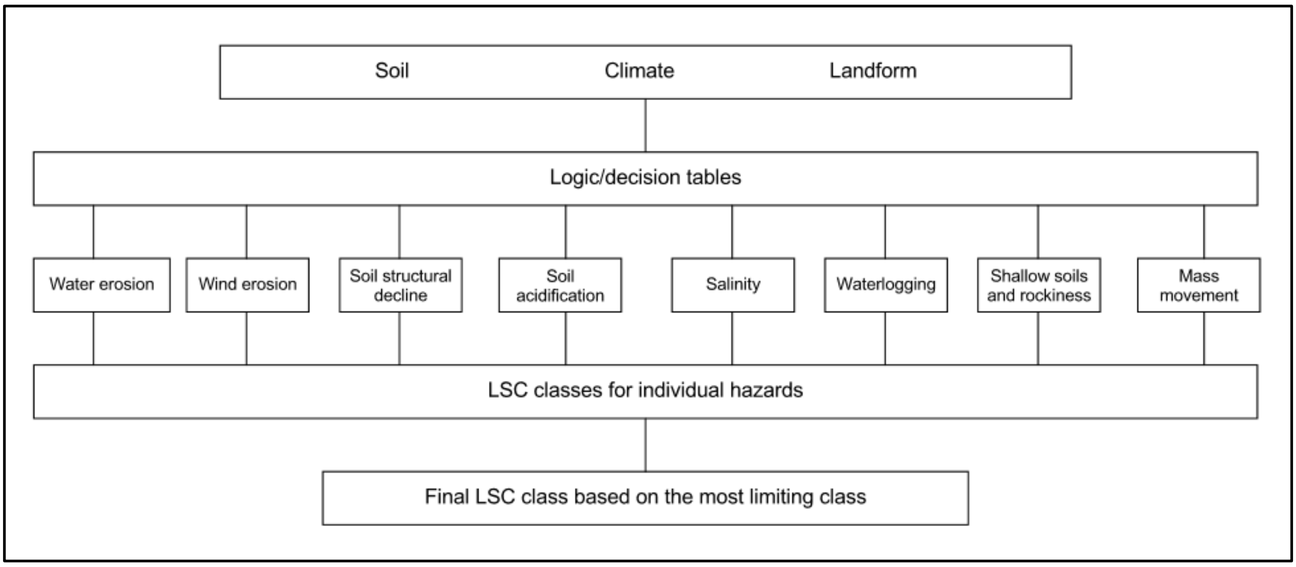

Figure 11. Biophysical information used to determine the LSC class.

The eight (8) main hazards and limitations include:

a) Water erosion (sheet, rill and gully);
b) Wind erosion;
c) Soil structure decline;
d) Soil acidification;
e) Salinity;
f) Waterlogging;
g) Shallow soils and rockiness; and
h) Mass movement.

5.2 Evaluation of Land and Soil Capability Classes

The ratings for individual LSC hazards and limitations relative to each SMU are provided in Table 11.

Table 11. Land and soil capability classes for each SMU in the study area (NSW OEH, 2012).

Hazard/Limitation	Soil Mapping Unit				
	Skinners			Cameron	
	A	B	C	D	E
Water Erosion	2	3	4	2	3
Wind Erosion	1	1	2	1	1
Soil Structural Decline	2	2	2	2	2
Soil Acidification	2	2	2	2	2
Salinity	1	1	1	1	1
Waterlogging	2	2	2	2	2
Shallow Soils and Rockiness	5[1]	5[1]	6	2	3
Mass Movement	1	1	1	1	1
LSC Class	5	5	6	2	3

[1] The LSC class for shallow rock was between Class 4 and 6 and was therefore assessed as Class 5.

Mapping of LSC Classes is provided in Figure 12.

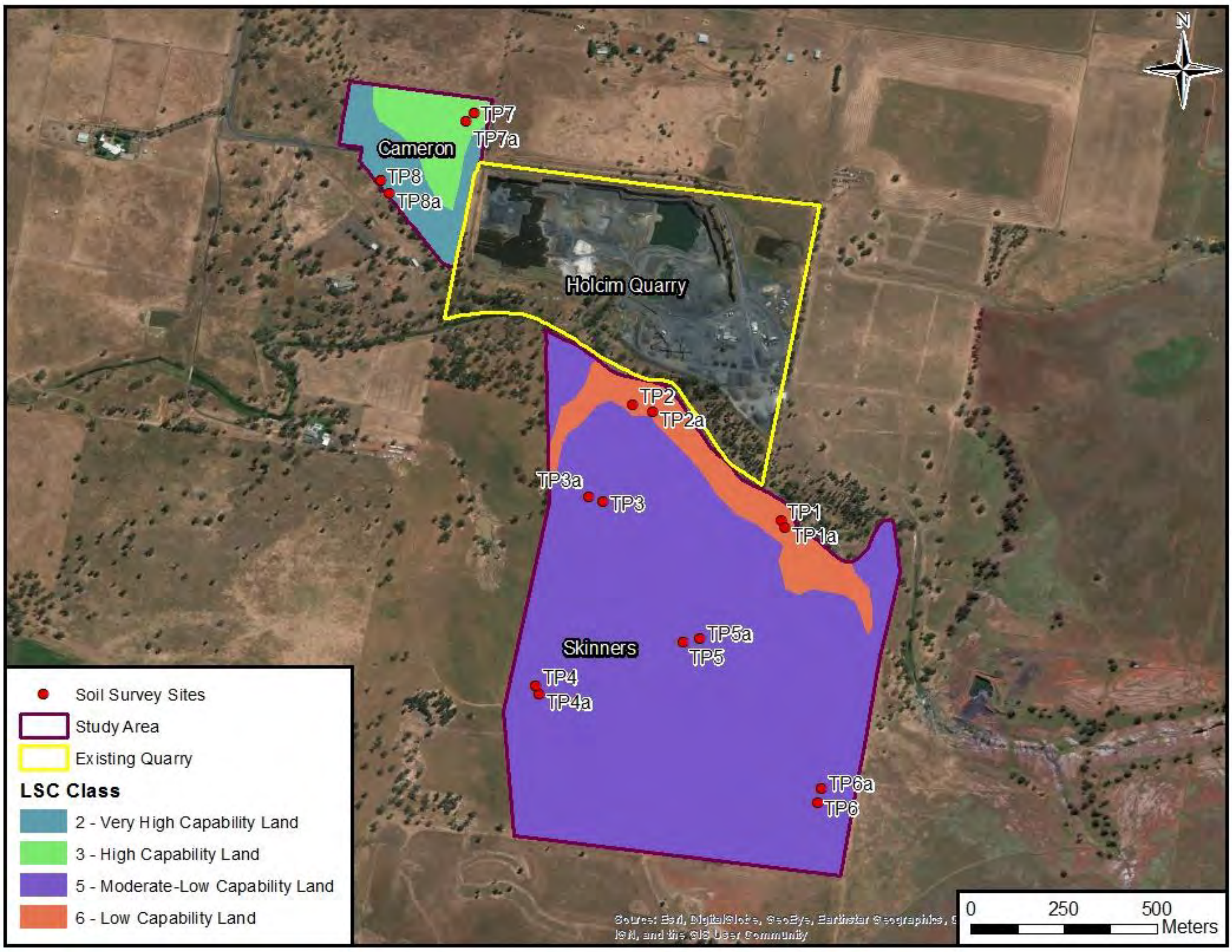

Figure 12. Land and Soil Capability Class mapping of the study area.

5.2.1 Cameron study area

Cameron has LSC Class 2 and Class 3 land. This land is capable of most land uses including cropping with cultivation, grazing, horticulture, forestry and nature conservation.

5.2.2 Skinners study area

The land use evaluation identifies that Skinners has LSC Class 5 and 6 land. Land use is primarily limited to grazing, forestry, nature conservation, and very occasional cultivation for (dryland) pasture establishment.

The primary limitation within the Skinners study area is shallow soils and rockiness. The area identified as Class 6 (Figure 8) has widespread rock outcrops that cover an estimated 30–50 % of this LSC Class and the soil depth is 0.3–0.7 m. The area identified as Class 5 (Figure 8) has localised rocky outcrops (< 30 % coverage) and the soil depth is 0.25–0.8 m.

The decision table in *The Land and Soil Capability Assessment Scheme* (NSW OEH, 2012) for Shallow Soils and Rockiness (where there are localised rock outcrops of less than 30 % coverage) rate a soil depth of 0.5–0.75 m as Class 4, a soil depth of 0.25–0.5 m as Class 6, and there is no depth given for Class 5. Since the soil depth range in this area falls across Classes 4 and 6, Class 5 was adopted as the most appropriate for this area. The current land use of the area rated as Class 5 is cultivated-improved pasture and there was no significant land degradation identified in this area during this investigation.

6 SOIL INVENTORY

Effective planning for rehabilitation of disturbed areas requires details on the quality and distribution of soil materials able or unable to support plant growth. This information will guide material handling processes such as stripping, stockpiling, storing, and amelioration. Detail on the suitability of different soil layers for each soil profile class is included in Section 5.

Successful rehabilitation to achieve post mining land use objectives requires adequate quantities of suitable growth media to support the desired vegetative community, and for the relevant landform and climate zone in which the site exists. Soil is biologically active and often fragile. When mismanaged, this leads to degradation of chemical and physical qualities, which in turn greatly reduces the likelihood of achieving rehabilitation success.

The quality of topsoil growth media requires special mention. The fertility of the topsoil materials has generally been assessed as moderate or high. However, inappropriate handling and stockpiling could easily degrade the fertility of these soils. The topsoils are mostly sands and loams that are high in organic matter, and it is this organic matter, and the associated micro-flora and micro-fauna, that is largely responsible for their chemical and physical fertility. Soil management protocols and unsuitable stockpiling practices that lead to the loss of organic matter and spoil biota will result in degradation of topsoil quality and negatively impact on the potential for rehabilitation success.

6.1 Growth Media Inventory

A summary of the growth media volumes available is provided in Table 12. Growth media volumes were estimated by assessing the extent of the soil landscape surface and multiplying this area by the average depth of available soil. Actual soil depth may vary due to changes in the landscape of each soil type. An error factor of ± 20 % is recommended to be applied to these volumes.

It is important to note these are estimates of the potential available growth media across the survey area, and quantities should be considered with caution. Bulk earthworks and handling of materials has the potential to mix different soil layers and materials and either improve, or degrade, the quality of materials as growth media.

Caution should be used with volume estimates as these are typically complex soil landscapes with a high degree of soil variability that cannot be delineated at this survey scale. Should growth media be salvaged from these areas, it may be useful and cost-effective to undertake more detailed survey work to delineate soils and allow the segregation of undesirable materials during stripping.

Table12: Potential growth media inventory for the 2018 clearing program.

SMU	Area (ha)	Available Growth Media Volumes +/- 20% (x 1000 m^3)			
		Topsoil	Subsoil	Marginal Subsoil	Poor Subsoil
A	53	53	185	N/A	N/A
B	26	26	117	N/A	N/A
C	8	8	30	N/A	N/A
D	6	6	54	N/A	N/A
E	5	5	40	N/A	N/A
Totals	98	64	426	N/A	N/A

6.2 Growth Media Depths

Guidance on soil stripping and amelioration is provided in Appendix D. The intention is that this can be easily separated from the main document and presented to the earthworks crews in a 'toolbox talk' format.

The depth of topsoil stripping and growth media salvaging should be determined by considering the quality of the soils available to be recovered, and the quality and volumes of growth media that will be required to support the target vegetation in the areas to be rehabilitated. Recommendations for stripping depths cannot be provided without access to greater details on the rehabilitation requirements. In the absence of such rehabilitation information, the following guidance is provided for discussion purposes.

- Soil should be recovered in layers and managed according to the quality and suitability of materials. For example topsoil and subsoil materials should not be mixed.
- The default depth of topsoil stripping should be approximately 100 mm, or depth to hazardous layers (e.g. sodic, saline, acidic layers) or weathered rock, whichever is shallower. This will salvage the seed bank and soil layers that generally have the highest fertility, organic matter, and biological health of the materials available, and it avoids hazardous materials that would pose limitations to plant growth. Such depths of topsoil are practicable for recovery and allow for the topsoil to be reinstated across final landforms and disturbed lands.
- Quality subsoil/substrate materials will also likely be required for rehabilitation to ensure there will be adequate depth to support plants between rainfall events. Across most of the study area there is a minimum of 0.2–0.5 m of reasonable quality (absent of hazardous limitations) subsoil/substrate materials in the root zone immediately below the topsoil.

Summary depths of growth media materials that could be stripped for each soil landscape are provided in Table 13.

Table13: Summary depths of available growth media materials for salvaging project wide.

SMU	Lower depth of material below existing ground level (mm)			
	Topsoil	Subsoil	Marginal Subsoil	Poor Subsoil
A	100	250–800	N/A	N/A
B	100	400–800	N/A	N/A
C	100	300–700	N/A	N/A
D	100	1000	N/A	N/A
E	100	700–1100	N/A	N/A

7 CONCLUDING REMARKS

This Land and Soil Capability Assessment provides an evaluation of the land use capability pre-mining. Report. The LSC across the study area includes 6 ha of Class 2 land (SMU-D); 5 ha of Class 3 land (SMU-E) 79 ha of Class 5 land (SMU–A & B); and 8 ha of Class 6 land (SMU_C).

The information within this report also provides technical soil and landscape details and recommendations to contribute to the management of soil for rehabilitation activities. Information within this report is available to inform and refine the following procedures:

- Topsoil and subsoil stripping;
- Soil balance calculations;
- Amelioration; and
- Soil related completion criteria.

8 LIMITATIONS

This report has been prepared by Landloch in response to, and subject to, the following limitations:

1. The specific instructions received from EMM Consulting;
2. The specific scope of works set out in correspondence with EMM Consulting;
3. It may not be relied upon by any third party not named in this report for any purpose except with the prior written consent of Landloch (which consent may or may not be given at the discretion of Landloch);
4. This report comprises the formal report, documentation sections, tables, figures and appendices as referred to in the index and must not be released to any third party or copied in part without all the material included in this report for any reason;
5. Field notes of ground observation sites are provided. These are a reference to document variability within soil profile classes of features such as horizon thicknesses, texture, and gravel content. Comments, notes, sketches and other details included in field notes are considered to be drafts, and represent the understanding of soils at that time in the fieldwork phase. Hence notes may differ slightly in detail from that included in the report;
6. The report relates to the site as at the date of the report. Conditions may change thereafter due to natural processes and/or site activities; and
7. No warranty or guarantee is made in regard to any use other than as specified in the scope of works and only applies to the depth tested and reported in this report and Landloch's Terms and Conditions.

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APPENDIX A – SURFACE DESCRIPTIONS

Surface Descriptions

Site ID	ASC	Easting	Northing	SMU	Observation Type	Morphological Type	Slope (%)	Geology Unit	Groundcover % (veg)	Veg/Litter	Stoniness (abundance)	Stoniness (size)
TP1	FE-AB	656391	6426527	C	Detailed	Simple Slope	18	Tb	60-80%	60/40	20-50%	<200mm
TP2	FE-AB	656058	6426844	C	Detailed	Simple Slope	10	Tb	60-80%	80/20	20-50%	<200mm
TP3	FE-AA	655987	6426584	B	Detailed	Simple Slope	5	Tb	60-80%	80/20	10-20%	<200mm
TP4	FE-AD	655826	6426092	B	Detailed	Simple Slope	4	Tb	60-80%	80/20	20-50%	<200mm
TP5	FE-AA	656163	6426204	A	Detailed	Plateau	1	Tb	60-80%	80/20	2-10%	<200mm
TP6	FE-AB	656463	6425769	A	Detailed	Plateau	1	Tb	60-80%	80/20	2-10%	<200mm
TP7	FE-AA	655708	6427631	E	Detailed	Crest	1	Tb	60-80%	80/20	2-10%	<200mm
TP8	FE-AA	655493	6427455	D	Detailed	Simple Slope	12	Tb	80-100%	80/20	2-10%	<200mm

Site ID	Surface Condition	Rock Outcrop (abundance and size)	Runoff	Drainage	Permeability	Site Disturbance	Dominant Vegetation
TP1	Soft	yes several, large	>90%	moderate	Slow	Complete Clearing (No cultivation)	grass & trees
TP2	Firm	yes several, large	>90%	moderate	Slow	Complete Clearing (No cultivation)	grass
TP3	Soft	yes several, large	70-90%	moderate	Moderate	Cultivation (No irrigation)	herbs
TP4	Firm	nil	70-90%	moderate	Slow	Complete Clearing (No cultivation)	grass
TP5	Soft	nil	<20%	moderate	Moderate	Cultivation (No irrigation)	herbs
TP6	Soft	nil	<20%	moderate	Moderate	Cultivation (No irrigation)	herbs
TP7	Soft	yes several, moderate	50-70%	moderate	Slow	Complete Clearing (No cultivation)	grass
TP8	Firm	yes several, moderate	>90%	moderate	Slow	Complete Clearing (No cultivation)	grass

APPENDIX B – SOIL PROFILE DESCRIPTIONS

Soil Profile Descriptions

Site ID	Total Depth (m)	Layer	Horizon	Depth	Boundary	Texture	Roots	Primary	Secondary	Mottles	Streaks	Moisture	Strength	Grade	Size	Type	%	Size	Shape	Comments
TP1	**0.5**	**1**	A	0.1	Gradual	Clay Loam	Many	Brown	Pale Red			Dry	Weak	Moderate	10-20mm	Polyhedral	40-60%	60-200mm	Sub-angular	reddish brown
		2	B	0.5	Clear	Clay Loam	Common	Brown	Pale Red			Dry	Weak	Moderate	10-20mm	Polyhedral	60-80%	60-200mm	Sub-angular	reddish brown
		3	C	>0.5																Weathered rock
TP1a	**0.4**	**1**	A	0.1																Check Site
		2	C	>0.4																
TP2	**0.3**	**1**	A	0.1	Gradual	Clay Loam	Many	Brown	Pale Red			Dry	Weak	Moderate	10-20mm	Polyhedral	40-60%	60-200mm	Sub-angular	reddish brown
				0.3	Gradual	Clay Loam	Common	Brown	Pale Red			Dry	Weak	Moderate	10-20mm	Polyhedral	60-80%	60-200mm	Sub-angular	reddish brown
		2	C	>0.3																Weathered rock
TP2a	**0.7**	**1**	A	0.1																check site; as above but deeper
		2	C																	
TP3	**0.4**	**1**	A	0.05	Clear	Light Clay	Many	Brown				Dry	Weak	Moderate	10-20mm	Polyhedral	20-40%	60-200mm	Sub-angular	
		2	B	0.15	Gradual	Light Medium Clay	Many	Dark Brown				Dry	Firm	Strong	20-50mm	Polyhedral	40-60%	60-200mm	Sub-angular	
		3	C	>0.4			Common	Dark Brown												
TP3a	**0.4**	**1**	A	0.1				Brown	Pale Red											
		2	B	0.3				Brown	Pale Red											reddish brown
		3	C																	
TP4	**0.8**	**1**	A	0.05	Clear	Light Clay	Many	Brown				Dry	Firm	Moderate	10-20mm	Polyhedral	2-10%	60-200mm	Sub-angular	No evidence of rock raking
		2	B21	0.3	Gradual	Medium Clay	Many	Dark Brown				Mod. Moist	Firm	Strong	20-50mm	Polyhedral	2-10%	60-200mm	Sub-angular	Some lenticular peds
		3	B22	0.6	Gradual	Medium Heavy Clay	Common	Dark Brown				Mod. Moist	Firm	Strong	50-100mm	Polyhedral	10-20%	60-200mm	Sub-rounded	Some lenticular peds
		4	C	0.8				Dark Grey												
TP4a	**0.5**	**1**						Pale Red												check site
		2						Pale Red												
TP5	**0.25**	**1**	A	0.05	Clear	Light Clay	Many	Pale Red				Dry	Weak	Moderate			2-10%	60-200mm	Sub-angular	
		2	B	0.25	Diffuse	Light Medium Clay	Many	Pale Red				Mod. Moist	Firm	Strong	20-50mm	Polyhedral	2-10%	60-200mm	Sub-angular	
		3	C																	
TP5a	**0.25**	**1**						P. Red				Dry	Weak	Moderate	5-10mm					Check site
TP6	**0.8**	**1**	A	0.05	Clear	Light Clay	Many	Brown				Dry	Firm	Moderate	5-10mm	Polyhedral	2-10%	60-200mm	Sub-angular	cultivation pan at 0.2 to 0.25
		2	B21	0.25	Gradual	Medium Heavy Clay	Many	Brown				Mod. Moist	Firm	Strong	20-50mm	Polyhedral	2-10%	60-200mm	Sub-angular	Some slicken sides
		3	B22	0.6	Gradual	Medium Heavy Clay	Few	Brown				Mod. Moist	Firm	Strong	20-50mm	Prismatic	10-20%	60-200mm	Sub-angular	Lenticular
		4	B/C	0.8	Clear	Light Clay	Few	Brown			Pale Yellow	Mod. Moist					40-60%	60-200mm	Sub-angular	
TP6a	**0.4**	**1**																		Check site
TP7	**1.1**	**1**	A	0.1	Gradual	Clay Loam	Many	Brown	Pale Red			Dry	Very Weak	Moderate	10-20mm	Polyhedral	2-10%	60-200mm	Sub-angular	reddish brown
		2	B21	0.3	Gradual	Light Clay	Common	Brown	Pale Red			Dry	Weak	Moderate	20-50mm	Polyhedral	2-10%	60-200mm	Sub-angular	reddish brown
		3	B22	0.65	Clear	Light Medium Clay	Few	Brown				Dry					60-80%	60-200mm	Sub-angular	no sample, rock
		4		>1.1			Few	Grey												white mottles
TP7a	**0.7**	**1**	A	0.1																check site; as above, but shallower rock
		2	B	0.2																
		3	C	>0.7																rock
TP8	**1**	**1**	A	0.1	Clear	Clay Loam	Many	Brown				Dry	Weak	Strong	20-50mm	Polyhedral	2-10%	60-200mm	Sub-angular	Profile in drain
		2	B21	0.3	Gradual	Light Clay	Common	Brown				Dry	Weak	Strong	20-50mm	Polyhedral	10-20%	60-200mm	Sub-angular	
		3	B22	0.6	Gradual	Light Medium Clay	Common	Brown				Dry	Weak	Strong	10-20mm	Polyhedral	20-40%	60-200mm	Sub-angular	
		4	C	>1.0			Few	Brown				Dry					40-60%	60-200mm	Sub-angular	weathered rock
TP8a	**1**	**1**																		check site; as above except shallow rock.

J/N: 3407.19d
Created by: JG

APPENDIX C – LABORATORY RESULTS

Table C1 – Moderately Deep Ferrosol (Topsoil)

Table C2 – Moderately Deep Ferrosol (Subsoil)

Table C3 – Shallow Ferrosol

TABLE C1. Laboratory Results
Soil Type 1 - Moderately Deep Ferrosol (Topsoil)

East West Enviroag Project Number: EW191047
Location: Holcim Quarry Dubbo
Landloch J/N: 3047.19d
Sample Collection Date: 7/06/2019
Sample Receival Date: 13/06/2019
Sample Analysis Date: 24/06/2019

	Lab No	191047-1		191047-5		191047-10		191047-16	
	Sample ID	TP1		TP4		TP6		TP8	
	Sample Depth (m)	0-0.1		0-0.1		0-0.1		0-0.1	
	Munsell Colour (code)	Dark Brown (7.5YR 3/4)		Dark Reddish Brown (5YR 3/2)		Redish Brown (5YR 4/3)		Dark Reddish Brown (5YR 3/4)	
	Field Texture	CL		LC		LC		CL	
Analyses	**Unit**	-		-		-		-	
pH - Water	pH units	6.42	*L.Acid*	6.24	*L.Acid*	5.68	*M.acid*	6.40	*L.Acid*
Electrical Conductivity	dS/m	0.14	*L.Sal*	0.18	*L.Sal*	0.37	*M.Sal*	0.11	*L.Sal*
Chloride	mg/kg	17.4	*VL.Sal*	34.6	*VL.Sal*	145.0	*L.Sal*	6.8	*VL.Sal*
Total Nitrogen - Kjeldahl	mg/kg	*	*	2689.0	*H*	2361.0	*M*	1369.0	*L*
Total Phosphorus - Nitric/Perchloric	mg/kg	*	*	375.0	*	364.0	*	630.0	*
Phosphorus - Colwell extr	mg/kg	*	*	43.6	*H*	55.0	*H*	23.2	*M*
Potassium - Colwell ext	mg/kg	*	*	606.0	*H*	623.00	*H*	1146.00	*VH*
Sulphur - KCl	mg/kg	*	*	11.7	*M*	20.1	*VH*	12.3	*H*
Organic Carbon	%	*	*	2.06	*H*	1.72	*M*	1.19	*M*
Copper	mg/kg	*	*	1.00	*M*	1.07	*M*	0.89	*M*
Iron	mg/kg	*	*	45.1	*	68.80	*	21.0	*
Manganese	mg/kg	*	*	20	*M*	47.3	*M*	23	*M*
Zinc	mg/kg	*	*	0.39	*L*	0.49	*L*	0.29	*L*
Boron	mg/kg	*	*	0.71	*L*	0.77	*L*	0.79	*L*
Cation Extraction Method	Rayment& Lyons	15A1	*	15A1	*	15A2	*	15A1	*
Cation Exchange Capacity	meq/100g	21.2	*M*	17.6	*M*	14.4	*M*	15.6	*M*
Ex Calcium Percent	%	67.0	*Normal*	57.5	*L*	52.2	*L*	62.6	*L*
Ex Magnesium Percent	%	20.0	*H*	31.9	*H*	33.8	*H*	18.0	*H*
Ex Potassium Percent	%	12.14	*H*	8.70	*H*	9.80	*H*	18.80	*H*
Ex Sodium Percent	%	0.7	*N.Sodic*	1.8	*N.Sodic*	4.1	*N.Sodic*	0.6	*N.Sodic*
Ex Aluminium Percent	%	0.07	*VL*	0.06	*VL*	0.08	*VL*	0.07	*VL*
Exchangeable Calcium	mg/kg	2838	*	2021	*	1506	*	1951	*
Exchangeable Magnesium	mg/kg	509	*	673	*	584	*	336	*
Exchangeable Potassium	mg/kg	1002	*	596	*	551	*	1142	*
Exchangeable Sodium	mg/kg	35.5	*	73	*	137	*	21.7	*
Exchangeable Aluminium	mg/kg	1.38	*	1.00	*	1.00	*	1.00	*
Exchangeable Calcium	meq/100g	14.20	*H*	10.10	*H*	7.53	*M*	9.76	*M*
Exchangeable Magnesium	meq/100g	4.24	*H*	5.61	*H*	4.87	*H*	2.80	*M*
Exchangeable Potassium	meq/100g	2.57	*VH*	1.53	*H*	1.41	*H*	2.93	*VH*
Exchangeable Sodium	meq/100g	0.15	*L*	0.32	*M*	0.60	*M*	0.09	*VL*
Exchangeable Aluminium	meq/100g	0.02	*VH*	0.01	*H*	0.01	*H*	0.01	*H*
Calcium/Magnesium Ratio	-	3.3	*Low Ca*	1.8	*Low Ca*	1.5	*Low Ca*	3.5	*Low Ca*
Gravel >2.0mm	%	*	*	0.2	*	0.3	*	0.8	*
Coarse Sand 0.2-2.0mm	%	*	*	18.6	*	17.0	*	25.5	*
Fine Sand 0.02-0.2mm	%	*	*	38.6	*	34.1	*	31.9	*
Silt 0.002-0.02mm	%	*	*	12.3	*	11.8	*	15.4	*
Clay <0.002mm	%	*	*	30.4	*	36.8	*	26.5	*
ADMC	%	*	*	12.9	*	7.8	*	8.4	*
Emerson Aggregate	Class	*	*	7.0	*Stable*	7.0	*Stable*	3b	*SlightDisp*
Phosphorus Buffer Index	mg/kg	*	*	86.2	*	84.2	*	126.0	

TABLE C1. Laboratory Results
Soil Type 1 - Moderately Deep Ferrosol (Topsoil)

East West Enviroag Project Number: EW191047
Location: Holcim Quarry Dubbo
Landloch J/N: 3047.19d
Sample Collection Date: 7/06/2019
Sample Receival Date: 13/06/2019
Sample Analysis Date: 24/06/2019

	Lab No	Mean		LCL 95%	UCL 95%	Std Dev	Count	CI 95% (+/-)	10%ile		90%ile		Min	Max
	Sample ID													
	Sample Depth (m)													
	Munsell Colour (code)													
	Field Texture													
Analyses	**Unit**													
pH - Water	pH units	6.19	L.Acid	5.85	6.52	0.35	4	0.34	5.85	M.acid	6.41	L.Acid	5.68	6.42
Electrical Conductivity	dS/m	0.20	M.Sal	0.09	0.31	0.12	4	0.11	0.12	L.Sal	0.31	M.Sal	0.11	0.37
Chloride	mg/kg	50.95	VL.Sal	-11.51	113.41	63.74	4	62.46	9.98	VL.Sal	111.88	L.Sal	6.80	145.00
Total Nitrogen - Kjeldahl	mg/kg	2139.67	M	1361.96	2917.37	687.27	3	777.71	1567.40	M	2623.40	H	1369.00	2689.00
Total Phosphorus - Nitric/Perchloric	mg/kg	456.33	*	286.03	626.64	150.50	3	170.30	366.20	*	579.00	*	364.00	630.00
Phosphorus - Colwell extr	mg/kg	40.60	H	22.37	58.83	16.11	3	18.23	27.28	M	52.72	H	23.20	55.00
Potassium - Colwell ext	mg/kg	791.67	VH	444.29	1139.04	306.98	3	347.37	609.40	H	1041.40	VH	606.00	1146.00
Sulphur - KCl	mg/kg	14.70	H	9.40	20.00	4.69	3	5.30	11.82	M	18.54	H	11.70	20.10
Organic Carbon	%	1.66	M	1.16	2.15	0.44	3	0.50	1.30	M	1.99	H	1.19	2.06
Copper	mg/kg	0.99	M	0.88	1.09	0.09	3	0.10	0.91	M	1.06	M	0.89	1.07
Iron	mg/kg	44.97	*	17.92	72.01	23.90	3	27.05	25.82	*	64.06	*	21.00	68.80
Manganese	mg/kg	29.93	M	12.82	47.04	15.12	3	17.11	20.32	M	42.40	M	19.70	47.30
Zinc	mg/kg	0.39	L	0.28	0.50	0.10	3	0.11	0.31	L	0.47	L	0.29	0.49
Boron	mg/kg	0.76	L	0.71	0.80	0.04	3	0.05	0.72	L	0.79	L	0.71	0.79
Cation Extraction Method	Rayment& Lyons	*	*	*	*	*	*	*	*	*	*	*	*	*
Cation Exchange Capacity	meq/100g	17.20	M	14.28	20.12	2.98	4	2.92	14.76	M	20.12	M	14.40	21.20
Ex Calcium Percent	%	59.83	L	53.56	66.09	6.40	4	6.27	53.79	L	65.68	Normal	52.20	67.00
Ex Magnesium Percent	%	25.93	H	18.01	33.84	8.08	4	7.91	18.60	H	33.23	H	18.00	33.80
Ex Potassium Percent	%	12.36	H	7.92	16.80	4.53	4	4.44	9.03	H	16.80	H	8.70	18.80
Ex Sodium Percent	%	1.81	N.Sodic	0.20	3.42	1.64	4	1.61	0.63	N.Sodic	3.43	N.Sodic	0.60	4.13
Ex Aluminium Percent	%	0.07	VL	0.06	0.08	0.01	4	0.01	0.06	VL	0.08	VL	0.06	0.08
Exchangeable Calcium	mg/kg	2079.00	*	1535.09	2622.91	555.02	4	543.91	1639.50	*	2592.90	*	1506.00	2838.00
Exchangeable Magnesium	mg/kg	525.50	*	385.35	665.65	143.02	4	140.15	387.90	*	646.30	*	336.00	673.00
Exchangeable Potassium	mg/kg	822.75	*	534.63	1110.87	294.00	4	288.12	564.50	*	1100.00	*	551.00	1142.00
Exchangeable Sodium	mg/kg	66.80	*	16.26	117.34	51.58	4	50.54	25.84	*	117.80	*	21.70	137.00
Exchangeable Aluminium	mg/kg	1.10	*	0.91	1.28	0.19	4	0.19	1.00	*	1.27	*	1.00	1.38
Exchangeable Calcium	meq/100g	10.40	H	7.67	13.12	2.78	4	2.72	8.20	M	12.97	H	7.53	14.20
Exchangeable Magnesium	meq/100g	4.38	H	3.21	5.55	1.19	4	1.17	3.23	H	5.39	H	2.80	5.61
Exchangeable Potassium	meq/100g	2.11	VH	1.37	2.85	0.76	4	0.74	1.45	H	2.82	VH	1.41	2.93
Exchangeable Sodium	meq/100g	0.29	L	0.07	0.51	0.23	4	0.22	0.11	L	0.52	M	0.09	0.60
Exchangeable Aluminium	meq/100g	0.01	H	0.01	0.02	0.01	4	0.00	0.01	H	0.02	H	0.01	0.02
Calcium/Magnesium Ratio	-	2.53	Low Ca	1.52	3.53	1.02	4	1.00	1.59	Low Ca	3.44	Low Ca	1.50	3.50
Gravel >2.0mm	%	0.43	*	0.07	0.80	0.32	3	0.36	0.22	*	0.70	*	0.20	0.80
Coarse Sand 0.2-2.0mm	%	20.37	*	15.26	25.48	4.52	3	5.11	17.32	*	24.12	*	17.00	25.50
Fine Sand 0.02-0.2mm	%	34.87	*	31.00	38.73	3.42	3	3.86	32.34	*	37.70	*	31.90	38.60
Silt 0.002-0.02mm	%	13.17	*	10.96	15.37	1.95	3	2.21	11.90	*	14.78	*	11.80	15.40
Clay <0.002mm	%	31.23	*	25.35	37.12	5.20	3	5.88	27.28	*	35.52	*	26.50	36.80
ADMC	%	9.70	*	6.55	12.85	2.79	3	3.15	7.92	*	12.00	*	7.80	12.90
Emerson Aggregate	Class	*	*	*	*	*	*	*	*	*	*	*	*	*
Phosphorus Buffer Index	mg/kg	98.80	*	72.12	125.48	23.58	3	26.68	84.60	*	118.04	*	84.20	126.00

TABLE C2. Laboratory Results
Soil Type 1 - Moderately Deep Ferrosol (Subsoil)

East West Enviroag Project Number: EW191047
Location: Holcim Quarry Dubbo
Landloch J/N: 3047.19d
Sample Collection Date: 7/06/2019
Sample Receival Date: 13/06/2019
Sample Analysis Date: 24/06/2019

	Lab No	191047-6		191047-7		191047-11		191047-12	
	Sample ID	TP4		TP4		TP6		TP6	
	Sample Depth (m)	0.2-0.3		0.5-0.6		0.2-0.3		0.5-0.6	
	Munsell Colour (code)	Very Dark Grey (5YR 3/1)		Dark Grey (10YR 4/1)		Dark Reddish Grey (5YR 4/2)		Brown (7.5YR 4/3)	
	Field Texture	MC		MHC		MHC		MHC	
Analyses	**Unit**	-		-		-		-	
pH - Water	pH units	8.60	*H.Alk*	8.99	*H.Alk*	8.26	*M.Alk*	9.20	*E.Alk*
Electrical Conductivity	dS/m	0.17	*L.Sal*	0.24	*M.Sal*	0.53	*M.Sal*	0.79	*H.Sal*
Chloride	mg/kg	22.2	*VL.Sal*	41.8	*VL.Sal*	328.0	*M.Sal*	282.0	*L.Sal*
Cation Extraction Method	Rayment& Lyons	15A1	*	15A1	*	15C1	*	15C1	*
Cation Exchange Capacity	meq/100g	34.0	*H*	44.3	*VH*	15.9	*M*	18.3	*M*
Ex Calcium Percent	%	42.4	*L*	47.4	*L*	27.7	*L*	20.4	*L*
Ex Magnesium Percent	%	51.3	*H*	46.5	*H*	52.3	*H*	57.7	*H*
Ex Potassium Percent	%	2.09	*Normal*	1.04	*Normal*	1.40	*Normal*	1.13	*Normal*
Ex Sodium Percent	%	4.3	*N.Sodic*	5.1	*N.Sodic*	18.6	*H.Sodic*	20.8	*H.Sodic*
Ex Aluminium Percent	%	0.03	*VL*	0.03	*VL*	0.07	*VL*	0.06	*VL*
Exchangeable Calcium	mg/kg	2884	*	4197	*	880	*	745	*
Exchangeable Magnesium	mg/kg	2094	*	2469	*	997	*	1266	*
Exchangeable Potassium	mg/kg	277	*	179	*	87	*	80.4	*
Exchangeable Sodium	mg/kg	333	*	515	*	679	*	875	*
Exchangeable Aluminium	mg/kg	1.00	*	1.00	*	1.00	*	1.00	*
Exchangeable Calcium	meq/100g	14.40	*H*	21.00	*VH*	4.40	*L*	3.73	*L*
Exchangeable Magnesium	meq/100g	17.50	*VH*	20.60	*VH*	8.31	*VH*	10.55	*VH*
Exchangeable Potassium	meq/100g	0.71	*H*	0.46	*M*	0.22	*L*	0.21	*L*
Exchangeable Sodium	meq/100g	1.45	*H*	2.24	*VH*	2.95	*VH*	3.80	*VH*
Exchangeable Aluminium	meq/100g	0.01	*H*	0.01	*H*	0.01	*H*	0.01	*H*
Calcium/Magnesium Ratio	-	0.8	*Low Ca*	1.0	*Low Ca*	0.5	*Low Ca*	0.4	*P.Unstab*
Gravel >2.0mm	%	0.1	*	0.7	*	0.1	*	29.3	*
Coarse Sand 0.2-2.0mm	%	10.6	*	15.7	*	18.7	*	16.2	*
Fine Sand 0.02-0.2mm	%	25.2	*	22.4	*	19.9	*	19.1	*
Silt 0.002-0.02mm	%	12.0	*	9.1	*	9.5	*	11.4	*
Clay <0.002mm	%	52.1	*	52.0	*	51.7	*	23.9	*
ADMC	%	24.5	*	22.2	*	25.1	*	12.2	*
Emerson Aggregate	Class	5.0	*Slaking*	4.0	*Slaking*	2.0	*Disp.*	4.0	*Slaking*

TABLE C2. Laboratory Results
Soil Type 1 - Moderately Deep Ferrosol (Subsoil)

East West Enviroag Project Number: EW191047
Location: Holcim Quarry Dubbo
Landloch J/N: 3047.19d
Sample Collection Date: 7/06/2019
Sample Receival Date: 13/06/2019
Sample Analysis Date: 24/06/2019

	Lab No	191047-13		191047-14		191047-15		191047-17		191047-18		191047-19	
	Sample ID	TP7		TP7		TP7		TP8		TP8		TP8	
	Sample Depth (m)	0-0.1		0.2-0.3		05-0.6		0.2-0.3		0.5-0.6		0.8-0.9	
	Munsell Colour (code)	Dark Reddish Brown (5YR 3/3)		Dark Reddish Brown (5YR 3/3)		Reddish Brown (5YR 4/4)		Dark Reddish Brown (5YR 3/4)		Dark Reddish Brown (5YR 3/4)		Yellowish Red (5YR 4/6)	
	Field Texture	CL		LC		LMC		LC		LMC		Weathered Rock	
Analyses	**Unit**	-		-		-		-		-		-	
pH - Water	pH units	5.77	*M.acid*	6.46	*L.Acid*	8.00	*M.Alk*	6.57	*L.Acid*	6.81	*Neutral*	7.43	*L.Alk*
Electrical Conductivity	dS/m	0.12	*L.Sal*	0.08	*VL.Sal*	0.08	*VL.Sal*	0.09	*L.Sal*	0.05	*VL.Sal*	0.06	*VL.Sal*
Chloride	mg/kg	9.6	*VL.Sal*	26.9	*VL.Sal*	11.2	*VL.Sal*	17.3	*VL.Sal*	6.7	*VL.Sal*	5.6	*VL.Sal*
Cation Extraction Method	Rayment& Lyons	15A1	*	15A1	*	15A1	*	15A1	*	15A1	*	15A1	*
Cation Exchange Capacity	meq/100g	13.0	*M*	11.6	*L*	63.3	*VH*	16.2	*M*	17.1	*M*	20.0	*M*
Ex Calcium Percent	%	64.0	*L*	61.1	*L*	61.5	*L*	66.0	*Normal*	67.0	*Normal*	64.0	*L*
Ex Magnesium Percent	%	19.6	*H*	28.7	*H*	33.8	*H*	20.2	*H*	22.6	*H*	25.5	*H*
Ex Potassium Percent	%	15.00	*H*	8.45	*H*	2.63	*Normal*	12.50	*H*	8.20	*H*	9.05	*H*
Ex Sodium Percent	%	1.4	*N.Sodic*	1.6	*N.Sodic*	2.0	*N.Sodic*	1.2	*N.Sodic*	2.1	*N.Sodic*	1.4	*N.Sodic*
Ex Aluminium Percent	%	0.09	*VL*	0.10	*VL*	0.02	*VL*	0.07	*VL*	0.07	*VL*	0.06	*VL*
Exchangeable Calcium	mg/kg	1658	*	1418	*	7790	*	2133	*	2289	*	2559	*
Exchangeable Magnesium	mg/kg	304	*	400	*	2567	*	391	*	464	*	612	*
Exchangeable Potassium	mg/kg	756	*	382	*	648	*	788	*	546	*	706	*
Exchangeable Sodium	mg/kg	42.6	*	41.6	*	292	*	46.3	*	80.5	*	65.6	*
Exchangeable Aluminium	mg/kg	1.00	*	1.00	*	1.00	*	1.00	*	1.00	*	1.00	*
Exchangeable Calcium	meq/100g	8.29	*M*	7.09	*M*	39.00	*VH*	10.70	*H*	11.40	*H*	12.80	*H*
Exchangeable Magnesium	meq/100g	2.53	*M*	3.33	*H*	21.40	*VH*	3.26	*H*	3.87	*H*	5.10	*H*
Exchangeable Potassium	meq/100g	1.94	*H*	0.98	*H*	1.66	*H*	2.02	*VH*	1.40	*H*	1.81	*H*
Exchangeable Sodium	meq/100g	0.19	*L*	0.18	*L*	1.27	*H*	0.20	*L*	0.35	*M*	0.29	*L*
Exchangeable Aluminium	meq/100g	0.01	*H*	0.01	*H*	0.01	*H*	0.01	*H*	0.01	*H*	0.01	*H*
Calcium/Magnesium Ratio	-	3.3	*Low Ca*	2.1	*Low Ca*	1.8	*Low Ca*	3.3	*Low Ca*	3.0	*Low Ca*	2.5	*Low Ca*
Gravel >2.0mm	%	*	*	*	*	*	*	9.1	*	4.0	*	*	*
Coarse Sand 0.2-2.0mm	%	*	*	*	*	*	*	16.0	*	17.0	*	*	*
Fine Sand 0.02-0.2mm	%	*	*	*	*	*	*	31.6	*	27.6	*	*	*
Silt 0.002-0.02mm	%	*	*	*	*	*	*	12.2	*	11.5	*	*	*
Clay <0.002mm	%	*	*	*	*	*	*	31.1	*	39.9	*	*	*
ADMC	%	*	*	*	*	*	*	9.1	*	10.0	*	*	*
Emerson Aggregate	Class	*	*	*	*	*	*	5.0	*Slaking*	3b	*SlightDisp*	*	*

TABLE C2. Laboratory Results
Soil Type 1 - Moderately Deep Ferrosol (Subsoil)

East West Enviroag Project Number: EW191047
Location: Holcim Quarry Dubbo
Landloch J/N: 3047.19d
Sample Collection Date: 7/06/2019
Sample Receival Date: 13/06/2019
Sample Analysis Date: 24/06/2019

	Lab No	Mean		LCL 95%	UCL 95%	Std Dev	Count	CI 95% (+/-)	10%ile		90%ile		Min	Max
	Sample ID													
	Sample Depth (m)													
	Munsell Colour (code)													
	Field Texture													
Analyses	**Unit**													
pH - Water	pH units	7.61	L.Alk	6.88	8.34	1.18	10	0.73	6.39	L.Acid	9.01	E.Alk	5.77	9.20
Electrical Conductivity	dS/m	0.22	M.Sal	0.07	0.37	0.25	10	0.15	0.06	VL.Sal	0.56	H.Sal	0.05	0.79
Chloride	mg/kg	75.13	VL.Sal	-0.56	150.82	122.12	10	75.69	6.59	VL.Sal	286.60	L.Sal	5.60	328.00
Cation Extraction Method	Rayment& Lyons	*	*	*	*	*	*	*	*	*	*	*	*	*
Cation Exchange Capacity	meq/100g	25.37	H	14.97	35.77	16.78	10	10.40	12.86	M	46.20	VH	11.60	63.30
Ex Calcium Percent	%	52.15	L	41.65	62.65	16.95	10	10.50	26.97	L	66.10	Normal	20.40	67.00
Ex Magnesium Percent	%	35.82	H	26.70	44.94	14.71	10	9.12	20.14	H	52.84	H	19.60	57.70
Ex Potassium Percent	%	6.15	H	2.95	9.34	5.16	10	3.20	1.12	Normal	12.75	H	1.04	15.00
Ex Sodium Percent	%	5.85	N.Sodic	1.24	10.46	7.43	10	4.61	1.38	N.Sodic	18.82	H.Sodic	1.20	20.80
Ex Aluminium Percent	%	0.06	VL	0.04	0.08	0.03	10	0.02	0.03	VL	0.09	VL	0.02	0.10
Exchangeable Calcium	mg/kg	2655.30	*	1372.78	3937.82	2069.27	10	1282.52	866.50	*	4556.30	*	745.00	7790.00
Exchangeable Magnesium	mg/kg	1156.40	*	598.60	1714.20	899.97	10	557.80	382.30	*	2478.80	*	304.00	2567.00
Exchangeable Potassium	mg/kg	444.94	*	272.34	617.54	278.48	10	172.60	86.34	*	759.20	*	80.40	788.00
Exchangeable Sodium	mg/kg	297.06	*	109.74	484.38	302.23	10	187.32	42.50	*	698.60	*	41.60	875.00
Exchangeable Aluminium	mg/kg	1.00	*	#NUM!	#NUM!	0.00	10	#NUM!	1.00	*	1.00	*	1.00	1.00
Exchangeable Calcium	meq/100g	13.28	H	6.86	19.70	10.36	10	6.42	4.33	L	22.80	VH	3.73	39.00
Exchangeable Magnesium	meq/100g	9.65	VH	4.99	14.30	7.51	10	4.66	3.19	H	20.68	VH	2.53	21.40
Exchangeable Potassium	meq/100g	1.14	H	0.70	1.58	0.71	10	0.44	0.22	L	1.95	H	0.21	2.02
Exchangeable Sodium	meq/100g	1.29	H	0.48	2.11	1.31	10	0.81	0.19	L	3.04	VH	0.18	3.80
Exchangeable Aluminium	meq/100g	0.01	H	0.01	0.01	0.00	10	0.00	0.01	H	0.01	H	0.01	0.01
Calcium/Magnesium Ratio	-	1.87	Low Ca	1.16	2.58	1.14	10	0.71	0.49	P.Unstab	3.30	Low Ca	0.40	3.30
Gravel >2.0mm	%	7.22	*	-1.87	16.31	11.36	6	9.09	0.10	*	19.20	*	0.10	29.30
Coarse Sand 0.2-2.0mm	%	15.70	*	13.52	17.88	2.72	6	2.18	13.15	*	17.85	*	10.60	18.70
Fine Sand 0.02-0.2mm	%	24.30	*	20.46	28.14	4.80	6	3.84	19.50	*	29.60	*	19.10	31.60
Silt 0.002-0.02mm	%	10.95	*	9.89	12.01	1.32	6	1.06	9.30	*	12.10	*	9.10	12.20
Clay <0.002mm	%	41.78	*	32.01	51.56	12.22	6	9.78	27.50	*	52.05	*	23.90	52.10
ADMC	%	17.18	*	11.16	23.20	7.53	6	6.02	9.55	*	24.80	*	9.10	25.10
Emerson Aggregate	Class	*	*		*	*	*	*	*	*	*	*	*	*

TABLE C3. Laboratory Results
Soil Type 2 - Shallow Ferrosol

East West Enviroag Project Number: EW191047
Location: Holcim Quarry Dubbo
Landloch J/N: 3047.19d
Sample Collection Date: 7/06/2019
Sample Receival Date: 13/06/2019
Sample Analysis Date: 24/06/2019

	Lab No	191047-2		191047-3		191047-4		191047-8		191047-9	
	Sample ID	TP2		TP3		TP3		TP5		TP5	
	Sample Depth (m)	0-0.1		0-0.05		0.05-0.15		0-0.1		0.1-0.2	
	Munsell Colour (code)	Dark Brown (7.5YR 3/4)		Dark Reddish Brown (5YR 3/3)		Dark Reddish Brown (5YR 2.5/2)		Red (2.5YR 4/6)		Red (2.5YR 4/6)	
	Field Texture	CL		LC		LMC		LC		MC	
Analyses	**Unit**	-		-		-		-		-	
pH - Water	pH units	6.17	*L.Acid*	6.25	*L.Acid*	6.45	*L.Acid*	5.22	*H.Acid*	6.22	*L.Acid*
Electrical Conductivity	dS/m	0.06	*VL.Sal*	0.11	*L.Sal*	0.10	*VL.Sal*	0.14	*L.Sal*	0.14	*L.Sal*
Chloride	mg/kg	7.1	*VL.Sal*	4.3	*VL.Sal*	7.3	*VL.Sal*	9.8	*VL.Sal*	24.0	*VL.Sal*
Cation Extraction Method	Rayment& Lyons	15A1	*	15A1	*	15A1	*	15A1	*	15A1	*
Cation Exchange Capacity	meq/100g	14.6	*M*	17.8	*M*	17.5	*M*	8.8	*L*	10.9	*L*
Ex Calcium Percent	%	60.0	*L*	61.1	*L*	58.4	*L*	58.6	*L*	65.2	*Normal*
Ex Magnesium Percent	%	26.9	*H*	32.6	*H*	37.5	*H*	31.6	*H*	31.7	*H*
Ex Potassium Percent	%	12.00	*H*	5.50	*H*	2.21	*Normal*	6.92	*H*	2.02	*Normal*
Ex Sodium Percent	%	1.1	*N.Sodic*	0.8	*N.Sodic*	1.8	*N.Sodic*	2.6	*N.Sodic*	0.9	*N.Sodic*
Ex Aluminium Percent	%	0.08	*VL*	0.06	*VL*	0.06	*VL*	0.22	*VL*	0.10	*VL*
Exchangeable Calcium	mg/kg	1748	*	2169	*	2048	*	1034	*	1418	*
Exchangeable Magnesium	mg/kg	470	*	695	*	788	*	335	*	414	*
Exchangeable Potassium	mg/kg	682	*	381	*	151	*	238	*	85.8	*
Exchangeable Sodium	mg/kg	35.8	*	31.6	*	73.8	*	53.3	*	23.7	*
Exchangeable Aluminium	mg/kg	1.00	*	1.00	*	1.00	*	1.74	*	1.00	*
Exchangeable Calcium	meq/100g	8.74	*M*	10.80	*H*	10.20	*H*	5.17	*M*	7.09	*M*
Exchangeable Magnesium	meq/100g	3.92	*H*	5.79	*H*	6.57	*H*	2.79	*M*	3.45	*H*
Exchangeable Potassium	meq/100g	1.75	*H*	0.98	*H*	0.39	*M*	0.61	*M*	0.22	*L*
Exchangeable Sodium	meq/100g	0.16	*L*	0.14	*L*	0.32	*M*	0.23	*L*	0.10	*L*
Exchangeable Aluminium	meq/100g	0.01	*H*	0.01	*H*	0.01	*H*	0.02	*VH*	0.01	*H*
Calcium/Magnesium Ratio	-	2.2	*Low Ca*	1.9	*Low Ca*	1.6	*Low Ca*	1.9	*Low Ca*	2.1	*Low Ca*

TABLE C3. Laboratory Results
Soil Type 2 - Shallow Ferrosol

East West Enviroag Project Number: EW191047
Location: Holcim Quarry Dubbo
Landloch J/N: 3047.19d
Sample Collection Date: 7/06/2019
Sample Receival Date: 13/06/2019
Sample Analysis Date: 24/06/2019

	Lab No	Mean		LCL 95%	UCL 95%	Std Dev	Count	CI 95% (+/-)	10%ile		90%ile		Min	Max
	Sample ID													
	Sample Depth (m)													
	Munsell Colour (code)													
	Field Texture													
Analyses	**Unit**													
pH - Water	pH units	6.06	M.acid	5.64	6.48	0.48	5	0.42	5.60	M.acid	6.37	L.Acid	5.22	6.45
Electrical Conductivity	dS/m	0.11	L.Sal	0.08	0.14	0.03	5	0.03	0.08	VL.Sal	0.14	L.Sal	0.06	0.14
Chloride	mg/kg	10.50	VL.Sal	3.67	17.33	7.79	5	6.83	5.42	VL.Sal	18.32	VL.Sal	4.30	24.00
Cation Extraction Method	Rayment& Lyons	*	*	*	*	*	*	*	*	*	*	*	*	*
Cation Exchange Capacity	meq/100g	13.92	M	10.42	17.42	3.99	5	3.50	9.64	L	17.68	M	8.80	17.80
Ex Calcium Percent	%	60.66	L	58.24	63.08	2.77	5	2.42	58.48	L	63.56	L	58.40	65.20
Ex Magnesium Percent	%	32.06	H	28.76	35.36	3.77	5	3.30	28.78	H	35.54	H	26.90	37.50
Ex Potassium Percent	%	5.73	H	2.14	9.32	4.09	5	3.59	2.10	Normal	9.97	H	2.02	12.00
Ex Sodium Percent	%	1.44	N.Sodic	0.78	2.10	0.76	5	0.66	0.84	N.Sodic	2.28	N.Sodic	0.80	2.60
Ex Aluminium Percent	%	0.10	VL	0.05	0.16	0.07	5	0.06	0.06	VL	0.17	VL	0.06	0.22
Exchangeable Calcium	mg/kg	1683.40	*	1275.78	2091.02	465.05	5	407.62	1187.60	*	2120.60	*	1034.00	2169.00
Exchangeable Magnesium	mg/kg	540.40	*	371.61	709.19	192.57	5	168.79	366.60	*	750.80	*	335.00	788.00
Exchangeable Potassium	mg/kg	307.56	*	100.08	515.04	236.71	5	207.48	111.88	*	561.60	*	85.80	682.00
Exchangeable Sodium	mg/kg	43.64	*	26.07	61.21	20.04	5	17.57	26.86	*	65.60	*	23.70	73.80
Exchangeable Aluminium	mg/kg	1.15	*	0.86	1.44	0.33	5	0.29	1.00	*	1.44	*	1.00	1.74
Exchangeable Calcium	meq/100g	8.40	M	6.38	10.42	2.31	5	2.02	5.94	M	10.56	H	5.17	10.80
Exchangeable Magnesium	meq/100g	4.50	H	3.10	5.91	1.61	5	1.41	3.05	H	6.26	H	2.79	6.57
Exchangeable Potassium	meq/100g	0.79	H	0.26	1.32	0.61	5	0.53	0.29	L	1.44	H	0.22	1.75
Exchangeable Sodium	meq/100g	0.19	L	0.11	0.27	0.09	5	0.08	0.12	L	0.28	L	0.10	0.32
Exchangeable Aluminium	meq/100g	0.01	H	0.01	0.02	0.00	5	0.00	0.01	H	0.02	H	0.01	0.02
Calcium/Magnesium Ratio	-	1.94	Low Ca	1.74	2.14	0.23	5	0.20	1.72	Low Ca	2.16	Low Ca	1.60	2.20

APPENDIX D – SOIL RECOVERY TOOLBOX

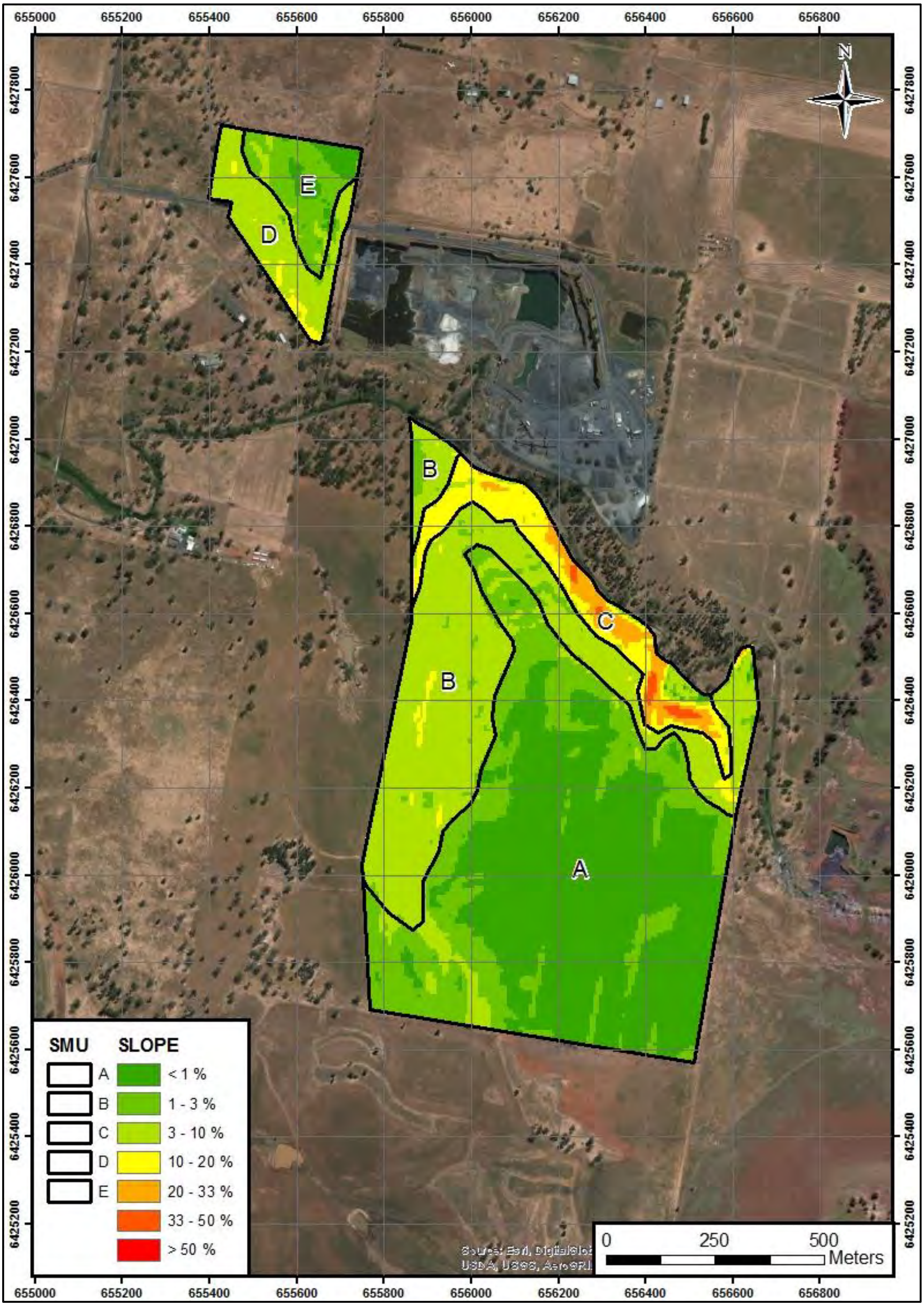
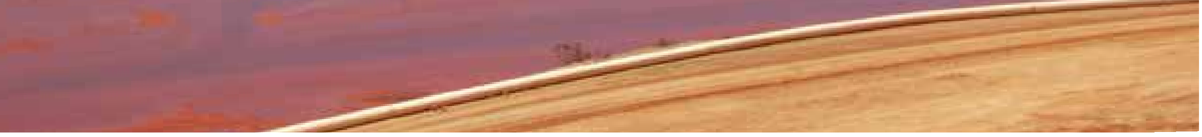
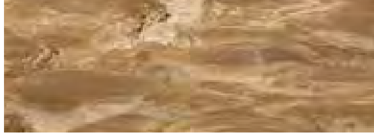


Figure D1. Soil stripping areas.

Table D1. Soil Recovery Summary Details

SMU	Stripping Depth (mm)	Texture	Rehabilitation Suitability	Amelioration	Rock content
SKINNERS STUDY AREA					
A, B, & C	0 to 100[1]	Light CLAY	TOPSOIL	NIL	2–10% cobbles. Rock outcrop and shallow rock common
	100 to >250[2]	Medium to medium heavy CLAY	SUBSOIL	Agricultural gypsum at 3 t/ha, per 300 mm of excavation	2–60% cobbles. Rock outcrop and shallow rock common
CAMERON STUDY AREA					
D& E	0 to 100[1]	Clay LOAM	TOPSOIL	NIL	2–10% cobbles. Rock outcrop and shallow rock common
	100 to >1000[2]	Light to light medium CLAY	SUBSOIL	Agricultural gypsum at 3 t/ha, per 300 mm of excavation	10–60% cobbles. Rock outcrop and shallow rock common

Notes: [1] Depth is ± 50 mm; [2] Depth is ± 100 mm



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