Appendix F

Land resources and rehabilitation study

Soil and rehabilitation assessment

Gunlake Extension Project

Prepared for Gunlake Quarries Pty Limited | 5 February 2016

Soil and rehabilitation assessment

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Soil and rehabilitation assessment

Final

Report J14119RP9 | Prepared for Gunlake Quarries Pty Limited | 5 February 2016

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1 Introduction

1.1 Overview

Gunlake Quarry is a hard rock quarry operated by Gunlake Quarries Pty Limited (Gunlake). It is located approximately 7 kilometres (km) north-west of Marulan in the Goulburn Mulwaree local government area (Figure 1.1). Gunlake Quarry has been operating since 2009 and Gunlake is proposing to expand these operations.

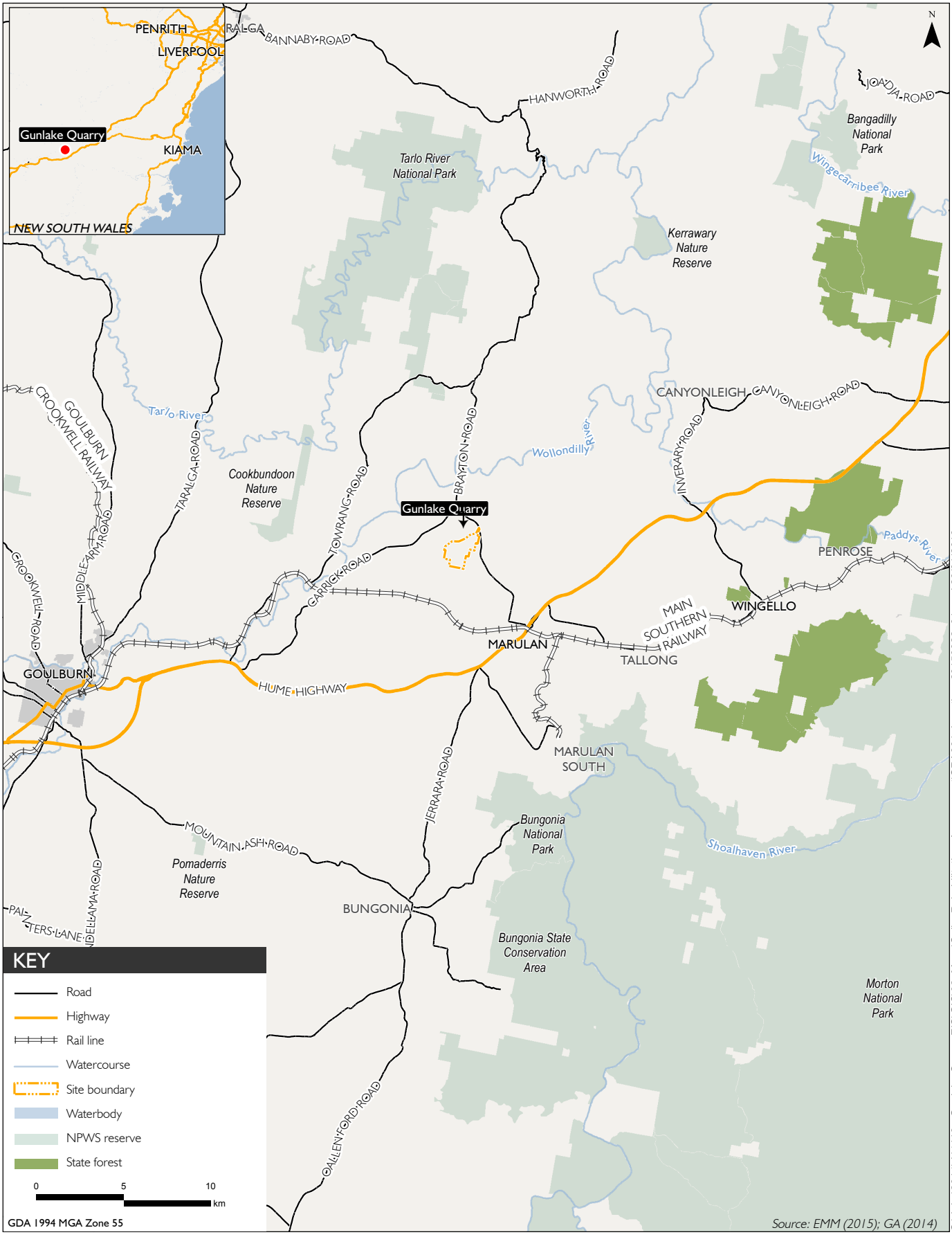
Gunlake Quarry currently operates under project approval 07-0074 issued by the Minister for Planning in September 2008 under Part 3A of the *NSW Environmental Planning and Assessment Act 1979* (EP&A Act). The project approval has been modified on three occasions.

The Gunlake Quarry extension (the extension project) seeks to enable an increased rate of extraction at Gunlake Quarry to assist in meeting the identified demand for construction materials, including quarried aggregate, for the local area and Sydney.

Gunlake is seeking a new development consent for the proposal under Part 4, Division 4.1 of *the NSW Environmental Planning and Assessment Act 1979* (EP&A Act) as the proposal is a State significant development (SSD), to allow:

- 2 million tonnes per annum (Mtpa) of saleable products to be produced;
- an increase in truck movements to an average of 440 movements per day (ie 220 laden trucks) and a maximum rate of 690 movements per day;
- extension of the quarry pit footprint to approximately 54 ha;
- 24 hour per day primary crushing;
- additional overburden emplacement (approximately 10 ha) to accommodate the increase in production; and
- blasting twice weekly.

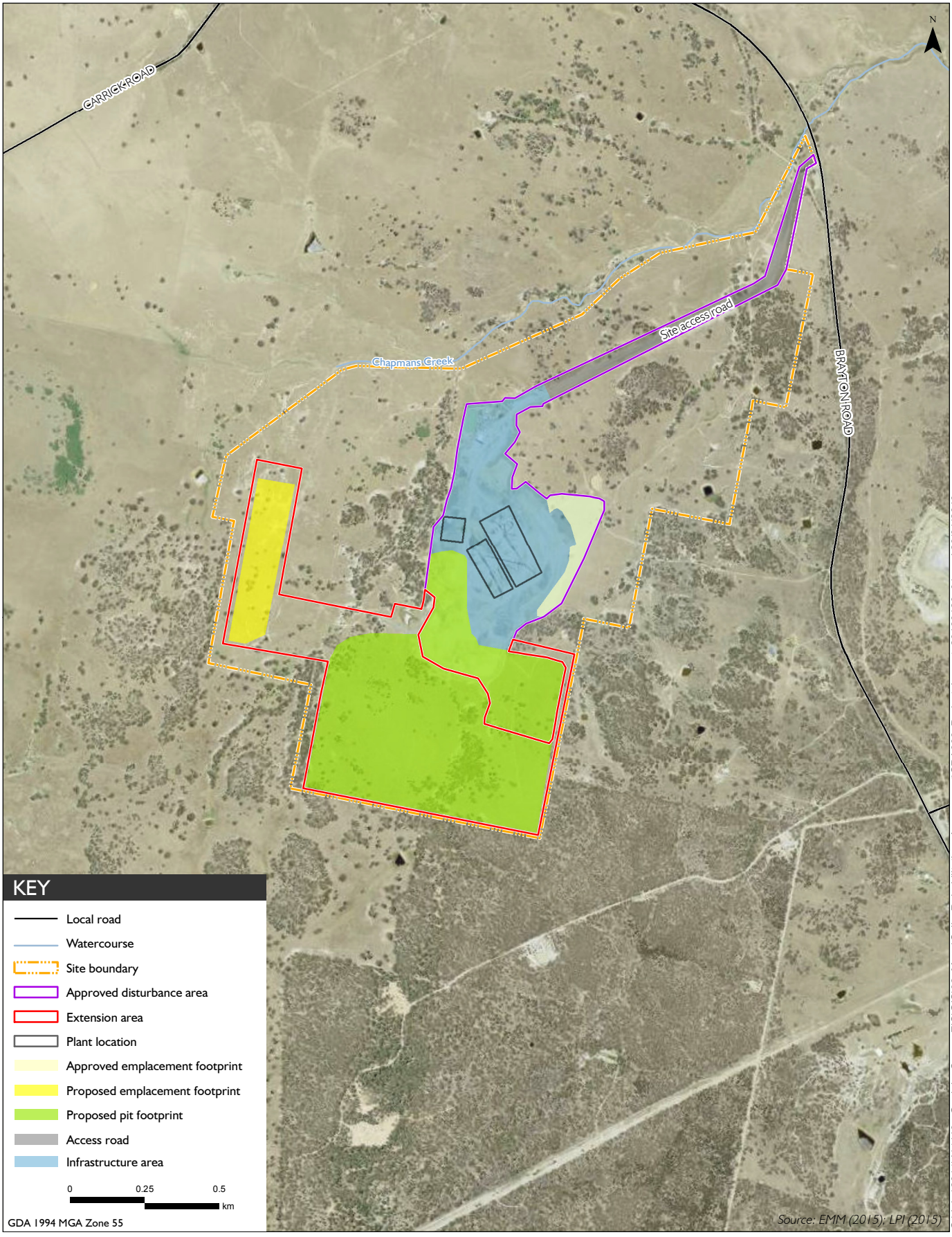
The extension project is shown in Figure 1.2.



Location of Gunlake Quarry

Gunlake Quarry
Soils and rehabilitation assessment

Figure 1.1



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Project elements

Gunlake Quarry
Soils and rehabilitation assessment

Figure 1.2

In addition, Gunlake seeks to maintain the approval for all aspects of the existing operations for Gunlake Quarry under Project Approval 07-0074. A summary of the extension project is provided in Table 1.1.

Table 1.1 Project summary

Project element	Currently approved	Proposed
Quarrying method	Hard rock quarrying by open cut methods	No change
Resource	Approximately 180 million tonnes	No change
Saleable product	750,000 tonnes per annum (tpa)	Increase to 2,000,000 Mtpa
Quarry life	30 years	30 years from approval. There is sufficient resource (180 Mt) for quarrying to continue at 2 Mtpa for 90 years
Beneficiation	Onsite crushing and stockpiling of quarried rock	No change
Infrastructure	As outlined in Section 1.4.1	Upgrade infrastructure as required to produce 2 Mtpa of products
Product transport	An average of 164 truck movements per day	Increase truck movements to an average of 440 movements per day and a maximum of 690 movements per day
Operational workforce	25 on-site employees and 25 to 38 truck drivers (full-time equivalent)	Increase of approximately 7 on-site employees and 20 truck drivers
Hours of operation	6:00 am Monday to 6:00 pm Saturday, including crushing between 7:00 am and 6:00 pm, Monday to Saturday and maintenance at any time, Monday to Saturday	Modify existing hours of operation to allow crushing 24 hours a day (except Sundays and public holidays) and maintenance anytime (including Sundays and public holidays)

1.2 Approvals process

The extension project requires development consent under Part 4, Division 4.1 of the EP&A Act. Division 4.1 specifically relates to the assessment of development deemed to be state significant development (SSD). The extension project meets the requirements for SSD.

An application for SSD must be accompanied by an environmental impact statement (EIS), prepared in accordance with the *NSW Environmental Planning and Assessment Regulation 2000* (EP&A Regulation).

An approval under the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is required for the extension project.

1.2.1 Secretary's environmental assessment requirements

The EIS has been prepared to address specific requirements provided in the revised Secretary's environmental assessment requirements (SEARs) for the SSD application, issued on 13 October 2015.

This soil resource assessment and rehabilitation strategy has been prepared to address specific requirements for land resources in the SEARs (Table 1.2).

Table 1.2 Relevant SEARs for this assessment

Requirement	Section addressed
Land resources (soil)	
Potential impacts on soils and land capability (including potential erosion and land contamination).	Sections 3 and 4
Potential impacts on landforms (topography), paying particular attention to the long term geotechnical stability of any new landforms (such as overburden dumps).	Section 5
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*.	Section 5
Rehabilitation	
Rehabilitation including the proposed rehabilitation strategy for the site having regard to the key principles in the *Strategic Framework for Mine Closure*.	Section 5
Rehabilitation objectives, methodology, monitoring programs, performance standards and proposed completion criteria.	Section 5
Nominated final land use, having regard to any relevant strategic land use planning or resource management plans or policies.	Section 5
The potential for integrating this strategy with any other rehabilitation and/or offset strategies in the region.	Section 5

1.3 Purpose of this report

EMM Consulting Pty Ltd (EMM) was commissioned by Gunlake to undertake a desktop soil resources assessment and rehabilitation strategy for the Gunlake Quarry. The objectives of the assessment are to address the SEARs and inform the EIS as to the nature of the soils occurring in the Gunlake Quarry site and the area of approved and proposed disturbance (the project area), the potential impacts on those soils and how those potential impacts will be mitigated through rehabilitation. To this end, the objectives of this report are to:

- classify and map soil types within the quarry site;
- describe and map land and soil capability (LSC) within the quarry site;
- identify potential impacts on soil resources that may result from the project; and
- provide measures for managing soil resources and mitigating potential impacts through rehabilitation including a discussion of rehabilitation objectives, methodology, monitoring programs, performance standards and proposed completion criteria.

To achieve these objectives, this report includes the following elements:

- a description of a previous soil survey completed for the quarry site (SEEC 2008) and Soil Profile Attribute Data Environment (SPADE) soil profiles (OEH 2014b). Soils are described according to the Australian Soil and Land Survey Field Handbook (NCST 2008), grouped according to Great Soil Group and Land System and classified according to the Australian Soil Classification System (Isbell 2002);
- a map of the location of the LSC and an interpretation of the attributes of land resources in terms of suitability for the major agricultural land uses of the area;

- a description of physical and chemical properties of the soils that will influence the degree of potential impacts and inform management measures; and
- a description measures for managing soil resources and mitigating potential impacts through rehabilitation including a discussion of rehabilitation objectives, methodology, monitoring programs, performance standards and proposed completion criteria.

This report was prepared in consideration of the following guidelines:

- *Guidelines for Surveying Soil and Land Resources* (NCST 2008);
- *the Australian Soil Classification System* (Isbell 2002);
- *Agricultural Impact Assessment Guidelines* (DP&I 2012) and *Agfact AC25: Agricultural Land Classification* (NSW Agriculture);
- *the Land and Soil Capability Assessment Scheme: Second Approximation* (NSW OEH 2012) (LSC assessment scheme); and
- *Strategic Framework for Mine Closure* (ANZMEC & MCA) 2000).

1.4 Project overview

1.4.1 Project schedule

A quarry life of 30 years from the date of approval is proposed. This assessment considers quarry closure after 30 years. However, there is sufficient resource for many more years of quarrying if approval following future development applications.

Final rehabilitation, decommissioning and monitoring is expected to take about 2 years.

The quarry site is approximately 227 ha, and includes the following key elements:

- a quarry pit providing hard rock resources;
- overburden emplacement bund for the long-term storage of overburden and rejects;
- topsoil emplacement bunds for short-term storage of topsoil used for rehabilitation;
- an infrastructure area for crushing and screening of the quarried rock;
- haul roads for transport of hard rock and access tracks for light vehicle access;
- ancillary infrastructure to support operations including offices, amenity buildings and other minor infrastructure; and
- undisturbed areas.

i Quarry pit

Following the removal of overburden, conventional drill and blast techniques are used to quarry the rock faces that are up to approximately 13 m high. Quarrying started at the northern end of the pit and is proceeding south.

ii Overburden emplacements

An overburden emplacement bund has been constructed to the east of the infrastructure area to provide a permanent location for overburden. As approved, it will be extended to the north and south. A second emplacement will be constructed to the west of the extended pit.

The existing overburden emplacement bund has been located to maximise its acoustic and visual screening properties.

iii Soil stockpiles

Topsoil and subsoil is stripped and replaced directly onto completed sections of the final landform. Where this is impractical and stockpiling is necessary, topsoil and subsoil is stockpiled separately in short-term topsoil.

iv Infrastructure area

Following extraction, quarried rock is transported to the infrastructure area via haul roads. The rock processing area contains the following components:

- primary crusher;
- secondary crushers and screens;
- tertiary crushers and screens;
- main screen;
- interconnecting conveyors; and
- product stockpiles.

v Haul roads and access tracks

A heavy vehicle haul road provides access between the truck parking area, the infrastructure area. The haul road will be extended and realigned during the life of the quarry. Light vehicle access tracks will be realigned as the pit progresses.

vi Ancillary infrastructure

The existing quarry infrastructure includes the following:

- site office;
- toilet and ablution facilities;
- weighbridge;

- truck wash;
- crib hut;
- hardstand and truck parking area;
- light vehicle parking area;
- bunded fuel bay;
- maintenance workshop and wash bay; and
- light vehicle parking facilities.

The disturbance area for each element is summarised in Table 1.3.

Table 1.3 Disturbance areas

Project element	Disturbance area (ha)
Quarry pit (approved and proposed)	48.2
Overburden emplacement bunds	9.7
Short-term topsoil emplacement bund	41.2
Quarry plant operational area	
Haul roads	
Ancillary infrastructure	
Undisturbed area	128.09
Total	227.2

2 Existing environment

2.1 Climate

Gunlake Quarry has a temperate climate, with warm summers and temperatures below 15°C in winter. According to the Australian Bureau of Meteorology, it receives a mean annual rainfall of approximately 650 millimetres (mm) and experiences approximately 1,277 mm mean annual evaporation (Goulburn data). Rainfall is fairly evenly distributed throughout the year, but with a peak in November and a trough in July. Evaporation is greater in late spring and summer.

2.2 Topography

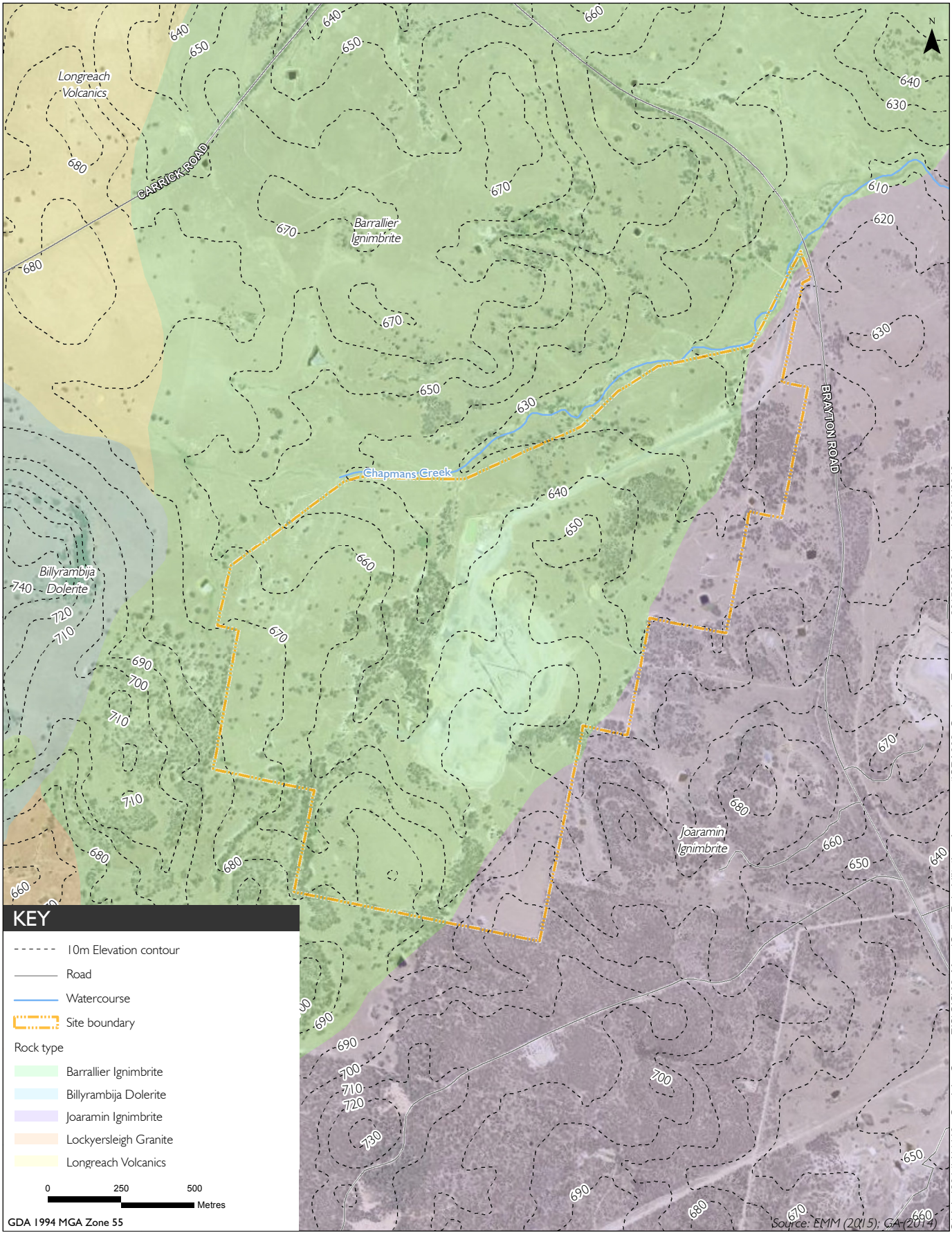
The quarry site is typified by undulating rises and valleys between low hills with slopes ranging from 2 to 10% and rising to 680 m Australian Height Datum (AHD) in the south-west corner of the quarry site. There are rock outcrops on crests and a high density of surface cobbles in some areas. The aspect varies with ridge lines and contours.

2.3 Geology

The quarry site is located regionally within the Bindook Volcanic Complex of Devonian age which includes two important members; the Barralier Ignimbrite and the Joaramin Ignimbrite. This complex comprises a north-north-east trending series of volcanic units located north of the intrusive Marulan Granite.

2.4 Surface water

There are two surface water resources in the immediate vicinity of Gunlake Quarry, Chapmans Creek and Jaorimin Creek (Figure 2.1. The two creeks are ephemeral watercourses that flow during and immediately following large rainfall events. Chapmans Creek flows north-east alongside the boundary of Gunlake Quarry and discharges to Joarimin Creek. Joarimin Creek runs north-south to the west of the quarry site and joins the Wollondilly River approximately 8.6 km to the north-east of site. The Wollondilly River is the major river in the region and is one of the key tributaries to Warragamba Dam, which is located 65 km to the north-east of the quarry. Johnniefelds Dam is located on Jaorimin Creek upstream of its confluence with Chapmans Creek and does not receive runoff from Chapmans Creek, or the quarry site.



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Geology and topography

Gunlake Quarry
Soils and rehabilitation assessment

Figure 2.1

2.5 Vegetation and land use

The land in the quarry site is used for livestock grazing. These areas are vegetated with native and improved pasture grasses, including some broadleaved weeds. There are some patches of highly disturbed remnant woodland remaining.

The dominant pasture species were Ryegrass (*Lolium rigidum*), Phalaris (*Phalaris* spp.), Clover (*Trifolium repens, T. subterraneum*) and native grasses, including Redgrass (*Bothriochloa macra*), Kangaroo grass (*Themeda triandra*), and *Poa* spp (SEEC 2008).

Weed species present included Fescue (*Vulpia* spp.), Capeweed (*Arctotheca calendula*) and Dandelion (*Taraxacum officinale*).

On steeper slopes, crests and areas with many cobbles, vegetation consisted of highly disturbed native woodland. Dominant species present were Red Stringybark (*Eucalyptus macroryhnca*), Red Gum (*Eucalyptus blakelyi*) and White Box (*Eucalyptus albens*).

Detailed vegetation descriptions are provided in the *Gunlake Quarry Extension Project Biodiversity Assessment Report* (EMM 2016).

Eight broad vegetation community types occur in the quarry site, of which the last three are highly modified or artificial communities (Ecotone 2008):

1. Cabbage Gum/Yellow Box/Argyle Apple Riparian Floodplain Woodland;
2. Yellow Box/Blakeley's Red Gum/Stringybark Open Woodland;
3. Argyle Apple/Stringybark Open Forest/Woodland;
4. White Gum/Argyle Apple Woodland;
5. Stringybark/Wattle Ridgetop Open Forest;
6. Cultivated Pine Plantations and Fruit Orchard;
7. Dams with Fringing Vegetation; and
8. Cleared, open grassland/Derived Pasture with a mix of introduced and native pasture grasses, remnant native flora species and scattered introduced or remnant native trees.

3 Soil assessment

3.1 Soil survey

A soil survey was completed for the quarry site by SEEC in 2008 (eight soil test pits) to confirm the extent and boundary of the soil landscape units mapped by DLWC/SCA (2002). Three soils were described in the field for texture to a maximum depth of 1,000 mm and selected samples taken of topsoil and subsoil. Samples from three testpits were tested at a laboratory for:

- electrical conductivity (EC);
- pH;
- cation exchange capacity (CEC);
- sodium (Na);
- potassium (K);
- calcium (Ca);
- magnesium (Mg);
- aluminium (Al);
- phosphorous (P); and
- Emerson aggregate test (EAT) for dispersion.

The results have been reproduced in Table 3.1. Soil sufficiency concentrations have been added from Baker and Eldershaw (1993), DERM (2011) and Peverill, Sparrow and Reuter, (1999). In Table 3.1, cells highlighted in red are outside the recommended soil sufficiency range.

The SEEC assessment determined the following general features of soils in the quarry site (ie topsoil and subsoil):

- soils are dispersive and are moderately to highly erodeable;
- soils are moderately acidic in the A horizon (topsoil);
- soils are non-saline to slightly saline;
- soils have a low to moderate cation exchange capacity;
- the ratio of calcium to magnesium infers calcium deficiency in soils;
- soils have very low P levels; and
- soils have a very low to moderate K level.

Australian soil classifications for sample locations were not determined by SEEC (2008).

Table 3.1 Laboratory test results for soil analysis from SEEC (2008)

Location	Description	EC	pH	CEC	Na	K	Ca	Mg	Al	P	EAT	Texture
Unit		**dS/cm**	**-**	**me/100 g**	**me/100 g**	**me/100 g**	**me/100 g**	**me/100 g**	**me/100 g**	**mg/kg**	**-**	
Soil sufficency[1]		**-**	**-**	**12-25**	**<0.7**	**>0.3**	**>5**	**>1**	**-**	**-**		
8	Subsoil sampled at 1,000 mm	0.14	6.3	19.8	3.2	0.7	1.8	11.7	<0.1	1	2(2) some dispersion (obvious milkiness)	Sandy clay loam
12	Topsoil sampled at 300 mm	0.02	5.6	6.2	0.2	0.7	1.8	1.4	0.6	4	3(1) dispersion (slight milkiness)	Sandy loam
	Subsoil sampled at 1,000 mm	0.07	5.2	19.1	1.1	0.6	0.8	8.1	4.2	1	2(1) Some dispersion (slight milkiness)	Light clay
14	Topsoil sampled at 300 mm	0.03	5.8	24.6	0.9	0.7	6.5	11.3	2.2	<1	3(1) dispersion (slight milkiness)	Sandy clay
	Subsoil sampled at 1,000mm	0.03	6.0	24.5	1.3	0.3	4.7	12.9	<0.1	<1	3(2) dispersion (obvious milkiness)	Sandy clay

Notes: *1. Sources: Baker and Eldershaw (1993), DERM (2011) and Peverill, Sparrow and Reuter (1999).*

2. Red shading means that the sample has not met the soil sufficiency (note 1).

3. Amber shading means that the sample is on the cut-off for soil sufficiency (note 1).

3.2 Desktop assessment

Existing information on soils and soil environments for the quarry site was sourced from:

- the guidelines listed in Section 1.3;
- background soils information in the *Soil and Agricultural Impact Assessment* (SEEC 2008);
- Soil Landscapes of the *Soil Landscapes of the Sydney Catchment Authority Hydrological Catchments* 1:100,000 (DLWC/SCA 2002);
- Great Soil Group (GSG) *Soil Type Mapping of NSW* (NSW OEH 2014a);
- NSW Government inherent soil fertility mapping;
- NSW Government LSC classes mapping; and
- SPADE online database (NSW OEH 2014b).

3.2.1 Soil landscapes

The 1:100,000 scale soil landscape mapping prepared by DLWC/SCA (2002) identifies four soil landscapes across quarry site (Figure 3.1). These comprise:

1. Bindook Road: undulating low hills on Devonian Bindook Porphry, occurring in the Canyonleigh hills physiographic region;
2. Garland: low lying rises and valleys between hills in granitic terrain;
3. Midgee: rolling low hills in Ordovician metasediments terrain; and
4. Wyangala: soils developed on rolling low granitic hills with slopes ranging from 10–30%.

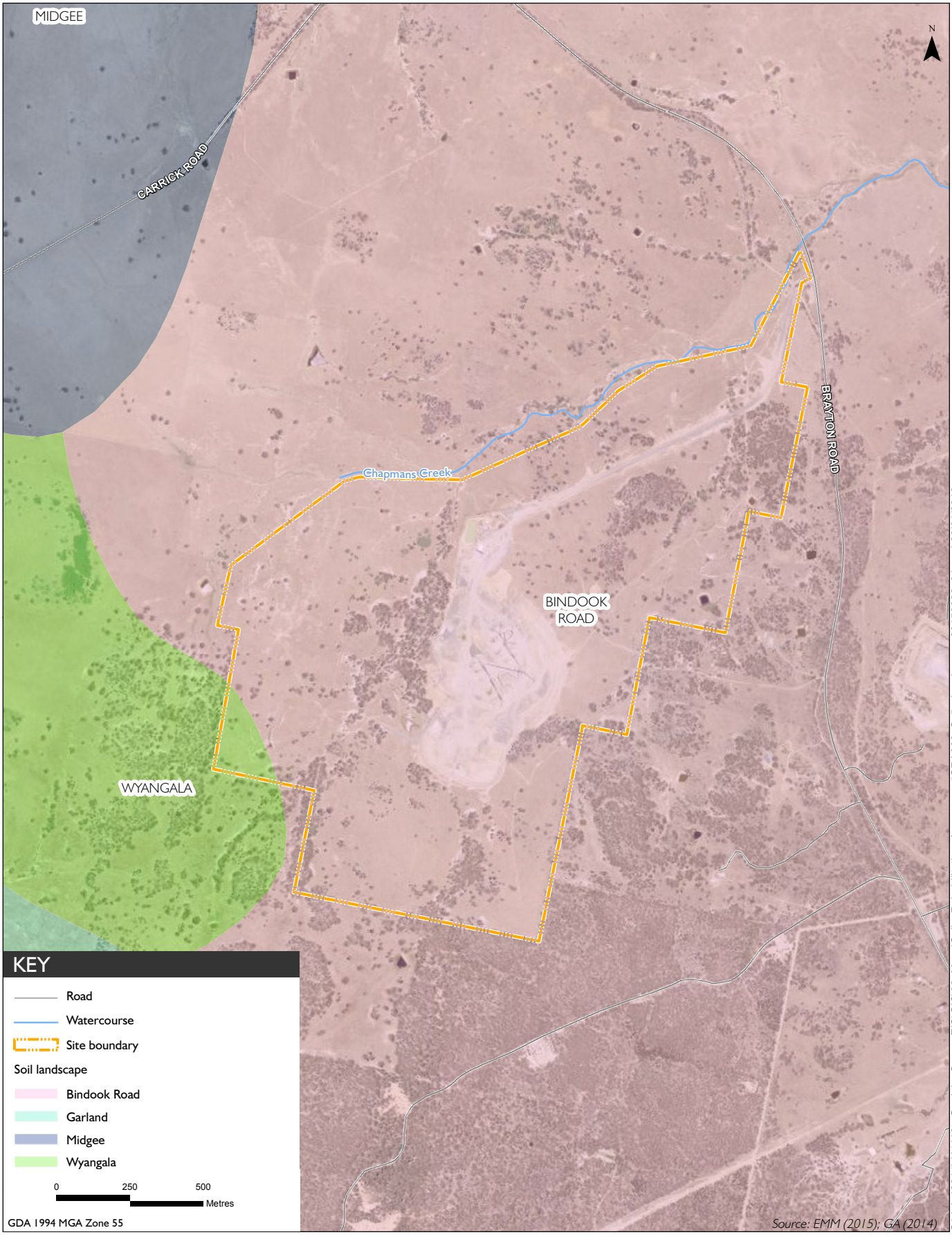
Further description of the soil landscape units is provided in Table 3.2.

3.2.2 Great soil groups

Great Soil Groups in the quarry site, identified from NSW Government mapping (OEH 2014a) and with reference to Isbell (2002), comprise: Soloths and Yellow Podzolic soils (less fertile). The following describes the general characteristics of each of these Great Soil Groups:

- Soloths: Similar to a solodic soil, ie soils have a strong contrast between the texture of the A and B horizons and a bleached A2 horizon, but acidic throughout the profile. Tends to be a more typical soil of the humid regions where the exchangeable cations in the B horizon of the solodised soils have been leached out; and
- Yellow Podzolic soils (less fertile): These soils are texture-contrast soils with a light textured A horizon overlying a heavier textured, structured B horizon. A distinct pale A2 horizon is usually, but not always present and the profile is acidic. The B horizons are characterised by moderate polyhedral or angular blocky structure and tend to be friable when moist.

Common relationships between soil landscapes and Great Soil Groups in the quarry site are shown in Table 3.2. Their spatial distribution is shown in Figure 3.2.



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Soil landscapes

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Soils and rehabilitation assessment

Figure 3.1

Table 3.2 Soil landscapes in the quarry site

	Soil landscapes			
	Bindook Road	**Garland**	**Midgee**	**Wyangala**
Landscape	Low hills and rises on Bindook Porphyry (quartz porphyry) in the Moss Vale Tablelands, Canyonleigh Hills, Wollondilly Gorge and Wombeyan Hills. Local relief 10–50 m; altitude 541–965 m; slopes 3–12%; rock outcrop 2–10%. Extensively cleared open forest.	Low hills on Wollogorong Granite (granite) in the Baw Baw Hills. Local relief 10–70 m; altitude 648–943 m; slopes 5–15%; rock outcrop 2–10%. Extensively cleared woodland.	Rolling low hills and hills on undifferentiated Ordovician and Silurian sediments including sandstone, siltstone, greywacke, phyllite, shale, slate and quartzite. Local relief 30–100 m; altitude 600–900 m; slopes 10-30%.	Low hills to rolling hills south-east of Cowra. Local relief 40–140 m; altitude 300–600 m; slopes 10–20%; rock outcrop.
Common Australian Soil Classification (Great Soil Group)	Brown Kurosols (Red and Yellow Podzolic Soils), Natric Kurosols (Soloths). Subangular rock outcrops common.	Bleached Orthic Tenosols (Lithosol), Red Kurosols (Red Podzolic Soils), Brown/Yellow Kurosols (Yellow Podzolic Soils), Red/Yellow Kandosols (Red and Yellow Earths), and Brown Sodosols/Natric Kurosols (Solodic Soils/Soloths).	Yellow Earths and Yellow Podzolic Soils most common; some Red Podzolic Soils; Lithosols, Soloths and Red Earths.	Red Podzolic Soils, Siliceous Sands, Non-calcic Brown Soils, Yellow Podzolic Soils, Yellow Solodic Soils. Extensive granite outcrops.
Vegetation	Dry sclerophyll forest with shrub understorey. Mostly cleared. Dominant trees include *Eucalyptus macrorhyncha* (Red Stringybark), *E. amplifolia* (Cabbage Gum), *E. Mannifera* (Brittle Gum), *E. melliodora* (Yellow Box), *E. blakelyi* (Blakely's Red Gum) and *E. Cinerea* (Argyle Apple) with occasional *E. pauciflora* (Snow Gum) and *E. rubida* (Candlebark).	Savannah woodland, with native grasses wholly or partly replaced with introduced or nonendemic species. Mostly cleared. Dominant trees include Eucalyptus blakelyi (Blakely's red gum), E.dives (broad-leaved peppermint), E.melliodora (yellow box), E. bridgesiana (apple box) and E.mannifera (brittle gum) on poorer soils and E. pauciflora (snow gum) in colder hollows and on exposed windy sites.	Dry sclerophyll forest with shrub understory. Mostly cleared. Dominant trees include *Eucalyptus macrorhyncha* (Red Stringybark) and *Eucalyptus haemastoma* (Scribbly Gum).	White box community on higher areas and a grey box-yellow box community in valleys along the major creeks and rivers. Mostly cleared. Red ironbark and red stringybark are found on steep ridges. Associated species include Blakely's red gum, apple box and roughbarked apple.
Land capability	LSC: V (VI); grazing limitation - moderate to high; and cultivation limitation - high to very high.	LSC: V (VI); grazing limitation – moderate to high; and cultivation limitation – high to very high.	LSC: IV	LSC: IV–VI

Table 3.2 Soil landscapes in the quarry site

	Soil landscapes			
	Bindook Road	**Garland**	**Midgee**	**Wyangala**
Limitations to land capability	Localised steep slopes; localised salinity; and widespread low fertility.	Localised waterlogging; localised salinity; and widespread low fertility.	Localised salinity; and widespread low fertility.	Localised salinity; localised steep slopes; and widespread low fertility.

3.2.3 Australian soil classification

Soils in the project, identified from NSW Government mapping (OEH 2014a) and with reference to Isbell (2002), have the following general characteristics based on each of the Australian Soil Classifications:

- Kurosol: these soils have a clear or abrupt textural change at the A to B horizon boundary. The upper B2 horizon is strongly acidic, ie less than pH 5.5 in water; and
- Natric Kurosol: as per Kurosol but the major part of the upper 0.2 m of the B2 horizon is sodic.

The relationship between Australian Soil Classification, soil landscape and Great Soil Group is summarised in Table 3.3. The distribution of soils is shown in Figure 3.3.

Table 3.3 Relationship between Australian Soil Classification, soil landscape and Great Soil Group

	Australian Soil Classification	
	Kurosol	**Natric Kurosol**
Soil landscape	Bindook Road, Wyangala	Bindook Road
Great Soil Group	Yellow Podzolic soils (less fertile)	Soloths
Area (of project area)	44.1 ha	55 ha

3.2.4 Soil Profile Attribute Data Environment soil analysis

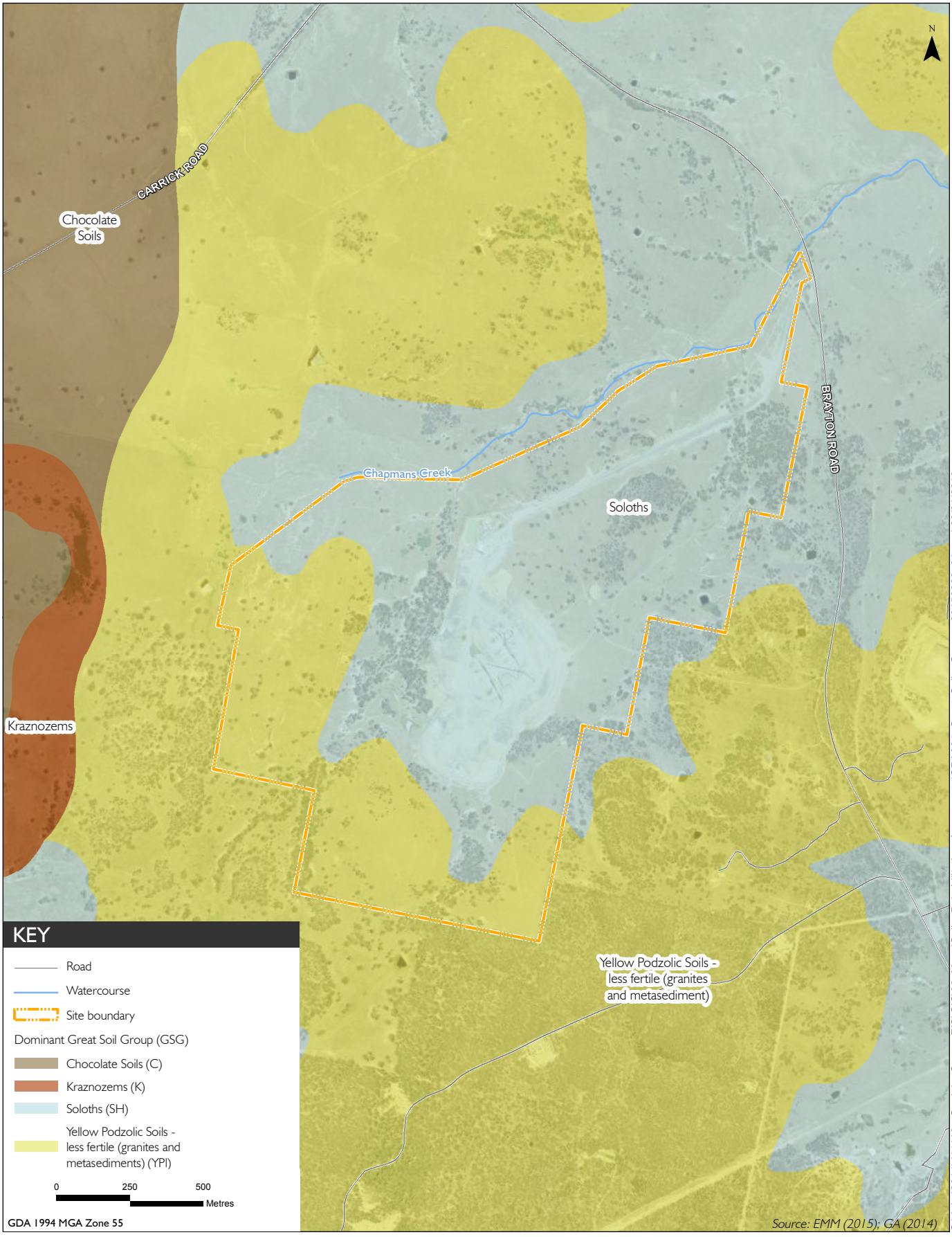
The SPADE soil profile database search identifies information on a number of soils profiles in the wider area. Two soil profiles occur adjacent to the quarry site, within 1 km of the project boundary (NSW OEH 2014b) (Figure 3.3):

- Profile 77 - Solodic Soil (Great Soil Group), noting that Solodic and Soloth Great Soil Groups are very similar (refer to Section 3.2.2)**;** and
- Profile 96 - Red Podzolic Soil (Great Soil Group), noting that the only difference between Red Podzolic Soil and Yellow Podzolic Soil Great Soil Groups is colour.

Both SPADE profiles are located on the Bindook Road soil landscape.

3.2.5 Inherent soil fertility

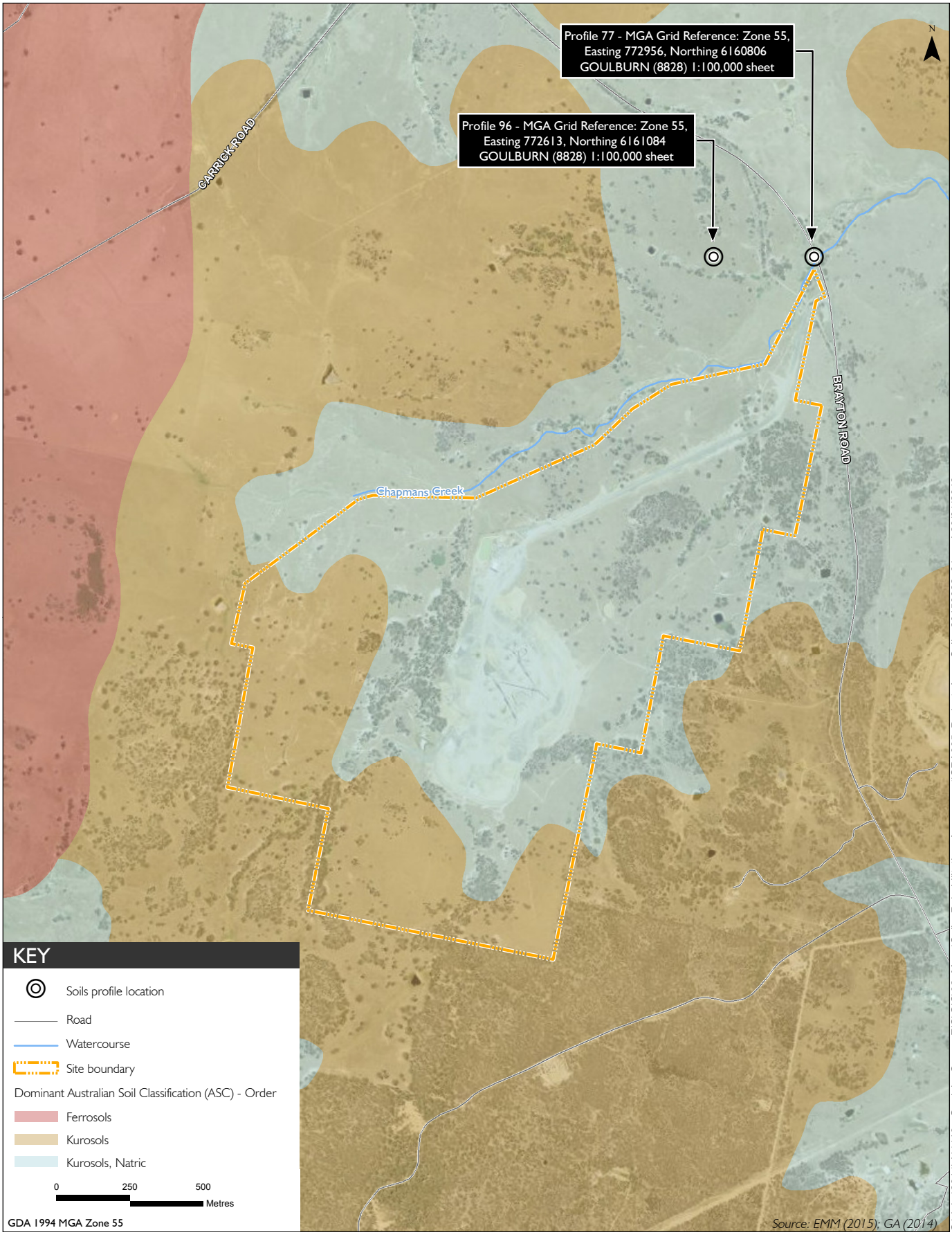
The inherent fertility of soils in NSW mapping (NSW OEH 2013a) identifies soils at the quarry site as having Moderately Low (2) fertility. Moderately Low (2) includes soils with low fertilities, such that, only plants suited to grazing generally can be supported. Large inputs of fertiliser are required to make the soil useable for arable purposes.



Great Soil Groups

Gunlake Quarry
Soils and rehabilitation assessment

Figure 3.2



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Soils identified in the wider area

Gunlake Quarry
Soils and rehabilitation assessment

Figure 3.3

3.2.6 Hydrologic soil group

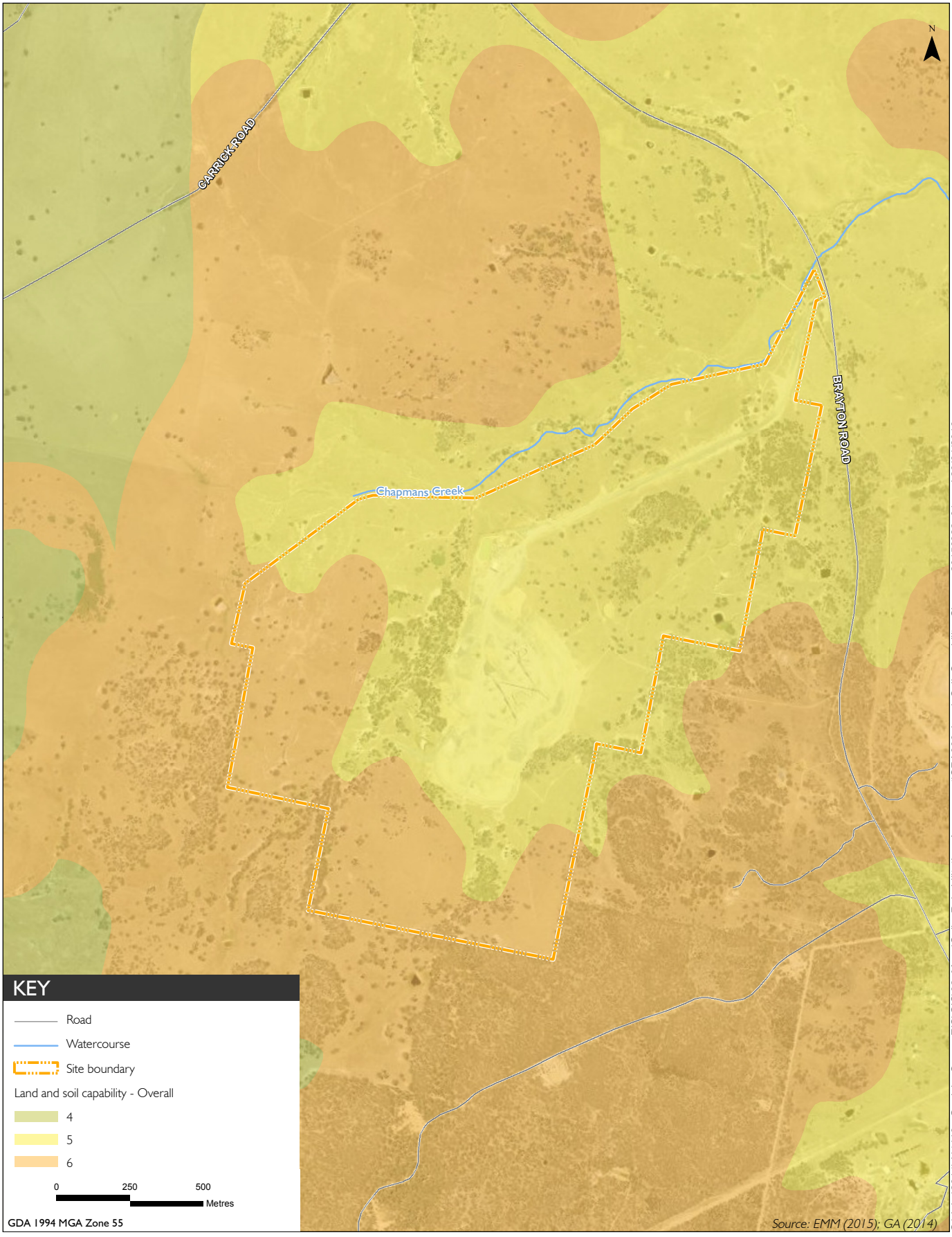
The hydrologic soil group mapping in NSW (NSW OEH 2013a) identifies soils at the quarry site as predominantly D - very slow infiltration (55.2 ha) with some C - slow infiltration (43.9 ha):

- C: soils having slow infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.

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

3.2.7 Land and soil capability

The quarry site is mapped in the *Land and Soil Capability Mapping of NSW* (NSW OEH 2013b) as predominantly LSC Class 5 - Severe limitations (55.2 ha) and Class 6 - Very severe limitations (43.9 ha). Figure 3.4 shows the spatial distribution of Class 5 and Class 6 land within the quarry site.



Land and soil capability classes

Gunlake Quarry

Soils and rehabilitation assessment

Figure 3.4

4 Potential impacts on soil resources

Potential impacts of the project on soil resources are associated with temporary loss of land due to construction and operation of quarry infrastructure and permanent loss of land due to quarrying. Activities that may impact on soil physical and chemical properties and post-quarrying land use including the following:

- excavation of soil to access the resource;
- permanent storage of overburden;
- temporary to long-term storage of soil in stockpiles;
- compaction of soil by machinery on rocks;
- potential contamination of soil resulting from storage of fuel and chemicals and refuelling activities; and
- loss of soil through wind and water erosion.

These activities can reduce the capability of land and soils and also reduce its quality as agricultural land.

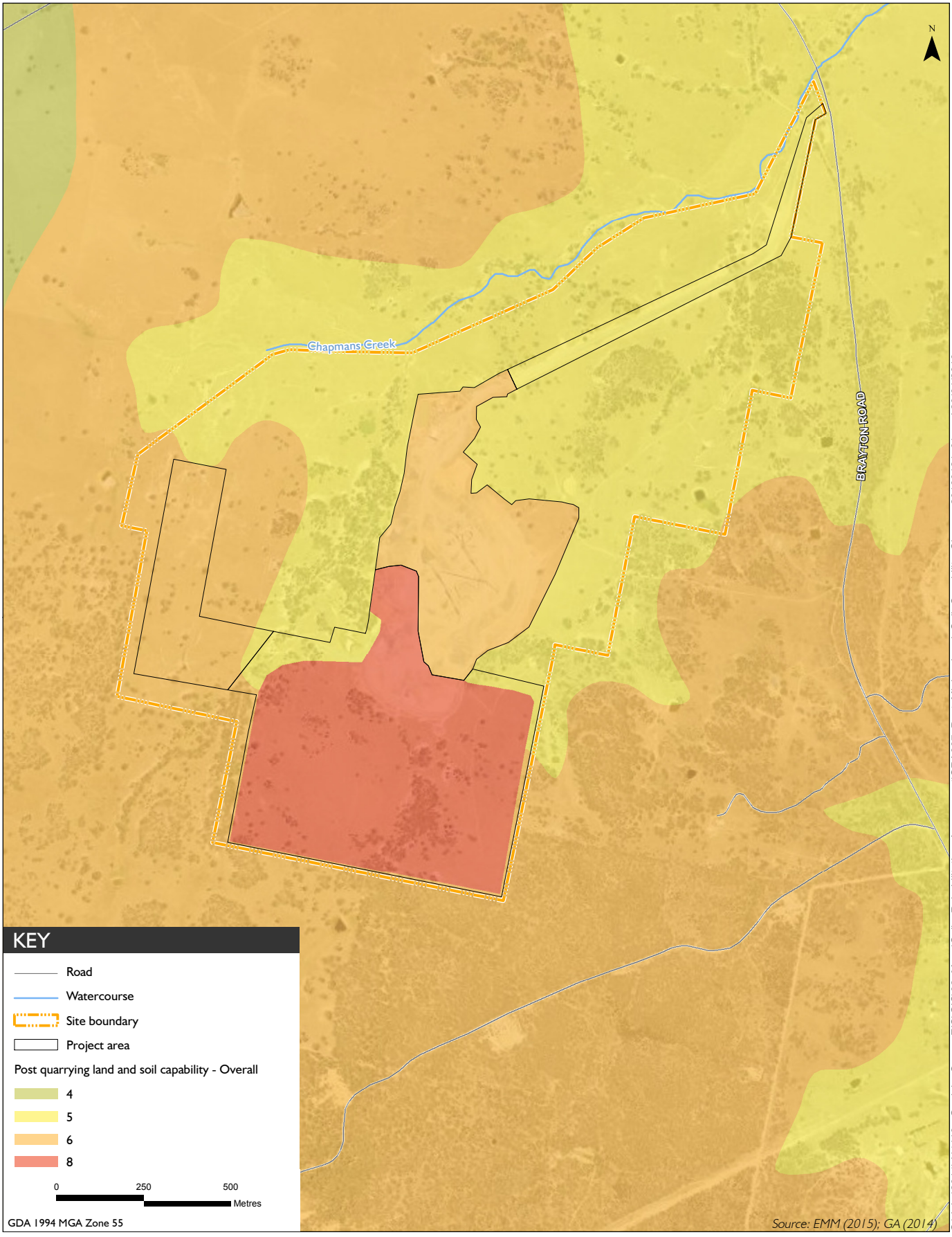
4.1 Post-quarrying land and soil capability

Table 4.1 presents the potential changes to LSC in the project area following quarrying and rehabilitation. Figure.4.1 shows the project area LSC following quarrying.

Table 4.1 Changes to land and soil capability

ASC	Pre-mining LSC	Area (ha)	Post-mining LSC	Area (ha)	Comment
Kurosol	6	44.1	6	14.0	Some land consumed by quarry.
			8	30.1	
Natric Kurosol	5	55.0	5[1]	10.9	Some land consumed by quarry.
			6	26.0	
			8	18.1	

Notes: 1. Assuming the roads are rehabilitated.



Post quarrying land and soil capability

Gunlake Quarry
Soils and rehabilitation assessment

Figure 4.1

5 Rehabilitation management and mitigation measures

5.1 Objectives

There are short-term and long-term rehabilitation objectives.

The short-term rehabilitation objectives are to:

- stabilise all earthworks, drainage lines and disturbed area that are no longer required for quarry operations to minimise erosion and sedimentation; and
- reduce the visibility of the activities from distant viewpoints.

The long-term rehabilitation objectives are to:

- provide a low maintenance, geotechnically stable and safe landform, which is commensurate with the future land uses on and around the project area;
- blend the created landforms within the project area with the surrounding landform as far as possible; and
- revegetate the disturbed areas in the project area with native tree, shrub and grass species and/or pasture species to a meet a final land use of light grazing.

To meet these objectives, the rehabilitation management and mitigation measures describe:

- decommissioning and rehabilitation activities;
- monitoring and maintenance; and
- reporting.

5.2 Scheduling of works

Rehabilitation will be progress as soon as disturbed areas are no longer requires. Final rehabilitation will be started as soon as possible after the completion of all quarry operations. Final rehabilitation will be staged based on a timeline for decommissioning of pits, buildings and other supporting infrastructure. A detailed schedule of works will be developed 12 to 24 months prior to the confirmed closure.

5.3 Integration of this strategy with other rehabilitation and/or offset strategies in the region

Rehabilitation will aim to establish a site similar to its previous natural condition (EMM 2016, Ecotone 2008 and Section 5.8).

5.4 Decommissioning

At closure, Gunlake will decommission and remove the quarry plant operational area, fuel storages, workshop and site buildings. Roads that are not required for the post-quarry landuses will be decommissioned and rehabilitated.

5.5 Final landform

Following rehabilitation, there will be four domains comprising of:

- the overburden emplacement bunds;
- the quarry pit void;
- access roads, tracks and other disturbed areas; and
- water management structures.

The rest of the quarry site will retain its current landform and will be used for flora and fauna conservation and light grazing.

5.5.1 Overburden emplacement areas

The overburden emplacement areas will be retained and will provide shelter and light grazing for livestock. Final slopes of the overburden emplacement area will typically 2.5 (H):1 (V) grade.

Contour banks will be progressively installed on the rehabilitated landform. The dimensions of the individual banks will be determined on the basis of the individual sub-catchment areas, but will be typically less than 0.7 m high and less than 3.0 m in cross-sectional area. Drop structures will be constructed on the slopes of the final landform within the overburden emplacement areas to assist in controlling the flow of water off these slopes.

5.5.2 Void

The void will contain standing water (RHDHV 2015) and the walls above the water will be largely rocks. It is unlikely to provide any ongoing grazing potential and may provide opportunity for future storage or deposition of a wide range of materials (Figure 5.1). The slopes of the quarry will be close to vertical as shown in Figure 5.1. Crushed rock will be placed on the upper walls to provide a plant growth medium on the benches and available topsoil will be returned if it is available and deemed necessary at the time of rehabilitation.

A fence or safety bund will be placed around the perimeter to the pit to prevent accidental vehicle access. Signs instructing people to stay out of the void due to steep slopes and standing water will be installed.

5.5.3 Access roads, tracks and other disturbed areas

At the end of the quarry life, Gunlake will:

- remove, rip or otherwise rehabilitate all on-site roads not required for post-quarry landuses;
- rip the compacted rock on hardstand areas, grade the ripped areas to promote laminar flow of surface water, replace previously stockpiled subsoil and topsoil and apply seed and fertilizer;

- install appropriate drainage controls; and
- install fencing and gates at appropriate locations.

Access roads, tracks and other disturbed areas will have a final land use of light grazing.

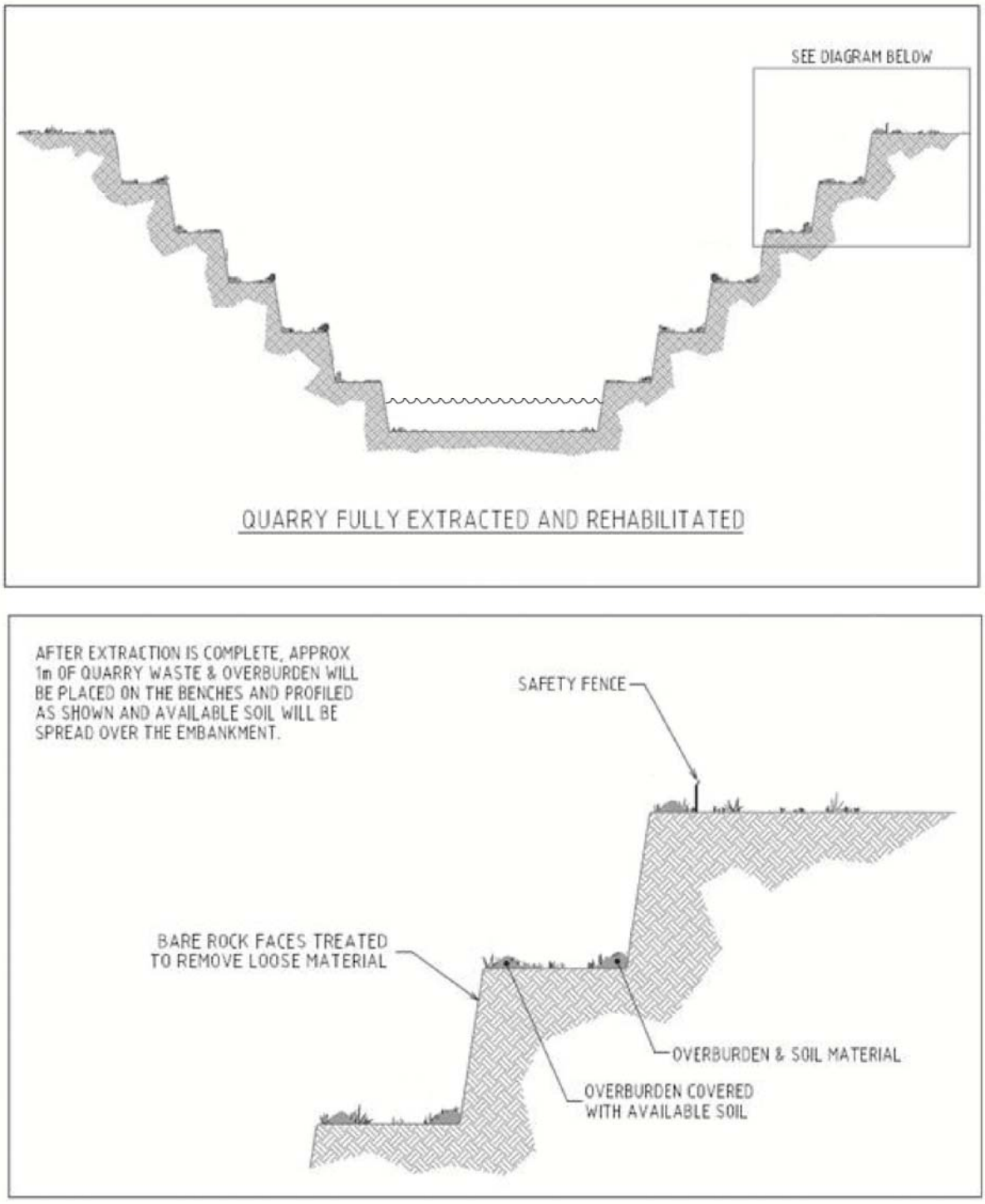


Figure 5.1 Conceptual rehabilitated quarry landform

5.5.4 Water management structures

Where practicable, water management structures such as contour banks and drains, will be constructed with longitudinal gradients, which permit the transfer of water at non-erosive velocities, ie <1 (V):200 (H). Consequently, specialised rehabilitation treatments will generally not be required. Similarly, drop structures constructed on the slopes of the overburden emplacement area will be retained and allowed to revegetate naturally. However, in the event that unacceptable levels of erosion occur, fast growing species identified as having a particular soil conservation application and/or specialised treatments such as bitumen/jute meshing or rock lining will be implemented.

5.6 Soil management

Soil resources in the project area will generally be managed through:

- installing appropriate erosion and sediment control measures (ESC) during early works in any newley disturbed areas;
- identifying and quantifying the soil requirements for rehabilitation works over the quarry life based on quarry progression information and the nature of quarry activities;
- identifying soil resources (including topsoil and soil with specific management requirements) and locations of stockpiles across the quarry;
- optimising the recovery of topsoil and useable subsoil during stripping operations;
- stockpiling soil appropriately and managing stockpiled soil to minimise resource degradation (including installation of ESCs and application of amelioration measures where required); and
- carrying out rehabilitation works in appropriate conditions to minimise deterioration of the soil resource and to maximise rehabilitation success.

The following sections provide greater detail on the above general soil resource management practices.

5.7 Erosion and sediment control

Erosion and Sediment Control Plan (ESC) measures will continue to be implemented throughout the life of the project. ESC measures will be area-specific within the project area to maximise effectiveness (Table 5.1) and will be consistent with the practices described in *Managing Urban Stormwater: Soils and Construction – Volume 2E Mines and Quarries* (DECC). Reference may also be made as appropriate to *Selection of Top Dressing Material for Rehabilitation of Disturbed Areas in the Hunter Valley* (Elliott and Veness 1981).

As far as possible, prior to any vegetation clearing:

- ESCs will be installed with priority given to sloped areas and areas adjacent to drainage lines;
- all construction and operational activities will be planned and carried out to ensure that there is no damage to soil and vegetation outside the area designated for clearing;
- where practicable, consideration will be given to the timing of disturbance and vegetation clearing ahead of project activities to ensure disturbed areas are exposed for the shortest possible time; and

- disturbed areas will be stabilised and progressively rehabilitated as quickly as possible.

Table 5.1 Erosion and sedimentation control measures by area

Area	Erosion and sediment control measures
Areas cleared of vegetation	• divert run-off from undisturbed areas away from the works; • windrow vegetation debris along the contour; • minimise the length of time that soil is exposed; and • direct run-off from cleared areas to ESCs such as sediment basins.
Exposed subsoils	• minimise the length of time that subsoil is exposed; and • direct run-off from cleared areas to ESCs such as sediment basins.
Overburden emplacement areas	• direct all run-off from overburden emplacement area to sediment dams; • avoid placement of sodic waste material on external batters; • control surface drainage to minimise the formation of active gullies; • use soil and rock mulching to armour long slopes; and • direct run-off from cleared areas to ESCs such as sediment basins.
Topsoil stockpiles	• locate stockpiles away from drainage lines or windy areas in order to minimise the risk of soil and wind erosion; • install ESC measures; • if stockpile is to be retained for a period greater than 6 months, deep rip and revegetate the stockpile and apply an appropriate fertiliser; • topsoil stockpiles to have an embankment grade of approximately 1(V):4(H) and maximum height of 2 m to limit the potential for erosion of the outer face and to maintain viability; • construct stockpiles with a 'rough' surface condition to reduce erosion hazard, improve drainage and promote revegetation; and • construct stockpiles using equipment that minimises structural degradation of the soil.
Subsoil stockpiles	• only subsoils identified as suitable for rehabilitation should be stockpiled as subsoil stockpiles; • locate stockpiles away from drainage lines or windy areas in order to minimise the risk of soil and wind erosion; • subsoil stockpiles can have a maximum height of 2 m; • install ESC measures; • if stockpile is to be retained for a period greater than 6 months, supply a topsoil cap to revegetate the stockpile; • construct stockpiles with a 'rough' surface condition to reduce erosion hazard, improve drainage and promote revegetation; and • construct stockpiles using equipment that minimises structural degradation of the soil.
Void	• remove loose rock from vertical faces to ensure stability and minimise erosion; • apply rock mulch to control erosion and provide a plant growth medium; and • apply seed and fertiliser as necessary to ensure rapid re-establishment of vegetation.
Infrastructure	• provide protection in drains (eg rip rap, revegetate) where water velocity may cause scouring; • confine traffic to maintained tracks and roads; • install sediment traps, silt fences, hay bales and other ESCs; and • rehabilitate disturbed areas around construction sites promptly.
Access roads and tracks	• optimise surface drainage and stabilise drainage lines.

5.7.1 Topsoil stripping, management and application

i General soil stripping procedures

When stockpiling is necessary, topsoil and subsoil will be stockpiled separately within stockpiles not exceeding 2 m high.

Soil will be removed by an excavator and loaded dump trucks before being transferred to the topsoil stockpile area or the overburden emplacement area. Blasting will not be required as this work will only involve removing approximately 25 mm of topsoil and 2 m of overburden.

Individual subsoil and topsoil stockpile areas will be constructed with the dimensions of each stockpile reflecting the method of construction, the area available and avoidance of natural or created drainage lines. Stockpiles will be seeded using a non-persistent cover crop to reduce erosion potential and assist in the maintenance of the biological viability of the soil resource. During stockpile establishment, the surfaces will be left with a rough surface to assist in runoff control, seed retention and germination.

The positioning of the topsoil stockpiles will accommodate surface topography in order to avoid the occurrence of overland and/or concentrated surface water flows which might otherwise result in erosion. However, where natural protection from surface water flows is not readily achievable, upslope protection earthworks such as contour banks or straw bale protection will be installed. Where appropriate, silt-stop fencing or similar protection will be placed immediately downslope of topsoil stockpile areas and retained until such time as a stable cover of vegetation has developed.

ii Soil stockpile management

In order to effectively manage the stripped topsoil and subsoil, an inventory of soils stripped, re-spread and/or stockpiled will be maintained throughout the life of the quarry.

This soil inventory will serve several purposes including:

- ensuring appropriate volumes of soil are stripped, consistent with the soil requirements of the final landform;
- identifying the age of various topsoil emplacement areas and therefore assist in minimising the length of time soils remain stockpiled; and
- assisting in using the most appropriate soils for the different elements of the final landform.

iii Soil application

Topsoil and subsoil will be applied to landforms once they are recontoured and drainage works are completed. Collection drains and sedimentation basins will be installed to collect runoff and remove suspended sediment.

Topsoil will only be applied to area no longer required for project activities. Topsoil application will consider the identified post-quarrying LSC and land use. Consideration will be given to the following:

- the volume of growth media material available compared with the estimated volume needed for successful rehabilitation;

- topsoil and subsoil placement will be undertaken from the top of slopes or top of sub-drainage catchments to minimise erosion damage created by storm run-off from bare upslope areas. More erodible soils will be placed on flatter rehabilitation areas to minimise erosion potential;

- topsoil and subsoil will be placed along the general run of the contour to minimise the incidence of erosion. It will not to be placed in the invert of drainage lines or drainage works; and

- prior to seeding, topsoil may be cross ripped to encourage rainfall infiltration and minimise runoff.

5.8 Revegetation

5.8.1 Stabilisation species

The overburden emplacements, void and other disturbed land will be stabilised following construction of the final landform with a non-persistent cover crop and pasture seed, such as those listed in Table 5.2. The actual seed and fertiliser mix will be determined in conjunction with agronomists from the local Department of Primary Industries - Agriculture (DPI-Agriculture).

5.8.2 Tree species

A selection of locally occurring tree species will then be planted in these domains. Seed will be collected from trees in the Marulan district. The seed will be used to raise nursery tube stock for planting. A list of suitable tree species is included in Table 5.3. These species were identified in the flora and fauna impact assessment completed by Ecotone (2008) as being suitable for revegetation. Subject to the extent of establishment of natural vegetation from replaced topsoil, seed of locally occurring shrub species may also be broadcast to encourage the re-establishment of the shrub layer.

Table 5.2 Pasture species seed mix suitable for revegetation

Season	Pasture species	Rate (kg/ha)	Fertiliser
Warm season grasses	Bombatsi Panic	1–2	250 kg/ha di-ammonium phosphate
	Green Panic[1]	2–4	
	Rhodes Grass[1]	1–2	
	Purple Pigeon Grass	1–2	
Annual Legumes	Subterranean Clover	4–5	
Cool season Legumes	Barrel (Sephi) medic	2–4	
	Snail (sava) medic[1]	3–5	
	Wooly Pod Vetch	4–6	
	Serradella (Elagara)	1–2	
	Lucerne	0.5	
Cool season grasses	Phalaris (Sirolan or Holdfast)	1–2	
	Wallaby Grass	0.3–1	

Notes: 1. Specific soil conservation application.

Table 5.3 Tree species suitable for revegetation

Scientific Name	Common Name
Eucalyptus amplifolia	Cabbage Gum
Eucalyptus blakelyi	Blakely's Red Gum
Eucalyptus bridgesiana	Apple Gum
Eucalyptus cinerea	Argyle Apple
Eucalyptus eugenoides	Thin-leaved Stringybark
Eucalyptus macrorhyncha	Red Stringybark
Eucalyptus melliodora	Yellow Box
Eucalyptus rossii	White Gum
Eucalyptus sieberi	Silver Top Ash
Eucalyptus viminalis	Ribbon Gum
Leptospermum polygalifolium	Lemon-scented Tea-tree
Leptsospermum trinervium	Paperbark Tea-tree

5.8.3 Weed management

Precautions to prevent excessive development of weeds within rehabilitated areas will be taken. When appropriate, this will include campaign weed spraying prior to the stripping of topsoil. The appropriate noxious weed control or eradication methods and programs will be undertaken in consultation with the DPI-Agriculture and/or the local Goulburn Mulwaree Council Noxious Weeds Inspector.

5.9 Final land use

The area selected for quarrying has low agricultural potential and is predominantly limited to restricted grazing. The void left at the completion of quarrying will have no agricultural potential. Final slopes of the overburden emplacement areas will typically be 2.5 (H):1 (V) grade, which will allow the areas to be used for grazing.

5.10 Rehabilitation monitoring

An ongoing rehabilitation monitoring program will be conducted throughout and beyond the operation of the quarry. Areas being rehabilitated will regularly be inspected and assessed against the short-term and long-term rehabilitation objectives outlined in Section 5.1.

During regular inspections, aspects of rehabilitation to be monitored will include:

- evidence of any erosion or sedimentation from areas that are in the vegetation establishment phase;
- success of initial vegetation cover establishment;
- success of tree and shrub plantings and direct seeding;
- adequacy of drainage controls; and
- general stability of the rehabilitation site.

It is envisaged that rehabilitation monitoring will be undertaken for two years following the completion of all rehabilitation. The exact period would reflect seasonal conditions during that period. In any event, maintenance will continue until such time as the objectives have been achieved.

Further detail on rehabilitation monitoring is provided in Section 5.12.

5.11 Rehabilitation maintenance

Where rehabilitation success appears limited, maintenance activities will be initiated. These may include re-seeding, and where necessary, re-topsoiling and/or the application of specialised treatments such as composting mulch to areas with poor vegetation establishment. Tree guards will be placed around planted seedlings should grazing by native animals be excessive. If drainage controls are found to be inadequate for their intended purpose, or compromised by grazing stock or wildlife, these will be replaced and/or temporary fences installed to exclude grazing of native vegetation by native or domestic fauna.

Should areas of excessive erosion and sedimentation be identified, remedial works will be undertaken. These works include importation of additional fill, subsoil or topsoil material or redesigning of water management structures to address erosion.

5.12 Completion criteria

The preliminary completion criteria and monitoring program for the quarry are shown in Table 5.4. The criteria aim to determine the success of the rehabilitation of the project area.

Criteria will be reviewed and finalised when preparing the final rehabilitation plan.

Table 5.4 Preliminary completion criteria and monitoring program for final rehabilitation

Rehabilitation element	Monitoring indicator	Monitoring criteria	Recommendations	Monitoring frequency
Decommissioning	Timeline	Plan and execute final rehabilitation in a timely and resource efficient manner.	Develop a closure execution plan that contains measurable criteria for executing closure.	Prior to decommissioning.
Landform stability	Slope gradient	To be determined after a quantity survey is completed.	A geotechnical inspection/report to confirming long-term stability of the quarry walls. The report will be made by an appropriately qualified professional.	Prior to high walls being rehabilitated or covered by spoil.
		Slopes of the final landform do not exceed 38 degrees (with the exception of quarry walls).		As spoil is being dumped, shaped and prior to soil coverage.
		There are no signs of mass movement within the quarry void.		Annual for two years.

Table 5.4 Preliminary completion criteria and monitoring program for final rehabilitation

Rehabilitation element	Monitoring indicator	Monitoring criteria	Recommendations	Monitoring frequency
	Erosion control	Erosion and sediment control measures have been implemented.		Annual for two years.
		Erosion and sediment control measures have been maintained.		Annual for two years.
		There is no gully erosion present with a depth greater than 100 mm.		Annual for two years.
		There is no sediment present at the bottom of slopes deeper than 100 mm.		Annual for two years.
	Surface water drainage	Surface water diversions have been installed above the final void.		Annual for two years.
		There is no evidence of surface water entering the final void.		Annual for two years.
Topdressing	Topsoil and subsoil	Topsoil and subsoil is layered in the correct order.		During soil coverage and prior to revegetation.
Water quality	ANZECC 2000 guidelines	Sampling and laboratory analysis.	Determine water quality limits for each land use from the ANZECC 2000 guidelines.	Annual for two years.
Vegetation	Land use	Establishment of improved pastures for grazing.	Refer to the following monitoring indicators.	Review at the end of two years.
	Surface cover	Minimum of 75% vegetative cover (excluding weeds). Survey of multiple sites using 1 m^2 quadrats.		Annual for two years.
		No bare soil >1 m^2. Survey of multiple sites using 1 m^2 quadrats.		Annual for two years.
	Mid and upper story	More than 75% of shrub/trees are healthy (ranking of healthy/sick/dead).		Annual for two years.
	Species composition	Established rehabilitation is a diverse species mixture of at least 50% of the original species planted. Survey of multiple sites using 1 m^2 quadrats.		Annual for two years.
	Weeds presence	Weeds comprise no more than 10% of rehabilitated pasture. Survey of multiple sites using 1 m^2 quadrats.		Annual for two years.

Table 5.4 Preliminary completion criteria and monitoring program for final rehabilitation

Rehabilitation element	Monitoring indicator	Monitoring criteria	Recommendations	Monitoring frequency
	Resilience to disturbance	Established pasture species survive and/or regenerate. Survey of multiple sites using 1 m^2 quadrats.		Annual for two years.
		Fencing is present around unstable rehabilitation, tree planting and between different land uses.		Annual for two years.

6 Conclusion

DLWC/SCA mapping identified four soil landscapes across the quarry site: Bindook Road, Garland, Midgee and Wyangala. There were two soil types indentified in the proposed project area, namely:

- Kurosol (44.1 ha); and
- Natric Kurosol (55 ha).

The Kurosols fall under the Yellow Podzolic Great Soil Group whereas the Natric Kurosol falls under Soloths. Soils at the site have a class 2 fertility (moderately low). Generally only plants suitable for grazing can be supported. The Hydrologic Soil Group for the Kurosols is C (slow infiltration) and D (very slow infiltration) for Natric kurosols. Pre-mining soil land capability classes for the Natric Kurosols are 5 (severe limitations) and 6 (very severe limitations) for the Kurosols.

Activities related to operations that have the potential to impact soil resources include the excavation of soil, permanent storage of overburden, temporary to long term storage of soil in stockpiles, machinery usage and the storage of fuel and chemicals. These activities have the potential to reduce the capability and agricultural suitability of the soil and landscape through contamination, compaction and erosion. LSC for the post-mining landscape will range from 6-8 for the Kurosols and 5-8 for the Natric Kurosols. Mitigation measures have been recommended to minimise impacts with a focus on runoff, erosion and sediment control.

Revegetation will occur through the use of stabilisation species and native trees once the final landform is shaped. The proposed final land use will be restricted grazing other than the final void which has no agricultural potential. Landform stability, topdressing, water quality and vegetation will be closely watched as part of a monitoring program. Maintenance activities that may be required include weeding, re-topsoiling and applying soil amendments.

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