Warkworth Mining Limited

FINAL

WARKWORTH MINE EXTENSION

Soil Survey and Land Resource Assessment Report

February 2010

MML00-002

GSS ENVIRONMENTAL

Environmental, Land and Project Management Consultants

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

1.0 INTRODUCTION

GSS Environmental (GSSE) was commissioned by Mitchell McLennan on behalf of Warkworth Mining Limited (WML) to undertake a soil and land assessment for the proposed Warkworth Mine Extension (Warkworth Extension).

The proponent for the proposed Warkworth Extension is WML. A general plan showing Warkworth Mine's location within the region is shown in **Figure 1.** Warkworth Mine began operations in 1981 with integration of the Warkworth and Mount Thorley Mines occurring in February 2004 to form an operation known as Mount Thorley Warkworth (MTW). Warkworth and Mount Thorley Mines currently operate under two separate Development Consents held under Part four of the EP&A Act (1979).

The proposed Warkworth Extension includes a westerly extension of the North Pit and West Pit. These extensions cross Wallaby Scrub Road and enter parts of Warkworth Mine's Green Offset zones. The West Pit extension also involves mining within the northern part of the Mount Thorley lease area. Other smaller pits (CD South and Woodlands pit) will be completed in accordance with current approvals. The Warkworth Extension area covers 1,271 hectares (ha) and is here-in-after referred to as the 'study area'. **Figure 2** shows the study area.

A summary of the proposed Warkworth Extension is as follows:

1. maintain maximum approved production rates of 18Mtpa of ROM coal;
2. maintain approximately 13Mtpa of ROM coal capacity at the Warkworth CPP;
3. extend the mine life from the current consent life of 2021 to 2031, which is an extension of current approved mining activities of some 11 years while including the existing area approved for mining;
4. transfer and disposal of overburden at Mount Thorley Mine;
5. replace aging equipment fleet to allow for improved mining efficiencies; and
6. upgrade some support infrastructure.

1.1 Objectives

The major objectives of the assessment undertaken by GSSE include:

- assess areas to be disturbed by the Warkworth Extension at a sufficient level of detail to satisfy the requirements of the Department of Industry and Investment (DII);
- assess pre and post mining rural land capability and class assessment in accordance with Department of Environment, Climate Change and Water (DECCW) guidelines including figures of each;
- assess pre and post mining agricultural suitability assessment in accordance with DII guidelines;
- assess topsoil resources for mining and infrastructure area rehabilitation, management and mitigation measures;
- assess suitable post-mining land uses for the open cut operations; and
- assess potential impacts of the expansion project on alluvial soils of the Wollombi Brook and associated tributaries.

0 10 20 30 40 50km Scale: 1 : 1 000 000 (A4)	**FIGURE 1** Regional Locality Plan	Project: Warkworth Mine Extension Soil Survey (2009) Client: Warkworth Mining Limited

Version	Date:	Author:	Checked:	Approved:		File: Fg1_MML00-002_Loc Plan_091030
1	6/10/09	LF	AC	RM	GSS ENVIRONMENTAL Environmental, Land and Project Management Consultants	Projection: N/A
2	30/10/09	LF	AC	RM		

LEGEND

- Constraints boundary
- Tenement boundary
- Study area boundary (Limit of Destruction)
- Alluvial soil profile pits (GSSE 2009)

FIGURE 2

Soil and Land Resources Study Area

Project: Warkworth Mine Extension Soil Survey (2009)

Client: Warkworth Mining Limited

File: Fg2_MML00-002_Soilpit_091208

Projection: MGA94 Zone 56

Version:	Date:	Author:	Checked:	Approved:
1	30/10/09	LF	AC	RM
2	12/11/09	LF	AC	RM
3	08/12/09	CC	AC	RM

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1.2 Location

Warkworth Mine is situated in the Hunter Valley coalfields of New South Wales (NSW) approximately 15 kilometres (km) south-west from the township of Singleton (refer **Figure 1**). The site is generally bounded by the Golden Highway to the north and east and by Putty Road to the south. Positioned to the east and north of Warkworth Mine is the Hunter River and to the west the Wollombi Brook. The Hunter Valley Coalfields is an active coal extraction area and nearby mines to Warkworth Mine include Hunter Valley Operations (HVO) to the north, Wambo Mine to the northwest, Mount Thorley to the south and Bulga Mine further south.

1.3 Geology

The study area is located in the Central Lowlands topographic zone within the Sydney Basin geological province. The rocks underlying the study area belong to the *Jerrys Plains subgroup of the Wittingham Coal Measures* and to the *Farley Formation, Rutherford Formation, Mulbring Siltstone, Muree Sandstone, Branxton Formation* and *Singleton Coal Measures*. These measures are of Late Permian age and the underlying rocks include coal seams, claystone, tuff, siltstone, sandstone and conglomerate which are overlain in patches by Quaternary Aeolian Sand (Glen and Beckett, 1993). The rocks have been folded resulting in westerly dips of up to 35 degrees on the southern side of the study area.

Two landscape units underpin the study area. These are the Jerrys Plains and Branxton units as delineated by the Soil Landscapes of the Singleton 1:250,000 Sheet (Kovac & Lawrie, 1991). The Jerrys Plains unit underpins most of the study area east of Wallaby Scrub Road and south of Putty Road. The Branxton unit underpins most of the study area west of Wallaby Scrub Road. An additional small landscape unit of Warkworth also occurs in the study area. **Table 3** describes these landscape units.

1.4 Topography

The terrain within the survey area is comprised mostly of low undulating hills and rises with slopes of less than five per cent and broad shallow valleys. The area also contains some closely spaced valleys and steeper slopes of 10-20 per cent. Saddleback Ridge forms the main north-trending ridge through the middle of the lease and separates the Wollombi Brook and Hunter River catchments. A lower ridge runs parallel to Wallaby Scrub Road extending in a north-westerly direction. Overall elevations range from 50-165 metres (m) with the highest point occurring in the southern part of Saddleback Ridge. Slopes have an overall east aspect with drainage trending north towards the Hunter River. There are also some drainage lines sloping west to Wollombi Brook.

1.5 Vegetation

The two main soil landscape units in the study area are associated with particular vegetation types. The Jerrys Plains landscape unit occurs east of Wallaby Scrub Road and typically supports Eucalypt woodland species. These species include the Grey Boxes, Forest Red Gums, Spotted Gums, Narrow-leaved Ironbarks and Bulloaks. Vegetation has been mostly cleared for pastoral activities, however, in the northwestern part of the study area the Jerrys Plains unit is still heavily wooded and supports the endangered Warkworth Sands Woodland vegetation community. The Branxton soil landscape occurs west of Wallaby Scrub Road and typically supports a dry sclerophyll forest. The dominant canopy species are similar to aforementioned with the additions of Rough-barked Apple and Paperbark *Melaleuca decora* combined with a decrease in Spotted Gum density. Extensive clearing has also occurred throughout the Branxton soil landscape unit for pastoral grazing activities.

2.0 SURVEY METHODOLOGY

2.1 Introduction

A site inspection was undertaken by GSSE in August 2009 to classify the soil profile types, particularly those associated with the Wollombi Brook (**Figure 2**). These were located outside the study area however information obtained from the profiles was used to confirm and extrapolate results from previous studies within the study area. Previous studies, as outlined below in **Section 2.2**, have comprehensive surveys of the study area in recent times for both soil attributes and land capability. Accordingly, the soil and land resource assessment for the study area has been developed through desktop studies of previous soil and landscape assessments.

This assessment has been undertaken to determine the following:

1. to classify and determine the soil types in the study area;
2. to assess the suitability of existing soils for future rehabilitation;
3. to identify pre and post mining rural land capability and agricultural suitability; and
4. to identify potential impacts of the extension project on the alluvial soils of the Wollombi Brook and associated tributaries.

The desktop review and survey have been conducted in accordance with the methodology outlined below. The soils and land resource assessment results are presented in **Section 3** of this report.

2.2 Soil Mapping

An initial soil map was developed using the following resources and techniques:

1) Aerial photographs and topographic maps

Aerial photo and topographic map interpretation was used as a remote sensing technique allowing detailed analysis of the landscape, and mapping of features expected to be related to the distribution of soils within the study area.

2) Previous soil survey results

A number of previous studies have been undertaken in the area. Information sourced for this report was compiled from the following studies:

- Kovac & Lawrie (1991) Singleton 1:250,000 Soil Landscapes Sheet

  Describes soil landscapes within the study area at a scale of 1:250,000;

- Global Soil Systems (2002) Warkworth Coal Mine Extension Soil and Land Capability Assessment (includes information provided by HLA Envirosciences (1994) Soil and Land Capability Assessment)

  Describes 17 soil profile sites to assist with the 2002 Warkworth Mine extension soil and land resource assessment. This assessment is bounded by the Golden Highway to the north, Wallaby Scrub Road to the east and Putty Road to the south and covers approximately 50 per cent of the study area;

- Lockwood PV (2009) Mount Thorley-Warkworth extension area soil survey

  Describes 74 soil profile sites and produced a detailed 1:25,000 soils map. This map assessed a similar area as covered by Global Soil Systems in 2002, and covers approximately 30 per cent of the study area;

- Lockwood PV (2007) Warkworth Sands soil survey: Soil sampling and analysis within the Green Offsets and at Archerfield

  Describes 200 soil profile sites and provided a detailed 1:25,000 soils map. This soil survey is west of Wallaby Scrub Road and north of the Golden Highway and covers approximately 50 per cent of the study area. Archerfield is a Green Offset area located north of Warkworth Mine; and

- ERM Mitchell McCotter (1995) Extension of Mount Thorley Operations: Environmental Impact Statement

  Describes five profile soils and provides a detailed soils map located predominately south of Putty Road and east of Charlton Road, and covers approximately 10 per cent of the study area.

These previous studies were assessed and soil units were matched according to descriptive soil profile descriptions. The naming convention of the soil units was developed using a GSSE developed system based on the Northcote Key (1979).

3) Stratified observations

Following the production of a broad soil map, surface soil exposures, topography and vegetation throughout the area was visually assessed to verify potential soil units.

2.3 Soil Profiling

Four additional soil profiles were assessed at selected sites by GSSE in August 2009 to assist in determining the characteristics of soils associated with the Wollombi Brook alluvium. Subsurface exposures were undertaken by backhoe excavation. The test pit locations were selected to assess the potential impact of the extension project on alluvial soils of the Wollombi Brook and associated tributaries. The soil layers were generally distinguished on the basis of changes in texture, structure and colour. Soil colours were assessed according to the Munsell Soil Colour Charts (Macbeth, 1994). Photographs of soil profile exposures were also taken.

Soil profiles were also observed throughout the study area by assessing surface exposures located in existing erosion gullies, access tracks and creek banks. Soil profile site locations are shown in **Figure 2.**

2.4 Field Assessment

Soil profiles within the study area were assessed generally in accordance with the Australian Soil and Land Survey Field Handbook soil classification procedures (McDonald *et al*, 1998). Soil layers at each profile site were also assessed according to a procedure devised by Elliot and Veness (1981) for the recognition of suitable topdressing material. This procedure assesses soils based on grading, texture, structure, consistence, mottling and root presence. The system remains the benchmark for land resource assessment in the Australian coal mining industry. A more detailed explanation of the Elliot and Veness procedure is presented in **Appendix 1** to this report.

2.5 Soil Laboratory Testing

Soil samples from the study area have been rigorously tested for physical and chemical attributes during past surveys. Laboratory analysis of soil samples compliments field assessment and enables soil stripping depth and topdressing recommendations to be determined. Soils are analysed to establish the suitability of surface and near-surface soil horizons as growth media for use in post disturbance rehabilitation operations. Soils are routinely analysed for colour, particle size, Emerson aggregate test, pH and electrical conductivity. A description of the significance of each test and typical values for each soil characteristic is included in **Appendix 2**. **Appendix 3** contains a glossary of commonly used soil terms.

2.6 Land Capability Assessment

The land capability assessment of the study area was conducted in accordance with DECCW's rural land capability classification system. The system consists of eight classes, which classify land on the basis of an increasing soil erosion hazard and decreasing versatility of use. It recognises the following three types of land uses:

- land suitable for cultivation;
- land suitable for grazing; and
- land not suitable for rural production.

These capability classifications identify limitations on the use of the land as a result of the interaction between the physical resources and a specific land use. The principal limitation recognised by these capability classifications is the stability of the soil mantle (Emery KA, 1986).

The method of land capability assessment takes into account a range of factors including climate, soils, geology, geomorphology, soil erosion, topography, and the effects of past land uses. The classification does not necessarily reflect the existing land use, rather it indicates the potential of the land for uses such as crop production, pasture improvement and grazing. Existing remote sensing data was also utilised where available (Department of Natural Resources, 2005).

The system allows for land to be allocated into eight possible classes (with land capability decreasing progressively from Class I to Class VIII). The classes are described in **Table 1** below.

A description of land capability classification for all land within the study area is discussed further in **Section 3.5**.

Table 1 – Rural Land Capability Classes

Land Class	Land Suitability	Land Definition
I	Regular Cultivation	No erosion control requirements
II	Regular Cultivation	Simple requirements such as crop rotation and minor strategic works
III	Regular Cultivation	Intensive soil conservation measures required such contour banks and waterways
IV	Grazing, occasional cultivation	Simple practices such as stock control and fertiliser application
V	Grazing, occasional cultivation	Intensive soil conservation measures required such contour ripping and banks
VI	Grazing only	Managed to ensure ground cover is maintained
VII	Unsuitable for rural production	Green timber maintained to control erosion
VIII	Unsuitable for rural production	Should not be cleared, logged or grazed
U	Urban areas	Unsuitable for rural production
M	Mining and quarrying areas	Unsuitable for rural production

Source: Emery KA (1986) Soil Conservation Service of NSW (now known as DECCW)

2.7 Agricultural Suitability Assessment

The agricultural suitability assessment of the study area was conducted in accordance with the DII's agricultural suitability classification system. The system consists of five classes, providing a ranking of lands according to their productivity for a wide range of agricultural activities with the objective of determining the potential for vegetative growth within certain limits.

The classification is based upon the effects of climate, topography and soil characteristics, the cultural and physical requirements for various crops and pastures, and existing socio-economic factors including local infrastructure and geographic location. These factors combine to determine the productive potential of the land and its capacity to produce crops, pastures and livestock. The classes are described in **Table 2** below.

Table 2 – Agricultural Suitability Classification System

Class	Agricultural Suitability	Land Definition
1	Highly productive land suited to both row and field crops	Arable land suitable for intensive cultivation where constraints to sustained high levels of agricultural production are minor or absent.
2	Highly productive land suited to both row and field crops	Arable land suitable for regular cultivation for crops but not suited to continuous cultivation. It has a moderate to high suitability for agriculture but edaphic (soil factors) or environmental constraints reduce the overall level of production and may limit the cropping phase to a rotation with sown pastures.
3	Moderately productive lands suited to improved pasture and to cropping within a pasture rotation	Grazing land or land well suited to pasture improvement. It may be cultivated or cropped in rotation with pasture. The overall level of production is moderate as a result of edaphic or environmental constraints. Erosion hazard or soil structural breakdown limit the frequency of ground disturbance, and conservation or drainage works may be required.
4	Marginal lands not suitable for cultivation and with a low to very low productivity for grazing	Land suitable for grazing but not for cultivation. Agriculture is based on native or improved pastures established using minimum tillage. Production may be high seasonally but the overall level of production is low as a result of a number of major constraints, both environmental and edaphic.
5	Marginal lands not suitable for cultivation and with a low to very low productivity for grazing	Land unsuitable for agriculture or at best suited only to light grazing. Agricultural production is very low or zero as a result of severe constraints, including economic factors, which preclude improvement.

Source: NSW Agriculture & Fisheries (1990) (now known as DII).

3.0 RESULTS

3.1 Desktop Review

3.1.1 Soil Landscape units

Two soil landscape units underpin the study area. These are the Jerrys Plains and Branxton units as delineated by the Soil Landscapes of the Singleton 1:250,000 Sheet (Kovac & Lawrie, 1991). The Jerrys Plains unit covers most of the study area east of Wallaby Scrub Road and south of Putty Road. The Branxton unit covers most of the study area west of Wallaby Scrub Road. An additional small landscape unit of Warkworth also occurs in the study area. **Table 3** describes these landscape units.

Table 3 – Landscape Units

Landscape Unit	Geology	Typical Landform	Typical Soils*
Jerrys Plains (jp)	*Jerrys Plains Subgroup of the Wittingham Coal Measures* *Parent rock:* Lithic sandstone, mudstone, some siltstone lenses and polymictic conglomerates.	Undulating low hills to the south and west of Jerrys Plains. Hills range in elevation from 80-180m; slopes 2-10% with local relief around 60m.	The main soil type for this landscape unit is Soloths. Soloths occur on hillcrests and midslopes; Solodic soil occur on the lower slopes and in the drainage depressions, with Solodised Solonetz soils found on hill slopes where drainage is impeded by bedrock.
Branxton (bx)	*Farley Formation, Rutherford Formation, Mulbring Siltstone, Muree Sandstone, Branxton Formation and Singelton Coal Measures* *Parent rock:* Sandstone, mudstone, siltstone, shale, tuff, coal, conglomerate and limestone.	Undulating rises to low hills and creek flats. Hulls range in elevation from 50-80m; sloped 3-5% with local relief of 10-40m.	Typically Red Podzolics occur on the hill crests, Yellow Pozolics on the midslopes, and Yellow Soloths on the lower slopes and in the drainage lines.
Warkworth (ww)	*Tertiary gravel and sand and Quaternary alluvium* (aeolian sand)	This unit covers the linear sand dunes found on old river terraces of the Hunter River downstream from Warkworth.	Siliceous Sands
* Soils defined using the Great Soil Groups (Stace et al., 1968)			

Source: Kovac & Lawrie (1991)

3.1.2 Soil Units

3.1.2.1 Wollombi Brook Soil Units

A site inspection was undertaken in August 2009 to classify the soil profile types associated with the Wollombi Brook. The objective of the field assessment was to observe soil profiles (to a maximum depth of 1.5m) that may be of alluvial nature due to their proximity to the Wollombi Brook.

No shallow aquifers (i.e. < 1.5m depth) were identified. The identified soil units were Brown Duplex Loam, Grey-Pink Duplex Loam and Uniform Sand. These profiles were used to confirm and extrapolate results from previous studies within the study area. Descriptions of these soil profiles are included in **Appendix 4**.

3.1.2.2 Study Area

The desktop study of previous soil surveys, as listed in **Section 2.2**, provided high quality data at a scale one order of magnitude greater resolution than the landscape mapping units. These surveys covered 92 per cent of the study area with less than 8 per cent of the area was not comprehensively mapped (4.3 per cent to the southwest and 3.5 per cent to the northwest). These small units of land were located within larger well defined landscape units.

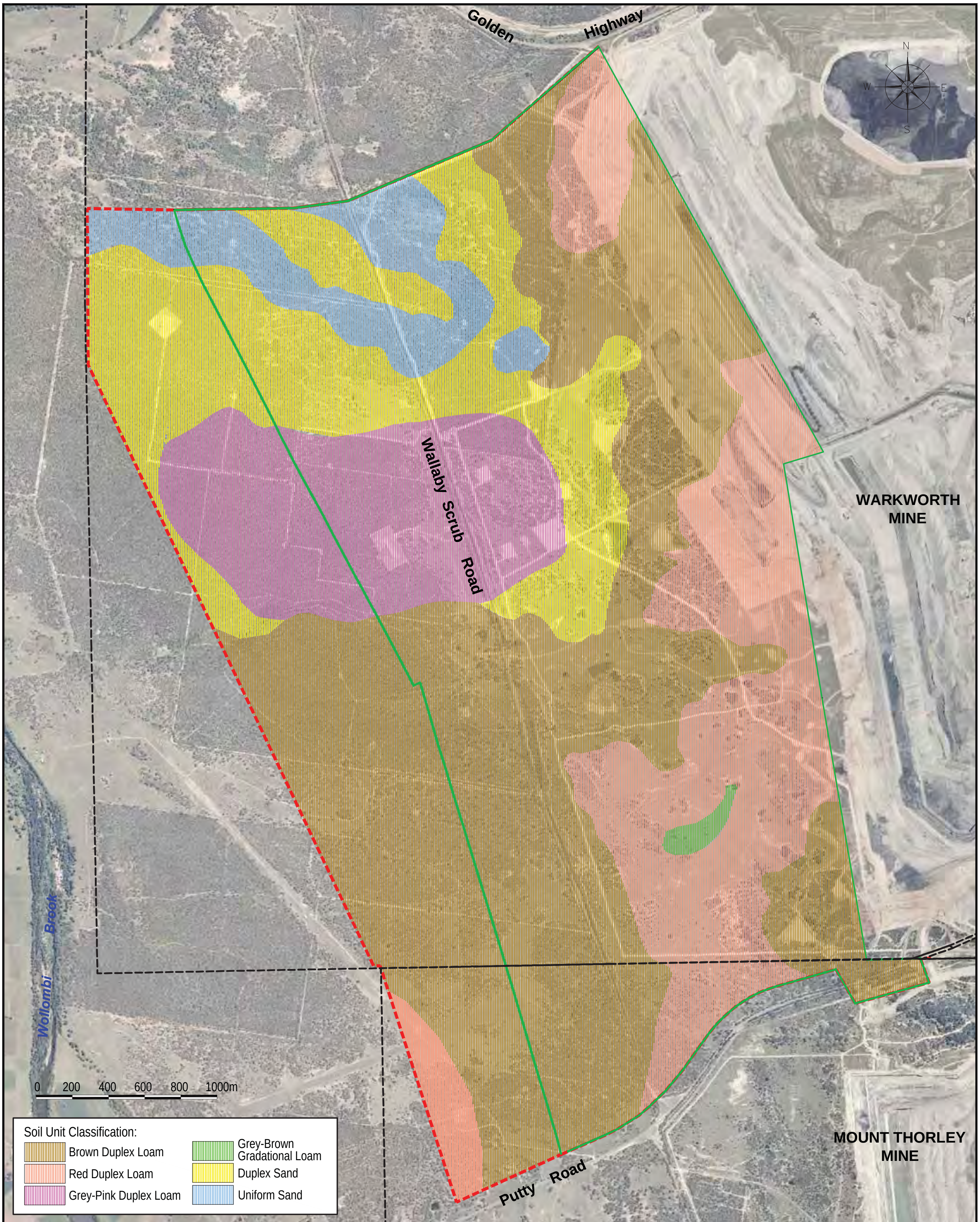
Six soil units were identified within the study area. These units coverage within the study area (expressed as per cent) are provided below:

1. Brown Duplex Loam (40.8%)
2. Red Duplex Loam (25.1)
3. Duplex Sand (16.5%)
4. Grey-Pink Duplex Loam (10.2%)
5. Uniform Sand (6.9%)
6. Grey-Brown Gradation Loam (0.5%)

A soil unit classification comparison shows the correlation between the soil naming conventions used in the assessed reports (refer **Table 4). Tables 5 to 10** describe each of the six soil units. **Figure 3** illustrates the spatial distribution of the soil units.

Table 4 – Soil Unit Classification Comparison

GSSE 2009	Global Soil Systems 2002	Lockwood 2007, 2009	ERM Mitchell McCotter 1995	Kovac & Lawrie 1991
(Soil classification system)	(Adapted Northcote Key)	(Australian Soil Classification)	(Adapted Northcote Key)	(Great Soil Groups)
Brown Duplex Loam	Brown Duplex Loam Yellow Duplex Sandy Loam	Sodosols (Brown and yellow)	Grey-yellow and brown mottled duplex soils	Yellow Soloths (jp unit)
Red Duplex Loam	Red Duplex Loam	Sodosols (red)	Hard pedal red-yellow and yellow-brown duplex Loam	Red Soloths (jp unit)
Duplex Sand	n/a*	Shallow Warkworth sands (Sodosols)	n/a*	Yellow Soloth (bx unit)
Grey-Pink Duplex Loam	n/a*	Sodosols (grey)	n/a*	Yellow Podzolic (bx unit)
Uniform Sand	Uniform Sand	Deep Warkworth sands (Tenosols)	Apedal Massive Sands	Siliceous sands (ww unit)
Grey-Brown Gradational Loam	Grey-Brown Gradational Loam	n/a	Gravelly Sands/Grey-yellow apedal duplex soils	Red earths (jp unit)
*Soil unit outside of area covered by relevant organization				



LEGEND
- Constraints boundary
- Tenement boundary
- Study area boundary (Limit of Disturbance)

FIGURE 3

Soil Units

Project: Warkworth Mine Extension Soil Survey (2009)

Client: Warkworth Mining Limited

Version	Date:	Author:	Checked:	Approved:
1	8/10/09	LF	AC	RM
2	30/10/09	LF	AC	RM
3	12/11/09	LF	AC	RM
4	08/12/09	CC	AC	RM

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File: Fg3_MML00-002_Soil Units_091208

Projection: MGA94 Zone 56

Brown Duplex Loam

Description: This soil unit is characterised by an abrupt texture change between the dark brown silty/ loam surface soil and the clayey brown sandy clay loam and yellowish brown medium heavy clay subsurface layers (duplex soil) (**Table 5**). This soil unit is identified in the Australian Soil Classification as a Sodosol and has also in the past been referred to in Great Soil Group terminology as Solonetz, Solodised-Solonetz and Solodic soils.

Location: This soil unit is the dominant soil in the Warkworth Mine study area (40.8 per cent cover) and is associated with undulating hillslopes, particularly mid-low sloping land and creek flats. This common soil unit was profiled during the Wollombi Brook investigation, refer **Appendix 4, Plate 1** and **Plate 2**.

Management: The surface 0.10m of topsoil is suitable for stripping and reuse as a topdressing material in rehabilitation works. Some topsoil profiles exhibited high sodicity values, however, soil aggregate stability was reasonable due to significant soil organic carbon content. In addition this topsoil's loamy soil texture is desirable for rehabilitation works.

The subsoil is unsuitable for rehabilitation works as it is highly sodic and dispersive.

The topsoil requires standard erosion and sediment control measures if disturbed. Given the soil's sodicity range, additional measures for stockpiling the soil and its reuse during rehabilitation works is recommended. These measures include stockpiling the soil where it is not exposed to wet conditions after stripping as this will limit dispersion and erosion, and the use of soil ameliorants such as gypsum and biosolids to improve aggregate cohesion (refer **Section 4)**.

Table 5 – Brown Duplex Loam Profile

<table>
<tr><th>Layer</th><th>Depth</th><th colspan="2">Description</th></tr>
<tr><th>#</th><th>(m)</th><th>Field</th><th>Laboratory</th></tr>
<tr><td>1</td><td>0.00 - 0.02</td><td>Dark (yellowish) brown (10 YR 4/4) silty loam to loam exhibiting weak peds of 10 millimetres (mm) or massive pedality. Boundary abrupt.</td><td rowspan="2">Moderately acidic with an average pH of 6.0 (range 5.4 - 6.3, n = 5) and non-saline with low Electrical Conductivity (ECe) of less than 1dS/m 9 (range 0.46 – 1.19dS/m, n = 5).

Moderately sodic with an average Exchangeable Sodium Percentage (ESP) of 12%, (range 5 - 18.9, n = 5) with generally stable soil aggregates as indicated by Emerson Aggregate Test (EAT) classifications of 3-5.</td></tr>
<tr><td>2</td><td>0.02 - 0.12</td><td>Dark yellowish brown (10 YR 5/4) silty loam with massive pedality. Boundary sharp.</td></tr>
<tr><td>3</td><td>0.12 - 0.45</td><td>Brown (7.5 YR 5/8 - 7.5 YR 4/6) heavy clay with a strong structure (polyhedral to prismatic). Boundary gradual.</td><td rowspan="3">Moderately acidic with an average pH of 6.0 (range 5.8 - 6.7, n = 12) and non-saline with average low ECe of less than 2dS/m (range 0.34 - 4.24, n = 12; note >4dS/m was an exception).

Highly sodic with an average ESP of 27% (range 14.3 - 37.1; n = 5) and low aggregate stability with EAT classes of 1 and 2 (n = 10).</td></tr>
<tr><td>4</td><td>0.45 - 0.70</td><td>Yellowish brown (10 YR 5/6) heavy clay with strong structure (polyhedral to angular blocky peds). Boundary gradual.</td></tr>
<tr><td>5</td><td>0.70 - 2.00</td><td>Yellowish (10 YR 6/6) medium clay to silty clay with moderate structure (polyhedral to angular blocky peds).</td></tr>
<tr><td colspan="4">n = number of replicate soil profile sites, actual data replicates often larger as vertical sampling per layer varied (e.g. layer 2 may have been sampled at 0.05 and 0.10m at some soil profile sites).</td></tr>
</table>

Red Duplex Loam

Description: This soil unit is characterised by an abrupt texture change between the dark brown loamy surface soil and the reddish-brown medium clay subsurface soil (duplex soil) (**Table 6**).

Location: This soil unit is the second most dominant soil in the Warkworth Mine's study area (25.1 per cent cover) and is largely associated with the central ridge area in the south-eastern part of the study area.

Management: The surface 0.10m of this soil is marginally suitable for stripping and reuse as topdressing in rehabilitation. The subsoil is not recommended for reuse in rehabilitation due to the limiting factors of apedal texture, high sodicity and possible dispersion problems due to aggregate instability.

The topsoil requires standard erosion and sediment control measures if disturbed. Given the topsoil's weak textural structure and possible sodic issues additional measures for soil stockpiling and soil reuse during rehabilitation works are recommended. Suitable measures include storing the soil where it is not exposed to wet conditions after stripping as this will limit dispersion and erosion, and the use of soil ameliorants (e.g. gypsum) to improve aggregate cohesion. Soil ameliorants that add carbon to the soil (e.g. biosolids) may be an appropriate measure as this will improve soil aggregate stability (refer **Section 4**).

Table 6 – Red Duplex Loam Profile

<table>
<tr><th>Layer</th><th>Depth</th><th colspan="2">Description</th></tr>
<tr><th>#</th><th>(m)</th><th>Field</th><th>Laboratory</th></tr>
<tr><td>1</td><td>0.0 006</td><td>Brown (10 YR 4/6) loam. A subplastic, slightly sticky, crumbly soil exhibiting weak pedality with 20 - 50mm earthy subangular blocky peds. The soil contains very few 20 – 60mm stones and many roots.</td><td rowspan="2">Moderately acidic with an pH of 6.0 - 6.4 (n =2) and non-saline with low ECe of less than 1dS/m (n =2).

Aggregate stability is good with an EAT class 3(3) (n = 1). Some possible sodic indications from an associated soil type have been observed.</td></tr>
<tr><td>2</td><td>0.06 - 0.20</td><td>Dull brown (7.5 YR 5/4) sandy clay loam. A subplastic, weak crumbly apedal soil with no stones. Roots are common.</td></tr>
<tr><td>3</td><td>0.20 - 0.60</td><td>Bright reddish brown (5 YR 5/8) light medium clay. A plastic, slightly sticky, moderately strong, apedal clay with less than 2% dispersed 20 - 60mm stones.</td><td>Slightly acidic with an pH of 6.3 (range 5.5 - 6.8, n = 4) and non-saline with average low ECe of less than 1dS/m (range 0.43 - 0.90, n = 4).

Highly sodic with an ESP of 29% (n = 1) and a variable aggregate stability with EAT classes of 1, 2, 3b and 5 (n = 4).</td></tr>
<tr><td>4</td><td>0.60 - >1.40</td><td>Weathered fine grained grey sandstone.</td><td>n/a</td></tr>
<tr><td colspan="4">n = number of replicate soil profile sites, actual data replicates often larger as vertical sampling per layer varied (e.g. layer 2 may have been sampled at 0.05 and 0.10m at some soil profile sites).</td></tr>
</table>

Duplex Sand

Description: This soil unit is characterised by an abrupt texture change between the sandy surface soil and the medium-heavy clayey subsurface soil (duplex soil). Subsurface soils may be greyish, brownish or yellowish in colour (**Table 7**).

Location: This soil unit is the third most dominant soil in the Warkworth Mine study area (16.5 per cent cover) and is associated with the Uniform Sands in the northern part of the study area.

Management: The top 0.30m of topsoil is suitable to marginally suitable for stripping and reuse as topdressing in rehabilitation works. The top 0.05m of this soil is of suitable nature and the subsequent 0.25m is of marginal nature due to its single grain structure. It is recommended that the full 0.30m of topsoil be utilised, however, additional measures to treat the 0.05-0.30m fraction are recommended. These measures are discussed below.

The subsoil is not recommended for reuse in rehabilitation activities due to the limiting factors of texture, high sodicity and dispersion. Sodicity in the topsoil was observed to increase in a minority of soil profiles which contained clayey sand textures. As sodicity is related to exchangeable cations and soil clay content, these few outliers with small clay contents do not impact overall stripping depth recommendations.

The topsoil requires standard erosion and sediment control measures if disturbed and given its textural structure additional measures are recommended. Suitable measures include storing the soil where it is not exposed to wet conditions after stripping as this will limit dispersion and erosion, and the use of soil ameliorants (e.g. gypsum and biosolids) to improve aggregate cohesion (refer **Section 4**).

This soil unit is closely related to the uniform soil unit (**Table 9**) which supports the endangered Warkworth Sands vegetation community. This soil may contain a viable seed-bank for this community and utilisation of all sandy topsoil to aid restoration efforts in alternative Green Offset zones is feasible. Stripping depth may be in places as deep as 1m for this purpose.

Table 7 – Duplex Sand Profile

Layer	Depth	Description	
#	(m)	Field	Laboratory
1	0.00 - 0.05	Dark yellowish brown (105 YR 4/4) loamy sand with weak subangular structure and very weak consistence. Boundary gradual.	Moderately acidic with an average pH of 6.0 (range 5.8 - 7.5, n = 5) and non-saline with low ECe of less than 1dS/m (range 0.17 - 2.05dS/m, n = 5). Sodicity was low with average ESP of 6.15% (range 2.3 - 12.3, n = 5) and moderate to high aggregate stability with EAT class measurements of 5. The higher ESP was a class 3b.
2	0.05 - 0.30	Pale brown (10 YR 7/3) sand with single grain structure and loose consistence. Boundary abrupt.	
3	0.30 - 0.50+	Light brownish grey to brown (10 YR 6/2 - 10 YR 5/3) medium heavy clay with strong blocky structure and strong consistence.	Slightly acidic with an average pH of 6.3 (range 5.5 - 7.6, n = 13) and non-saline with low ECe of less than 1dS/m (range 0.16 - 1.86dS/m, n = 12). Highly sodic however with an ESP range of 10-50% (n = 3) and low-moderate aggregate stability with EAT classifications of 1 and 2 (n = 12).

n = number of replicate soil profile sites, actual data replicates often larger as vertical sampling per layer varied (e.g. layer 2 may have been sampled at 0.05 and 0.10m at some soil profile sites).

Grey-Pink Duplex Loam

Description: This soil unit is characterised by an abrupt texture change between the grey-brown sandy-loam surface soil and the underlying grey-pinkish clayey subsurface soil (**Table 8**). This soil unit is also identified in the Australian Soil Classification as a Sodosol. A distinguishing feature of this duplex unit is the grey clayey subsurface horizon. Grey colours occur in the landscape as seasonal saturation of the soil profile mobilises insitu-pigment bearing minerals (iron oxides) which are subsequently lost to free draining waters.

Location: This soil unit occurs mainly in and around Wallaby Scrub Road sloping towards Wollombi Brook. This soil unit generally occurs in the landscape on the lower-slopes and is a minor soil unit covering 10.2 per cent of the study area. Grey layers also occur higher up the hill-slope (termed gley) where impermeable or poorly draining horizons result in a localised saturated environment which favours mobilisation and loss of pigment bearing minerals.

This soil unit was profiled the during the Wollombi Brook investigation, refer **Appendix 4, Plate 3** and **Plate 4**.

Management: The surface 0.30m of this soil is suitable for stripping and reuse as topdressing in rehabilitation. The subsoil is not recommended for reuse in rehabilitation due to the limiting factors of textural structure and likely high sodicity and dispersion issues.

The topsoil soil requires standard erosion and sediment control measures if disturbed. Caution during stripping is advised as mixing of the quality topsoil with the subsoil will negatively impact on rehabilitation works.

Table 8 – Grey-Pink Duplex Loam Profile

Layer	Depth	Description	
#	(m)	Field	Laboratory
1	0.0 - 0.05	Brown (10 YR 4/3) sandy loam with massive structure and weak consistence. Boundary clear.	Moderately acidic with a pH of 6.0 and non-saline with low ECe of less than 0.5dS/m (n = 1). Non sodic with ESP of 5% and high aggregate stability with an EAT classification of 5 (n = 1).
2	0.05 - 0.30	Light grey to pinkish-grey (10 YR 7/2 - 7.5YR 6/2) sandy loam with weak (20 - 30mm block peds) to massive pedality and weak consistence. Boundary abrupt.	
3	0.30 - 0.50+	Light brownish - grey to pinkish-grey (10 YR 6/2 - 7.5YR 6/2) medium clay with moderate structure (blocky, angular peds) and strong consistence.	Slightly acidic with an average pH of 6.3 (range 5.9 - 6.7, n = 2) and non-saline with low ECe of less than 2dS/m (range 1.11 - 2.43dS/m, n = 2). A high sodic value was recorded (ESP of 30%) combined with a low-moderate aggregate stability with EAT classifications of 1 and 2 (n = 2).
n = number of replicate soil profile sites, actual data replicates often larger as vertical sampling per layer varied (e.g. layer 2 may have been sampled at 0.05 and 0.10m at some soil profile sites).			

Uniform Sand

Description: This soil unit is characterised by predominately yellowish-brown sand throughout the soil profile for a minimum of two metres (**Table 9**).

Location: This minor soil unit (6.9 per cent of the study area) occurs in the northern part of the study area, predominately to the north-western boundary. This deep sand is associated with the Warkworth Sands vegetation community. It has developed from aeolian deposition of sand particles and its location reflects recent and past wind direction (McKensie et al., 2008). It is termed a continental dune. This soil unit is identified in the Australian Soil Classification as a Tenosol as it exhibits weak pedological development.

This soil unit was profiled during the Wollombi Brook investigation, refer **Appendix 4, Plate 5** and **Plate 6**.

Management: This soil is not suitable for stripping and reuse as topdressing in mine rehabilitation works due to its single grain sandy structure.

This soil supports the endangered Warkworth Sands vegetation community and as such the stripping and reuse of this soil to support restoration/recreation works in alternative Green Offset zones is feasible. Recommended stripping depth is 1-2m. This soil does not present any sodic, erodibility or acidity issues that would prevent its re-use in this context, either in its removal, transport or storage. Due to its single grain texture, preventing wind erosion during storage is recommended. This soil is strongly acidic which is appropriate for this specific vegetation community. Generally strong soil acidity is not considered optimal for mine rehabilitation works.

Table 9 – Uniform Sand Profile

Layer	Depth	Description	
#	(m)	Field	Laboratory
1	0.00 - 0.05	Grey or Brown sand (7.5 YR 5/1 - 7.5 YR 4/2) sand. Single grained with loose consistence. Boundary diffuse to gradual.	Strongly acidic with a pH of 4.7 - 5.3 throughout the profile (n = 2) and non-saline with low average ECe of less than 1.5dS/m (range 0.13 - 10.23, n = 2). Non sodic with ESP of <3% (range 1.8 - 6.8, n = 2).
2	0.05 - 2.00	Pink-greyish or light brown (7.5 YR 6/2 - 7.5 YR 6/4) sand. Single grained with loose consistence.	

n = number of replicate soil profile sites, actual data replicates often larger as vertical sampling per layer varied (e.g. layer 2 may have been sampled at 0.05 and 0.10m at some soil profile sites).

Grey-Brown Gradational Loam

Description: This soil unit is characterised by a gradual texture change between the brownish black surface loam and the underlying greyish brown sandy clay loam and sandy clay (**Table 10**).

Location: This soil unit is minor covering 0.5 per cent of the study area, and occurs on top of the central ridge to the south-east of the study area.

Management: The surface 0.08m of this soil is suitable for stripping and reuse as topdressing in rehabilitation. The topsoil requires standard erosion and sediment control measures if disturbed.

The subsoil is not recommended for reuse in rehabilitation due to the limiting factors of high stone content and apedal texture.

Table 10 – Grey-Brown Gradational Loam Profile

Layer	Depth	Description	
#	(m)	Field	Laboratory
1	0.00 - 0.08	Brownish-Black (5 YR 2/2) loam with weak structure and 10 - 20mm subangular peds. Contains less than 2% stones and many roots.	*No laboratory results for this minor soil unit.*
2	0.08 - 0.32	Greyish brown (7.5 YR 6/2) sandy clay loam with moderately strong apedal structure. Contains 20 - 50% subrounded unweathered stones up to 60mm across. Boundary is gradational.	
3	0.32 - 0.56	Brownish-grey (7.5 YR 5/1) sandy clay with moderately strong apedal structure. Contains up to 50% of 2-6mm subangular stones and few roots. Boundary is diffuse.	
4	>0.56	Weathered sandstone, orange mottled with grey	

3.2 Topdressing Suitability

Laboratory soil analytical results were used in conjunction with the field assessment (refer **Appendix 1**) to determine the depth of soil material suitable for recovery and re-use as a topdressing material in rehabilitation.

Weak structural soil texture and subsoil sodicity were the two most common and significant limiting factors in determining stripping depth throughout the study area. Some of the soils within the study area are only marginally suitable for use as topdressing materials, however, revegetation of coal fields for pastoral use in the Upper Hunter region generally have a greater degree of success when marginal soils are used relative to alternative use of overburden material (ERM Mitchell McCotter, 1994).

The recommended stripping depth for each soil unit, together with area of land and calculated volumes are provided in **Table 11** below and recommended stripping depths are illustrated in **Figure 4**. The total volume of topsoil available is 1,674,670 cubic metres (m^3), when a handling loss of 10 percent is allowed, (**Table 11**) which approximately equates to an available re-spread topdressing depth of approximately 130mm.

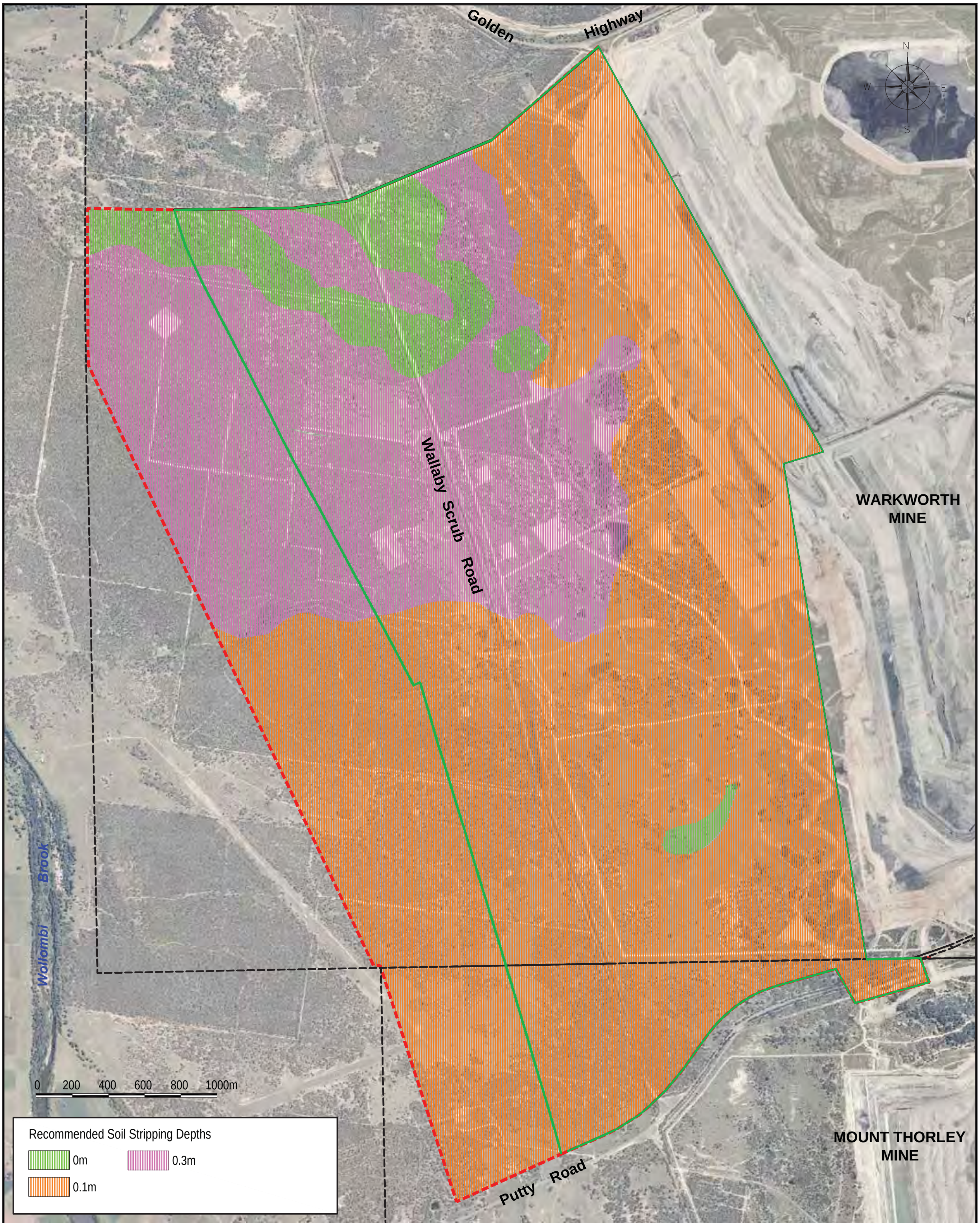
Table 11 – Recommended Stripping Depths for Rehabilitated Landforms

Soil Type	Recommended Stripping Depth (m)	Stripping area (ha)	Volume (m^3)
Brown Duplex Loam	0.1	518.57	518,568
Red Duplex Loam	0.1	319.02	319,021
Duplex Sands	0.3*	209.72	629,145
Grey-Pink Duplex Loam	0.3	129.64	388,926
Uniform Sands	nil**	nil	nil
Grey-Brown Gradational Loam	0.08	6.36	5,084
Total Volume			1,860,744
Total Volume with 10% handling loss allowance			**1,674,670**

* Stripping to 1m for vegetation restoration activities in green offset zones may be viable.

** Stripping recommended up to 2m for vegetation restoration activities in Green Offset zones may be viable.

Allowing for a 10 per cent handling loss, approximately 1,674,670m^3 of suitable topdressing is available within the study area. The majority of topsoil disturbance will result from the excavation of the open cut pit. The Duplex Sands which are located primarily in the northern part of the study area will generate the largest topsoil resource. This is closely followed by the Brown Duplex Loam which is evident throughout the study area, and the Grey-Pink Duplex Loam which is located primarily east of Wallaby Scrub Road.



LEGEND
- Constraints boundary
- Tenement boundary
- Study area boundary (Limit of Disturbance)

FIGURE 4

Recommended Soil Stripping Depths for Rehabilitated Landforms

Project: Warkworth Mine Extension Soil Survey (2009)

Client: Warkworth Mining Limited

Version	Date:	Author:	Checked:	Approved:
1	8/10/09	LF	AC	RM
2	30/10/09	LF	AC	RM
3	12/11/09	LF	AC	RM
4	08/12/09	CC	AC	RM

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File: Fg4_MML00-002_Soil Strip_091208

Projection: MGA94 Zone 56

3.3 Erosion Potential

Soil samples were laboratory tested for dispersion using EAT and ESP tests. These tests indicate the susceptibility of a soil to losing its structure and binding capacity when wet, and therefore the erosion potential of the soil. The results showed a similar pattern with all soil units whereby sodicity increased significantly with depth. The exception was the Uniforms Sands which exhibited limited chemical variability throughout the solum.

The appropriate erosion and sediment control measures should be in place prior to surface disturbance of these soils, as the risk of erosion is high once the subsoil is exposed. Appropriate measures are outlined in **Section 4** of this report. All subsoils are dispersive except the Uniform Sands.

3.4 Potential Acid Generating Material

The potential for acid generation from the topsoil and subsoil (regolith) within the study area is low. This does not include acid potential within the overburden material (consolidated bedrock below two to three metres depth), which was not assessed during this survey.

Acid Sulphate Soils (ASS), which are the main cause of acid generation within the soil mantle, are commonly found less than five metres above sea level, particularly in low-lying coastal areas such as mangroves, salt marshes, floodplains, swamps, wetlands, estuaries, and brackish or tidal lakes. There has been little history of acid generation from regolith material in the Singleton area (which is located approximately 80km from the coast).

3.5 Land Capability

The pre-mining and post-mining rural land capability classification of the study area was carried out in accordance with DECCW. A comparison of the pre and post-mining rural land capability classification is provided in **Table 12**.

Table 12 – Comparison of Pre and Post Mining Rural Land Capability Classes

Land Class	Pre-mining		Post-mining		Change per Class
no.	ha	%	ha	%	%
I	nil	-	nil	-	n/a
II	nil	-	nil	-	n/a
III	nil	-	nil	-	n/a
IV	224.46	17.66%	204.25	16.07%	-1.59%
V	736.54	57.95%	54.53	4.29%	-53.66%
VI	310.00	24.39%	23.89	1.88%	-22.51%
VII	nil	-	609.70	47.97%	+47.97%
VIII	nil	-	378.63	29.79%	+29.79%
Total	**1271**		**1271**		

3.5.1 Pre-mining

Figure 5 illustrates the boundaries for pre-mining land capability by class and **Table 12** provides specifics on the classes by area. The study area encompasses classes IV, V and VI.

The western part of the study area is classified as Class IV land (17.66 per cent). This land comprises the better classes of grazing land and whilst it can sustain cultivation for an occasional crop, it is not suitable for cultivation on a regular basis owing to limitations of slope and erosion potential. Soil conservation practices such as stocking rate control, application of fertiliser and re-establishment of permanent pasture are also recommended.

The eastern part of the study area is classified as Class V land (57.95 per cent). The land is suitable for grazing with occasional cultivation. Structural soil conservation measures are generally required because of slope gradient and soil type / depth and these measures include contour ripping and construction of banks. The south-eastern part of the study area is classified as Class VI land (24.39 per cent). This land is suitable for grazing only and requires soil conservation measures that provide for sufficient ground cover.

3.5.2 Post-mining

Figure 6 illustrates the boundaries for post-mining land capability by class and **Table 12** provides specifics on each class by area. The post-mining study area encompasses land capability class IV and V as well as VI, VII and VIII.

The rehabilitated landforms east of Wallaby Scrub Road are classified Class IV lands (16.07 per cent). The rehabilitated landforms will be suitable for grazing but not be suitable for regular cultivation. Grazing land use is based on native or improved pastures established using minimum tillage amongst stands of native trees and shrubs.

The final void, located primarily east of Wallaby Scrub Road, is classified Class VII and the high wall surrounding the void is Class VIII (47.97 and 29.79 per cent respectively). Class VIII denotes land as unsuitable for rural production. The regraded low wall to the north of the rehabilitated landform and the steeper benches on the landform are Class VI land (1.88 per cent).

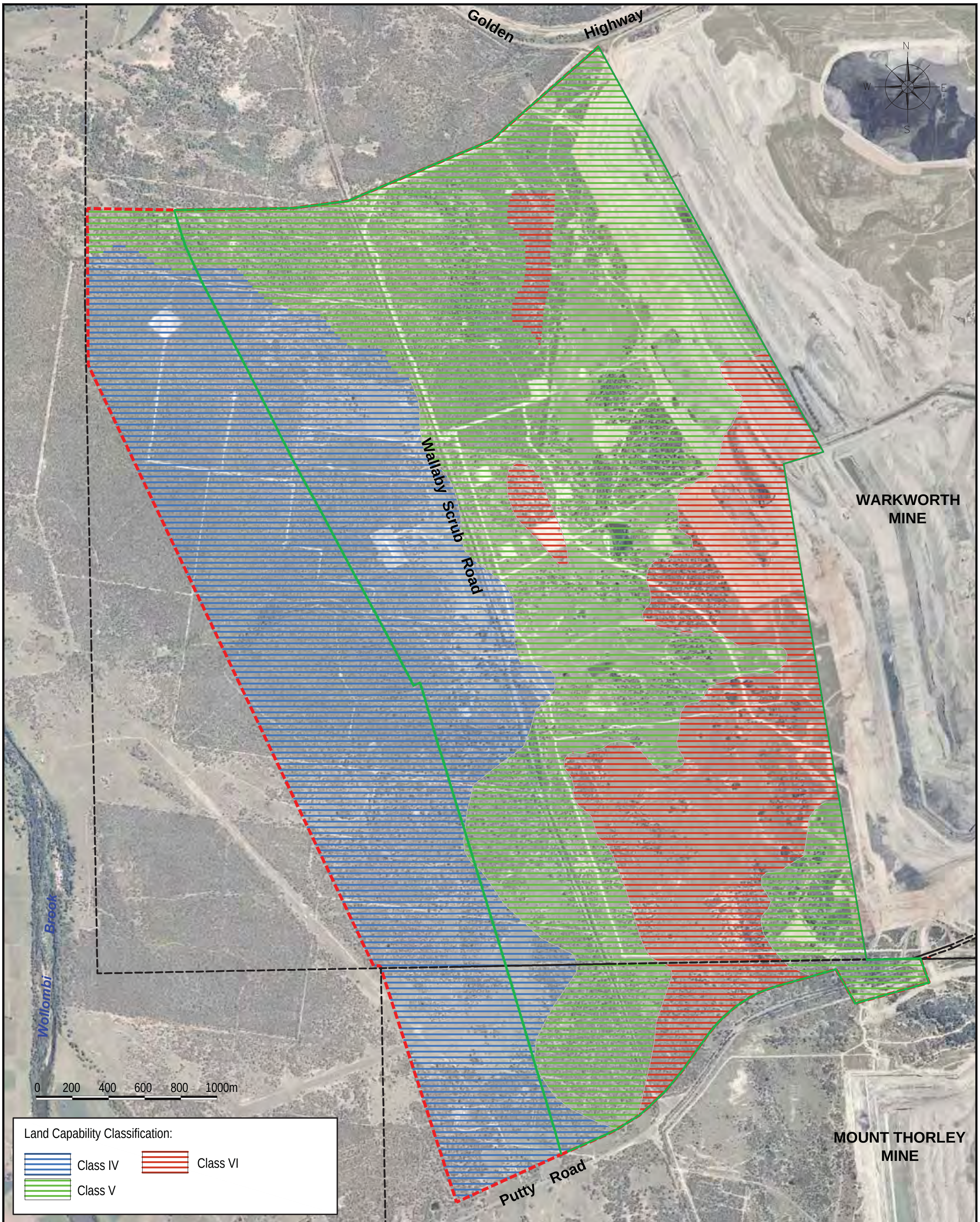
Two small pockets of Class V land (4.29 per cent) occur in the most northern and south-eastern parts of the study area.

3.6 Agricultural Suitability

The pre-mining and post-mining agricultural land suitability classification of the study area was carried out in accordance with DII. A comparison of the pre and post mining agricultural land suitability classification is provided in **Table 13**.

Table 13 – Comparison of Pre and Post-mining Agricultural Land Suitability Classes

Land Class	Pre-mining		Post-mining		Change per Class
no.	ha	%	ha	%	%
1	nil	-	nil	-	n/a
2	nil	-	nil	-	n/a
3	224.46	17.66%	nil	-	-17.66%
4	736.54	57.95%	236.28	18.59%	-39.36%
5	310.00	24.39%	1034.72	81.41%	+57.02%
Total	**1271**		**1271**		



LEGEND
- Constraints boundary
- Tenement boundary
- Study area boundary (Limit of Disturbance)

FIGURE 5

Pre-Mining Land Capability

Project: Warkworth Mine Extension Soil Survey (2009)

Client: Warkworth Mining Limited

Version	Date:	Author:	Checked:	Approved:
1	8/10/09	LF	AC	RM
2	30/10/09	LF	AC	RM
3	12/11/09	LF	AC	RM
4	08/12/09	CC	AC	RM

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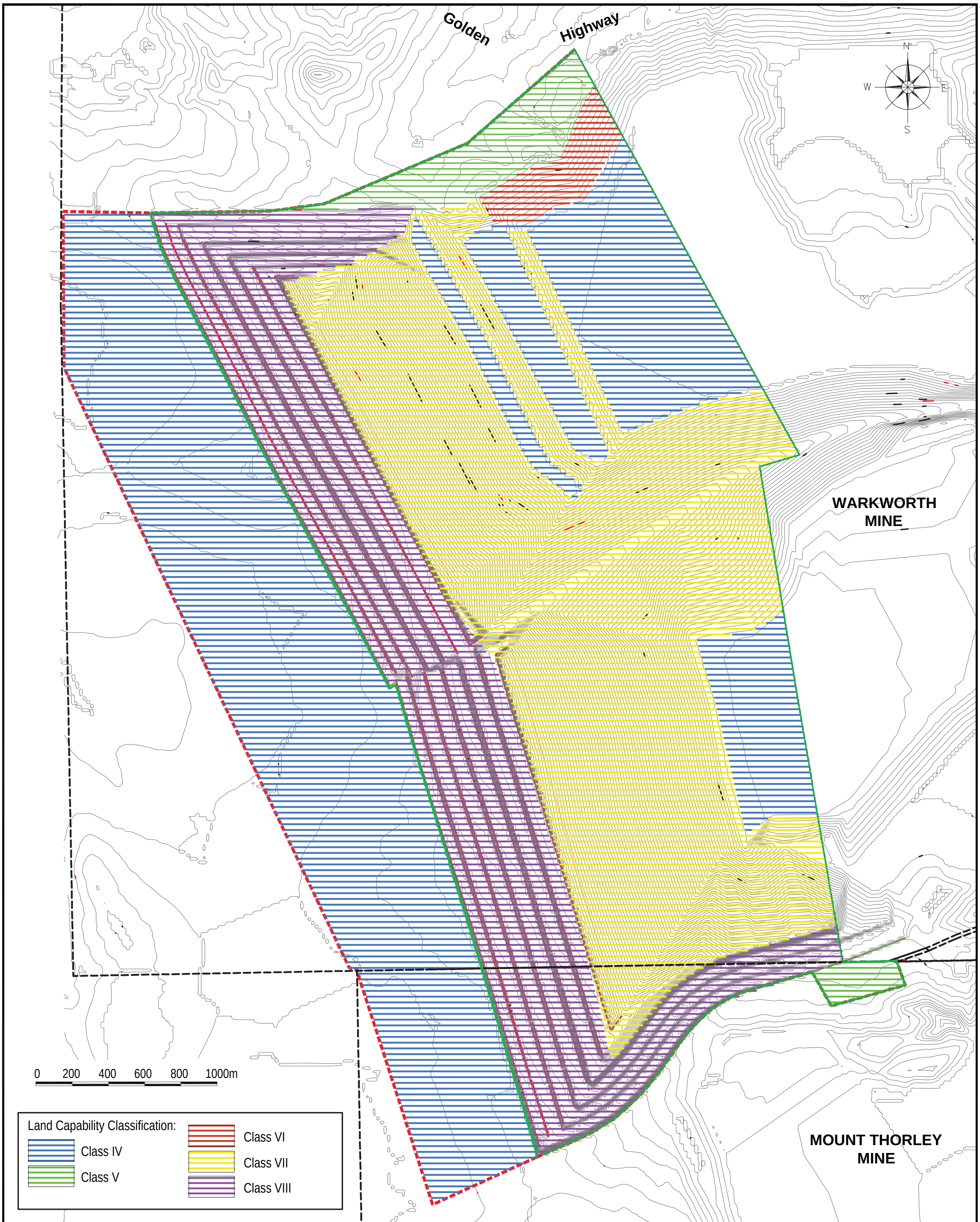
File: Fg5_MML00-002_Land Cap_091208

Projection: MGA94 Zone 56



LEGEND
Constraints boundary
Tenement boundary
Study area boundary
(Limit of Disturbance)

FIGURE 6

Post Mining Land Capability

Project:
Warkworth Mine Extension
Soil Survey (2009)

Client:
Warkworth Mining Limited

Version	Date:	Author:	Checked:	Approved:
1	8/10/09	LF	AC	RM
2	30/10/09	LF	AC	RM
3	12/11/09	LF	AC	RM
4	08/12/09	CC	AC	RM

GSS ENVIRONMENTAL
Environmental, Land and Project Management Consultants

File:
Fg6_MML00-002_PostLC_091208

Projection:
MGA94 Zone 56

3.6.1 Pre-mining

Figure 7 illustrates the boundaries for pre-mining agricultural land suitability by class and **Table 13** provides specifics on the classes by area.

The study area encompasses the agricultural classes 3, 4 and 5. The western part of the study area is classified Class 3 land (17.66 per cent). This is moderately productive land and is suited to grazing, improved pasture use, and some rotation cropping within a pasture regime. The eastern part of the study area is classified Class 4 land (57.95 per cent). Class 4 land is considered to be marginally productive for agricultural purposes and is not suited to cultivation. Grazing is suitable and pasture improvement, with preferably native pasture species, is to be established using minimal tillage.

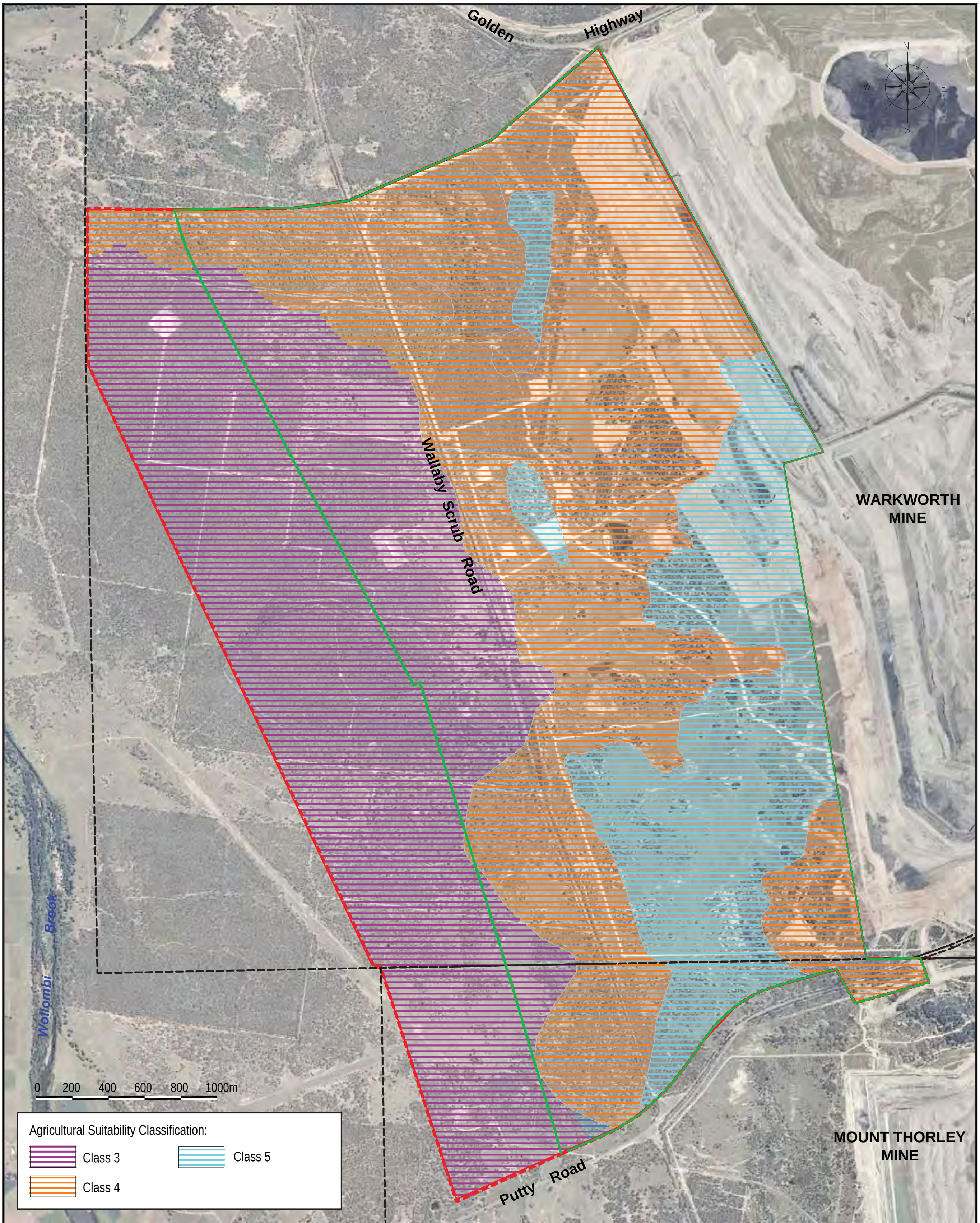
The pockets of Uniform Sand to the north and the Red Duplex Loam to the east of the study area are classified Class 5 (24.39%). Class 5 lands are considered to be marginal with light grazing “at best” being the only suitable agricultural activity. It is not recommended that the Uniform Sands be grazed as they support the endangered Warkworth Sands Vegetation community.

3.6.2 Post-mining

Figure 8 illustrates the boundaries for post mining land suitability by class and **Table 13** provides specifics on the classes by area.

The post mining study area encompasses similar agricultural suitability classes as described in pre-mining, these being classes 4 and 5.

The rehabilitated landforms are classified Class 4 as well as two small land pockets located outside of direct mining activities (total class 4 per cent is 18.59). The final void and its associated high wall at year 2031 are classified Class 5 (81.41 per cent).



LEGEND

- Constraints boundary
- Tenement boundary
- Study area boundary (Limit of Disturbance)

FIGURE 7

Pre-mining Agricultural Suitability

Project: Warkworth Mine Extension Soil Survey (2009)

Client: Warkworth Mining Limited

File: Fg7_MML00-002_Ag Suit_091208

Projection: MGA94 Zone 56

Version	Date:	Author:	Checked:	Approved:
1	8/10/09	LF	AC	RM
2	30/10/09	LF	AC	RM
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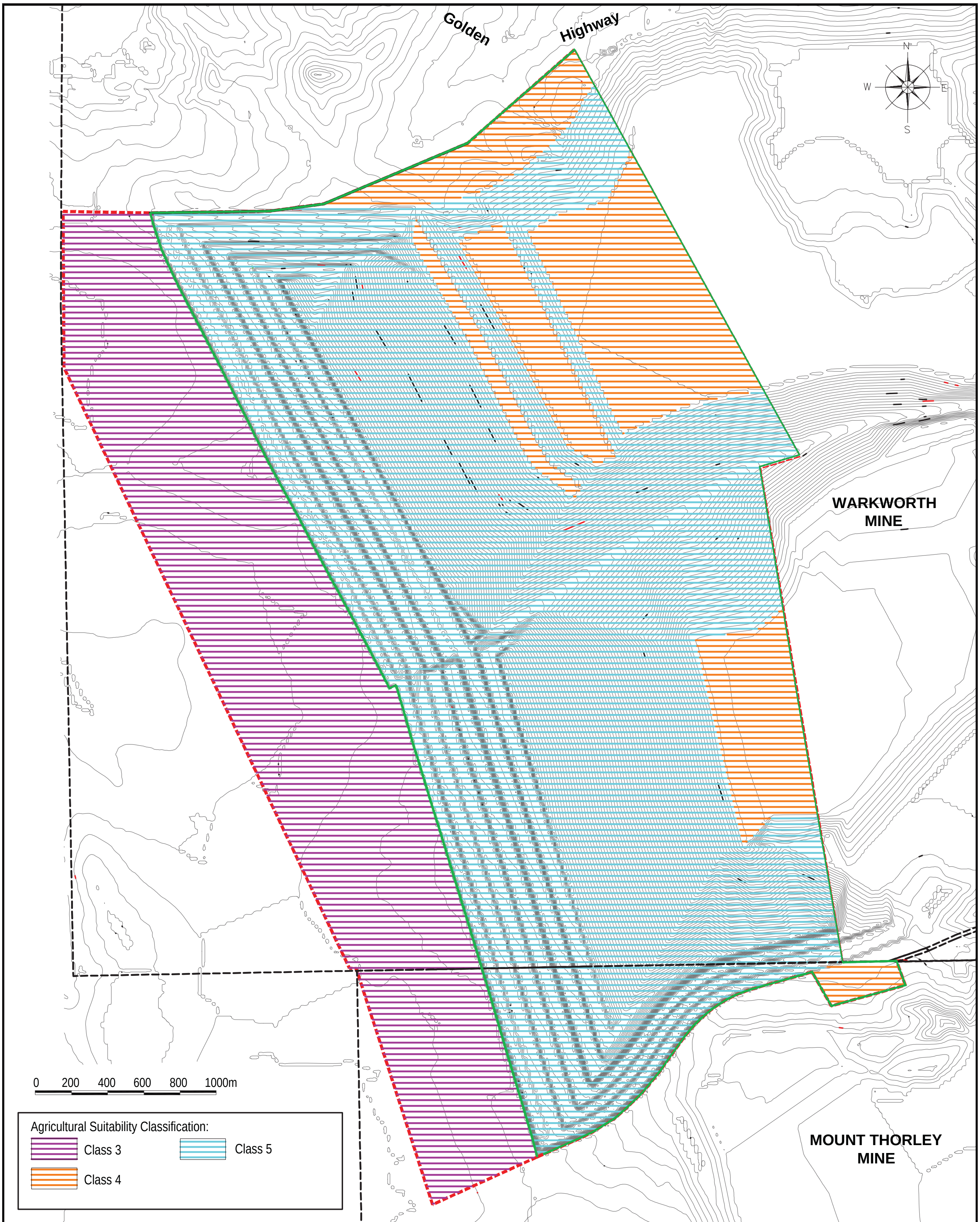

LEGEND
- Constraints boundary
- Tenement boundary
- Study area boundary (Limit of Disturbance)

FIGURE 8

Post Mining
Agricultural Suitability

Project: Warkworth Mine Extension Soil Survey (2009)

Client: Warkworth Mining Limited

Version	Date:	Author:	Checked:	Approved:
1	8/10/09	LF	AC	RM
2	30/10/09	LF	AC	RM
3	12/11/09	LF	AC	RM
4	08/12/09	CC	AC	RM

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Environmental, Land and Project Management Consultants

File: Fg8_MML00-002_PostASuit_091208

Projection: MGA94 Zone 56

4.0 DISTURBANCE MANAGEMENT

In order to reduce the potential for degradation within the study area and adjoining lands, the following management and mitigation strategies are recommended for implementation during mining.

4.1 Topsoil Stripping and Handling

Where topsoil stripping and transportation is required, the following topsoil handling techniques are recommended to prevent excessive soil deterioration:

- strip material to the depths stated in **Table 11**, subject to further investigation as required. Due to the widespread inherent variability in topsoil sodicity it is recommended that rapid field tests using a SASKIT field kit (Rengasamy & Churchman, 2005) be undertaken prior to topsoil stripping. The field kit test results will increase sodic survey intensity and provide detailed variability data that will maximise stripping effectiveness for rehabilitation outcomes. These field results should be used in conjunction with the guidelines provided in **Table 11**.
- topsoil should be maintained in a slightly moist condition during stripping. Material should not be stripped in either an excessively dry or wet condition.
- place stripped material directly onto reshaped overburden and spread immediately (if mining sequences, equipment scheduling and weather conditions permit) to avoid the requirement for stockpiling.
- grading or pushing soil into windrows with graders or dozers for later collection by open bowl scrapers, or for loading into rear dump trucks by front-end loaders, are examples of preferential less aggressive soil handling systems. This minimises compression effects of the heavy equipment that is often necessary for economical transport of soil material.
- soil transported by dump trucks may be placed directly into storage. Soil transported by scrapers is best pushed to form stockpiles by other equipment (e.g. dozer) to avoid tracking over previously laid soil.
- the surface of soil stockpiles should be left in as coarsely textured a condition as possible in order to promote infiltration and minimise erosion until vegetation is established, and to prevent anaerobic zones forming. The addition of gypsum to the surface soil is recommended to promote aggregate stability.
- as a general rule, maintain a maximum stockpile height of three meters. Clayey soils should be stored in lower stockpiles for shorter periods of time compared to sandier soils.
- if long-term stockpiling is planned (i.e. greater than 12 months), seed and fertilise stockpiles as soon as possible. An annual cover crop species that produce sterile florets or seeds should be sown. A rapid growing and healthy annual pasture sward provides sufficient competition to minimise the emergence of undesirable weed species. The annual pasture species will not persist in the rehabilitation areas but will provide sufficient competition for emerging weed species and enhance the desirable micro-organism activity in the soil.
- prior to re-spreading stockpiled topsoil onto reshaped overburden (particularly onto designated tree seeding areas), an assessment of weed infestation on stockpiles should be undertaken to determine if individual stockpiles require herbicide application and / or “scalping” of weed species prior to topsoil spreading.
- an inventory of available soil should be maintained to ensure adequate topsoil materials are available for planned rehabilitation activities.
- topsoil should be spread to a minimum depth of 0.10m.

4.2 Topsoil Re-spreading and Seeding

4.2.1 Re-spreading

Where possible suitable topsoil should be re-spread directly onto reshaped landforms. Where topsoil resources allow, topsoil should be spread to a nominal depth of 100mm on all re-graded spoil.

All soils identified in the study area are of low fertility and accordingly fertiliser additions are recommended. Most soils in the study area also exhibited sodic properties. Sodic soils are not optimal for rehabilitation works as the clay particles tend to disperse and swell producing poor physical soil conditions. These conditions include waterlogging and hard-setting crusts which in turn negatively affect infiltration rates, plant-available water capacity, seedling emergence and root development (Rengasamy & Churchman, 2005).

The application of soil ameliorants that decrease soil dispersibility and increase soil aggregate stability is an important soil rehabilitation management tool. Historically, gypsum has been successfully applied as an ameliorant as it displaces the problematic sodium ion from clay. Accordingly, gypsum application to re-spreaded soils is highly recommended.

Soil carbon also increases soil aggregate stability and adding carbon as a soil ameliorant will improve soil structure (Hammes & Schmidt, 2009). Carbon ameliorants that may be beneficial for this study site's rehabilitated landforms include mulch, biochar and biosolids.

The spreading of topsoil, addition of soil ameliorants and application of seed should be carried out in consecutive operations to reduce the potential for topsoil loss to wind and water erosion.

4.2.2 Seedbed Preparation

Thorough seedbed preparation should be undertaken to ensure optimum establishment and growth of vegetation. All topsoiled areas should be lightly contour ripped (after topsoil spreading) to create a "key" between the soil and the spoil. Ripping should be undertaken on the contour and the tynes lifted for approximately two metres every 200m to reduce the potential for channelised erosion. Best results will be obtained by ripping when soil is moist and when undertaken immediately prior to sowing. The respread topsoil surface should be scarified prior to, or during seeding, to reduce run-off and increase infiltration. This can be undertaken by contour tilling with a fine-tyned plough or disc harrow.

4.3 Landform Design, Erosion Control

Rehabilitation strategies and concepts proposed below have been formulated according to results of industry-wide research and experience.

4.3.1 Post Disturbance Regrading

The main objective of regrading is to produce slope angles, lengths and shapes that are compatible with the proposed land use and not prone to an unacceptable rate of erosion. Integrated with this is a drainage pattern that is capable of conveying runoff from the newly created catchments whilst minimising the risk of erosion and sedimentation.

4.3.2 Erosion and Sediment Control

The most significant means of controlling surface flow on disturbed areas is to construct contour furrows or contour banks at intervals down the slope. The effect of these is to divide a long slope into a series of short slopes with the catchment area commencing at each bank or furrow. This prevents runoff from reaching a depth of flow or velocity that would cause erosion. As the slope angle increases, the banks or furrows must be spaced closer together until a point is reached where they are no longer effective.

Contour ripping across the grade is by far the most common form of structural erosion control on mine sites as it simultaneously provides some measure of erosion protection and cultivates the surface in readiness for sowing.

Graded banks are essentially a much larger version of contour furrows, with a proportionately greater capacity to store runoff and/or drain it to some chosen discharge point. The banks are constructed away from the true contour, at a designed gradient (half a per cent to one per cent) so that they drain water from one part of a slope to another; for example, towards a watercourse or a sediment control dam.

Eventually, runoff that has been intercepted and diverted must be disposed of down slope. The use of engineered waterways using erosion blankets, ground-cover vegetation and/or rip rap is recommended to safely dispose of runoff down slope.

The construction of sediment control dams is recommended for the purpose of capturing sediment laden runoff prior to off-site release. Sediment control dams are responsible for improving water quality throughout the mine site and, through the provision of semi-permanent water storages, enhance the ecological diversity of the area.

The following points should be considered when selecting sites for sediment control dams.

- each dam should be located so that runoff may be easily directed to it, without the need for extensive channel excavation or for excessive channel gradient. Channels must be able to discharge into the dam without risk of erosion. Similarly, spillways must be designed and located so as to safely convey the maximum anticipated discharge.
- the material from which the dam is constructed must be stable. Dispersible clays will require treatment with lime, gypsum and/or bentonite to prevent failure of the wall by tunnel erosion. Failure by tunnelling is most likely in dams which store a considerable depth of water above ground level, or whose water level fluctuates widely. Dams should always be well sealed, as leakage may lead to instability, as well as allowing less control over the storage and release of water.
- the number and capacity of dams should be related to the total area of catchment and the anticipated volume of runoff. The most damaging rains, in terms of erosion and sediment problems are localised, high intensity storms.

5.0 REFERENCES

Department of Natural Resources (2005) *Land Capability Spatial Data*. Resource Information Unit, Hunter Region.

Elliot G.L., Veness, R.A. (1981) *Selection of Topdressing Material for Rehabilitation of Disturbed Areas in the Hunter Valley*, J. Soil Cons. NSW 37 37-40.

Emery K.A. (1986) *Rural Land Capability Mapping*. Soil Conservation Service of NSW. Sydney, NSW.

ERM Mitchell McCotter (1995) Extension of Mount Thorley Operations: Environmental Impact Statement.

Glen R.A., J. Beckett (1993) Hunter Coalfield regional geology, 2nd edition.

Global Soil Systems (2002) Warkworth coal mine extension: soil and land capability survey report. (Project No CNA 2-1, Issue 2)

Hammes K., Schmidt M.W. (2009) Changes of Biochar in soil. In ‘Biochar environmental management science and technology’. (Eds J. Lehmann and S. Joseph) (CSIRO, Australia)

Isbell RF (1996) 'The Australian Soil Classification.' (CSIRO Publishing: Melbourne).

Kovac M., Lawrie, J.M. (1991) *Soil Landscapes of the Singleton 1:250 000 Sheet*. Soil Conservation Service of NSW, Sydney.

Lockwood PV (2007) Warkworth Sands soil survey: Soil sampling and analysis within the Green Offsets and at Archerfield. University of England, Armidale.

Lockwood PV (2009) Mount Thorley-Warkworth extension area soil survey. University of England, Armidale.

Macbeth (1994) *Munsell Soil Colour Charts* Revised Edition.

McDonald RC, Isbell RF, Speight JG, Walker J, Hopkins MS (1990) 'Australian soil and land survey field handbook.' (Inkata Press: Melbourne).

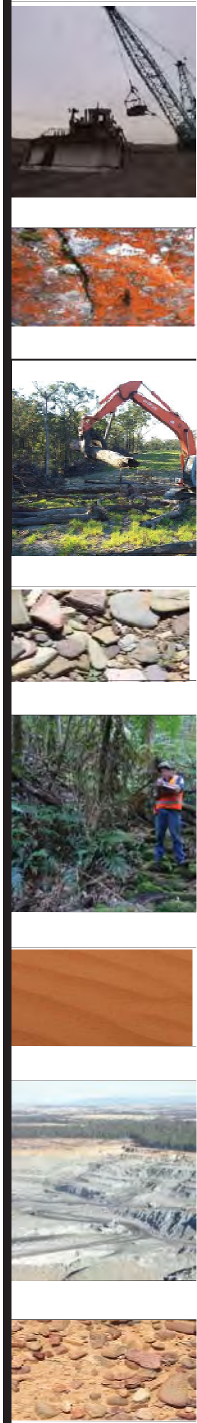
McKensie I., Jacquier D., Neil J., Brown K. (2004) Australian soils and landscapes: an illustrated compendium. (CSIRO, Australia).

NSW Agriculture & Fisheries (1990) *Agricultural Suitability Maps – Uses and Limitations*. Agfact AC.9 Second Edition.

Northcote, K.H. (1979) A Factual Key for the recognition of Australian Soils. (Rellim Technical Publications, South Australia).

Rengasamy P., G.J. Churchman (2005) Cation exchange capacity, exchangeable cations and sodicity. In ‘Soil analysis: an interpretation manual’. (Eds K.I. Peverill, L.A. Sparrow and D.J. Reuter) (CSIRO, Australia).

Stace, H. C. T., Hubble, G. D, Brewer, R., Northcote, K. H., Sleeman, J. R., Mulcahy, M. J, Hallsworth, E. G. (1968) ‘A Handbook of Australian Soils.’ (Rellim Technical Publications, South Australia).



Field Assessment Procedure

APPENDIX 1

FIELD ASSESSMENT PROCEDURE

Elliot and Veness (1981) have described the basic procedure, adopted in this survey, for the recognition of suitable topdressing materials. In this procedure, the following soils factors are analysed. They are listed in decreasing order of importance.

Structure Grade

Good permeability to water and adequate aeration are essential for the germination and establishment of plants. The ability of water to enter soil generally varies with structure grade (Charman, 1978) and depends on the proportion of coarse peds in the soil surface.

Better structured soils have higher infiltration rates and better aeration characteristics. Structureless soils without pores are considered unsuitable as topdressing materials.

Consistence – Shearing Test

The shearing test is used as a measure of the ability of soils to maintain structure grade.

Brittle soils are not considered suitable for revegetation where structure grade is weak or moderate because peds are likely to be destroyed and structure is likely to become massive following mechanical work associated with the extraction, transportation and spreading of topdressing material.

Consequently, surface sealing and reduced infiltration of water may occur which will restrict the establishment of plants.

Consistence – Disruptive Test

The force to disrupt peds, when assessed on soil in a moderately moist state, is an indicator of solidity and the method of ped formation. Deflocculated soils are hard when dry and slake when wet, whereas flocculated soils produce crumbly peds in both the wet and dry state. The deflocculated soils are not suitable for revegetation and may be identified by a strong force required to break aggregates.

Mottling

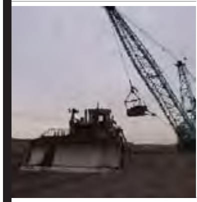
The presence of mottling within the soil may indicate reducing conditions and poor soil aeration. These factors are common in soil with low permeability's; however, some soils are mottled due to other reasons, including proximity to high water-tables or inheritance of mottles from previous conditions. Reducing soils and poorly aerated soils are unsuitable for revegetation purposes.

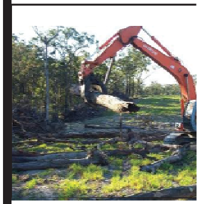
Macrostructure

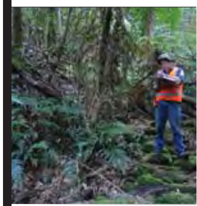
Refers to the combination or arrangement of the larger aggregates or peds in the soil. Where these peds are larger than 10 cm (smaller dimension) in the subsoil, soils are likely to either slake or be hardsetting and prone to surface sealing. Such soils are undesirable as topdressing materials.

Texture

Sandy soils are poorly suited to plant growth because they are extremely erodible and have low water holding capacities. For these reasons soils with textures equal to or coarser than sandy loams are considered unsuitable as topdressing materials for climates of relatively unreliable rainfall, such as the Hunter Valley.








Soil Information

APPENDIX 2

TEST SIGNIFICANCE AND TYPICAL VALUES

Particle Size Analysis

Particle size analysis measures the size of the soil particles in terms of grainsize fractions, and expresses the proportions of these fractions as a percentage of the sample. The grainsize fractions are:

clay	<0.002mm
silt	0.002 to 0.02mm
fine sand	0.02 to 0.2mm
medium & coarse sand	0.2 to 2mm

Particles greater than 2mm, that is gravel and coarser material, are not included in the analysis.

Emerson Aggregate Test

Emerson aggregate test measures the susceptibility to dispersion of the soil in water. Dispersion describes the tendency for the clay fraction of a soil to go into colloidal suspension in water. The test indicates the credibility and structural stability if the soil and its susceptibility to surface sealing under irrigation and rainfall. Soils are divided into eight classes on the basis of the coherence of soil aggregates in water. The eight classes and their properties are:

Class 1:	Very dispersible soils with susceptibility to high tunnel erosion.
Class 2:	Moderately dispersible soils with some susceptibility to tunnel erosion.
Class 3:	Slightly or non-dispersive soils which are generally stable and suitable for soil conservation earthworks.
Class 4-6:	More highly aggregated materials which are less likely to hold water. Special compactive efforts are required in the construction of earthworks.
Class 7-8:	Highly aggregated materials exhibiting low dispersion characteristics.

The following subdivisions within Emerson classes may be applied:

(1) Slight milkiness, immediately adjacent to the aggregate.
(2) Obvious milkiness, less than 50% of the aggregate affected.
(3) Obvious milkiness, more than 50% of the aggregate affected.
(4) Total dispersion, leaving only sand grains.

Salinity

Salinity is measured as electrical conductivity on a 1:5 soil:water suspension to give EC (1:5). The effects of salinity levels expressed as EC at 25^{o} (dS/cm), on plants are:

0 to 1:	Very low salinity, effects on plants mostly negligible.
1 to 2:	Low salinity, only yields of very sensitive crops are restricted.
Greater than 2:	Saline soils, yields of many crops restricted.

pH

The pH is a measure of acidity and alkalinity. For 1:5 soil:water suspensions, soils having pH values less than 4.5 are regarded as strongly acid, 4.5 to 5.0 moderately acidic, and values greater than 7.0 are regarded as alkaline. Most plants grow best in slightly acidic soils.

LABORATORY TEST METHODS

Particle Size Analysis

Determination by sieving and hydrometer of percentage, by weight, of particle size classes: Gravel >2mm, Coarse Sand 0.2-2mm, Fine Sand 0.02-0.2mm, Silt 0.002-0.2mm and Clay <0.002mm; SCS standard method (Bond et al., 1990)

Emerson Aggregate Test

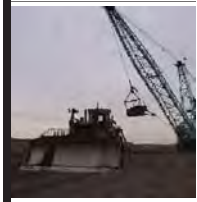
An eight class classification of soil aggregate coherence (slaking and dispersion) in water. SCS standard method closely related to Australian Standard AS1289. The degree of dispersion is included in brackets for class 2 and class 3 aggregates (Bond et al., 1990).

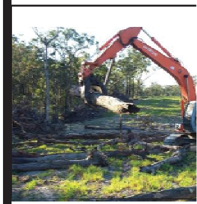
EC

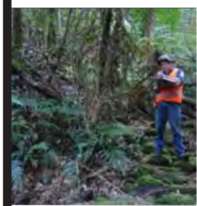
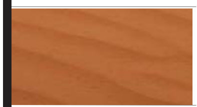
Electrical Conductivity determined on a 1:5 soil:water suspension. Prepared from the sample's fine earth fraction (Bond et al., 1990).

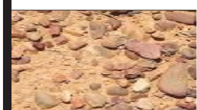
pH

Determined on a 1:5 soil:water suspension, Prepared from the sample's fine earth fraction (Bond et al., 1990).







Glossary

APPENDIX 3

GLOSSARY

A Horizon

The original top layer of mineral soil divided into A1 (typically from 5 to 30 cm thick; generally referred to as topsoil.

Alluvial Soils

Soils developed from recently deposited alluvium, normally characterise little or no modification of the deposited material by soil forming processes, particularly with respect to soil horizon development.

Brown Clays

Soil determined by high clay contents. Typically, moderately deep to very deep soils with uniform colour and texture profiles, weak horizonation mostly related to structure differentiation.

Consistence

Comprises the attributes of the soil material that are expressed by the degree and kind of cohesion and adhesion or by the resistance to deformation or rupture.

Electrical Conductivity

The property of the conduction of electricity through water extract of soil. Used to determine the soluble salts in the extract, and hence soil stability. (Soil Landscapes of Singleton 1991)

Emmerson's Aggregate Test (EAT)

A classification of soil based on soil aggregate coherence when immersed water. Classifies soils into eight classes and assists in identifying whether soils will slake, swell or disperse (Soil Landscapes of Singleton, 1991)

Gravel

The >2 mm materials that occur on the surface and in the A1 horizon and include hard, coarse fragments.

Lithosols

Stony or gravelly soils lacking horizon and structure development. They are usually shallow and contain a large proportion of fragmented rock. Textures usually range from sands to clay loams.

Loam

A medium, textured soil of approximate composition 10 - 25% clay, 25 - 50%, silt and <50% sand.

Mottling

The presence of more than one soil colour in the same soil horizon, not including different nodule or cutan colours.

Particle Size Analysis (PSA)

The determination of the of the amount of the different size fractions in a soil sample such as clay, silt, fine sand, coarse sand and gravel. (Soil Landscapes of Singleton 1991)

Pedality

Refers to the relative proportion of peds in the soil (as strongly pedal, weakly pedal or non-pedal).

pH

A measure of the acidity or alkalinity of a soil.

Solodic Soils

Strong texture differentiation with a very abrupt wavy boundary between A and B horizons, a well-developed bleached A2 horizon and a medium to coarse blocky clay B horizon.

Soloths

Similar to a solodic soil 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.

Podzolics

Podzolic soils are acidic throughout and have a clear boundary between the topsoil and subsoil. The topsoils are loams with a brownish grey colour. The lower part of the topsoil has a pale light colour and may be bleached with a nearly white, light grey colour.

Ped

An individual, natural soil aggregate. (Soil Landscapes of Singleton 1991)

Sodicity

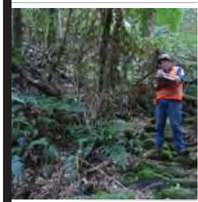
A measure of exchangeable sodium in the soil. High levels adversely affect soil stability, plant growth and/or land use.

Soil mantle

The upper layer of the Earth’s mantle, between consolidated bedrock and the surface, that contains the soil. Also known as the regolith.








Soil Profiles from Site Inspection

APPENDIX 4

Brown Duplex Loam

Description: Brown Duplex Loam; description as per **Section 3.1.2.1** in the main report.

Location: This profile was located northwest of the study area. In the landscape it was in a depression and is associated with low slopes and creek flats.

Layer #	Depth (m)	Description
1	0.0- 0.15	Grey-brown silty loam with moderate consistence. Weak pedality (sub-angular 5-10mm); many roots; stones 2-10%; and boundary clear.
1	0.15 - 0.30	Grey clayey loam with moderate consistence. Moderate pedality (sub-angular 10-20mm); few roots; stones 2%; and boundary gradual.
2	0.30 – 1.00	Grey medium clay with 40-50% yellow-brown mottles. Consistence is strong; pedality is massive; no roots or stones.

Plate 1: Grey-Brown Duplex Loam - Profile

Plate 2: Grey-Brown Duplex Loam - Landscape

Grey-Pink Duplex Loam

Description: This soil unit is characterised by an abrupt texture change between the grey-brown sandy-loam surface soil and the underlying grey clayey subsurface soil. A distinguishing feature of this duplex unit is the grey clayey subsurface horizon. This horizon is grey in colour as seasonal saturation mobilises insitu pigment bearing minerals (iron oxides) which are subsequently lost to free draining waters.

Location: This profile was located southwest of the study area. In the landscape it was on a lower slope and is associated with undulating hills mid-low slopes.

Layer #	Depth (m)	Description
1	0.0 - 0.30	Grey-brown sandy loam with weak consistence. A weak pedality (sub-angular 2-5mm); roots common to many; stones increasing with depth, 2-10%; and boundary clear and wavy.
2	0.30 – 1.0	Grey sandy clay with 20-50% yellow-brown mottles. Consistence is moderate; pedality is massive; roots few to none; and stones are relatively abundant, 10-20%.

Plate 3: Pink-Grey Duplex Loam - Profile

Plate 4: Pink-Grey Duplex Loam - Landscape

Fine Uniform Sand

Description: This soil unit is characterised by little textural change within the soil profile, and contains limited silt and clay particles.

Location: This profile was located northwest of the study area and is part of the Uniform Sand soil unit which supports the endangered Warkworth Sands vegetation community.

Landuse: The land overlying these soils is currently designated as a restoration area with grazing excluded and rehabilitation of remnant vegetation undertaken by Warkworth Mine. Vegetation is sparse and consists of Old-man Banksia, Flax-leaf Wattle and an understory of Coffee Bush.

Layer #	Depth (m)	Description
1	0.00 - 0.25	Grey-brown loamy with weak consistence. A weak pedality (sub-angular 2mm); roots many; stones 2-10%; and boundary clear and even.
2	0.25 – 1.0	Yellow fine sand with very weak consistence; apedal pedality with no roots or stones.

Plate 5 : Uniform Sand - Profile

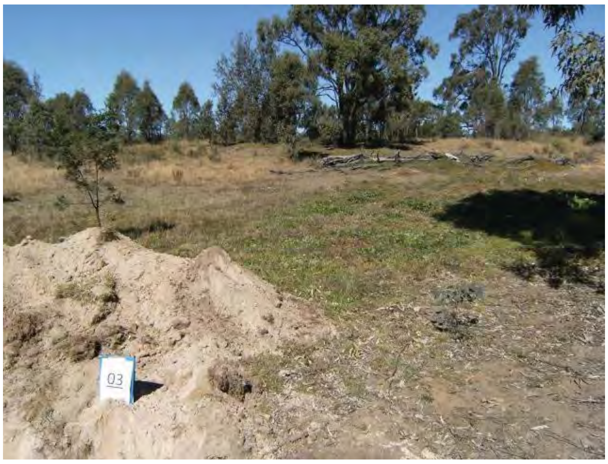


Plate 6: Uniform Sand - Landscape