WHITEHAVEN COAL

Narrabri Coal Operations Pty Ltd

ABN: 15 129 850 139

Narrabri Coal Mine
Stage 2 Longwall Project

Soils and Land Capability
Assessment of the Mining Area

Prepared by:

Geoff Cunningham Natural Resource Consultants

November 2009

Specialist Consultant Studies Compendium
Volume 2, Part 9a

Narrabri Coal Operations Pty Ltd

ABN: 15 129 850 139

Narrabri Coal Mine
Stage 2 Longwall Project

Soils and Land Capability Assessment of the Mining Area

Prepared for:
R.W. Corkery & Co. Pty. Limited
Level 1, 12 Dangar Road
PO Box 239
BROOKLYN NSW 2083

Tel: (02) 9985 8511
Fax: (02) 9985 8208
Email: brooklyn@rwcorkery.com

On behalf of:
Narrabri Coal Operations Pty Ltd
Level 9, 1 York Street
PO Box R1113
SYDNEY NSW 1225

Tel: (02) 8507 9700
Fax: (02) 8507 9701
Email: thaggarty@whitehaven.net.au

Prepared by:
Geoff Cunningham Natural Resource Consultants Pty Ltd
9 The Crest
KILLARA NSW 2071

Tel: (02) 9416 1995
Fax: (02) 9416 6626
Email: geoffcun@bigpond.net.au

November, 2009

CONTENTS

Page

CONTENTS

Page

APPENDICES

TABLES

FIGURES

Executive Summary

A reconnaissance soil survey has been undertaken over a 50km^2 [approx] area associated with the proposed Narrabri Coal Mine Stage 2 Longwall Project.

Sampling sites were selected after a stereoscopic airphoto interpretation of the Mine Site identified that a number of different landform units were present. These landform units were then associated with surface the three geology formations occurring over the Mine Site [Garrawilla Volcanics, Pilliga Sandstone, Purlawaugh Formation] to identify suitable sites for sampling.

Each of the fourteen Geological Formation / Landform Units was then sampled in the field and the soil characteristics recorded in detail. Some of these Geological Formation / Landform Units were sampled only once while others were sampled a number of times.

Thirty six soil profiles were excavated to a depth of 2.5m (or a shallower depth if bedrock was encountered or the backhoe could not penetrate further). The individual horizons in each profile were described in detail in the field.

55 horizons from 14 profiles were subjected to laboratory analysis at the Department of Lands' soil testing laboratory at Scone to determine soil texture, dispersibility and salinity characteristics. A summary of the local soil properties, based on the results of the laboratory analysis and computer modelling, is as follows.

- Soil pH values within the Mine Site are generally within the range that supports plant growth.
- Soil textures vary from sandy soils generally associated with the Pilliga Sandstone and many of the drainage lines to more clayey soils within the other two geological formations.
- Soil depth varies but in many cases it was possible to excavate the profiles to the full 250cm depth. The exceptions were usually on ridge crests and some upper slopes.
- Soil dispersibility, as measured by the Dispersion % and Emerson Aggregate Test showed that many subsoils were dispersible. The potential impacts of this dispersibility when associated with subsidence cracks is discussed.
- Soil salinity of a slight to moderate degree was evident in some subsoils. Again the potential impact of this salinity when associated with subsidence cracking is covered.
- Estimates of soil erodibility as predicted by the SOILOSS computer model are include for most Geological Formation / Landform Units.

Each of the excavated soil profiles is fully described in **Appendix 1** of this document.

Pre-mining Land Capability and Agricultural Land Suitability within the Mine Site is discussed as is the likely post mining and subsidence classification.

Based on the recorded soil attribute data, it was then possible to identify soil characteristics that might potentially cause problems on the subsidence areas – particularly those

- on forested land;
- on cropland;
- on native and improved pasture land;
- near the subsidence cracks;
- along the drainage lines that traverse the Mine Site;
- along roads and tracks;
- at farm dam and ground tank sites; and
- in areas where tank drains and soil conservation bank and waterway systems had been constructed.

Potential impacts of subsidence on these sites and means of overcoming any problems that develop are discussed. It should be emphasised that the discussion of likely subsidence – associated problems does not imply that such problems **will develop**. The aim of the discussion has been to alert the Proponent to as many possible impact scenarios as possible so that, should they develop, management will be in a position to identify early warning signs and take appropriate corrective action.

1 INTRODUCTION AND DESCRIPTION OF PROJECT

1.1 Introduction

A reconnaissance soil survey and land capability study was undertaken over the area identified as the Mine Site in **Figure 1**. The study area comprises some 50km^2 of farmland and forested country located between 26km and 30km south of Narrabri and to the west of the Kamilaroi Highway and adjacent to Jacks Creek State Forest.

The landforms within the study area vary from low crest to slopes, floodplains and drainage lines.

Three broad geological formations cover the study area. These are the:

- Pilliga Sandstone;
- Purlawaugh Formation, and
- Garrawilla Volcanics.

The aim of this reconnaissance soil survey has been to provide soil attribute data that can be used to determine the likely impacts on the different soil types that occur within the Mine Site as a result of changes in landform surface levels and cracking associated with the subsidence that occurs after longwall mining. In addition, the soil attribute data will allow the provision of general advice on rehabilitation and repair of structures and systems that are likely to be impacted by subsidence.

Field sampling was undertaken on 5th, 6th and 7th January, 2009.

1.2 Description of Project

Narrabri Coal Operations Pty Ltd ("the Proponent") proposes to convert the approved Narrabri Coal Mine from a continuous miner operation with an approved annual production rate of 2.5Mtpa to a longwall mining operation with a maximum annual production rate of 8Mtpa.

Longwall mining would involve the sequential development of heading gate roads approximately 305m apart oriented north-south from the main headings [“West Mains”] and developed for the full distance to the northern and southern boundaries of ML 1609 [up to 4.15km]. Once each set of roadways are fully developed, the longwall equipment would be installed and the coal recovered as the longwall unit retreats back towards the West Mains between the two roadways. All coal would be conveyed back to the Pit Bottom Area for transfer to the surface via the approved conveyor drift.

The longwall unit would recover 4.2m of coal from the bottom of the Hoskissons Seam [leaving up to 5.2m of coal in-situ] retreating at a rate of approximately 15m per day. At this rate, each longwall panel would take approximately 1 year to complete. Based on the proposed mining schedule, there could be up to three longwall panels being prepared [gate road development] or mined [longwall unit retreat].

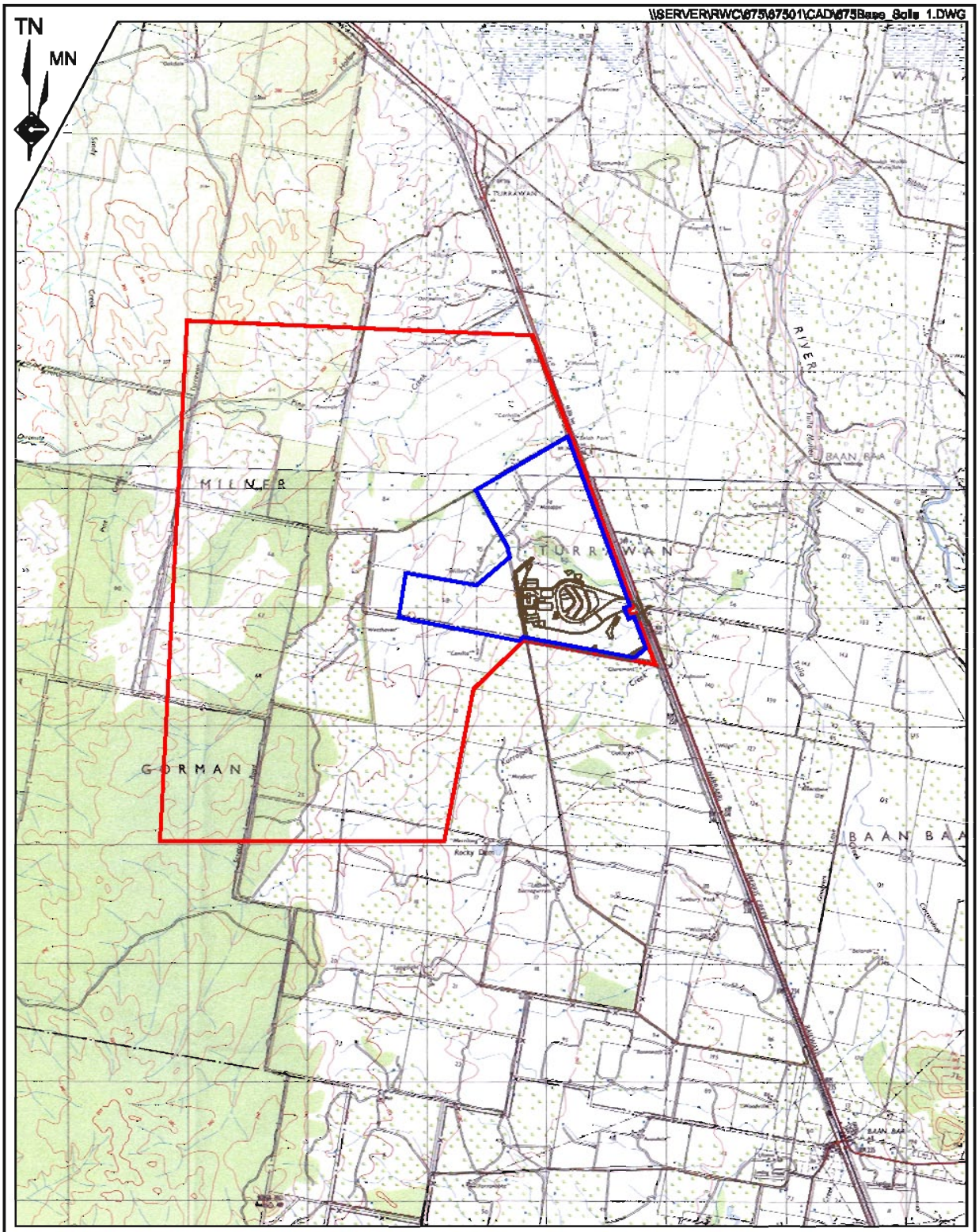


Figure 1
LOCAL SETTING OF THE MINE SITE

Note: A colour version of this figure is available on the Project CD

1.3 Projected Surface Disturbance Caused by Subsidence

Longwall mining will inevitably cause subsidence within the longwall panels and the sides of the chain pillars.

The subsidence assessment by Ditton Geotechnical Services Pty Ltd [DGS, 2009] was based on 305m wide longwall panels with a 4.2m mining height at depths of 160m to 380m below the surface.

Under these conditions, a maximum predicted subsidence of 2.17m would occur where mining is 160m below the ground surface [ie. towards the east], increasing to 2.44m in the west where mining is up to 380m below the ground surface. Given this level of predicted subsidence, DGS [2009] anticipates that subsidence would extend the following distances beyond the limit of mining [ie. the boundary of the potential longwall panels].

- 150m to 220m beyond the western boundary (23^o to 31^o draw angle).
- 35m to 70m beyond the eastern boundary (12^o to 21^o draw angle).
- 130m to 200m beyond the northern and southern boundaries at the western end, reducing to 35m to 70m in the east (12^o to 31^o draw angle).

The ground surface would tend to subside more towards the centre of the panel, ie. away from the chain pillars between the longwall panels. As a consequence of this differential subsidence, DGS [2009] has predicted the following possible impacts.

- Surface cracking of between 20mm and 190mm.
- Altered surface gradients of up to 6% [3°] along creeks.
- Potential ponding depths of 0.5m to 1.5m within the watercourses in the flatter areas of the Mine Site.
- Possible interaction between discontinuous sub-surface fracturing and surface cracks [where cover depths are <215m] leading to possible creek flow re-routing.
- Possible impacts on subsurface aquifers within 110m to 180m above the proposed panels as a result of direct hydraulic connection to the workings.

Based on the above summary of potential subsidence, the impacts are likely to be largely limited to the Mine Site, the majority of which is owned by the Proponent. The potential impacts and proposed management of these impacts relevant to this assessment are described below.

- **Surface Cracking**. DGS [2009] proposes that surface cracks which occur as a result of subsidence would be filled in as they are identified. Due to the relatively deep soil profile above the longwall panels, it is likely that many of the smaller width cracks would be filled in naturally by the actions of wind, water and natural soil movement. A bulldozer or grader would be used to fill in the wider cracks by pushing the surrounding soil into the cracks. It is possible that some surface cracks may not be able to be filled in by dozer / grader profiling, eg. for wider than expected cracks, or cracking through drainage lines where surface profiling may impact on the flow path of water. In these instances, subsoil material would be

excavated from within the reject emplacement area and used to backfill the crack[s].

- **Drainage Line Ponding**. DGS [2009] also notes that a number of the drainage lines over the Mine Site fall at very gentle gradients and may be susceptible to potential ponding depths of between 0.5m and 1.5 m. The actual ponding depths will depend upon several other factors, such as rain duration, surface cracking and effective percolation rates of the surface soils and fractured rock bars/outcrops along the creeks. The Proponent would monitor the impact of any changes to surface drainage paths and surface vegetation in areas of ponding development after each longwall is extracted [if they occur], with stream re-direction or modification works to be undertaken in consultation with an appropriately qualified hydrological professional and/or the DWE.
- **Erosion and Landslips**. With the exception of where surface cracking may occur along or through steeply eroded banks present within the creeks [which are likely to slump or topple if cracks develop through them], DGS [2009] considers it unlikely that the predicted subsidence would cause localised surface slope instability or *en-masse* sliding, ie. a landslip, of the ridges or hills. To minimise the likelihood of slope instability from increased erosion due to cracking or changes to drainage patterns after extraction, the Proponent would:
  - monitor surface slope displacement along subsidence cross lines;
  - infill surface cracks as they occur;
  - regrade or revegetate areas significantly affected by erosion; and
  - regularly review and appraise any significant changes to surface slopes after each longwall is extracted.

2 LITERATURE REVIEW

2.1 Narrabri Soil Conservation Service Technical Manual

The Narrabri Soil Conservation Service Technical Manual [Anon, 1978] shows the study area located on the boundary of the Red Brown Earth soils and the Pilliga Scrub soils. Details of these soils are presented below.

2.1.1 Red Brown Earths

These are generally associated with gently undulating slopes and are typically hardsetting with a sandy loam to sandy clay loam A horizon overlying a sandy clay loam to light clay B horizon. The soils are predominantly red brown in colour and have a weak to moderate degree of structure. Many have an earthy appearance.

A typical profile description provided by Anon [1978] is:

0-10cm [A1 horizon] – dark brown [7.5YR8/3 moist], moderate fine blocky structure, rough ped fabric, sandy clay loam, pH 6.0; *gradual change to*:

10->100cm [B1 horizon] – brown [7.5YR4/4 moist], strong blocky structure, rough and smooth ped fabric, pH 7.5.

2.1.2 Pilliga Scrub Soils

These soils are mainly sandy solodised soils and sandy solodic soils. They possess a surface horizon of light texture that is sharply differentiated from the subsoil that has a well developed columnar structure with a sandy texture. There is usually a strongly bleached zone above the subsoil.

Other soils within this complex include deep siliceous sands, earthy sands, lithosols and red and yellow earths. Typical profiles of all of these soil types are provided by Anon [1978] and are presented below.

2.1.2.1 Sandy Solodised Soils

0-2cm [A1 horizon] – dark brown [7.5YR3/3 moist], apedal, sand, pH 6.5, *sharp change to:*

2-20cm [A2 horizon] – dull brown [7.5YR5/4 dry], sporadic bleach, apedal, wormy appearance when exposed, sharp change to:

20-60cm [B1 horizon] – greyish yellow brown [10YR5/2], apedal, sand, gradual change to:

60cm+ [B2 – C horizon] – mottled red, greyish yellow sand, apedal, hardpan, pH 6.0

2.1.2.2 Sandy Solodic Soils

0-5cm [A1 horizon] – brown [7.5YR3/3 moist], sand, apedal, pH 5.5; sharp change to:

5-8cm [A2 horizon] – dull yellow orange [7.5YR7/2 dry], sand, apedal, sharp change to:

8-50cm [B1 horizon] – mottled orange yellow [dominant 7.5YR4/6 moist], clayey sand, diffuse change to:

50-150cm [B2 horizon] – mottled yellow grey [dominant 10YR5/4] sandy clay, pH 6.5]

2.1.2.3 Siliceous Sands

No typical profile provided

2.1.2.4 Earthy Sands

No typical profile provided

2.1.2.5 Lithosols

0-25cm [A1 horizon] – loamy sand, brownish black [7.5YR3/2 moist], weak crumb structure, sandy fabric, pH 7.0, diffuse boundary to

25-60cm [C horizon] – weathering regolith of rounded large stones, orange [7.5yR6/6 moist], diffuse change to

Sandstone conglomerate parent material.

2.1.2.6 Red Earths

0-10cm [A1 horizon] – dark brown [7.5YR3/3 moist], moderate subangular blocky structure, rough ped fabric, silty clay loam, pH 6.5, gradual change to

10- 50cm [B1 horizon] – dark brown [7.5YR3/4 moist], weak subangular blocky structure, earthy appearance, silty light clay, stones present, pH 7.0

2.1.2.7 Yellow Earths

No typical profile provided

2.2 Soil Survey and Land Capability Study for Narrabri Coal Project Stage 1 [GCNRC 2006]

This study covered a very limited section of the lands associated with the Longwall Project.

Three soil mapping units were identified in this study that examined soil profiles in the vicinity of the [then] proposed rail loop, pit top and ventilation shaft. The descriptions of the layers found in the profiles of the three SMUs identified within the study area are set out below.

2.2.1 SMU 1 –Soils of the Floodplain of a tributary of Kurrajong Creek

Soil to 250cm+ deep, lower slope[floodplain] location, ;surface condition hardsetting, some surface stone present.

Topsoil to 12cm - sandy loam; many roots; pH 6.0; stones and gravel absent; brown moderately pedal [50%], weak consistence dry; not hydrophobic.

Subsoil of four layers, medium clay or medium-heavy clay in upper layers, sandy light clay at base of excavation; few roots; no lime present; no manganese present; pH 8.0 to 9.5; stones and gravel generally absent; brown or yellowish brown coloured sometimes mottled in colours of brown, yellow and grey; highly pedal very firm to very strong consistence dry; not hydrophobic.

2.2.2 SMU 2 – Soils of the Slopes and Crests near the Rail Loop and Mine Facilities

Soil to 250cm deep, sometimes only 125cm; mid- to upper slope location; surface condition soft, loose or self-mulching; usually medium amounts of rounded / angular surface stone to 4cm present.

Topsoil sandy clay, sandy light clay, light clay, medium clay, medium to heavy clay, heavy clay; roots common to many; pH 5.5 to 7.0; some to much rounded angular gravel to 0.5-4cm present; not mottled; not bleached; brown coloured; highly pedal firm to very strong consistence dry; not hydrophobic.

Subsoil consisting of two to four horizons; medium clay or medium to heavy clay to heavy clay textured; stones and gravel absent or containing some to much grave and larger stones in the lower horizons; variously coloured brown, reddish brown, dusky red, yellowish red; sometimes mottled in colours of grey, brown, red and yellow; highly pedal; not hydrophobic.

2.2.3 SMU 3 – Soils of the Crests near the Ventilation Shaft

Soil to 68cm deep, crest location, surface condition firm, medium amounts of surface stone to 15cm present.

Topsoil to 15cm deep, sandy clay loam; many roots; no lime present; no manganese present; pH 4.5-5.0; some gravel to 2cm; not mottled; not bleached; reddish brown [5YR4/4] dry, dark reddish brown [5YR3/3] moist; peds earthy-faced, moderately pedal [50%], polyhedral, 5-10mm in size; weak consistence dry; hydrophobic

Subsoil consisting of a single layer, sandy clay textured; pH 4.5-5.0; containing mainly flat and angular gravel 1-2cm and some angular sandstone to 10cm; not mottled; not bleached; red coloured; earthy fabric, massive, not hydrophobic; *bedrock*

3 SOIL SAMPLING AND DESCRIPTION METHODOLOGY

3.1 Survey Scale and Sampling Intensity

The soil sampling process undertaken at the Mine Site comprised two main segments – a preliminary stereoscopic airphoto interpretation of the area to be sampled and the actual field sampling tasks.

The field survey and sampling process used for this study was extensive in its scale because of the size of the area to be covered and the fact that there would be only a small proportion of the area that would be directly disturbed by normal operations associated with coal mining.

In this case the main impact of the Longwall Project would be in the subsidence that would follow mining.

The intensive rehabilitation work normally associated with open cut coal mines would not be required at this site and so the need for intensive soil sampling that would be required to identify in detail soil attributes and their suitability for use in the rehabilitation process was removed.

The sampling intensity for broad scale soil surveys [1: 50 000 and 1: 100 0000 scale] recommended in the publication *'Soil and Landscape Issues in Environmental Impact Assessment'* [Technical Report No. 34, Department of Land and Water Conservation, Sydney [2000].is 0.5 to 1 per km^2.

The sampling intensity of 36 pits is well within this range.

3.2 Preliminary Stereoscopic Airphoto Interpretation

The preliminary stereoscopic airphoto assessment of the Mine Site used Narrabri Coal Project Run 1 prints 42 to 50, Run 2 prints 51 to 59 and Run 3 prints 60 to 63 supplied by Fugro Spatial Solutions Pty Ltd.

The stereoscopic assessment indicated that there was a mixture of landform units that required sampling to gain an appreciation of the likely reaction of the soils within the study area to subsidence caused by longwall mining.

Initially, ten different landform units were identified.

- Broad drainage lines on Pilliga Sandstone.
- Ridges and crests on Pilliga Sandstone.
- Slopes on Pilliga Sandstone.
- Drainage lines on Purlawaugh Formation.
- Floodplains on Purlawaugh Formation.
- Ridges and crests Purlawaugh Formation.
- Slopes on Purlawaugh Formation.
- Drainage lines on Garrawilla Volcanics.
- Floodplains on Garrawilla Volcanics.
- Slopes on Garrawilla Volcanics.

Each of these landform units was programmed to be sampled at a one or a number of locations to ascertain the variation in soil types over each unit.

3.3 Sampling Methodology

The soils and land capability study for the Longwall Project involved the following:

- Excavation of 36 test pits using an excavator digging to a depth where bedrock is encountered or a depth where the excavator refuses to penetrate further or to a depth of 2.5 metres whichever is the deepest.

- Full description of the soil profiles at each of the test pit locations after
- For each test profile [site] described, details of the following soil properties were noted.
  - Texture
  - Fabric
  - Structure
  - Consistence
  - Boundary sharpness
  - Colour [moist and dry]
  - Gravel/stone occurrence
  - Presence of roots
  - Presence of lime
  - Presence of manganese
  - pH

Soil pH was measured using the Raupach method [Raupach indicator and barium sulphate]. Soil colour [moist and dry] was determined using Munsell soil colour charts [Macbeth, 1992].

3.4 Location of the Soil Profile Pits

The locations of the soil sampling sites within the Mine Site are shown in **Figure 2** with the GPS locations of the soils pits set out in **Table 1.**

The soil profiles at each pit location were described in the field after a detailed examination of the different layers.

Fifty five samples from all horizons in 14 profiles [No's. 4, 7, 16, 18, 20, 21, 24, 25, 26, 27, 28, 29, 34 and 36] were forwarded to the Department of Lands' NATA - registered soil testing laboratory at Scone for more detailed analysis to determine the following properties.

- Range of particle size [particle size analysis].
- Dispersion percentage.
- Coherence [Emerson aggregate test].
- Electrical conductivity.

4 RESULTS OF THE SOIL SURVEY

Field descriptions of all 36 excavated profiles are contained in **Appendix 1**.

The laboratory data supplied by the Department of Lands laboratory at Scone is summarised in **Tables 2** and **3.**

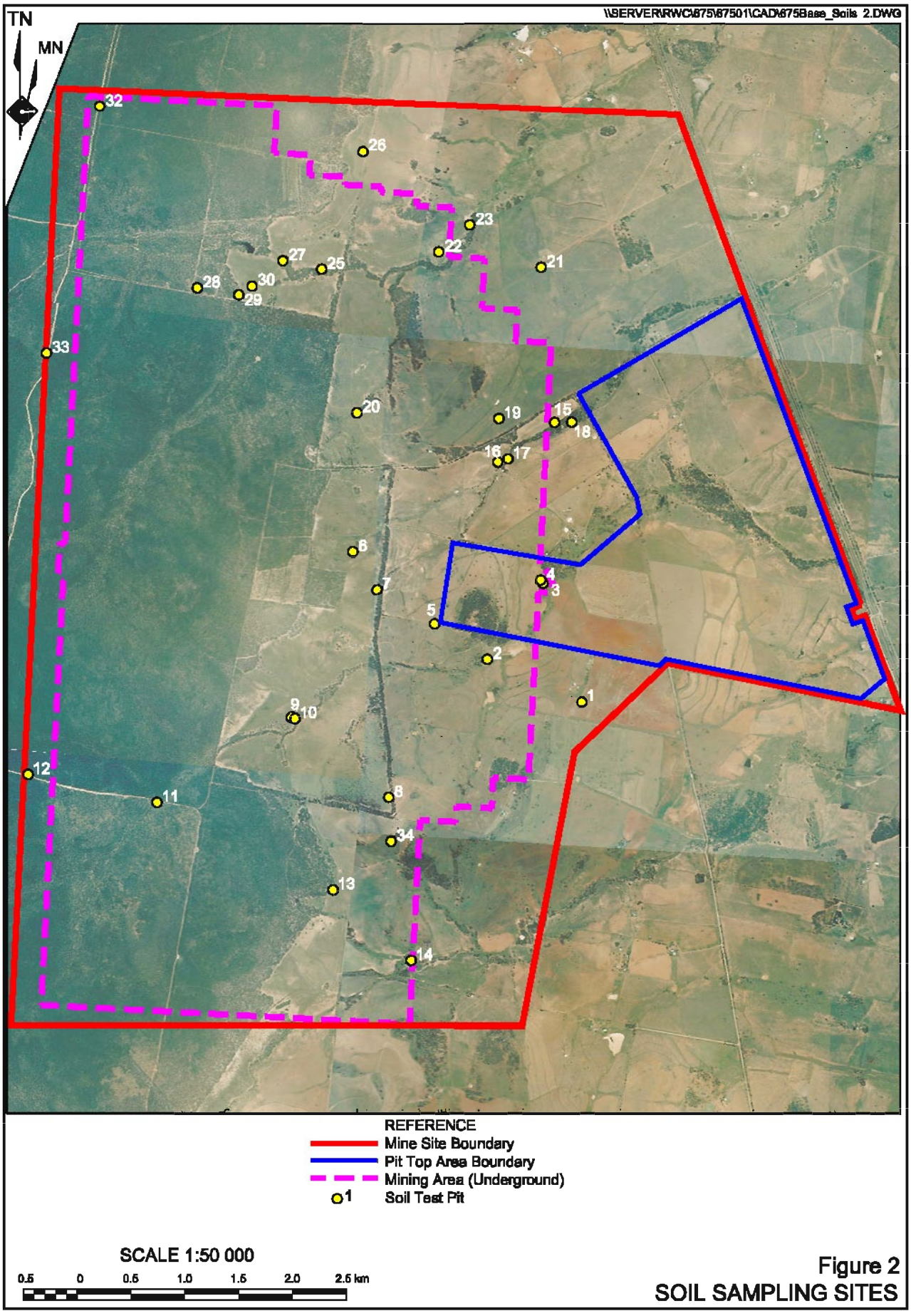


Figure 2
SOIL SAMPLING SITES

Table 1
Soil Pit Locations [AMG Coordinates]

Pit Number	Easting	Northing	Geological Formation / Landform Unit
1	776839E	6619123N	Garrawilla - upper slope
2	775961E	6619515N	Purlawaugh - floodplain
3	776479E	6620220N	Garrawilla - floodplain
4	776457E	6620249N	Garrawilla - floodplain
5	775472E	6619843N	Purlawaugh - crest
6	774712E	6620513N	Pilliga - upper slope
7	774935E	6620162N	Purlawaugh - lower slope
8	775045E	6618233N	Purlawaugh - lower slope
9	774140E	6618981N	Purlawaugh - floodplain
10	774175E	6618966N	Purlawaugh - drainage line
11	772893E	6618186N	Pilliga - drainage line
12	771697E	6618446N	Pilliga - crest
13	774528E	6617375N	Purlawaugh - upper slope
14	775253E	6616719N	Purlawaugh - floodplain
15	776585E	6621714N	Garrawilla - plain
16	776058E	6621346N	Purlawaugh - floodplain
17	776154E	6621375N	Purlawaugh - drainage line
18	776745E	6621716N	Garrawilla - drainage line
19	776069E	6621749N	Purlawaugh - midslope
20	774749E	6621804N	Purlawaugh - drainage line
21	776460E	6623153N	Garrawilla - upper slope
22	775510E	6623296N	Purlawaugh - floodplain
23	775798E	6623546N	Purlawaugh - drainage line
24	775153E	6623752N	Purlawaugh - crest
25	774421E	6623136N	Purlawaugh - drainage line
26	774806E	6624233N	Purlawaugh - midslope
27	774062E	6623214N	Pilliga - drainage line
28	773267E	6622961N	Pilliga - upper slope
29	773653E	6622897N	Pilliga - lower slope
30	773776E	6622983N	Pilliga - crest
31	774531E	6623013N	Purlawaugh - upper drainage line
32	772361E	6624651N	Pilliga - midslope
33	772038E	6623235N	Pilliga - drainage line
34	771866E	6622357N	Pilliga - crest
35	775067E	6617825N	Purlawaugh - midslope
36	774908E	6617773N	Purlawaugh - upper drainage line

Table 2
Physical Laboratory Analysis Data for Selected Soil Profiles
[Whole Soil Particle Size Analysis]

Page 1 of 2

Pit No.	Layer	Texture [Fine Earth]#	Depth [cm]	PSA % Clay	PSA % Silt	PSA % Fine Sand	PSA% Coarse Sand	PSA % Total Sand	PSA % Gravel
4	1	sandy loam	0-25	16	5	43	35	78	1
	2	clay	25-81	46	6	25	22	47	1
	3	clay	81-160	45	6	31	18	49	<1
	4	clay	160-230	36	11	28	24	52	1

Table 2 (Cont)
Physical Laboratory Analysis Data for Selected Soil Profiles
[Whole Soil Particle Size Analysis]

Pit No.	Layer	Texture [Fine Earth]#	Depth [cm]	PSA % Clay	PSA % Silt	PSA % Fine Sand	PSA% Coarse Sand	PSA % Total Sand	PSA % Gravel
7	1	sandy loam	0-25	14	5	27	54	81	<1
	2	sandy clay loam	25-42	27	3	27	43	70	<1
	3	sand	42-79	6	2	27	63	90	2
	4	sandy loam	79-144	13	9	24	52	76	2
	5	clay loam	144-260	27	12	27	27	54	<1
16	1	sandy loam	0-39	12	5	37	46	83	<1
	2	sandy loam	39-59	16	4	33	47	80	<1
	3	sandy loam	59-87	16	3	37	44	81	<1
	4	sandy clay loam	87-170	27	2	29	42	71	<1
	5	clay loam	170-255	30	16	27	27	54	<1
18	1	silty clay loam / silty clay	0-30	40	27	27	6	33	<1
	2	clay loam	30-69	29	16	28	27	55	0
	3	sandy clay loam / clay loam	69-97	25	6	27	40	67	2
	4	sandy clay loam	97-250	20	5	19	54	73	2
20	1	loam	0-31	18	12	30	40	70	<1
	2	sandy clay loam	31-92	21	6	23	50	73	<1
	3	clay	92-262	26	10	27	18	45	26
21	1	silty clay loam	0-36	32	26	30	11	41	1
	2	clay	36-97	57	15	18	9	27	1
	3	clay	97-136	60	13	15	10	25	2
	4	clay	136-210	36	17	27	18	45	2
24	1	sand	0-27	8	2	30	60	90	<1
	2	sand	27-53	8	2	31	58	89	1
	3	sandy clay loam	53-127	19	3	23	52	75	3
25	1	sandy loam	0-60	15	10	41	34	75	0
	2	sand	60-140	3	1	24	71	95	1
	3	sandy loam	140-270	12	0	12	74	86	2
26	1	clay	0-30	40	10	33	17	50	<1
	2	clay	30-107	51	12	23	12	35	2
	3	clay	107-154	54	10	27	9	36	<1
	4	clay	154-204	40	4	51	5	56	<1
27	1	sand	0-20	6	2	29	63	92	<1
	2	sand	20-97	2	0	31	66	97	1
	3	sandy clay loam	97-163	22	5	32	41	73	<1
	4	sandy clay loam	163-223	26	6	23	45	68	<1
29	1	loamy sand	0-23	11	7	26	55	81	1
	2	sandy loam	23-37	13	8	23	49	72	7
	3	clay	37-110	64	9	9	15	24	3
	4	clay	110-220	40	14	30	10	40	6
34	1	loamy sand	0-21	9	1	21	37	58	32
	2	sandy loam	21-63	8	3	11	24	35	54
	3	sandy loam	63-110	11	4	5	70	75	10
28	1	sandy loam	0-15	12	2	22	64	86	<1
	2	sandy loam	15-47	14	4	19	63	82	<1
	3	sandy clay loam	47-125	21	1	21	56	77	1
	4	sandy clay loam	125-180	23	1	18	50	68	8
36	1	loam	0-22	22	16	41	20	61	1
	2	clay loam	22-42	33	11	35	19	54	2
	3	clay loam	42-66	34	8	30	26	56	2
	4	sandy clay loam	66-94	17	4	15	27	42	37
	5	silty clay loam	94-222	37	30	37	2	39	0

Note: PSA = Particle Size Analysis # texture based on laboratory measurements

Table 3
Physical Laboratory Analysis Data for Selected Soil Profiles
[Whole Soil Particle Size Analysis]

Pit No.	Layer	Texture [Fine Earth]#	Depth [cm]	D%	D% Level of Dispersion	EAT	EAT Level of Dispersion
4	1	sandy loam	0-25	25	slight	3[2]	slight
	2	clay	25-81	9	slight	5	slight
	3	clay	81-160	10	slight	3[2]	slight
	4	clay	160-230	40	moderate	2[3]	very high
7	1	sandy loam	0-25	13	slight	3[2]	slight
	2	sandy clay loam	25-42	77	very high	2[3]	very high
	3	sand	42-79	0	negligible	2[2]	very high
	4	sandy loam	79-144	0	negligible	3[1]	slight
	5	clay loam	144-260	67	very high	3[3]	moderate
16	1	sandy loam	0-39	29	slight	3[2]	slight
	2	sandy loam	39-59	94	very high	2[3]	very high
	3	sandy loam	59-87	50	high	2[3]	very high
	4	sandy clay loam	87-170	54	high	2[3]	very high
	5	clay loam	170-255	12	slight	2[1]	high to moderate
18	1	silty clay loam / silty clay	0-30	17	slight	3[2]	slight
	2	clay loam	30-69	91	very high	2[2]	high
	3	sandy clay loam / clay loam	69-97	78	very high	2[1]	high to moderate
	4	sandy clay loam	97-250	78	very high	2[1]	high to moderate
20	1	loam	0-31	18	slight	3[2]	slight
	2	sandy clay loam	31-92	74	very high	2[1]	high to moderate
	3	clay	92-262	92	very high	2[2]	high
21	1	silty clay loam	0-36	8	slight	3[2]	slight
	2	clay	36-97	12	slight	5	slight
	3	clay	97-136	10	slight	4	negligible
	4	clay	136-210	15	slight	4	negligible
24	1	sand	0-27	38	moderate	3[1]	slight
	2	sand	27-53	40	moderate	3[1]	slight
	3	sandy clay loam	53-127	24	slight	3[1]	slight
25	1	sandy loam	0-60	21	slight	3[1]	slight
	2	sand	60-140	33	moderate	3[1]	slight
	3	sandy loam	140-270	67	very high	2[1]	high to moderate
26	1	clay	0-30	24	slight	3[2]	slight
	2	clay	30-107	25	slight	4	negligible
	3	clay	107-154	48	moderate	1	very high
	4	clay	154-204	26	slight	2[1]	high to moderate
27	1	sand	0-20	17	slight	8 / 3[1]	negligible to slight
	2	sand	20-97	0	negligible	3[1]	slight
	3	sandy clay loam	97-163	64	very high	2[3]	very high
	4	sandy clay loam	163-223	69	very high	2[3]	very high
28	1	sandy loam	0-15	8	slight	8 / 3[1]	negligible to slight
	2	sandy loam	15-47	14	slight	3[1]	slight
	3	sandy clay loam	47-125	9	slight	3[1]	slight
	4	sandy clay loam	125-180	8	slight	5	slight
29	1	loamy sand	0-23	31	moderate	3[1]	slight
	2	sandy loam	23-37	50	slight to moderate	3[1]	slight
	3	clay	37-110	12	slight	3[2]	slight
	4	clay	110-220	11	slight	3[2]	slight
34	1	loamy sand	0-21	23	slight	3[1]	slight
	2	sandy loam	21-63	14	slight	5	slight
	3	sandy loam	63-110	7	slight	5	slight

Table 3 (Cont)
Physical Laboratory Analysis Data for Selected Soil Profiles
[Whole Soil Particle Size Analysis]

Pit No.	Layer	Texture [Fine Earth]#	Depth [cm]	D%	D% Level of Dispersion	EAT	EAT Level of Dispersion
36	1	loam	0-22	18	slight	3[1]	slight
	2	clay loam	22-42	19	slight	3[1]	slight
	3	clay loam	42-66	25	slight	4	negligible
	4	sandy clay loam	66-94	37	moderate	4	negligible
	5	silty clay loam	94-222	84	very high	2[2]	High
Note: PSA = Particle Size Analysis # texture based on laboratory measurements							

5 DISCUSSION OF SOIL ANALYSES

Because of the different approach to soil survey used in this study, the soils ***have not been assigned to traditional Soil Mapping Units [SMUs]*** that are described in both physical and chemical terms in relation to their suitability for stripping and stockpiling and later reuse in rehabilitation.

In this study, the soils of each Geological Formation / Landform Unit have been described in terms of their physical and chemical attributes by listing the salient data from the field descriptions and laboratory data.

From these attribute summaries, the likely behaviour of the soils within each of these Geological Formation / Landform Unit following subsidence associated with longwall coal mining has been described.

5.1 Explanation of the Laboratory Tests

5.1.1 Physical Attributes

The laboratory analysis results contained in **Table 2** are important in assessing the erodibility of the soil units found within the study area.

The three tests [Particle Size Analysis, Dispersion %, Emerson Aggregate Test] carried out on samples from each of the horizons within the six selected soil profiles, when considered together, provide a good indication of the soil's likely behaviour in relation to the erosive forces encountered in the field.

5.1.1.1 Particle Size Analysis

The Particle Size Analysis [PSA] test shows the amounts of gravel, clay, silt, fine sand and coarse sand contained within each sample.

The results shown in **Table 2** are those contained in the laboratory test report.

From this data it is evident that most soils analysed contain very low levels of gravel. Horizons with higher levels of gravel were generally located at depth in the profile.

The texture class of each soil layer is determined by analysis of the material [fine earth fraction] that is less than 2mm in size – i.e. the sample from each tested horizon with the gravel removed. The calculated texture of the fine earth fraction of each of the layers tested in the laboratory is shown in **Table 2**.

5.1.1.2 Dispersion Percentage

The Dispersion Percentage [D%] test indicates the proportion of the soil material less than 0.005 mm in size that will disperse on wetting [i.e. the clay and some of the silt fractions].

Hazelton and Murphy [in press] provide the following guides to the interpretation of D% values [**Table 4**]

Table 4
Interpretation of Dispersion Percentage Values
[after Hazelton and Murphy, in press]

D% Value	Dispersion Rating
< 6	Negligible
6 – 30	Slight
30 – 50	Moderate
50 – 65	High
> 65	very high

In interpreting the results of the values of dispersion percentage obtained in laboratory testing it is important to consider other related soil attributes such as the Particle Size Analysis [PSA] and Emerson Aggregate Test [EAT] data.

Soil horizons with high clay contents and high Dispersion % values will be more dispersive in practice than those with a high Dispersion % value and a low clay content in the soil.

5.1.1.3 Emerson Aggregate Test

This test provides a measure of the coherence of soil aggregates when they are immersed in water. Natural peds are used [Houghton and Charman, 1986] and the method used by the former Department of Land and Water Conservation to determine the Emerson Class Number is fully described in Craze et al [1993].

Basically, the degree of soil aggregate stability increases from Class 1 through to Class 8. Classes 2 and 3 have a number of subclasses based on the degree of dispersion.

Aggregates in Emerson Classes 1 and 2 are generally regarded as being unstable while those in classes 4 to 8 are considered to be stable.

Hazelton and Murphy [in press] present a summary of the Emerson Aggregate Classes. This is contained in **Table 5.**

Table 5
Comparison of Aggregate Dispersibility and Emerson Aggregate Classes
[after Hazelton and Murphy, in press]

Aggregate Dispersibility	Emerson Aggregate Classes*
Very High	1 and 2[3]
High	2[2]
High to Moderate	2[1]
Moderate	3[4] and 3[3]
Slight	3[2], 3[1] and 5
Negligible / Aggregated	4,6,7,and 8

*** NOTE** – the subclasses of the Emerson Aggregate Test [EAT] Classes are as follows:
[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 [NB – Class 2[4] is equivalent to Class 1]

5.2 Soil Chemical Attributes

Laboratory testing of the samples extended only to an examination of the electrical conductivity. Soil pH was measured in the field using the Raupach method. The results of the laboratory analyses and the field pH measurements are contained in **Table 6.**

Table 6
Soil Chemical Attributes – Laboratory and Derived Data

Page 1 of 2

Pit No.	Layer	Texture [Fine Earth]#	Depth [cm]	pH	EC [dS/m]#	Multi-lier	Calculated EC_e	Soil Salinity Status
4	1	sandy loam	0-25	5.5	<0.01	14	<0.14	non-saline
	2	clay	25-81	7.0	0.01	5.8	0.06	non-saline
	3	clay	81-160	7.0	<0.01	5.8	<0.06	non-saline
	4	clay	160-230	7.0	<0.01	5.8	<0.06	non-saline
7	1	sandy loam	0-25	6.5	<0.01	14	<0.14	non-saline
	2	sandy clay loam	25-42	7.0	0.13	9.5	1.24	non-saline
	3	sand	42-79	7.0	0.29	23	6.67	moderately saline
	4	sandy loam	79-144	7.0	0.23	14	3.22	slightly saline
	5	clay loam	144-260	6.0	0.41	8.6	3.53	slightly saline
16	1	sandy loam	0-39	6.0	<0.01	14	<0.14	non-saline
	2	sandy loam	39-59	7.0	0.03	14	0.42	non-saline
	3	sandy loam	59-87	8.0	0.02	14	0.48	non-saline
	4	sandy clay loam	87-170	8.5	0.11	9.5	1.05	non-saline
	5	clay loam	170-255	9.0	0.39	8.6	3.35	slightly saline
18	1	silty clay loam / silty clay	0-30	6.5	0.01	8.6	0.09	non-saline
	2	clay loam	30-69	8.0	0.05	8.6	0.43	non-saline
	3	sandy clay loam / clay loam	69-97	8.0	0.06	9.5	0.57	non-saline
	4	sandy clay loam	97-250	9.0	0.16	9.5	1.52	non-saline
20	1	loam	0-31	6.5	0.05	9.5	0.48	non-saline
	2	sandy clay loam	31-92	6.5	0.03	9.5	0.29	non-saline
	3	clay	92-262	7.0	0.43	5.8	2.50	slightly saline

Table 6 (Cont)
Soil Chemical Attributes – Laboratory and Derived Data

Pit No.	Layer	Texture [Fine Earth]#	Depth [cm]	pH	EC [dS/m]#	Multi-lier	Calculated EC_e	Soil Salinity Status
21	1	silty clay loam	0-36	6.0	<0.01	8.6	<0.09	non-saline
	2	clay	36-97	7.0	0.01	5.8	0.06	non-saline
	3	clay	97-136	8.0	0.22	5.8	1.28	non-saline
	4	clay	136-210	8.5	0.14	5.8	0.81	non-saline
24	1	sand	0-27	5.0	<0.01	23	<0.23	non-saline
	2	sand	27-53	5.5	<0.01	23	<0.23	non-saline
	3	sandy clay loam	53-127	6.0	<0.01	9.5	<0.10	non-saline
25	1	sandy loam	0-60	6.5	0.01	14	0.14	non-saline
	2	sand	60-140	6.5	<0.01	14	0.14	non-saline
	3	sandy loam	140-270	5.5	0.05	14	0.70	non-saline
26	1	clay	0-30	7.5	0.05	5.8	0.29	non-saline
	2	clay	30-107	8.0	0.38	5.8	2.20	slightly saline
	3	clay	107-154	7.5	0.76	5.8	4.41	moderately saline
	4	clay	154-204	4.5	0.36	5.8	2.10	slightly saline
27	1	sand	0-20	6.5	<0.01	23	<0.23	non-saline
	2	sand	20-97	6.5	<0.01	23	<0.23	non-saline
	3	sandy clay loam	97-163	6.5	0.04	9.5	0.38	non-saline
	4	sandy clay loam	163-223	7.0	0.08	9.5	0.76	non-saline
28	1	sandy loam	0-15	4.5	<0.01	14	<0.14	non-saline
	2	sandy loam	15-47	4.5	<0.01	14	<0.14	non-saline
	3	sandy clay loam	47-125	5.0	<0.01	9.5	<0.10	non-saline
	4	sandy clay loam	125-180	6.0	<0.01	9.5	<0.10	non-saline
29	1	loamy sand	0-23	5.5 to 6.0	<0.01	23	<0.23	non-saline
	2	sandy loam	23-37	5.5 to 6.0	<0.01	14	<0.14	non-saline
	3	clay	37-110	4.5	0.05	5.8	0.29	non-saline
	4	clay	110-220	4.5	0.32	5.8	1.86	non-saline
34	1	loamy sand	0-21	5.5	<0.01	23	<0.23	non-saline
	2	sandy loam	21-63	5.0	<0.01	14	<0.14	non-saline
	3	sandy loam	63-110	5.0	<0.01	14	<0.14	non-saline
36	1	loam	0-22	6.5	0.01	9.5	0.10	non-saline
	2	clay loam	22-42	7.0	0.01	8.6	0.09	non-saline
	3	clay loam	42-66	8.5	0.08	8.6	0.69	non-saline
	4	sandy clay loam	66-94	8.5	0.09	14	1.26	non-saline
	5	silty clay loam	94-222	9.5 to 10	0.49	8.6	4.21	moderately saline

5.2.1 Soil pH

In general, the pH [water] range in most soils is between 4.0 and 8.5 although pH values above and below this range are measured at times [Glendinning, 1990].

This range of soil pH levels is generally accepted as being one that is suitable for plant growth.

The pH 6.0 to 6.5 range is usually regarded as the optimum for growth of most plants and there are some more serious impacts on the growth of many species at the lower, or acid, end of the range.

As the pH scale [between 0 and 14] is a logarithmic one, a soil with a pH of 5.0 is ten times as acid as a soil of pH 6.0 and 100 times as acid as one with a pH of 7.0.

Perusal of the data in the pH column in **Table 5** indicates that all of the topsoils tested showed pH levels within the 4.0 to 8.5 range – usually between 5.0 and 7.0.

5.2.2 Electrical Conductivity

Soil salinity is a measure of the presence of water-soluble salts, mainly of sodium, calcium and magnesium in the soil solution. These salts may be chlorides, sulphates or carbonates and can have a major impact on plant growth if they occur in sufficiently large quantities.

The level of salinity in a soil sample is determined by measuring the electrical conductivity [EC] of a 1:5 soil / water suspension.

As the published salinity tolerance data for crops and pastures is based on the electrical conductivity of a saturated extract of the soil solution, a series of conversion factors, based on the estimated water holding capacity of soil sample, are used to convert the measured EC value to one for the conductivity of the saturated extract [EC_e].

The electrical conductivity of the 1:5 soil / water suspension and that of the saturated extract are measured in units called deciSiemens / metre [dS/m].

The measured level of electrical conductivity of the 1:5 soil / water suspension is multiplied by the appropriate factor in **Table 7** [extracted from Hazelton and Murphy, in press] based on the measured soil texture.

Table 7
Texture Class Multipliers for Calculating EC_e Values

Soil Texture Class	Multiplier Factor
loamy sand, clayey sand, sand	23
sandy loam, fine sandy loam, light sandy clay loam	14
loam, loam fine sandy, silt loam, sandy clay loam	9.5
clay loam, silty clay loam, fine sandy clay loam, sandy clay, silty clay, light clay	8.6
light medium clay	7.5
medium clay	5.8
Heavy clay	5.8

Table 6 shows the calculated EC_e values for the samples analysed in the laboratory and shows the salinity status of the various horizons based on these EC_e values.

Hazelton and Murphy [in press] note that EC_e values below 2.0 indicate non-saline horizons while values between 2 and 4 indicate slight salinity. Values between 4 and 8 indicate moderate salinity while those between 8 and 16 indicate high salinity.

5.2.3 Likelihood of Encountering Acid Sulfate Soils

Acid sulfate soils are basically confined to coastal estuarine floodplain areas in New South Wales.

These soils are extremely acidic soil layers that develop as a consequence of the aeration of soil materials that are rich in iron sulfides, primarily pyrite [FeS].

When drainage or excavation brings these previously waterlogged soil layers into contact with oxygen, the pyrite is oxidised to form sulfuric acid.

If the production of acid exceeds the neutralising capacity of the particular soil such that the pH falls below 4.0, these soils are known as acid sulfate soils.

The soils at the study area commonly increase in alkalinity with depth [often to pH 9.5 - 10] and are not waterlogged. There are some profiles that follow this trend down the profile and then revert to an acid pH at the lowest depth sampled.

There is a considerable quantity of neutralising capacity in most soils at the site. As a consequence of these features and the fact that the site is not located on a coastal estuarine floodplain it is extremely unlikely that any acid sulfate soils will impact in any way on the mine during its working life or on the success of subsequent rehabilitation.

5.3 Erosion Potential

The soils within the study area are variably affected by soil erosion. Removal of vegetation cover and the development of subsidence cracks at the surface and in the subsoil will increase the likelihood of erosion particularly in heavy rain events.

Most of the topsoils are relatively sandy and so will erode quickly if unprotected.

The study area contains many sets of soil conservation bank and waterway systems – particularly on the Purlawagh Formation and Garrawilla Volcanics. This suggests that soil erosion has been a problem in the past.

5.4 SOILOSS Program

An appropriate method of assessing the erosion hazard associated with the soils of the study area is to use the SOILOSS computer program devised by Rosewell and Edwards [1988] and updated by Rosewell [1993].

This program computes soil loss values for a given site under various land uses and climatic [rainfall] conditions and so provides an indication of erosion hazard.

SOILOSS is based on the Universal Soil Loss Equation or USLE described by Wischmeier and Smith [1978] and subsequently updated as the Revised Universal Soil Loss Equation or RUSLE [Renard et al, 1993].

The USLE is

A = R * K * L * S * P * C where

A is the average annual soil loss [tonnes / hectare]
R is the rainfall erosivity factor, a measure of the erosive power of the rain
K is the soil erodibility factor, a measure of the resistance of the soil to erosion
L is the slope length factor
S is the slope steepness factor
P is the support practice factor, a measure of the effect on erosion of soil conservation measures such as contour cultivation and bank systems
C is the crop and cover management factor

In using SOILOSS, the rainfall erosivity factor is obtained from maps provided with the program manual [Rosewell, 1993].

Soil erodibility is either estimated from details of the soil type and soil surface texture by comparison with a table of soils presented by the program or is derived from a knowledge of soil particle size analysis, organic matter content, surface soil structure and profile permeability.

Slope length and steepness factors are derived from field measurements and / or examination of topographic maps or airphotos.

The support practice factor is estimated by the program from a description of the land management practices in use, details of cultivation direction and information on bank systems if these are present.

To determine the value of the 'K' factor for use in the program, a generic or standard method can be utilised from within the program to indicate the likely soil losses from a range of crop rotations and management practices.

In addition, a more detailed approach can be used to determine likely soil loss given the availability of precise detail relating to sowing dates, cultivation practices etc.

Provision is made within the program for estimating soil loss from areas with a range of non-arable uses.

Table 8 provides details of the calculated erodibility values [K] and erodibility ratings for topsoils and subsoils from all of the soil profiles from the study area that were tested in the laboratory.

The erodibility estimates contained in **Table 8** for all of the Geological Formation / Landform Units recorded from the study area have been calculated using part of the overall SOILOSS program capability and the Particle Size Analysis and other data for the typical soil profiles from the study area that were subjected to laboratory testing.

Table 8
'K' [Erodibility] Values for all Geological Formation / Landform Units

Geological Formation	Landform Unit [Profile Number]	Topsoil	K Value	Subsoil	K Value	Average K Value
Garrawilla Volcanics	Upper Slope [21]	0-36cm	0.025 moderate	97-136 cm	0.015 low	0.020 low to moderate
	Floodplain [4]	0-25 cm	0.024 moderate	81-160 cm	0.021 moderate	0.023 moderate
	Drainage Line [18]	0-30 cm	0.023 moderate	39-87 cm	0.030 moderate	0.027 moderate
Pilliga Sandstone	Crest [34]	0-21 cm	0.018 low	63-110 cm	0.006 low	0.012 low
	Upper Slope [28]	0-15 cm	0.011 low	47-125 cm	0.011 low	0.011 low
	Lower Slope [29]	0-23 cm	0.016 low	37-110 cm	0.004 low	0.010 low
	Drainage Line [27]	0-20 cm	0.015 low	97-163 cm	0.020 low to moderate	0.018 low
Purlawaugh Formation	Crest [24]	0-27 cm	0.019 low	53-127 cm	0.021 moderate	0.020 low to moderate
	Mid Slope [26]	0-30 cm	0.018 low	107-154 cm	0.019 low	0.019 low
	Lower Slope [7]	0-25 cm	0.018 low	79-144 cm	0.028 moderate	0.023 moderate
	Floodplain [16]	0-39 cm	0.022 moderate	59-87 cm	0.030 moderate	0.026 moderate
	Upper Drainage Line [36]	0-22 cm	0.027 moderate	66-94 cm	0.026 moderate	0.027 moderate
	Drainage Line [20]	0-31 cm	0.022 moderate	31-92 cm	0.023 moderate	0.023 moderate
	Drainage Line [25]	0-60 cm	0.026 moderate	60-140 cm	0.016 low	0.021 moderate

The only value for which estimates were used in the calculations were those for organic matter %.

To determine relevant organic matter values for soils in the vicinity of the study area the topsoil and subsoil organic matter levels quoted by Banks [1995] for the soils of the nearby Curlewis 1:100 000 scale map sheet area ere reviewed and estimates made for use in the SOILOSS model.

For the Pilliga Sandstone the organic matter values used were 3.0% [topsoils] and 0.5% [subsoils. For the Purlawaugh Formation and Garrawilla Volcanics values of 5.5 [topsoil] and 0.7% were used.

The Erodibility classes used were < 0.020 = LOW; 0.020 – 0.040 = MODERATE; > 0.040 = HIGH.

6 LAND CAPABILITY AND AGRICULTURAL LAND SUITABILITY

6.1 Land Capability

6.1.1 Overview of the Methodology

Houghton and Charman [1986] in their "Glossary of Terms Used in Soil Conservation" define land capability as follows.

> "*The ability of land to accept a type and intensity of use permanently, or for specified periods under specific management, without permanent damage.*"

Houghton and Charman [1986] further notes that land capability is *"…an expression of the effect of biophysical land resources, including climate, on the ability of land to sustain use without damage under various uses such as crop production requiring regular tillage, grazing, woodland or wildlife. Land capability involves consideration of:*

- *the various land resources;*
- *the production to be obtained from the land;*
- *the activities or inputs required to achieve that production;*
- *the risks of damage to the land, on-site or off-site, resulting from those activities; and*
- *the inter-relations of the above."*

Houghton and Charman [1986] note that land capability is taken into account in determining land suitability – another form of land classification relating to use for various purposes.

Land that is used beyond its capability ultimately loses its productive capacity as a consequence of exhaustion of soil nutrient supplies or the development of various forms of land degradation.

The land capability classification system used in New South Wales has been described by Emery [undated] and is a modification of the system devised and used by the former USDA Soil Conservation Service in the United States of America.

Emery's paper [in its *Table 1*] contains details of the Land Capability legend used on land capability maps prepared by the former Soil Conservation Service of New South Wales [now part of DECC].

This shows the hierarchical classification used in the eight class system based on the management and protection needs of different types of land ranging from land needing no special soil conservation works or practices [Class I] through to land that is unsuitable for agricultural or pastoral production [Class VIII].

Emery's table also shows two other land capability classes – Mining and Urban land use – and also deals with class subscripts used to further subdivide some capability classes. The information presented by Emery is contained in **Appendix 2**.

6.1.2 Land Capability for the Study Area

The 1: 100 000 scale Land Capability map of the Baan Baa map sheet area prepared by the former Soil Conservation Service of NSW [DNR, Parramatta - GIS] shows the study area mapped mainly as **Class III** land with a small areas of **Class IV** land and larger areas of **Class VI** and **Class VII** land near Jack's Creek State Forest.

The State Forest was not mapped but it would be **Class VII** land.

Class III land is *sloping land suitable for cropping on a rotational basis. Structural soil conservation works such as graded banks, waterways and diversion banks, together with soil conservation practices such as conservation tillage and adequate crop rotations are required.*

Class IV land is *land not capable of being regularly cultivated but suitable for grazing with occasional cultivation and requiring soil conservation practices such as pasture improvement, application of fertiliser and minimal cultivation for the establishment or re-establishment of permanent pasture.*

Class VI land is *land suitable for grazing with no cultivation. Soil conservation practices including limitation of stock, broadcasting of seed and fertiliser, prevention of fire and destruction of vermin are required along with some isolated structural works.*

Class VII land is *land best suited to green timber and generally comprises areas of steep slopes, shallow soils and/or rock outcrop. Adequate ground protection must be maintained by limiting grazing and minimising damage by fire.*

6.1.3 Current Assessment

After field assessments during the January 2009 soil survey, it is evident that:

- much of the area that has been cleared and farmed in the past is **Class III** land;
- the lands along the major drainage lines are **Class IV** land; and
- the lands of the rocky ridges and the sandy soils adjacent to the Jack's Creek State Forest are **Class VII** land.

This land capability assessment applies to the study area alone. [See **Figure 3**].

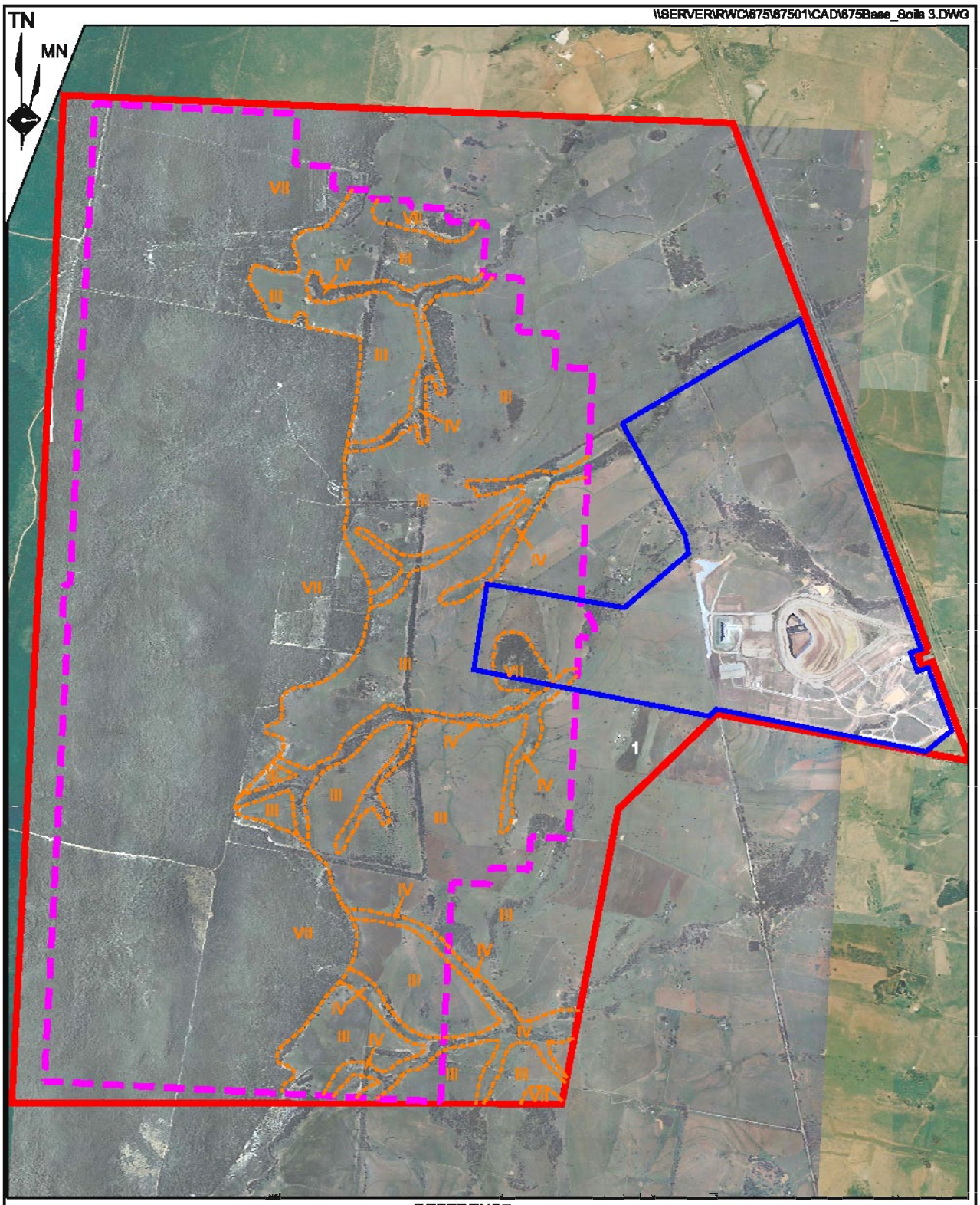


Figure 3
LAND CAPABILITY OF THE MINE SITE

6.1.4 Post Subsidence Assessment

In general, the land capability classification outlined in section 7.1.3 should remain for the Mine Site after mining and subsidence. There may be some individual areas where the impacts of subsidence are greater than would be expected and these may have a downgraded land capability due to waterlogging, erosion, salinity etc should such occur.

6.2 Agricultural Land Suitability Classification

6.2.1 NSW Agriculture Assessment

Information supplied by NSW Department of Primary Industries [Agriculture] at Tamworth indicates that the Department has classified the lands of the study area using its agricultural land suitability system [Cunningham *et al*, undated; Hulme *et al*, 2002].

The mapped agricultural suitability of the lands indicates the presence of **Class 2**, **Class 3** and **Class 4** [Agricultural Suitability] lands. The area comprises mainly **Class 3** land with minor areas of **Classes 2** and **4.**

Class 2 land is *'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*.'

Class 3 land is *'grazing land that is 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 [soil related] or environmental constraints. Erosion hazard or soil structural breakdown limit the frequency of ground disturbance, and conservation or drainage works may be required*.'

Class 4 land is *'land suitable for grazing but not for cultivation. Agriculture is based on native pastures established using minimum tillage techniques. 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 [soil related]'*.

6.2.2 Current Assessment

After the field survey of the Mine Site it is apparent that the NSW Department of Primary Industries [Agriculture] assessment of the agricultural land suitability of the study area is generally correct however the Class 4 lands would more appropriately be generally classified as **Class 5** lands.

These lands are similar to those in Jack's Creek State Forest.

Class 5 land is *'land unsuitable for agriculture or at best suited only to light grazing. Agricultural production is very low to zero as a result of severe constraints, including economic factors, which preclude improvement'*.

6.2.3 Post Subsidence Assessment

The post subsidence assessment should not change for the Mine Site after mining and subsidence. There may be some individual areas where the impacts of subsidence are greater than would be expected and these may have a downgraded agricultural land suitability due to waterlogging, erosion, salinity etc should such occur.

7 SOIL ATTRIBUTES AND LIMITATIONS FOR THE IDENTIFIED GEOLOGICAL FORMATION / LANDFORM UNITS

7.1 Soil Attributes

7.1.1 Garrawilla Volcanics

7.1.1.1 Garrawilla Volcanics Drainage Line [Profile 18]

Surface condition firm; surface stone absent

- **Topsoil [1 horizon]**: 30cm deep; medium to heavy clay texture; pH 6.5; well structured; slightly dispersible [D% and EAT]; not hydrophobic; non-saline; many roots.
- **Subsoil [3 horizons]:** to 250cm depth; medium clay or medium to heavy clay texture, sometimes sandy or gritty; gravel and stones absent, pH 8.0 to 9.0; well structured; lime nodules and manganese concretions common at depth; very high dispersibility [D%]; high or high to moderate dispersibility [EAT]; non-saline; roots less common with depth, recorded to 220cm.

7.1.1.2 Garrawilla Volcanics Floodplain [Profiles 3, 4, 15]

Surface condition loose to firm; surface stone absent or, sometimes, medium amounts of angular surface stone to 15cm present

- **Topsoil [1 horizon]** – 25cm, 39cm, 46cm deep; light sandy clay loam to sandy clay loam texture; pH 5.5 to 6.0; gravel and stones absent; well structured; not hydrophobic; slightly dispersible [D% and EAT]; roots common to many; analysed profile non-saline.
- **Subsoil [3 horizons]** – excavated to 230 -250cm depth; light clay, medium clay or medium to heavy clay texture, sometimes gritty; gravel and stones usually absent, sometimes single horizons with some angular gravel to 1-5cm; pH usually 6.0 to 7.5, sometimes 8.0 to 9.0 at depth; well structured; at times some large lime nodules present at depth; no manganese concretions or stains present; analysed profile showed slight to moderate dispersibility [D%]; slight to very high dispersibility [EAT]; non-saline; roots decreasing with depth, recorded to 108cm, 194cm and 147cm.

7.1.1.3 Garrawilla Volcanics Upper Slopes [Profiles 1 and 21]

Surface condition loose or self mulching; some angular surface gravel and stone 1-15cm present floaters in upper layers 20-40cm in size; sometimes bedrock only 150cm below the surface.

- **Surface Soil [1 horizon]:** 29 to 36cm deep; medium to heavy clay or heavy clay textured; pH 6.0 to 9.0; no lime concretions or satins visible; some angular gravel 1-10mm present; well structured; not hydrophobic; analysed profile slightly dispersible [D%], not or slightly dispersible [EAT]; non-saline; roots common to many.
- **Subsoil [3 or 4 horizons]:** light to medium clay, medium to heavy clay; heavy clay textured; excavated to 210 t0 250 cm depth; decomposed rock encountered at the base of the shallower profile; pH 7.0, 8.0, 8.5 and 9.0; lime stains usually present and lime concretions often present in lower horizons; manganese concretions and stains absent; gravel and stones absent or individual horizons with small angular gravel to 1cm, sometimes large floaters present; well structured; not hydrophobic; analysed profile slightly dispersible [D%], not or slightly dispersible [EAT]; non-saline; roots usually few, recorded to depths of 61cm and 190cm.

7.1.2 Pilliga Sandstone

7.1.2.1 Pilliga Sandstone Crests [Profiles 12, 30, 34]

Surface condition firm; some to much flat and angular or rounded surface stone to 20cm present.

- **Topsoil [1 horizon]** - clayey sand to sandy loam, sandy loam or sandy light clay textured; 20 to 21cm deep; pH 5.0 to 5.5; no lime concretions or satins visible; some to many angular / flat and round gravel to 2cm and flat angular stones to 10 - 20cm; well structured or massive; sometimes hydrophobic; many roots; analysed profile slightly dispersible [D% and EAT]; non-saline;
- **Subsoil [1 or 2 horizons]** – sandy clay loam or clayey sand textured; excavated to bedrock at 40cm, 90cm and 110cm; pH 4.5 to 6.0; no lime or manganese stains or concretions evident; much rounded and angular gravel and stones to 5 to 15cm plus flat angular stones to 20cm; floaters; sometimes present; poorly structures [massive]; not hydrophobic; analysed profile slightly dispersible [D% and EAT]; non-saline; roots usually to bedrock, sometimes to 134cm [into bedrock]

7.1.2.2 Pilliga Sandstone Drainage Line [Profiles 11, 27 and 33]

Surface condition loose to firm; surface stone absent

- **Surface Soil [1 horizon]** – clayey sand, sandy loam or light clay textured; 20 to 30cm deep; pH 4.5 to 6.5; gravel and stones absent; no lime or manganese

nodules or stains present; well structured or poorly structured [massive]; sometimes hydrophobic; roots few to many; analysed profile slightly dispersible [D%], not or slightly dispersible [EAT], non-saline.

- **Subsoil [2 to 4 horizons];** sand, clayey sand, sandy clay loam, light clay [sometimes sandy], sandy light to medium clay, sandy medium clay textured; excavated to 215, 223 and 170cm [water ingress from top subsoil horizon prevented further excavation]; pH 5.0 to 7.5; no lime or manganese stains or concretions evident; gravel and stones usually absent, sometimes odd small gravel to 5mm present; not hydrophobic; well structured or poorly structured [massive]; roots few to common, decreasing with depth, recorded to depths of 50cm [bedrock, 110cm and 120cm; analysed profile not dispersible in upper horizon, high to very high dispersibility in lower horizons [D%], slightly dispersible in upper subsoil horizon, very high dispersibility in lower subsoil horizons [EAT]; non-saline.

7.1.2.3 Pilliga Sandstone Lower and Mid-Slopes [Profiles 29 and 32]

Surface condition soft to loose or firm; surface stone absent except where eroded

- **Topsoil [1horizon] –** clayey sand to sandy loam, slightly gritty light to medium clay textured; 29 to 37cm deep; pH 4.0 to 5.5 – 6.0; gravel and stones absent or some gravel to 1cm present; no lime or manganese stains or concretions present; moderately to well structured; many roots; slightly hydrophobic; analysed profile moderately dispersible [D%], slightly dispersible [EAT]; non-saline.
- **Subsoil [2 to 3 horizons] -** clayey sand to sandy loam, light to medium clay, sandy medium clay, medium to heavy clay, heavy clay textured; excavated to 113 to 220cm depth; pH 4.5 to 6.0; no lime or manganese stains or concretions present; usually well structured, sometimes poorly structured [massive]; roots few to common, recorded to 220cm depth; not hydrophobic; analysed profile slightly dispersible [D% and EAT]; non-saline.

7.1.2.4 Pilliga Sandstone Upper Slopes [Profiles 6 and 28]

Surface condition firm; surface stone absent

- **Topsoil [1 Horizon]** - clayey sand to sandy loam, light to medium clay textured; 15 to 21 cm deep; pH 4.5 to 6.5; gravel and stones absent or occasional angular gravel to 5-10mm present; no lime or manganese stains or concretions present; moderately to well structured; many roots; sometimes hydrophobic; analysed profile slightly dispersible [D%], not or slightly dispersible [EAT]; non-saline.
- **Subsoil [3 or 4 horizons] -** sandy clay loam, sandy clay, medium clay [sometimes sandy], medium to heavy clay; excavated to 180cm and 230cm depth; pH 4.5 to 6.5 and, at time 9.0 to 9.5 at depth; gravel and stones absent; usually no lime or manganese stains or concretions present, sometimes flecks noted; often poorly structured [massive], sometimes well structured; not hydrophobic; roots many to absent, recorded to depths of 140cm and 180cm [into bedrock]; analysed profile slightly dispersible [D% and EAT]; non-saline.

7.1.3 Purlawaugh Formation

7.1.3.1 Purlawaugh Formation Crests [Profiles 5 and 24]

Surface condition loose to firm; surface stone absent or low to medium amounts of rounded / angular surface stone to 15cm present

- **Topsoil [1 horizon]** - clayey sand or sandy medium clay; 14cm to 27cm deep; pH 5.0 to 5.5; some angular gravel 5mm to 3cm present; no lime or manganese stains or concretions present; moderately to well structured; many roots; not or slightly hydrophobic; analysed profile moderately dispersible [D%], slightly dispersible [EAT]; non-saline.

- **Subsoil [2 horizons]** – medium clay [sometimes sandy]; excavated to 69cm and 127cm depth; pH 5.5 to 8.5; some to much angular gravel <5-10mm; no manganese stains or concretions; lime concretions present in some horizons; poorly structured to usually well structured; not hydrophobic; roots common to many, recorded to 127cm and 150 cm [into bedrock]; analysed profile slightly to moderately dispersible [D%], slightly dispersible [EAT]; non-saline.

7.1.3.2 Purlawaugh Formation Major Drainage lines [Profiles 10, 17, 20, 23 and 25]

Surface condition loose, soft or firm; surface stone absent

- **Topsoil [1 horizon]** – sand, clayey sand, sandy light clay textured, recorded depths 31cm, 40cm, 60cm, 100cm and 103cm; pH 6.0 to 7.5; gravel and stones absent; some rounded / angular gravel to 5 – 10mm present; no lime or manganese stains or concretions present; often poorly [massive / single grained] structured , sometimes well structured; roots few to many; sometimes hydrophobic, usually not; analysed profiles slightly dispersible [D% and EAT]; non-saline.
- **Subsoil [2 to 3 horizons]** - sand; clayey sand to sandy loam, sandy clay; medium to heavy clay [sometimes sandy] textured; excavated depths to 220cm, 250cm, 262cm, 279cm and 300cm;usually no lime or manganese stains or concretions present, sometimes lime flecks and small nodules recorded; pH usually 5.5 to 7.0, sometimes 9.0 or 9.5 – 10 at depth; gravel and stones usually absent or some rounded gravel to 1-4cm in individual horizons; some of the deepest horizons with much stone and decomposing rock; usually poorly structured [massive] or well structured in more clayey horizons; roots absent, few or common [in some upper subsoil layers], recorded to 140cm, 220cm, 230cm and 250cm depth; analysed profiles moderately to very highly dispersible [D%], slightly to high to moderately dispersible [EAT]; lowest horizon sometimes slightly saline.

7.1.3.3 Purlawaugh Formation Floodplains [Profiles 2, 9, 14, 16 and 22]

Surface condition loose to firm or hardsetting; surface stone absent

- **Topsoil [1 horizon] -** sandy loam, sandy clay loam, fine sandy clay loam, medium clay textured; recorded depths 14cm, 23cm, 28cm, 32cm and 39cm ; pH 6.0 to 6.5; gravel and stones usually absent; sometimes some rounded gravel to 1cm or some flattish stones to 20cm; no lime or manganese stains or concretions present; well structured; usually not hydrophobic; many roots; analysed profile slightly dispersible [D% and EAT]; non-saline.
- **Subsoil [2, 3 or 4 horizons]** - sandy loam, sandy clay loam; clay loam; light sandy clay loam; sandy light clay, light to medium clay [sometimes gritty]; medium clay [sometimes gritty] textured; excavated to depths of 210cm, 244cm, 250 cm and 255cm; pH 6.5 to 7.5, sometimes 8.0 or 9.0; ; gravel and stones usually absent, at times some angular gravel to 1cm present; usually no lime or manganese stains or concretions present, sometimes horizons have lime flecks visible; usually well structured, occasionally massive; not hydrophobic; roots few to many, at times absent at depth, recorded to 103cm, 110cm, 125cm, 142cm and 220cm; analysed profile dispersibility slight, high and very high [D%], high to moderate and very high [EAT]; lowest horizon slightly saline.

7.1.3.4 Purlawaugh Formation Lower Slopes [Profiles 7 and 8]

Surface condition loose; surface stone absent or some rounded surface stone 1-2cm present

- **Topsoil [1 horizon]** - sandy clay loam to light clay textured; recorded depths 21cm to 25cm; pH 6.5; gravel and stones absent; no lime or manganese stains or concretions present; well structured; sometimes slightly hydrophobic; many roots; analysed profile slightly dispersible [D% and EAT]; non-saline.
- **Subsoil [3 or 4 horizons]** - clay loam, gritty light clay, gritty light to medium clay, medium to heavy clay, heavy clay textured; excavated to depths of 235cm and 260cm; pH 6.5 to 7.5; some horizons 8.5 to 9.0, one lowest horizon 4.0; usually no lime or manganese stains or concretions present, some horizons with some to many lime nodules; well structured; not hydrophobic; few to many roots or roots absent from lower horizons, recorded depths 50cm and 193cm; analysed profile showed negligible to very high dispersibility [D%], high to moderate but usually very high dispersibility [EAT]; most subsoil horizons slightly to moderately saline.

7.1.3.5 Purlawaugh Formation Midslopes [Profiles 19, 26 and 35]

Surface condition firm, sometimes self mulching and cracked; surface stone absent or some angular surface stone <1cm and some flat sandstone to 15cm present

- **Topsoil [1 horizon] -** silty clay, light to medium clay, medium clay textured; recorded depths 10cm, 30cm and 37cm; pH 6.0 to 7.5; gravel and stones absent or some rounded or angular gravel to 2cm present, sometimes large flat stones to 25-30cm occur; no lime or manganese stains or concretions present; well structured; not hydrophobic; many roots; analysed profile slightly dispersible [D% and EAT]; non-saline.

- **Subsoil [3 or 5 horizons]** - light to medium clay, medium to heavy clay, heavy clay textured; excavated to depths of 204cm, 260cm and 270cm; pH 7.5 to 9.9, 4.5 in some lowest horizons; gravel and stones often absent or scattered to much rounded or angular gravel to 10cm present; some horizons with large lime nodules, manganese stains and concretions absent; usually well structured, sometimes massive; few to many roots or roots absent, recorded depths 130cm and 154cm; not hydrophobic; analysed profile shows slight to moderate dispersibility [D%], negligible, high to moderate or very high dispersibility [EAT]; lower horizons slightly to moderately saline.

7.1.3.6 Purlawaugh Formation Upper Slope [Profile 13]

Surface condition self mulching / cracked; some rounded surface stone present

- **Topsoil [1 horizon] -** medium to heavy clay; 25cm deep; pH 7.5; occasional rounded gravel to 1cm present; no lime or manganese stains or concretions present; well structured; many roots; not hydrophobic.
- **Subsoil [2 horizons] -** medium clay; excavated to depth of 259cm; gravel and stones absent, sometimes sandstone floaters present; pH 9.0 decreasing to 5.0 at depth; many lime nodules in one horizon; manganese stains and concretions absent; well structured; not hydrophobic; few roots or roots absent, recorded to 87cm depth.

7.1.3.7 Purlawaugh Formation Upper Drainage Lines [Profiles 31 and 36]

Surface condition firm; surface stone absent

- **Topsoil [1 horizon]** - light to medium clay [sometimes sandy]; recorded depths 20cm and 22cm; gravel and stones absent or some rounded and flattish gravel to 1-2cm present; pH 5.5 to 6.5; no lime or manganese stains or concretions present; well structured; not hydrophobic; many roots; analysed profile slightly dispersible [D% and EAT]; non-saline.
- **Subsoil [2 0r 4 horizons]** - medium clay [sometimes sandy or gritty], medium to heavy clay, heavy clay textured; excavated to bedrock, depths of 62cm and 222cm; rounded, angular or flat gravel, gravel to 2-3cm, grit to 2mm and , at times, many large flattened stones to 15 cm; decomposing rock present in one profile pH 5.5 to 8.5; one lowest horizon 9.5 to 10; usually no lime or manganese stains or concretions present, one horizon in one profile with many lime stains and small nodules present; well structured; roots few to many, recorded to 62cm and 120cm depth; not hydrophobic; analysed profile slightly, moderately to very highly dispersible [D%], not, slightly or highly dispersible [EAT]; lowest horizon moderately saline.

7.2 Soil Limitations

The reconnaissance soils study of the Mine Site has quantified a range of soil attributes that might possibly have some adverse impact on the Mine Site following subsidence after longwall mining.

Some of these attribute have been shown to be unlikely to be associated with land degradation problems. However, a number of soil properties that may be associated with land degradation after subsidence have been identified. These are summarised in **Table 9.**

Table 9
Topsoil and Subsoil Limitations

Page 1 of 2

Soil Attribute	Surface Geology		
	Garrawilla Volcanics	**Pilliga Sandstone**	**Purlawaugh Formation**
Soil Depth	not limiting; generally quite deep profiles on slopes, floodplains and in drainage lines; more likely to be shallower on upper sloes and crests	not limiting; generally less than 250cm and much shallower on crests and slopes	not limiting; usually very deep profiles except on the crests where shallower profiles are encountered
Soil Texture	not limiting; usually finer textured [more clayey]	not limiting; generally the most sandy soils in the Mine Site;	not limiting; a mix of often coarse texture topsoils and more clayey subsoils
Soil Surface Characteristics	not limiting; surface stone usually absent but noted on upper slopes; surface sometimes self-mulching; not hydrophobic	not limiting; surface stone usually absent but noted on upper slopes; surface sometimes self-mulching; often hydrophobic	not limiting; surface stone often absent but noted on slopes; surface sometimes self-mulching; not hydrophobic
pH	not limiting; generally favourable for plant growth; usually increasing with depth	not limiting; generally lower than in the other Geological Formations and not increasing much with depth	not limiting; generally favourable for plant growth; usually increasing with depth but some lower horizons quite acid
Erodibility [as determined by the SOILOSS model]	low to moderate; some limitations where subsidence results in slope increases	low; may be some limitations where subsidence results in slope increases and in drainage lines	usually moderate; may be some limitations where subsidence results in slope increases and in drainage lines
Topsoil Dispersibility	topsoils usually not or only slightly dispersible; not limiting	topsoils usually slightly or moderately dispersible; may be limiting near subsidence cracks or where slope gradient increases following subsidence	topsoils usually slightly dispersible; usually not limiting
Subsoil Dispersibility	variable but often moderated to high; limitation in vicinity of subsidence cracks	slightly to very highly dispersible, particularly in drainage lines; may be limiting near subsidence cracks or where slope gradient increases following subsidence but may be an advantage in filling cracks	often moderately to highly dispersible; may be limiting near subsidence cracks or where slope gradient increases following subsidence but may be an advantage in filling cracks
Salinity	salinity not recorded; not limiting	salinity not recorded; not limiting	the most saline land units with slight to moderate salinity detected in drainage line, floodplain and some slopes areas; limitation in areas associated with subsidence cracks where downslope saline areas may develop after erosion

8 POSSIBLE IMPACTS OF SUBSIDENCE FOLLOWING LONGWALL MINING

8.1 Possible General Impact of Subsidence above Longwall Panels on Drainage Lines

The major drainage lines through the Mine Site generally run at an angle to the alignment of the longwall panels. With subsidence, the overall drainage line bed will become a series of ridges and depressions within the actual landform unit as subsidence occurs.

In some instances, where the drainage lines are not deeply incised, there may be potential for water to be trapped or ponded outside the current boundaries of the drainage lines for a period after rain / flows as a consequence of the altered bed gradient from subsidence The time for this water to dissipate by infiltration or evaporation is unknown and would depend on the soil texture at the site to a large degree.

The drainage lines are currently relatively uniform in their basal gradients within the different landform units. Obviously, the drainage line bed gradient will change as the stream progresses down slope towards the Namoi River.

However, it is likely the drainage line bed will become a series of troughs and ridges – initially akin to forming a chain of ponds. As the drainage line beds have soils that are generally coarse in texture, it would be expected that over time the troughs will fill with sediment derived from erosion of the stream bed upstream and other debris until, finally a bed of relatively uniform grade will develop. The timeframe for this to occur is unknown.

Except for period of heavy rainfall when the drainage line would carry major flows there may be rainfall events when these drainage lines only run for part of their length because of the disruption to their grade caused by subsidence. This may have impacts on stock water supply in terms of filling dams and tanks lower down the regional slope.

The interesting feature about the drainage lines that were excavated was that even though their surface soils were dry most had a layer of clay material or rock at depth that appeared relatively impervious to moisture with the consequence that the water flowing below the surface is confined in sand beds.

Another impact of subsidence on drainage lines will be that of erosion associated with increased bed gradient. It is likely that gully head cutting will develop in some instances where soils are more clayey. Where the soils of the stream beds are sandy, the head cutting will probably still occur but be less noticeable as the soils will be less structured and the cutting action will create a more sloping grade in the stream bed rather than a vertical cut.

Associated with the mobilisation of soil material due to gradient changes will be the mobilisation of suspended and dissolved soil and organic material that will have the potential to pollute downstream waters and reduce water quality, at least for a period after subsidence occurs.

8.2 Possible General Impact of Subsidence Cracks on the Margins of Longwall Panels on Drainage Lines

In addition to the general impact of subsidence on the gradient of drainage line beds, there is likely to be an impact of cracks associated with subsidence where the longwall panels meet the retained pillars. Soil properties in the areas affected by cracking will influence the relative impact of this cracking on the ephemeral drainage lines of the Mine Site.

Potentially, these cracks have the ability to drain an unknown amount of water from the drainage line into the sub surface area. The probability of water reaching far below the surface at Narrabri is unknown, although likely to be very different than areas such as the Southern Coalfields of New South Wales (where rainfall is greater) where this phenomenon has been identified.

The drainage lines within the Mine Site are ephemeral and subject to long periods without flows although it is apparent that sub surface flows continue for at least some period after rain within the sandy soils of the bed. These flows appear to be retained within the "sand beds" above a more clayey and less permeable clay or rock base.

Whether or not the soils of the clay material under the sand beds are dispersive will probably have an impact on how long it takes for the subsidence cracks to fill and seal over. Dispersive soil material could be moved into the cracks quite rapidly and because of its lack of porosity when dispersed, would undoubtedly seal the crack area and greatly reduce water loss from the stream with in a relatively short period in much the same way as dispersion promoting chemicals are used to seal leaking farm dams.

8.3 Possible Impact on Tree and Shrub Growth

Soil sampling revealed that in many instances the root systems of trees and shrubs were concentrated relatively close to the surface. My experience in soil sampling over the past 15 years or so indicates that most eucalypt, cypress pine and shrub root systems are concentrated in the top 30 to 60cm of the soil profile.

Trees such as eucalypts and cypress pines certainly have tap roots that penetrate fairly deeply into the soils.

However, with the eucalypts, Florence [1996] notes that over time the trees become more dependent on the lateral root systems for their continued nutrient and moisture supplies and that the taproot becomes less important

The impacts of subsidence on trees and shrubs in the central parts of the longwall panel where compressive rather than 'tearing' forces are exerted can probably be expected to be minimal depending on how long the period of subsidence takes.

In most cases, it is likely that the trees and shrubs in the centre of the subsidence panel will just occupy a lower position in the landscape than they did previously. There could be implications for these trees and shrub from the ponding of water in some instance where soil permeability is low. The most likely sites for this scenario to develop is on the level floodplain lands and adjacent to drainage lines.

The trees and shrubs on the areas away from the centre of the subsidence panels towards the untouched chain pillar area are likely to really only be affected by the change in gradient of the site they occupy resulting in some tilting of their trunks. In time, the natural growth patterns of these species will ensure that new branch growth tends more to the upright.

For trees and shrubs in the zone affected by the subsidence cracks, there is likely to be some impact of root tearing. This is likely to be manifest by a lack of vigour or death of individual plants where the loss of roots is high. The process is very like that associated with deep ripping close to a tree to prevent its roots impacting on crop and pasture growth.

The degree to which any tree or shrub is affected would depend on the ability of the root system to provide alternative sources of water and nutrients to the aerial parts. If not, then dieback or death could be expected.

Impact of subsidence cracking on trees and shrubs is likely to be greatest in the currently heavily timbered areas. While there may be losses of some individuals in these areas there would be sufficient seed available in the soil to replace these losses quickly.

On the areas that have been largely cleared for agriculture there could be major detrimental implications for individual paddock trees if they are located on or close to large subsidence cracks.

8.4 Possible Impact on Native Pasture Growth

Native and naturalized pasture species generally have their root systems concentrated in the top 20-50cm of soil with the number of roots penetrating to depth being much less. Grass species root systems are fibrous and the impact of the cutting of individual roots is probably less that it is with trees and shrubs.

Little impact would be expected in the centre and sides of the subsidence zone.

However, in areas adjacent to the subsidence cracks, there may be depth or dieback of ground cover species due to drying out of the topsoil where the root systems are concentrated or severance of vital deeply penetrating roots that are sourcing available water when the surface soil is dry.

Herb species often have root systems that mimic, in a much smaller scale, the root systems of trees and shrubs. These root systems are often less fibrous than those of the grasses and comprise a mixture of tap roots and laterals. As with trees and shrubs the plants may be affected or killed if vital lateral roots are severed by the subsidence cracks.

However, overall, it is not anticipated that there would be major impacts on native or naturalized pasture species from the mine subsidence.

8.5 Possible Impact on Grain Crop and Forage Growth

Cereal and broadleaf pulse crops are likely to be affected in the same ways as native and naturalized grass and herb pasture species, as described in **Section 12.3**. The main impacts would be expected to occur at and adjacent to the subsidence crack as a result of drying out the upper soil and severance of major roots.

Cereal crop root systems are usually concentrated in the top 90-120cm of soil with deeper roots evident in some soils and some seasons. In dry times, the root systems can be quite shallow whereas in wetter seasons individual roots may penetrate almost to 2m or so.

Cultivation would be expected to fill any subsidence cracks relatively quickly so that the impact of the cracks on drying out soil moisture would disappear relatively quickly.

Similarly, as crops are annual in nature the impact of subsidence would probably really only affect crops that are actively growing at the time subsidence occurs.

Another impact of subsidence could be localized water ponding in more clayey soils with associated waterlogging problems for crops if the ponded water did not drain quickly.

8.6 Possible Impact on Sown Pasture Growth

Annual sown pasture species would not be greatly affected by subsidence except for plants growing adjacent to the subsidence cracks. The impacts would be expected to be similar to those described in **Section 12.4**.

However, for perennial pasture species such as Lucerne there may be severance of vital taproots near the subsidence cracks. The impact of this may be dieback or plant death. For the remainder of the subsidence panel, there should be little detrimental effect except for, perhaps, any induced waterlogging that may be detrimental.

8.7 Possible Impact on Soil Erosion

Subsidence will change the slope gradient of sections of the landscape within the subsidence panel. The degree of change will depend on the configuration of the landscape prior to subsidence occurring.

Some areas will not be much changed while others may be subjected to an increase in slope gradient that may require more intensive pasture management to retain adequate protective ground cover - for all time.

The greatest risk from soil erosion is expected to be associated with the subsidence crack lines in soils with moderate to high erodibility. Erosion that is triggered by a subsidence crack that is aligned down the slope on a sloping surface may quickly develop into a rill and then a gully line if soil conservation works are not employed.

The risk of this occurring would be on soils with moderate to high erodibility ratings [ie. high 'K' values]. Notably, the K values of all soils tested were low to moderate [see **Table 8**] suggesting the risk of gully erosion forming from surface cracks would be reduced.

There is also a risk associated with subsidence cracks aligned down the slope that they will cause the initiation of tunnel erosion on soils with dispersible subsoils such as in the landform units of [mainly] Purlawaugh Formation and Garrawilla Volcanics.

Rectification of this problem will require the use of appropriate stabilisation measures within a comparatively short period of time following subsidence.

8.8 Possible Impact on Soil Conservation Bank and Waterway Systems

Soil conservation bank systems are carefully surveyed and constructed to achieve the safe control, conveyance and disposal of runoff water.

Subsidence itself can radically change the surveyed grades of the banks and lead to channel erosion and eventual ineffectiveness.

Similarly, subsidence cracks can occur through banks and their associated channels making the whole system ineffective and leading to bank failure and concentration of runoff water such that it causes significant sheet, rill, gully and tunnel erosion elsewhere.

Bank and waterway systems are located on a number of areas within the Mine Site and these locations should be regularly monitored after subsidence to ensure that they are repaired by filling cracks and relocating sections whose grades have been altered by the subsidence.

This latter action should be undertaken after subsidence is complete.

8.9 Possible Impact on Soil Salinity

Surface soil salinity is currently not an issue at the Mine Site. However, the soils within the landform units of the Purlawaugh Geological formation are saline at depth.

Down slope aligned subsidence cracks that occur on sloping sections of these units would potentially be a source of induced soil salinity if the subsoils are dispersible and tunnelling action occurs. The sediment and soil solution that is spilled out onto downslope land after rains could potentially lead to the development of saline patches.

Again, the symptoms of soil salinity, such as bare ground and salt encrustations of the soil surface, should be watched for. If salinity begins to develop, appropriate action to stop tunnelling and revegetate the saline area with salt tolerant species should be initiated.

8.10 Possible Impact on Farm Dams

Where subsidence cracks develop through a farm or other dam or ground tank there will be an inevitable loss of stored water through seepage that will render the dam or tank completely or partially ineffective. The degree of impact will depend on the location of the dam or tank in the landscape with those on sloping ground being most susceptible to damage.

Dams or tanks that have banks that impound water may have these banks breached by subsidence cracks leading to water loss and soil erosion [rill, gully, sheet and tunnel erosion].

It is important that any breached banks and cracks be repaired as quickly as possible even during the subsidence process to prevent additional damage. While complete repair may not be possible until subsidence is complete, interim repairs are required to prevent erosion from heavy storm rains.

Final repairs to banks and subsidence cracks in the dam / tank base may require the cleaning out of the structure and the use of clay and / or appropriate dispersant chemicals to seal the cracks permanently.

Other facilities associated with farm dams and ground tanks that may be affected by subsidence cracks are tank drains. These can be breached by the cracks and become eroded and ineffective or their grades may be altered so that they no longer run water.

Affected tank drains required attention to ensure that they are restored as soon as possible after subsidence is complete. In the meantime, temporary repairs may be required to prevent land degradation.

8.11 Possible Impact on Roads and Tracks

Subsidence cracks aligned parallel to the road or track direction and located on the road or track have the potential to erode and form gullies on sloping sections.

Potential solutions to this problem include filling the cracks with soil and constructing properly designed protective low banks across the road or track at appropriate intervals to disperse runoff water onto safe disposal sites on the side of the road or track.

An alternative solution would be to relocate the track and construct appropriate erosion control works on sloping sections of the old track.

Where subsidence cracks cross the road or track at an angle, the cracks can be filled and an appropriately designed low bank constructed on the upslope side of the road or track to protect the filled material from being eroded away.

9 CONCLUSION

A reconnaissance soil survey has been undertaken over a 50km^2 [approx] area associated with the proposed Narrabri Coal Mine Stage 2 Longwall Project.

The sampling sites were selected after a stereoscopic airphoto interpretation of the Mine Site identified that a number of different landform units were present.

These landform units were then associated with surface the three geology formations occurring over the Mine Site [Garrawilla Volcanics, Pilliga Sandstone, Purlawaugh Formation] to identify suitable sites for sampling.

Each of the fourteen Geological Formation / Landform Units was then sampled in the field and the soil characteristics recorded in detail. Some of these Units were sampled only once while others were sampled a number of times.

Thirty six soil profiles were excavated to a depth of 2.5m or a shallower depth if bedrock was encountered or the backhoe could not penetrate further. The individual horizons in each profile were described in detail in the field.

Fifty five horizons from 14 profiles were subjected to laboratory analysis at the Department of Lands' soil testing laboratory at Scone to determine soil texture, dispersibility and salinity characteristics. A summary of the local soil properties, based on the results of the laboratory analysis and computer modelling, is as follows.

- Soil pH values within the Mine Site are generally within the range that supports plant growth
- Soil textures vary from sandy soils generally associated with the Pilliga Sandstone and many of the drainage lines to more clayey soils within the other two geological formations.
- Soil depth varies but in many cases it was possible to excavate the profiles to the full 250cm depth. The exceptions were usually on ridge crests and some upper slopes.
- Soil dispersibility, as measured by the Dispersion % and Emerson Aggregate Test showed that many subsoils were dispersible. The potential impacts of this dispersibility when associated with subsidence cracks is discussed.
- Soil salinity of a slight to moderate degree was evident in some subsoils. Again the potential impact of this salinity when associated with subsidence cracking is covered.
- Estimates of soil erodibility as predicted by the SOILOSS computer model are include for most Geological Formation / Landform Units.

Each of the excavated profiles is fully described in **Appendix 1** of this document.

Based on the recorded soil attribute data, it was then possible to identify soil characteristics that might potentially cause problems on the subsidence areas – particularly those

- on forested land;
- on cropland;
- on native and improved pasture land;

- near the subsidence cracks;
- along the drainage lines that traverse the Mine Site;
- along roads and tracks;
- at farm dam and ground tank sites; and
- in areas where tank drains and soil conservation bank and waterway systems had been constructed.

Potential impacts of subsidence on these sites and means of overcoming any problems that develop are discussed. It should be emphasised that the discussion of likely subsidence – associated problems does not imply that such problems **will develop**. The aim of the discussion has been to alert the Proponent to as many possible impact scenarios as possible so that, should they develop, management will be in a position to identify early warning signs and take appropriate corrective action

Pre-mining Land Capability and Agricultural Land Suitability within the Mine Site is discussed as is the likely post mining and subsidence classification.

10 REFERENCES

Anon [1978] - Narrabri Technical Manual. Soil Conservation Service of NSW, Sydney.

Banks, R.G. [1995] – Soil Landscapes of the Curlewis !: 100 000 Sheet [Breeza, Caroona, Pine Ridge, Colly Blue, Goran Lake].. Department of Conservation and Land Management, Sydney.

Cunningham, G.M., Higginson, F.R., Riddler, A.M.H. and Emery, K.A. [undated] **–** Systems Used to Classify Rural Lands in New South Wales. Soil Conservation Service of NSW and NSW Department of Agriculture, Sydney.

Dougall, B.M. [1950] – The Effects of Open-Cut Coal Mining on Agricultural Land. J. Sci. Fd. Agric. 11: 225 - 229

Elliott, G.L. and 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. [undated] – Rural Land Capability Mapping, Scale 1: 100 000. Soil Conservation Service of New South Wales, Sydney.

Florence, R.G. [1996] - Ecology and Silviculture of Eucalypt Forests. CSIRO Publishing, Collingwood.

GCNRC [2006] – Soil Survey and Land Capability Study of the Proposed Narrabri Coal Mine via Baan Baa, NSW. Geoff Cunningham Natural Resource Consultants Pty Ltd, Killara.

Glendinning, J.S. [1990] – Fertiliser Handbook. Incitec Ltd, Morningside.

Hazelton, P.A. and Murphy, B.W. [Eds] [in press] – What Do All the Numbers Mean? A Guide for the Interpretation of Soil Test Results. Department of Land and Water Conservation, Sydney and University of Technology, Sydney.

Hulme, T., Grosskopf, T. and Hindle, J. [2002] – Agricultural Land Classification. Agfact AC.25. NSW Agriculture, Orange.

Macbeth [1992] – Munsell Soil Colour Charts. 1992 Revised Edition. Macbeth Division of Kollmorgen Instruments Corporation, Newburgh, New York.

McDonald, R.C., Isbell, R.F., Speight, J.G., Walker, J. and Hopkins, M.S. [1990] – Australian Soil and Land Survey Field Handbook. Second edition. Inkata Press, Melbourne.

Northcote, K.H. [1971] – A Factual Key for the Recognition of Australian Soils. Rellim Technical Publications, Glenside.

Renard, K.G., Foster, G.R., Weesies, G.A., McCool, D.K. and Yoder, D.C. [1993] – Predicting Soil Erosion by Water: A Guide to Conservation Planning with the revised Universal Soil Loss Equation [RUSLE}. USDA Agriculture Handbook. Washington, DC

Rosewell, C.J. [1993] – SOILOSS, A Program to Assist in the Selection of Management Practices to Reduce Erosion. Second Edition. Department of Conservation and Land Management, Sydney.

Rosewell, C.J. and Edwards, K. [1988] – SOILOSS. A Program to Assist in the Selection of Management Practices to Reduce Erosion. Technical Handbook No. 11. Soil Conservation Service of NSW, Sydney.

Stace, H.C.T., Hubble, G.D., Brewer, R., Northcote, K.H., Sleeman, J.R., Mulcahy, M.J. and Hallsworth, E.G. [1968] – A Handbook of Australian Soils. Rellim Publications, Glenside.

Wischmeier, W.H. and Smith, D.D. [1978]– Predicting Rainfall Erosion Losses – A Guide to Conservation Planning. Handbook 537, USDA, Washington DC.

Appendix 1

Soil Profile Descriptions

This page has intentionally been left blank

Profile 1 [Garrawilla Volcanics - upper slope location]; *surface condition self mulching; some angular surface gravel 1-10cm present*

0-29cm - medium to heavy clay; roots common; no lime visible; no manganese present; pH 9.0; occasional angular gravel 1-5mm; not mottled; not bleached; dark brown [7.5YR3/3] dry, dark brown [7.5YR3/3] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-15mm in size; strong consistence dry; not hydrophobic; *clear to:-*

29-53cm - heavy clay; few roots; lime stains present; no manganese present; pH 9.0; occasional angular gravel 1-5mm; not mottled; not bleached; dark reddish brown [5YR3/2] dry, dark reddish brown [5YR3/3] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-15mm in size; very strong consistence dry; not hydrophobic; *gradual to:-*

53-84cm - medium to heavy clay; few roots; lime stains and nodules very common; no manganese present; pH 9.0; gravel and stones absent; not mottled; not bleached; reddish brown [5YR4/3] dry, reddish brown [5YR3/3] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-20mm in size; very strong consistence dry; not hydrophobic; *gradual to:-*

84-126cm - heavy clay; few roots; much lime staining; no manganese present; pH 9.0; gravel and stones absent; not mottled; not bleached; brown [7.5YR4/3] dry, brown [7.5YR4/4] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-10mm in size; very strong consistence dry; not hydrophobic; *gradual to:-*

126-250cm - light to medium clay; roots absent; many lime nodules present; no manganese present; pH 9.0; large floaters and some gravel present; mottled; not bleached; 90% light brownish grey [2.5Y6/2], 10% reddish yellow [7.5YR7/6] dry, 90% light brownish grey [2.5Y6/2], 10% reddish yellow [7.5YR6/8] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-10mm in size; very strong consistence dry; not hydrophobic;

Profile 2 [Purlawaugh Formation - drainage line location] *surface condition loose to firm; surface stone absent*

0-23cm - sandy loam; many roots; no lime present; no manganese present; pH 6.0; gravel and stones absent; not mottled; not bleached; brown [7.5YR4/3] dry, dark brown [7.5YR3/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-15mm in size; firm consistence dry; not hydrophobic; *abrupt to:-*

23-38cm - sandy loam; many roots; no lime present; no manganese present; pH 6.5; gravel and stones absent; not mottled; not bleached; brown [10YR4/3] dry, dark brown [7.5YR3/2] moist; peds rough-faced, highly pedal [100%], polyhedral, <5-10mm in size; weak consistence dry; not hydrophobic; *abrupt to:-*

38-77cm - gritty medium clay; many roots; no lime present; no manganese present; pH 6.5; gravel and stones absent; not mottled; not bleached; brown [10YR4/3] dry, very dark brown [10YR3/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-10mm in size; very strong consistence dry; not hydrophobic; *abrupt to:-*

77-108cm - sandy clay loam; few roots; no lime present; no manganese present; pH 7.0; gravel and stones absent; mottled; not bleached; 50% dark greyish brown [10YR4/2], 50% light brownish grey [10YR6/2] dry, 50% dark greyish brown [10YR4/2], 50% light brownish grey [10YR6/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-15mm in size; firm consistence dry; not hydrophobic; *gradual to:-*

108-250cm - light sandy clay loam; few roots; no lime present; no manganese present; pH 7.5; gravel and stones absent; mottled; not bleached; 95% light brownish grey [10YR6/2], 5% strong brown [7.5YR5/8] dry, 95% light brownish grey [10YR6/2], 5% strong brown [7.5YR5/6] moist; massive; fabric rough / smooth; not hydrophobic.

Profile 3 [Garrawilla Volcanics - floodplain location] *surface condition loose to firm; surface stone absent*

0-39cm - light sandy clay loam; many roots; no lime present; no manganese present; pH 6.0; gravel and stones absent; not mottled; not bleached; brown [7.5YR4/4] dry, dark brown [7.5YR3/3] moist; peds rough-faced, highly pedal [100%], polyhedral, 5-5mm in size; firm consistence dry; not hydrophobic; *clear to:-*

39-100cm - light clay; many roots; no lime present; no manganese present; pH 6.0; gravel and stones absent; not mottled; not bleached; very dark brown [7.5R2.5/2] dry, very dark brown [7.5R2.5/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-10mm in size; firm consistence dry; not hydrophobic; *gradual to:-*

100-134cm - medium clay; few roots; no lime present; no manganese present; pH 7.0; gravel and stones absent; not mottled; not bleached; strong brown [7.5YR4/6] dry, brown [7.5YR4/4] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-10mm in size; very firm consistence dry; not hydrophobic; *clear to:-*

134-250cm - medium to heavy clay; few roots; no lime present; no manganese present; pH 7.5; gravel and stones absent; mottled; not bleached; 95% brown [7.5YR5/2], 5% strong brown [7.5YR5/6] dry, 95% dark grey [7.5YR4/1], 5% strong brown [7.5YR5/6] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-15mm in size; very firm to strong weak consistence dry; not hydrophobic;

Profile 4 [Garrawilla Volcanics - floodplain location] *surface condition firm; medium amounts of angular surface stone to 15cm present*

0-25cm - sandy clay loam; roots common; no lime present; no manganese present; pH 5.5; gravel and stones absent; not mottled; not bleached; brown [7.5YR4/4] dry, dark brown [7.5YR3/3] moist; peds rough-faced, highly pedal [90%], polyhedral, 5-15mm in size; firm consistence dry; not hydrophobic; *clear to:-*

25-81cm - medium clay; few roots; no lime present; no manganese present; pH 7.0; some angular gravel to 1-5cm; not mottled; not bleached; weak red [10R4/4] dry, dusky red [10R3/4] moist; peds rough-faced, highly pedal [100%], polyhedral, 5-15mm in size; very strong consistence dry; not hydrophobic; *clear to:-*

81-160cm - medium to heavy clay; few roots; no lime present; no manganese present; pH 7.0; gravel and stones absent; not mottled; not bleached; red 10R4/6] dry, dusky red [10R3/4] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-10 mm in size; very strong consistence dry; not hydrophobic; *gradual to:-*

160-250cm - medium to heavy clay; roots absent; no lime present;no manganese present; pH 7.0; gravel and stones absent; not mottled; not bleached; red [2.5YR4/6] dry, dark reddish brown [2.5YR3/4] moist; peds rough- smooth-faced, highly pedal [100%], polyhedral/platy, <5-15mm in size; very strong consistence dry; not hydrophobic

Profile 5 [Purlawaugh Formation - crest location] *surface condition loose to firm; low to medium amounts of rounded / angular surface stone to 15cm present*

0-14cm - light clay; many roots; no lime present; no manganese present; pH 5.5; some angular gravel to 3cm; not mottled; not bleached; brown [7.5YR4/4] dry, very dark brown [7.5YR2.5/3] moist; peds rough-faced, highly pedal [100%], polyhedral, <5-10 mm in size; very firm consistence dry; slightly hydrophobic; *clear to:-*

14-43cm - sandy medium clay; many roots; no lime present; no manganese present; pH 6.0; much angular gravel 5-10mm; not mottled; not bleached; reddish brown [5YR4/4] dry, dark reddish brown [5YR3/4] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-10mm in size; very strong consistence dry; not hydrophobic; *clear to:-*

43-69cm - medium clay; many roots; many lime nodules present; no manganese present; pH 8.5; some gravel <5mm; not mottled; not bleached; reddish brown [5YR4/4] dry, reddish brown [5YR4/4 moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-10mm in size; very strong consistence dry; not hydrophobic; *abrupt to:-*

69-150cm - decomposing rock; many roots;

Profile 6 [Pilliga Sandstone- upper slope location] *surface condition firm; surface stone absent*

0-21cm - light to medium clay; many roots; no lime present; no manganese present; pH 6.5; gravel and stones absent; not mottled; not bleached; brown [7.5R4/3] dry, dark brown [7.5YR3/2] moist; peds rough-faced, highly pedal [100%], polyhedral, <5-10mm in size; very firm consistence dry; not hydrophobic; *abrupt to:-*

21-70cm - medium clay; roots common; no lime present; no manganese present; pH 6.5; gravel and stones absent; not mottled; not bleached; brown [7.5YR4/3] dry, brown [7.5R4/3] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-10mm in size; very strong consistence dry; not hydrophobic; *gradual to:-*

70-110cm - medium to heavy clay; few roots; some lime flecks present; no manganese present; pH 9.0; gravel and stones absent; not mottled; not bleached; brown [7.5yYR4/3] dry, brown

[7.5yYR4/3] moist; peds rough- smooth-faced, highly pedal [100%], polyhedral, 5-15mm in size; very strong consistence dry; not hydrophobic; *gradual to:-*

110-210cm - medium to heavy clay; few roots; no lime visible; no manganese present; pH 9.5; gravel and stones absent; not mottled; not bleached; brown [7.5YR4/2] dry, brown [7.5YR4/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral/platy, <5-10mm in size; very strong consistence dry; not hydrophobic; *diffuse to:-*

210-230cm - medium to heavy clay; roots absent; no lime visible; no manganese present; pH 4.5; gravel and stones absent; mottled; not bleached; 80% brown [7.5YR4/2], 15% red [2.5YR5/8], 5% very pale brown [10YR7/4 dry, 80% brown [7.5YR4/2], 15% red [2.5YR4/5], 5% yellowish brown [10YR5/4 moist; massive; fabric rough / smooth ; very strong consistence dry; not hydrophobic

Profile 7 [Purlawaugh - lower slope location] *surface condition loose; surface stone absent*

0-25cm - sandy clay loam; many roots; no lime present; no manganese present; pH 6.5; gravel and stones absent; not mottled; not bleached; pale brown [10YR6/3] dry, greyish brown [10YR5/2] moist; peds rough-faced, highly pedal [100%], polyhedral, <5-20mm in size; weak consistence dry; not hydrophobic; *abrupt o:-*

25-42cm - gritty light clay; roots common; no lime present; no manganese present; pH 7.0; gravel and stones absent; not mottled; not bleached; brown [10YR5/3] dry, brown [10YR5/3] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-15 mm in size; very strong consistence dry; not hydrophobic; *clear to:-*

42-79cm - clay loam; few roots; no lime present; no manganese present; pH 7.0; gravel and stones absent; not mottled; not bleached; pale brown [10YR6/3] dry, greyish brown [110YR5/2] moist; peds vesicular, highly pedal [100%], polyhedral, <5-15mm in size; very strong consistence dry; not hydrophobic; *gradual to:-*

79-144cm - gritty light to medium clay; few roots; no lime present; no manganese present; pH 7.0; gravel and stones absent; not mottled; not bleached; pale brown [10YR6/3] dry, dark greyish brown [10YR4/2] moist; peds vesicular, highly pedal [100%], polyhedral, <5-10mm in size; strong consistence dry; not hydrophobic; *gradual to:-*

144-260cm - slightly sandy light to medium clay; few roots; no lime present; no manganese present; pH 6.0; gravel and stones absent; mottled; not bleached; 80% light brownish grey [10YR6/2], 20% reddish brown [5YR5/4] dry, 80% dark greyish brown [10YR4/2], 20% reddish brown [5YR4/3] moist; peds rough- smooth-faced , highly pedal [100%], polyhedral, <5-10mm in size; very firm to strong consistence dry; not hydrophobic

Profile 8 [Purlawaugh - lower slope location] *surface condition firm; some rounded surface stone 1-2cm present*

0-21cm - light clay; many roots; no lime present; no manganese present; pH 6.5; gravel and stones absent; not mottled; not bleached; dark reddish brown [5YR3/2] dry, dark reddish brown

[5YR3/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-15mm in size; strong consistence dry; slightly hydrophobic; *clear to:-*

21-62cm - heavy clay; few roots; some lime nodules present; no manganese present; pH 8.5; some angular gravel to 3-4cm; not mottled; not bleached; reddish brown [5YR4/3] dry, dark reddish brown [5YR3/4] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-15mm in size; very strong consistence dry; not hydrophobic; *gradual to:-*

62-107cm - heavy clay; roots absent; many lime nodules present; no manganese present; pH 9.0; gravel and stones absent; not mottled; not bleached; reddish brown [5YR4/3] dry, reddish brown [5YR4/3] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-10mm in size; very strong consistence dry; not hydrophobic; *diffuse to:-*

107-182cm- medium to heavy clay; roots absent; no lime present; no manganese present; pH 7.5; lenses of rounded / angular gravel to 3-4cm; not mottled; not bleached; light brown [7.5YR6/3] dry, light brown [7.5YR6/3] moist; peds rough- / smooth-faced , highly pedal [100%], polyhedral, 5-10mm in size; very strong consistence dry; not hydrophobic; *diffuse to:-*

182-235cm - heavy clay; roots absent; no lime present; much manganese staining present; pH 4.0; gravel and stones absent; mottled; not bleached; 50% light grey [2.5Y7/2], 50% red [10R5/6] dry, 50% light yellowish brown [2.5Y6/3], 50% red [10R4/6] moist; peds smooth-faced, highly pedal [100%], polyhedral, 5-15mm in size; very strong consistence dry; not hydrophobic

Profile 9 [Purlawaugh Formation- floodplain location] *surface condition firm; surface stone absent*

0-14cm - sandy loam; many roots; no lime present; no manganese present; pH 6.0; some round gravel to 1cm; not mottled; not bleached; brown [10R5/3] dry, dark brown [10YR3/3] moist; peds earthy / vesicular, highly pedal [100%], polyhedral, 5-10mm in size; strong consistence dry; not hydrophobic; *abrupt to:-*

14-67cm - medium clay; many roots; some lime nodules present; no manganese present; pH 9.0; gravel and stones absent; mottled; not bleached; 50% brown [7.5YR5/4], 50% red [2.5YR4/6] dry, 50% brown [7.5YR4/4], 50% dark greyish brown [10YR4/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral/platy, 5-15mm in size; very strong consistence dry; not hydrophobic; *clear to:-*

67-122cm - medium clay; few roots; some lime flecks present; some manganese stains present; pH 9.0; gravel and stones absent; not mottled; not bleached; brown [10YR5/2] with reddish tinge dry, dark greyish brown [10YR4/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral/platy, 5-15mm in size; very strong consistence dry; not hydrophobic; *gradual to:-*

122- 244cm - slightly gritty medium clay; few roots; no lime visible; no manganese present; pH 9.0; some angular sandstone gravel to 3cm; not mottled; not bleached; greyish brown [10YR5/2] with a reddish tinge dry, dark greyish brown [10YR4/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-15mm in size; very strong consistence dry; not hydrophobic

Profile 10 [Purlawaugh Formation - drainage line location] *surface condition soft; surface stone absent*

0-100cm - clayey sand; many roots; no lime present; no manganese present; pH 6.5; some rounded / angular gravel to 1cm; not mottled; not bleached; brown [10YR4/3] dry, brown [7.5YR3/2] moist; peds rough-faced, highly pedal [80%], polyhedral, 5-10mm in size; weak consistence dry; not hydrophobic; *clear to:-*

100-130cm - sand; few roots; no lime present; no manganese present; pH 6.5; gravel and stones absent; not mottled; not bleached; light brownish grey [10YR6/2] dry, brown [10YR4/3] moist; massive; fabric rough; not hydrophobic; *gradual to:-*

130-160cm - clayey sand to sandy loam; few roots; no lime present; no manganese present; pH 6.0; some rounded gravel to 1cm; not mottled; not bleached; brown [10YR5/3] dry, brown [7.5YR5/3] moist; massive; fabric rough; not hydrophobic; *gradual to:-*

160-220cm - sandy clay; few roots; no lime present; no manganese present; pH 6.5; much stone and decomposing rock; mottled; not bleached; 50% brown [10YR4/3], 25% yellowish brown [10YR5/6], 25% red [10R4/6] dry, 50% dark greyish brown [10YR4/2], 25% yellowish brown [10YR5/6], 25% red [10R4/6] moist; massive; fabric vesicular; not hydrophobic

Profile 11 [Pilliga Sandstone - drainage line location] *surface condition loose to firm; surface stone absent*

0-29cm - sandy loam; few roots; no lime present; no manganese present; pH 4.5; gravel and stones absent; not mottled; not bleached; dark greyish brown [10YR4/2] dry, very dark greyish brown [10YR3/2] moist; peds rough-faced, highly pedal [80%], polyhedral, 5-10mm in size; weak consistence dry; not hydrophobic; *abrupt to:-*

29-43cm - clayey sand; roots; no lime present; no manganese present; pH 6.0; gravel and stones absent; not mottled; not bleached; light brownish grey [10YR6/2] dry, dark greyish brown [10YR4/2] moist; peds vesicular, highly pedal [100%], polyhedral, <5-10mm in size; firm consistence dry; not hydrophobic; *diffuse to:-*

43-215cm - sandy light clay; roots absent; no lime present; no manganese present; pH 7.5; gravel and stones absent; not mottled; not bleached; pale brown [10YR6/3] with yellowish brown tints dry, greyish brown [10YR5/2] moist; peds rough-faced, highly pedal [100%], polyhedral, <5-10mm in size; firm consistence dry; not hydrophobic

215+cm - layer 3 continues

Profile 12 [Pilliga Sandstone - crest location] *surface condition firm; some surface stone to 15cm, flat and angular*

0-20cm - sandy loam; many roots; no lime present; no manganese present; pH 5.0; some angular / flat and round gravel to 2cm; not mottled; not bleached; brown [10YR4/3] dry, very

dark brown [7.5YR2.5/2] moist; peds rough-faced, highly pedal [100%], polyhedral, 5-10mm in size; weak consistence dry; not hydrophobic; *abrupt to:-*

20-40cm - sandy clay loam; many roots; no lime present; no manganese present; pH 4.5; much angular gravel to 5cm; not mottled; not bleached; yellowish brown [10YR5/4] dry, dark brown [7.5YR3/4] moist; massive; fabric rough; not hydrophobic; *diffuse to:-*

40-65cm; broken rock, little if any soil - not sampled; many roots

Profile 13 [Purlawaugh Formation - upper slope location] *surface condition self mulching / cracked; some rounded surface stone present*

0-25cm - medium to heavy clay; many roots; no lime present; no manganese present; pH 7.5; occasional rounded gravel to 1cm; not mottled; not bleached; brown [10YR5/3] dry, dark greyish brown [10YR4/2] moist; peds rough- / smooth-faced , highly pedal [100%], polyhedral, <5-10mm in size; very strong consistence dry; not hydrophobic; *clear to:-*

25-89cm - medium clay; few roots; many lime nodules present; no manganese present; pH 9.0; sandstone floaters present; not mottled; not bleached; pale brown [10YR6/3] dry, brown [10YR5/3] moist; peds rough- smooth-faced, highly pedal [100%], polyhedral, <5-10mm in size; very strong consistence dry; not hydrophobic; *diffuse to:-*

89-259cm - medium clay; roots absent; no lime present; no manganese present; pH 5.0; gravel and stones absent; mottled; not bleached; 80% light brownish grey [10YR6/2], 20% brownish yellow [10YR6/6] dry, 80% brown [10YR5/3], 20% yellowish brown [10YR5/6] moist; peds smooth- faced, highly pedal [100%], polyhedral, <5-15mm in size; very strong consistence dry; not hydrophobic

Profile 14 [Purlawaugh Formation - drainage line location] *surface condition firm; surface stone absent*

0-32cm - medium clay; many roots; no lime present; no manganese present; pH 6.5; gravel and stones absent; not mottled; not bleached; reddish brown [5YR4/3] dry, dark reddish brown [2.5YR3/3] moist; peds rough- / smooth-faced , highly pedal [100%], polyhedral, <5-10mm in size; very strong consistence dry; not hydrophobic; *clear to:-*

32-90cm - clay loam; roots common; no lime present; no manganese present; pH 6.5; gravel and stones absent; not mottled; not bleached; dark reddish brown [5YR3/3] dry, dark reddish brown [5YR2.5/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-10mm in size; strong consistence dry; not hydrophobic; *clear to:-*

90-210cm - medium clay; few roots; no lime present; no manganese present; pH 7.5; gravel and stones absent; not mottled; not bleached; brown [7.5YR4/4] dry, brown [7.5YR4/4] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-15mm in size; very strong consistence dry; not hydrophobic

Profile 15 [Garrawilla Volcanics - floodplain location] *surface condition loose; surface stone absent*

0-46cm - light sandy clay loam; many roots; no lime present; no manganese present; pH 5.5; gravel and stones absent; not mottled; not bleached; dark yellowish brown [10YR4/4] dry, dark brown [7.5YR3/4] moist; peds vesicular, highly pedal [100%], polyhedral, 5-10mm in size; weak consistence dry; not hydrophobic; *clear to:-*

46-87cm - medium to heavy clay; few roots; no lime present; no manganese present; pH 7.0; gravel and stones absent; mottled; not bleached; 80% strong brown [7.5YR5/6], 20% yellowish brown [10YR5/4] dry, 80% strong brown [7.5YR5/6], 20% yellowish brown [10YR5/4] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-10mm in size; strong consistence dry; not hydrophobic; *diffuse to:-*

87-147cm - medium to heavy clay; few roots; no lime visible; no manganese present; pH 8.0; gravel and stones absent; mottled; not bleached; 90% greyish brown [10YR5/2], 10% yellowish brown [10YR5/4] dry, 90% greyish brown [10YR5/2], 10% dark yellowish brown [10YR4/4] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-10mm in size; strong consistence dry; not hydrophobic; *diffuse to:-*

147-230cm - gritty medium clay; roots absent; some large lime nodules present; no manganese present; pH 9.0; gravel and stones absent; not mottled; not bleached; brown [10YR5/3] dry, brown [10YR5/3] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-10mm in size; very strong consistence dry; not hydrophobic

Profile 16 [Purlawaugh Formation - level floodplain location] *surface condition loose; surface stone absent*

0-39cm - sandy clay loam; many roots; no lime present; no manganese present; pH 6.0; gravel and stones absent; not mottled; not bleached; brown [10YR4/3] dry, dark brown [7.5YR3/3] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-10mm in size; firm consistence dry; not hydrophobic; *clear to:-*

39-59cm - sandy clay loam; few roots; no lime present; no manganese present; pH 7.0; gravel and stones absent; not mottled; not bleached; brown [10YR4/3] dry, dark brown [7.5YR3/3] moist; peds vesicular, highly pedal [100%], polyhedral, 5-10mm in size; very strong consistence dry; not hydrophobic; *clear to:-*

59-87cm - sandy light clay; few roots; no lime visible; no manganese present; pH 8.0; gravel and stones absent; not mottled; not bleached; brown [7.5YR5/4] dry, strong brown [7.5YR4/4] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-10mm in size; strong consistence dry; not hydrophobic; *diffuse to:-*

87-170cm - light to medium clay; few roots; no lime visible; no manganese present; pH 8.0; gravel and stones absent; mottled; not bleached; 90% yellowish red [5YR5/6], 10% greyish brown [2.5Y5/2] dry, 90% yellowish red [5YR4/6], 10% greyish brown [2.5Y5/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-10mm in size; very strong consistence dry; not hydrophobic; *diffuse to:-*

170-255cm - light to medium clay; roots absent; some lime nodules and stains present; no manganese present; pH 9.0; occasional sandstone gravel to 4cm; not mottled; not bleached; light yellowish brown [2.5Y6/2] dry, light yellowish brown [2.5Y6/2] moist; peds rough-faced, highly pedal [100%], polyhedral, 5-10mm in size; very strong consistence dry; not hydrophobic

Profile 17 [Purlawaugh Formation - drainage line location] *surface condition firm; surface stone absent*

0-103cm - sand; many roots; no lime present; no manganese present; pH 7.0 to 7.5; gravel and stones absent; not mottled; not bleached; reddish brown [5YR5/4] dry, reddish brown [5YR4/3] moist; massive; fabric rough; not hydrophobic; *diffuse to:-*

130-200cm - medium to heavy clay; few roots; no lime visible; no manganese present; pH 9.0; gravel and stones absent; not mottled; not bleached; brown [10YR5/3] dry, brown [10YR5/3] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-15mm in size; very strong consistence dry; not hydrophobic; *diffuse to:-*

200-250cm - sandy medium to heavy clay; few roots; some lime flecks present; no manganese present; pH 9.0; gravel and stones absent; not mottled; not bleached; light yellowish brown [2.5Y6/3] dry, light brownish grey [2.5Y6/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-10mm in size; very strong consistence dry; not hydrophobic

Profile 18 [Garrawilla Volcanics – drainage line location] *surface condition firm; surface stone absent*

0-30cm - medium to heavy clay; many roots; no lime present; no manganese present; pH 6.5; gravel and stones absent; not mottled; not bleached; brown [7.5YR4/3] dry, very dark brown [7.5YR2.5/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-15mm in size; very strong consistence dry; not hydrophobic; *abrupt to:-*

30-69cm - gritty medium clay; roots common; no lime visible; no manganese present; pH 8.0; gravel and stones absent; not mottled; not bleached; red [2.5YR5/6] dry, reddish brown [2.5YR4/4] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-15mm in size; very strong consistence dry; not hydrophobic; *diffuse to:-*

69-97cm - medium to heavy clay; few roots; many lime nodules present; many manganese concretions present; pH 8.0; gravel and stones absent; mottled; not bleached; 80% brown [7.5YR5/3], 20% weak red [10R4/4] dry, 80% brown [10YR5/3], 20% reddish brown [5YR4/4 moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-15mm in size; very strong consistence dry; not hydrophobic; *diffuse to:-*

97-250cm - sandy medium to heavy clay; few roots; many lime nodules present; many manganese concretions present; pH 9.0; gravel and stones absent; not mottled; not bleached; greyish brown [10YR5/2] dry, greyish brown [10YR5/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-15mm in size; very strong consistence dry; not hydrophobic

Profile 19 [Purlawaugh Formation - midslope location] *surface condition firm; surface stone absent*

0-37cm - silty clay; many roots; no lime present; no manganese present; pH 6.0; gravel and stones absent; not mottled; not bleached; reddish brown [5YR4/3 dry, dark reddish brown [5YR3/3] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-15mm in size; very firm consistence dry; not hydrophobic; *abrupt to:-*

37-70cm - medium to heavy clay; many roots; no lime visible; no manganese present; pH 9.0; some rounded gravel to 5mm; not mottled; not bleached; dark brown [7.5YR3/4] dry, dark reddish brown [5YR3/3] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-10mm in size; very strong consistence dry; not hydrophobic; *clear to:-*

70-140cm - heavy clay; few roots; some large lime nodules present; no manganese present; pH 9.0; some rounded and angular gravel to 5mm; not mottled; not bleached; reddish brown [5YR4/3] dry, reddish brown [5YR4/4] moist; peds rough- smooth-faced, highly pedal [100%], polyhedral, <5-10mm in size; very strong consistence dry; not hydrophobic; *diffuse to:-*

140-270cm - light to medium clay; roots absent; some large lime nodules present; no manganese present; pH 9.0; gravel and stones absent; not mottled; not bleached; yellowish brown [10YR5/4] dry, yellowish brown [10YR5/4] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-15mm in size; very strong consistence dry; not hydrophobic

Profile 20 [Purlawaugh Formation – drainage line location] *surface condition firm; surface stone absent*

0-31cm - sandy light clay; roots common; no lime present; no manganese present; pH 6.5; some rounded and angular gravel to 5mm; not mottled; not bleached; brown [7.5YR4/3] dry, dark brown [7.5YR3/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-15mm in size; very strong consistence dry; not hydrophobic; *clear to:-*

31-92cm - sandy light to medium clay; roots common; no lime present; no manganese present; pH 6.5; gravel and stones absent; not mottled; not bleached; very dark greyish brown [10YR3/2] dry, very dark grey [10YR3/1] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-15mm in size; very strong consistence dry; not hydrophobic; *diffuse to:-*

92-262cm - medium to heavy clay; few roots; no lime present; no manganese present; pH 7.0; upper 40cm of horizon with rounded gravel to 4cm; not mottled; not bleached; greyish brown [2.5Y5/2] dry, light brownish grey [2.5Y6/2] moist; peds rough- smooth-faced, highly pedal [100%], polyhedral, 5-15mm in size; very strong consistence dry; not hydrophobic

Profile 21 - [Garrawilla Volcanics – upper slope location] *surface condition loose; some rounded / angular surface stone to 15cm present; floaters in upper layers 20-40cm in size; sometimes bedrock only 150cm below the surface*

0-36cm - heavy clay; many roots; no lime present; no manganese present; pH 6.0; some gravel to 1cm; not mottled; not bleached; dark brown [7.5YR3/3] dry, dark brown [7.5YR3/3] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-15mm in size; very strong consistence dry; not hydrophobic; *clear to:-*

36-97cm - medium to heavy clay; roots common; no lime present; no manganese present; pH 7.0; some gravel to 5mm; not mottled; not bleached; dark reddish brown [5YR2.5/5] dry, dark reddish brown [5YR2.5/5] moist; peds smooth-faced, highly pedal [100%], polyhedral, <5-20mm in size; very strong consistence dry; not hydrophobic; *diffuse to:-*

97-136cm - medium clay; few roots; lime flecks present; no manganese present; pH 8.0; gravel and stones absent; not mottled; not bleached; reddish brown [5YR3/3] dry, reddish brown [5YR3/3] moist; peds smooth-faced, highly pedal [100%], polyhedral/platy, <5-15mm in size; very strong consistence dry; not hydrophobic; *diffuse to:-*

136-210cm - light to medium clay; few roots; no lime visible; no manganese present; pH 8.5; much angular gravel to 3cm; mottled; not bleached; 80% reddish brown [5YR4/4], 20% yellowish brown [10YR5/8] dry, 80% reddish brown [5YR4/4], 20% dark yellowish brown [10YR4/6] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-10mm in size; very strong consistence dry; not hydrophobic

Profile 22 – [Purlawaugh Formation - floodplain location] *surface condition hard setting; surface stone absent*

0-28cm - fine sandy clay loam; many roots; no lime present; no manganese present; pH 6.5; some flattish stones 20cm x 20mm; not mottled; not bleached; brown [7.5YR5/3] dry, brown [7.5YR4/3] moist; peds rough-faced, highly pedal [100%], polyhedral, 5-10mm in size; very strong consistence dry; hydrophobic; *abrupt to:-*

28-86cm - medium clay; few roots; no lime visible; no manganese present; pH 8.0; gravel and stones absent; not mottled; not bleached; brown [7.5YR4/3] dry, dark brown [7.5YR3/4] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral/platy, 5-15mm in size; very strong consistence dry; not hydrophobic; *diffuse to:-*

86-180cm - gritty light to medium clay; few roots; lime nodules present; no manganese present; pH 9.0; some angular gravel to 1cm; not mottled; not bleached; brown [7.5YR4/3] dry, brown [7.5YR4/3] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-10mm in size; very strong consistence dry; not hydrophobic; *diffuse to:-*

180-250cm - light to medium clay; roots absent; no lime visible; no manganese present; pH 8.0; gravel and stones absent; mottled; not bleached; 50% dark greyish brown [10YR4/2], 50% brown 7.5YR5/4] dry, 50% brown [10YR5/3], 50% brown 7.5YR5/4] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral/platy, <5-15mm in size; very strong consistence dry; not hydrophobic

Profile 23 - [Purlawaugh Formation - drainage line location] *surface condition loose; surface stone absent*

0-40cm - clayey sand; many roots; no lime present; no manganese present; pH 6.0; gravel and stones absent; not mottled; not bleached; brown [7.5YR4/3] dry, very dark brown [7.5YR2.5/3] moist; peds rough-faced, poorly pedal [30%], polyhedral, <5-10mm in size; firm consistence dry; hydrophobic; *clear to:-*

40-150cm - sand; roots absent; no lime present; no manganese present; pH 6.5; gravel and stones absent; not mottled; not bleached; very pale brown [10YR7/3] dry, brown [10YR5/3] moist; massive; fabric rough; not hydrophobic; *abrupt to:-*

150-300cm - sandy medium clay; roots absent; some small lime nodules present; no manganese present; pH 9.5-10; some rounded gravel to 2cm; not mottled; not bleached; light grey [2.5Y7/2] dry, light grey [2.5Y7/2] moist; massive; fabric rough / smooth; not hydrophobic

Profile 24 [SMU] - [Purlawaugh Formation – drainage line location] *surface condition loose; surface stone absent*

0-27cm - clayey sand; many roots; no lime present; no manganese present; pH 5.0; some angular gravel to 5mm; not mottled; not bleached; reddish brown [5YR4/4] dry, reddish brown [5YR3/3] moist; peds rough-faced, moderately pedal [50%], polyhedral, 5-10mm in size; weak consistence dry; not hydrophobic; *abrupt to:-*

27-53cm - clayey sand; roots common; no lime present; no manganese present; pH 5.5; gravel and stones absent; not mottled; not bleached; yellowish red [5YR5/6] dry, yellowish red [5YR4/6] moist; peds rough-faced, poorly pedal [30%], polyhedral, <5-10 mm in size; firm consistence dry; not hydrophobic; *abrupt to:-*

53-127cm - sandy light to medium clay; roots common; no lime present; no manganese present; pH 6.0; some angular gravel to 5mm; not mottled; not bleached; red [2.5YR4/6] dry, red [2.5YR4/6] moist; peds rough-faced, highly pedal [100%], polyhedral, <5-10 mm in size; firm consistence dry; not hydrophobic

Profile 25 - [Purlawaugh Formation – drainage line location] *surface condition firm ; surface stone absent*

0-60cm - sand; few roots; no lime present; no manganese present; pH 6.5; gravel and stones absent; not mottled; not bleached; very pale brown [10YR7/3] dry, yellowish brown [10YR5/4] moist; massive; fabric rough; not hydrophobic; *abrupt to:-*

60-140cm - sandy clay loam; few roots; no lime present; no manganese present; pH 6.5; gravel and stones absent; not mottled; not bleached; brown [10YR4/2] dry, very dark greyish brown [10YR3/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, ,5-10mm in size; very firm consistence dry; not hydrophobic; *clear to:-*

140-270cm - clayey sand; roots absent; no lime present; no manganese present; pH 5.5; gravel and stones absent; not mottled; not bleached; brown [10YR5/3] dry, dark greyish brown [10YR4/2] moist; massive; fabric rough; not hydrophobic;

Profile 26 – [Purlawaugh Formation - midslope location] *surface condition self mulching / cracked; some angular surface stone <1cm and some flat sandstone to 15cm absent present*

0-30cm; light to medium clay; many roots; no lime present; no manganese present; pH 7.5; some rounded gravel to 2cm; not mottled; not bleached; very dark grey [10YR3/1] dry, very dark grey [10YR3/1] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-15mm in size; very strong consistence dry; not hydrophobic; *clear to:-*

30-107cm - heavy clay; few roots; many lime stains and nodules present; no manganese present; pH 8.0; some angular gravel to 4cm; not mottled; not bleached; very dark greyish brown [10YR3/2] dry, very dark greyish brown [10YR3/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-15mm in size; very strong consistence dry; not hydrophobic; *diffuse to:-*

107-154cm - heavy clay; roots absent; lime nodules present; no manganese present; pH 7.5; gravel and stones absent; not mottled; not bleached; dark brown [10YR3/3] dry, dark brown [7.5YR3/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-15mm in size; very strong consistence dry; not hydrophobic; *diffuse to:-*

154-204cm - light to medium clay; roots absent; no lime present; no manganese present; pH 4.5; gravel and stones absent; mottled; not bleached; 70% very pale brown [10YR8/2], 20% reddish yellow [5YR6/8, 10% brown [10YR5/3] dry, 70% light grey [2.5Y7/2], 20% yellowish red [5YR5/8], 10% brown [10YR5/3] moist; massive; fabric rough / smooth; not hydrophobic

Profile 27 - [Pilliga Sandstone - drainage line location] *surface condition loose; surface stone absent*

0-20cm - clayey sand; many roots; no lime present; no manganese present; pH 6.5; gravel and stones absent; not mottled; not bleached; brown [10YR5/3] dry, very dark greyish brown [10YR3/2] moist; massive; fabric rough / smooth; not hydrophobic; *abrupt to:-*

20-97cm - clayey sand; roots common; no lime present; no manganese present; pH 6.5; odd small gravel to 5mm; not mottled; not bleached; very pale brown [10YR7/4] dry, brown [7.5YR5/4] moist; massive; fabric rough; not hydrophobic; *abrupt to:-*

97-163cm - sandy light clay; few roots; no lime present; no manganese present; pH 6.5; gravel and stones absent; mottled; not bleached; 50% light yellowish brown [2.5Y6/3], 50% brownish yellow [10YR6/6] dry, 50% light yellowish brown [2.5Y6/3], 50% yellowish brown [10YR5/8] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-15 mm in size; very strong consistence dry; not hydrophobic; *diffuse to:-*

163-223+cm - sandy light to medium clay; roots absent; no lime present; some manganese stains present; pH 7.0; gravel and stones absent; not mottled; not bleached; yellowish brown [10YR5/4] dry, dark yellowish brown [10YR4/4] moist; peds rough-faced, highly pedal [100%], polyhedral, <5-10mm in size; very strong consistence dry; not hydrophobic

Profile 28 - [Pilliga Sandstone - upper slope location] *surface condition soft; surface stone absent*

0-15cm - clayey sand to sandy loam; many roots; no lime present; no manganese present; pH 4.5; occasional angular gravel to 5-10mm; not mottled; not bleached; brown [10YR4/3] dry, dark brown [7.5YR3/2] moist; peds rough-faced, moderately pedal [50%], polyhedral, 5-10mm in size; weak consistence dry; hydrophobic; *abrupt to:-*

15-47cm - sandy clay loam; many roots; no lime present; no manganese present; pH 4.5; occasional angular gravel to 5-10mm; not mottled; not bleached; strong brown [7.5YR5/6] dry, brown [7.5YR5/4] moist; massive; fabric rough; not hydrophobic; *abrupt to:-*

47-125cm - sandy clay; roots common; no lime present; no manganese present; pH 5.0; gravel and stones absent; not mottled; not bleached; reddish yellow [7.5YR6/8] dry, yellowish red [5YR4/6] moist; massive; fabric rough; not hydrophobic; *diffuse to:-*

125-180cm - sandy medium clay; few roots; no lime present; no manganese present; pH 6.0; gravel and stones absent; mottled; not bleached; 50% brownish yellow [10YR6/6], 50% yellow [10YR7/6] dry, 50% yellowish brown [10YR5/8], 50% yellowish brown [10YR5/6] moist; peds rough-faced, highly pedal [100%], polyhedral, <5-10mm in size; firm consistence dry; not hydrophobic

Profile 29 – [Pilliga Sandstone - lower slope location] *surface condition loose to firm; surface stone absent except where eroded*

0-23cm - clayey sand to sandy loam; many roots; no lime present; no manganese present; pH 5.5 to 6.0; gravel and stones absent; not mottled; not bleached; brown [10YR5/3] dry, dark brown [7.5YR3/2] moist; peds rough- / smooth-faced, moderately pedal [50%], polyhedral, 5-10mm in size; weak consistence dry; slightly hydrophobic; *abrupt to:-*

23-37cm - clayey sand to sandy loam; few roots; no lime present; no manganese present; pH 5.5 to 6.0; gravel to 2-3cm common; not mottled; bleached; pinkish white [7.5YR8/2] dry, brown [7.5YR5/3] moist; massive; fabric rough; not hydrophobic; *abrupt to:-*

37-110cm - heavy clay; few roots; no lime present; no manganese present; pH 4.5; some angular gravel to 3-4cm; mottled; not bleached; 95% light brownish grey [10YR6/2], 5% red [10R5/6] dry, 95% greyish brown [10YR5/2], 5% red [10R4/6] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-10mm in size; very strong consistence dry; not hydrophobic; *diffuse to:-*

110-220cm - medium to heavy clay; few roots; no lime present; no manganese present; pH 4.5; much angular gravel; not mottled; not bleached; greyish brown [10YR5/2] dry, dark greyish brown [10YR4/2] moist; peds smooth-faced, highly pedal [100%], polyhedral, <5-10mm in size; very strong consistence dry; not hydrophobic

Profile 30 - [Pilliga Sandstone - rocky crest location] *surface condition firm; much rounded / angular surface sandstone to 20cm present*

0-20cm - sandy light clay; many roots; no lime present; no manganese present; pH 5.5; much rounded and angular gravel and stones to 20cm; not mottled; not bleached; brown [7.5YR4/3] dry, dark brown [7.5YR3/2] moist; peds rough-faced, highly pedal [100%], polyhedral, 5-10mm in size; weak consistence dry; hydrophobic; *clear to:-*

20-68cm - sandy clay loam; many roots; no lime present; no manganese present; pH 5.5; much rounded and angular gravel and stones to 15cm; not mottled; not bleached; brown [7.5R5/4] dry, dark reddish brown [5YR3/3] moist; massive; fabric rough; not hydrophobic; *clear to:-*

68-90cm; clayey sand; roots common; no lime present; no manganese present; pH 6.0; much rounded and angular gravel and stones to 10cm; not mottled; not bleached; reddish brown [5YR5/4] dry, reddish brown [5YR4/4] moist; massive; fabric vesicular; not hydrophobic

Profile 31 - [Purlawaugh Formation- upper drainage line location] *surface condition firm; surface stone absent*

0-20cm - sandy light to medium clay; many roots; no lime present; no manganese present; pH 5.5; some rounded and flattish gravel to 1-2cm; not mottled; not bleached; strong brown [7.5YR4/6] dry, brown [7.5YR4/4] moist; peds rough-faced, highly pedal [100%], polyhedral, 5-15mm in size; weak consistence dry; not hydrophobic; *abrupt to:-*

20-46cm - sandy medium clay; roots common; no lime present; no manganese present; pH 5.5; some rounded gravel to 3cm and grit to 2mm; not mottled; not bleached; strong brown [7.5YR4/6] dry, strong brown [7.5YR4/6] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-10mm in size; very firm consistence dry; not hydrophobic; *abrupt to:-*

46-62cm - heavy clay; roots common; no lime present; no manganese present; pH 7.0; many flat stones to 8cm; not mottled; not bleached; brown [10YR5/3] with a strong brown [7.5YR5/8] tinge dry, brown [10YR5/3] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-10mm in size; very strong consistence dry; not hydrophobic

Profile 32 - [Pilliga Sandstone - midslope location] *surface condition soft to loose; surface stone absent*

0-37cm - slightly gritty light to medium clay; many roots; no lime present; no manganese present; pH 4.0; some gravel to 1cm; not mottled; not bleached; brown [7.5YR5/3] dry, dark brown [7.5YR3/2] moist; peds rough-faced, highly pedal [100%], polyhedral, 5-10mm in size; firm consistence dry; slightly hydrophobic; *clear to:-*

37-70cm - light to medium clay; roots common; no lime present; no manganese present; pH 4.5; some rounded and angular gravel to 2cm; not mottled; not bleached; light yellowish brown [10YR6/4]] dry, strong brown [7.5YR4/6] moist; peds rough-faced, highly pedal [100%], polyhedral, 5-10mm in size; strong consistence dry; not hydrophobic; *diffuse to:-*

70-113cm - sandy medium clay; roots common; no lime present; no manganese present; pH 6.0; some sandstone gravel to 3cm; not mottled; not bleached; very pale brown [10YR7/4] dry,

yellowish brown [10YR5/4] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5mm in size; firm consistence dry; not hydrophobic; *diffuse to:-*

113-223cm; bedrock; few roots;

Profile 33 - [Pilliga Sandstone - drainage line location] *surface condition loose to firm; surface stone absent*

0-30cm - light clay; many roots; no lime present; no manganese present; pH 5.5; gravel and stones absent; not mottled; not bleached; dark greyish brown [10YR4/2] dry, very dark brown [10YR2/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-10mm in size; weak consistence dry; hydrophobic; *clear to:-*

30-90cm - sandy clay loam; many roots; no lime present; no manganese present; pH 5.5; gravel and stones absent; not mottled; not bleached; dark greyish brown [10YR4/2] dry, very dark brown [10YR2/2] moist; peds vesicular, highly pedal [100%], polyhedral, <5-10mm in size; firm consistence dry; not hydrophobic; *abrupt to:-*

90-120cm - sand; few roots; no lime present; no manganese present; pH 5.5; gravel and stones absent; not mottled; not bleached; light brownish grey [10YR6/2] dry, brown [10YR5/3] moist; massive; fabric rough; not hydrophobic; *abrupt to:-*

120-170cm - sandy medium clay; few roots; no lime present; no manganese present; pH 5.0; gravel and stones absent; not mottled; not bleached; pale brown [10YR6/3] with darker brown tinge dry, greyish brown [10YR5/2] with darker brown tinge moist; massive; fabric rough; not hydrophobic

Profile 34 - [Pilliga Sandstone - crest location] *surface condition firm; much rounded gravel [to 2cm] and flat] surface stone [to 20cm] present*

0-21cm - clayey sand to sandy loam; many roots; no lime present; no manganese present; pH 5.5; many flat angular stones to 10cm; not mottled; not bleached; brown [7.5YR5/4] dry, dark brown [7.5YR3/4] moist; massive; fabric rough; not hydrophobic; *abrupt to:-*

21-63cm - sandy clay loam; many roots; no lime present; no manganese present; pH 5.0; some rounded waterwashed stones to 10cm and flat angular stones to 20cm plus some floaters; not mottled; not bleached; reddish yellow [5YR6/6] dry, red [2.5YR4/6] moist; massive; fabric rough; not hydrophobic; *clear to:-*

63-110cm - clayey sand; few roots; no lime present; no manganese present; pH 5.0; not mottled; not bleached; light brown [7.5YR6/4] with paler tinges dry, strong brown [7.5YR5/8] moist; massive; fabric rough; not hydrophobic; *gradual to:-*

110-134+ indurated sand; some tree roots

Profile 35 - [Purlawaugh - upper slope location] *surface condition firm; surface stone absent*

0-10cm - medium clay; many roots; no lime present; no manganese present; pH 7.0; large flat stones to 25-30cm plus some angular gravel to 2cm; not mottled; not bleached; brown [7.5YR3/3] dry, dark reddish brown [5YR3/2] moist; peds rough - faced, highly pedal [100%], polyhedral, <5-10mm in size; firm consistence dry; not hydrophobic; *abrupt to:-*

10-35cm - heavy clay; many roots; no lime present; no manganese present; pH 7.5; gravel and stones absent; not mottled; not bleached; reddish brown [5YR4/3] dry, reddish brown [5YR4/3] moist; peds smooth-faced, highly pedal [100%], polyhedral, 5-20mm in size; very strong consistence dry; not hydrophobic; *abrupt to:-*

35-60cm - heavy clay; few roots; many lime nodules and stains present; no manganese present; pH 9.0; gravel and stones absent; not mottled; not bleached; reddish brown [5YR4/3] dry, reddish brown [5YR4/3] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-15mm in size; very strong consistence dry; not hydrophobic; *clear to:-*

60-82cm - heavy clay; few roots; no lime visible; no manganese present; pH 9.0; much rounded and angular gravel to 10cm; not mottled; not bleached; pale yellow [2.5Y7/3] dry, pale yellow [2.5Y7/3] moist; massive; fabric rough / smooth; not hydrophobic; *clear to:-*

82-140cm - heavy clay; few roots; no lime present; no manganese present; pH 4.5; scattered rounded and angular gravel to 4cm; not mottled; not bleached; light grey [2.5Y7/2] dry, pale yellow [2.5Y8/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral / platy, 5-10mm in size; very strong consistence dry; not hydrophobic; *diffuse to:-*

140-260cm - heavy clay; few roots; no lime present; no manganese present; pH 4.5; scattered rounded and angular gravel to 4cm; mottled; not bleached; 50% red [2.5YR6/6], 50% very pale brown [10YR7/4] dry, 50% red [2.5YR5/8], 50% pale yellow [2.5Y7/3] moist; peds smooth-faced, highly pedal [100%], polyhedral, <5-10mm in size; very strong consistence dry; not hydrophobic

Profile 36 [SMU] - [Purlawaugh - upper drainage line location] *surface condition firm; surface stone absent*

0-22cm - light to medium clay; many roots; no lime present; no manganese present; pH 6.5; gravel and stones absent; not mottled; not bleached; brown [7.5YR4/3] dry, dark brown [7.5YR3/2] moist; peds rough-faced, highly pedal [100%], polyhedral, 5-15mm in size; very strong consistence dry; not hydrophobic; *abrupt to:-*

22-42cm - medium clay; many roots; no lime present; no manganese present; pH 7.0; some flat gravel to 2cm x 5mm; not mottled; not bleached; dark reddish brown [5YR3/3] dry, dark reddish brown [5YR3/2] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, 5-15mm in size; very strong consistence dry; not hydrophobic; *abrupt to:-*

42-66cm - heavy clay; roots common; many lime stains and small nodules present; no manganese present; pH 8,5; many large flattened stones to 15 cm; not mottled; not bleached; brown [7.5YR4/3] dry, dark brown [7.5YR3/4] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-10mm in size; very strong consistence dry; not hydrophobic; *abrupt to:-*

66-94cm - gritty medium to heavy clay; few roots; no lime visible; no manganese present; pH 8.5; some angular gravel to 3cm; not mottled; not bleached; yellowish brown [10YR5/4] dry, dark yellowish brown [10YR4/4] moist; peds rough- / smooth-faced, highly pedal [100%], polyhedral, <5-10mm in size; very strong consistence dry; not hydrophobic; *diffuse to:-*

94-222cm - heavy clay; few roots; no lime visible; no manganese present; pH 9.5-10; decomposing rock present; mottled; not bleached; 50% reddish yellow [7.5YR6/6], 50% light yellowish brown [2.5Y6/3] dry, 50% reddish yellow [10YR6/6], 50% light yellowish brown [2.5Y6/3] moist; peds smooth-faced, highly pedal [100%], polyhedral/platy, <5-10mm in size; very strong consistence dry; not hydrophobic

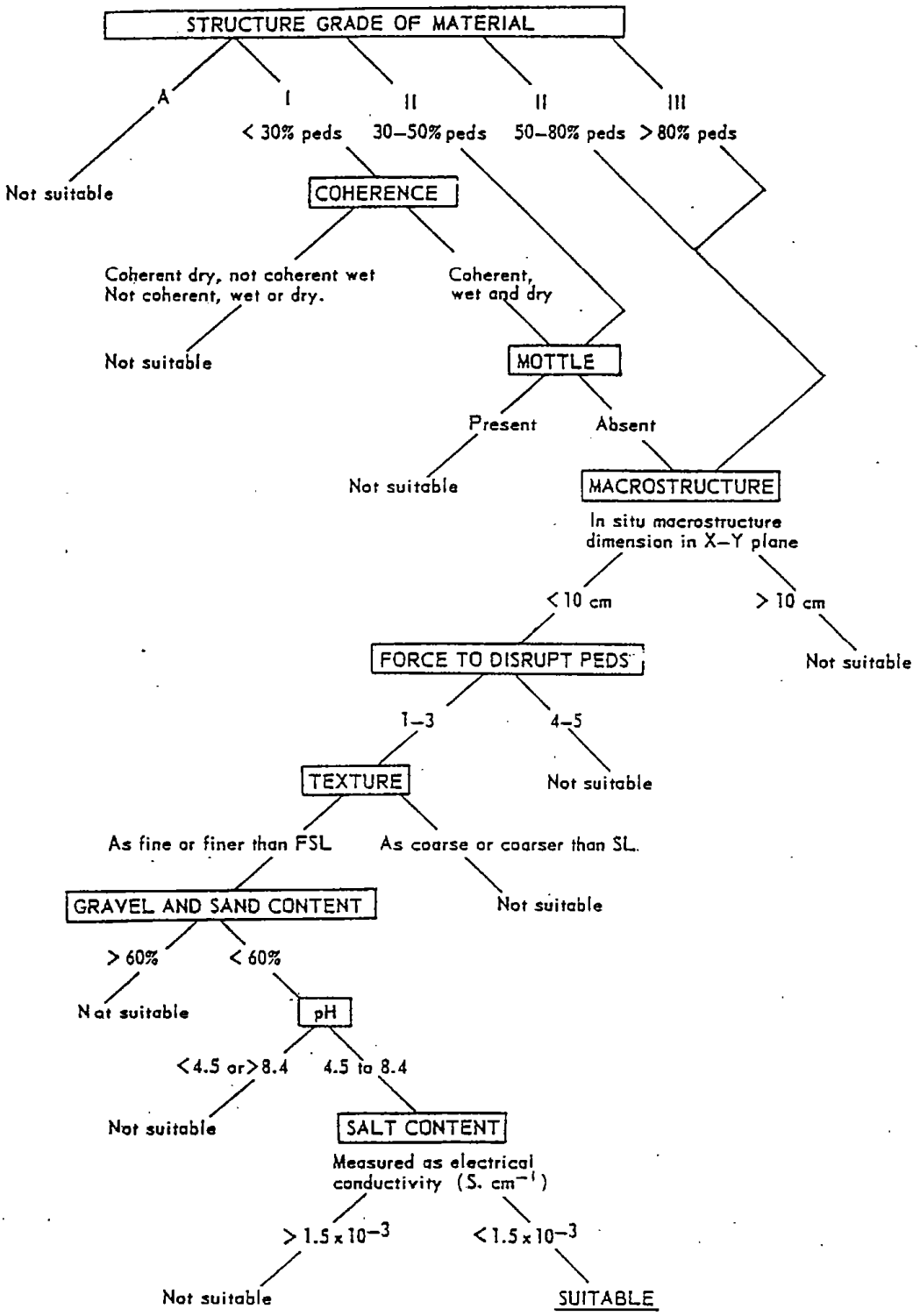
Appendix 2

Topsoil Stripping Suitability Key [after Elliott and Veness, 1981]

(No. of pages excluding this page = 1)

This page has intentionally been left blank

Procedure for the selection of material for use in topdressing of disturbed areas.



This page has intentionally been left blank