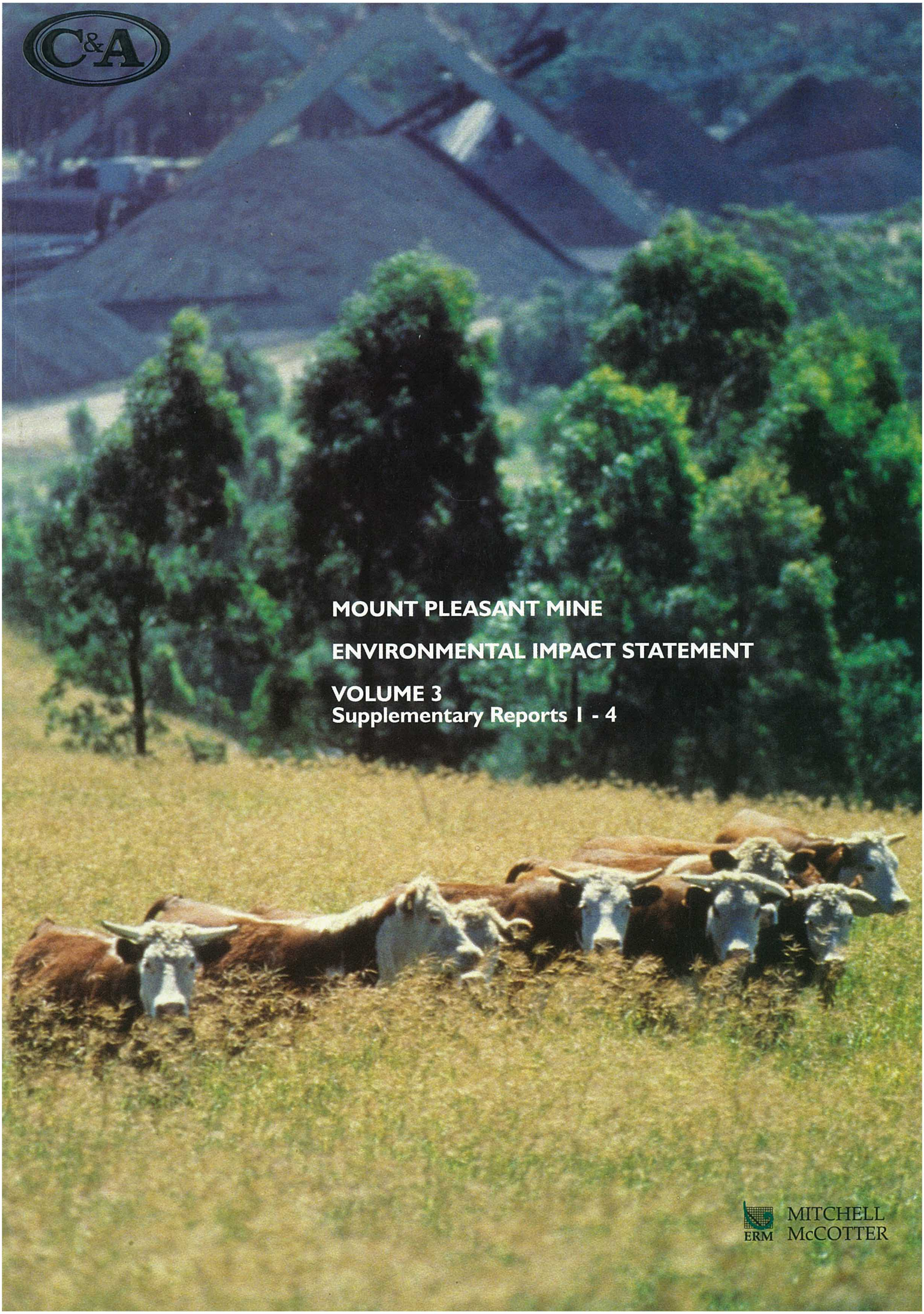
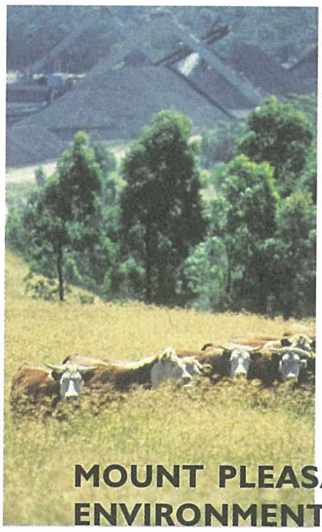


MOUNT PLEASANT MINE

ENVIRONMENTAL IMPACT STATEMENT

VOLUME 3
Supplementary Reports 1 - 4

ERM MITCHELL McCOTTER



MOUNT PLEASANT MINE
ENVIRONMENTAL IMPACT STATEMENT
For
COAL & ALLIED OPERATIONS Pty Ltd

94019
September, 1997

VOLUME 3 OF 4 - ISBN 0959292241

SET OF 4 VOLUMES ISBN 0959292268

Report No. 94019

Approved by: *Robert McCotter*
Position: Project Director
Signed:
Date: *5 September, 1997*

ERM Mitchell McCotter Quality System

Prepared by: *Stephen Hafer*
Position: Project Manager
Signed:
Date: *5 September, 1997*

VOLUME 3

Supplementary
Report No.

1

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

DEPARTMENT OF MINERAL RESOURCES
NEW SOUTH WALES

MINERAL RESOURCES DEVELOPMENT LABORATORY

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

(TO ACCOMPANY REPORT No R951201B)

By R. Mountford, C. Wall

12 January 1995

Report No: R951201A

Mineral Resources Development Laboratory
PO Box 76, Lidcombe NSW 2141

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE OF CONTENTS

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

1.0 INTRODUCTION

Open-cut or surface mining of coal is used extensively in the Upper Hunter Valley and involves the removal of overlying strata or overburden to facilitate the winning of coal. A characteristic of open cut coal mining is the disturbance of the stratigraphic relationship of strata due to their removal and replacement during mining. In most operations the original stratigraphic sequence is inverted and mixed, and forms overburden dumps. These dumps contain large quantities of unweathered, fragmented rock which are exposed to the weathering environment. Should water and air penetrate the dump, soluble salts may be leached and unstable minerals may break down releasing degradation products. Three chemical conditions may arise from overburden exposure and weathering, and result in environmental degradation. These are;

- high salinity
- sodicity and
- acidity

Each of these conditions may result in in-situ effects relating to the long term viability of rehabilitation of spoil heaps and/or effects at a distance as pollutants are carried off-site in ground and surface waters.

The assessment has been carried out using methods which characterise geological material with respect to acid producing potential, salinity producing potential and sodicity. In any mining venture, characterisation of possible waste rock types allows effective planning of mine waste management to be carried out at the mine planning stage.

For any mining operation, the long term environmental objectives of waste management plans associated with overburden dumps are:

- To ensure a high quality of waters draining from disturbed areas and,
- To successfully establish a self-sustaining vegetation cover.

Before a rehabilitation programme can be developed to optimise water quality and to produce an adequate vegetation cover, the characteristics of the material comprising the overburden dump material need to be understood. Characterisation of possible waste rock types with respect to acid producing potential allows effective planning of mine waste management to be carried out at the mine planning stage.

Miller and Murray (1988) state the objectives in carrying out acid-base analysis are to;

1. Determine the acid-forming characteristics of waste rock, ore and processing wastes;
2. Classify waste rock types with respect to the potential for acid generation;
3. Determine the impact on the quality of drainage from the mine and waste dumps; and
4. Provide design and management criteria for waste disposal, pollution control and rehabilitation.

Coal and Allied Operations Pty Ltd are currently exploring Coal Authorisation Area 459 near Singleton in the Hunter Valley in New South Wales. Sixty two samples representing the dominant lithology types which will report as waste rock in any future mining operation have been submitted to the Mineral Resources Development Laboratory for characterisation.

2.0 METHOD

The results of waste rock analysis, leachate and weathering tests are presented in the attached report (report number **R951201B**).

The samples were received as drill bore core segments. Table A-1 in the attached report R951201B gives laboratory registration numbers and corresponding drill core depths along with the description of each sample. Each sample was jaw crushed using a Braun Chipmunk Jaw Crusher and then reduced to less than 2mm diameter using a Bico Plate Pulverizer. This sample was used for water leaching and weathering tests. A subsample (30 g), taken from the less than 2mm material, was finely crushed to less than 100 micron using a chrome-steel ring grinder. This sample was used for the determination of sulphur, carbonate carbon, and total carbon.

Total sulphur was determined using Australian Standard Method AS1038 Part 6.3.3, utilising a Leco Model SC32 Automatic Sulphur Determinator. This method determines total sulphur and does not distinguish between sulphate and pyritic species. Total carbon was determined using a Leco Model WR12 Automatic Total Carbon Determinator. Total carbon concentration values were converted to equivalent carbon dioxide values. Because the samples were rocks from a coal rich area, it was not assumed that all carbon could be associated with carbonate mineralisation. Therefore carbonate carbon was also determined, also using the Leco Model WR12 Automatic Total Carbon Determinator. This was done by treating a subsample of rock sample with 1:1 hydrochloric acid, drying, then measuring the total carbon content. The difference in the carbon values represented the amount of organic carbon present in the original sample. This value was used in the NAPP (Net Acid Producing Potential) calculations. Results of analysis are given in Table A-1 in the attached report R951201B.

For the leach tests, electrical conductivity, pH, sulphate & chloride concentrations, cation concentrations, equivalent bicarbonate and alkalinity values were determined in a water extract of each sample (1 : 5; 20g : 100mL water) using the minus 2mm sample which was gently turned end on end for 16 hours. The samples were exposed to air several times during the determination to ensure oxygen was available for sulphide oxidation. The results for these tests are given in Table B - 1 in the attached report R951201B.

Several techniques have been used for the simulated weathering procedure used to characterise mine wastes. The method used in this study was a simple procedure where 20g of minus 2mm sample was well mixed with 15mL of water in a 120mL plastic screw-cap vial and placed in a forced air oven kept at a temperature of 40°. The vials were slowly evaporated and each sample was stirred with a glass rod every day, with 15 mL or more water added when necessary to keep the samples always moist and covered with water. The temperature of 40° was chosen because this temperature is close to the maximum that any waste rock will experience at the mine site and also any oxidation and solution reactions will be accelerated and the effects can be measured.

After periods of 5, 10, 15, 20 and 30 days, 100 mL water was added to each sample and the vial was gently agitated for an hour. The vials were centrifuged and the leachate was carefully decanted from the vial. Electrical conductivity, pH, and sulphate and chloride concentrations, cations (Calcium, Magnesium, and Sodium), and equivalent bicarbonate and alkalinity values were determined in this solution. The sample was covered with water (about 15mL) and the weathering procedure was continued. The pH, electrical conductivity, sulphate and chloride concentration and equivalent bicarbonate and alkalinity values found in the 1:5 soil:water extract solutions during the weathering tests are reported in the sections B and D of the attached report R951201B. The values for calcium, sodium, and magnesium are reported in sections C and E of the attached report R951201B.

Testing on all but ten samples was discontinued after 20 days weathering. For the remaining samples weathering was continued for 30 days. The sulphate values had dropped to around 10 mg/L and below for the majority of the samples. This value represents a release of less than about 0.01% of soluble salt species from the solid sample.

Electrical conductivity and pH measurement methods were based on:

- APHA Methods
- Australian Standard AS2300.1.6-1989, Methods for Chemical Testing for the Dairying Industry. Method 1.6: General methods and principles - Determination of pH.
- Standard Methods for Examination of Water and Wastewater, 18th Edition 1992, Part 2510B Electrical Conductivity.
  Part 4500-H + -B pH value Electrometric method

These measurements were made using a Metrohm 712 Conductometer and Radiometer PHM 95 pH/ion meter respectively. Each instrument was equipped with automatic temperature correction.

Major cations were determined using Flame Atomic Absorption Spectroscopy based on the following methods:

- AS 2134.1-1988 Recommended Practice for Chemical Analysis By Atomic Absorption Spectroscopy. Part 1 Flame AAS.
- Standard Methods for Examination of Water and Wastewater, 18th Edition 1992, Part 3000

Bicarbonate and Alkalinity values were determined using a Metrohm E636 Titroprocessor based on the following methods:

- Australian Standard AS2449-1981, Determination of Alkalinity, Acidity - Titration.
- Standard Methods for Examination of Water and Wastewater, 18th Edition 1992, Alkalinity Titration method.

Sulphate and Chloride values were determined on a Waters Chromatographic system based on the following methods:

- Australian Standard AS3741-1990, Recommended Practice for Chemical Analysis By Ion Chromatography.
- Standard Methods: Determination of Anions by Ion Chromatography, 4110C Single Column Ion Chromatography with Electronic Suppression of Eluent Conductivity and Conductrimetric Detection (proposed).

2.1 DISCUSSION OF METHODS

Two procedures are commonly used to predict the acid producing potential of mine waste samples, viz. acid - base accounting and weathering tests. Sobek et alia (1978) have reported extensive procedures for evaluating the potential of coal mining overburden and reject materials for acid generation. These procedures have since been used for assessment of wastes from base metal and precious metal mining operations.

With the acid-base accounting method, samples are analysed for neutralisation potential and sulphur content, and comparison of these values allows predictions to be made on whether acidic or alkaline drainage conditions are likely to develop.

When all sulphur is present as pyritic minerals, the total sulphur content will accurately quantify the potential acidity of materials. Using the stoichiometric equation for pyrite oxidation, the maximum potential acidity (APP or Acid Producing Potential) can be calculated in terms of calcium carbonate equivalent. The neutralisation potential of overburden materials (ANC or Acid Neutralising Capacity), the second component of a net acid-base account, measures the content of neutralising species present. Carbonates are the most commonly encountered neutralising species, however exchangeable bases, weatherable silicates and iron oxides can also be significant (Sobek *et al.* 1978).

Using the acid-base account, Sobek *et al.* (1978) have defined potentially toxic material as any overburden having a net potential deficiency of 0.5% calcium carbonate equivalent. Regardless of the acid-base account, materials which have a pH of less than 4.0 in a water slurry are defined as being acid-toxic.

In the case of weathered samples or samples containing gypsum (calcium sulphate, a commonly occurring mineral), sulphur occurs in the form of sulphates, and in samples containing significant amounts of organic material, organic sulphur is encountered. Sulphate sulphur and organic sulphur are not acid forming species, and for those samples where part of the total sulphur content occurs in these forms, the maximum potential acidity as calculated will be too high. It is for this reason that the calculations are referred to as maximum potential acidity (Sobek *et al.* 1978).

The acid-base accounting method is preferred by most assessment studies because it has significant cost advantage over weathering tests. It has been recognised, however, that the method suffers several important limitations (Hedlin and Erikson, 1988, Smith et alia, 1974 and Carrucio and Parizek, 1969). The limitations include problems with the determination of sulphur species and the interference of siderite in the determination of neutralisation potential. For these reasons it has been suggested that, at least for some samples, a better approach is to use the simulated weathering tests where samples are artificially weathered for an appropriate period and regularly collected leachates are monitored (Hedlin and Erikson, 1988).

Some samples contain insignificant amounts of sulphur and neutralising species and these present no problem regarding the potential for acid drainage production. In those cases where the test material is dominated by either acidic or basic materials, errors introduced by the acid-base procedure are not important. With samples that are roughly balanced with respect to acidic and basic materials, the errors of the acid-base accounting method may be unacceptable and weathering tests are generally required in these cases (Hedlin and Erikson, 1988).

Bradham and Caruccio (1990) have compared methods for acid leachate prediction in mining waste material. The methods were acid/base accounting, weathering cells, columns and soxhlets. When compared to observed field drainage quality emanating from areas from where the mine waste originated, the predictions made by the weathering cells were the most accurate (100% success). The weathering tests used in this study used weathering cells similar to those used by Bradham and Caruccio.

The "fine earth", or soil material passing the 2mm round hole sieve has generally been used by soil scientists for testing purposes (Jackson, 1958) and weathering tests have generally been carried out using this size fraction (Sobek, 1978, Miller and Murray, 1988).

Waste material from mining operations is reported to range up to a maximum diameter of approximately 45 cm for underground mines and 120 cm for open pits (Lapakko, 1988). Since simulated weathering tests are carried out on much smaller sized material (generally less than 2mm), the results obtained from the simulated weathering tests can be expected to be conservative values because of the greater surface area exposed under these test conditions. Because of the large size variation of material found in waste rock dumps, great difficulties are generally encountered in adequately sampling such dumps. This was not the case with samples used in this report since they were sampled from bore cores.

3.0 DISCUSSION OF RESULTS

3.1 ACIDITY

The pH of a 1:5 soil:water extract will give an indication of the presence and activity of acid producing material. A low pH indicates that pyrite oxidation has occurred. When pyrite is oxidised on exposure to the weathering environment, sulphuric acid is produced (which causes the acidity) and may in turn attack other minerals releasing environmentally hazardous species. In the discussion below the pH results have been related to the total sulphur results because total sulphur analysis of raw samples provides a rapid method of establishing the possibility of material being acid-producing (SPCC 1983).

The pH of an extract is used in weathering tests to support the Net Acid Producing Potential (NAPP) classifications. The NAPP, also known as the acid-base account, is calculated from the total sulphur content and the inherent Acid Neutralising Capacity (ANC) of a material. ANC is calculated as:

$$\text{ANC} = \text{total carbon } (\%CO_2) \times 2.27$$

NAPP is defined as follows:

$$\text{NAPP} = \%S \times 3.125 - \text{ANC}$$

Where, ANC and NAPP are in % $CaCO_3$ equivalents.

A positive NAPP indicates that the material is acid or potentially acid forming and a negative NAPP indicates that there is excess neutralising capacity and that the material is non-acid forming (Miller and Murray, 1988).

Soil pH is a measure of the acidity or alkalinity of the soil. A soil is referred to as being:

- acidic if the pH is less than 6.5
- neutral if the pH is between 6.5 and 8.0
- alkaline if the pH is greater than 8.0

(Charman and Murphy, 1991).

Soil pH levels generally fall between 4.0 and 9.0 with extreme figures being rare. When the pH is less than about 5.5 appreciable amounts of Aluminium, Manganese and Iron are soluble and may become toxic to vegetation, whereas trace elements such as Copper and Zinc may become limited at pH levels of greater than 7 (SPCC, 1983).

Most plants thrive best at a pH values between 6.0 and 7.5. Different plants have different tolerances to acidity or alkalinity. If soil pH is lower than 5.5 in a 1:5 soil:water extract, an acid soils problem can be suspected (Charman and Murphy, 1991).

3.1.1 Acid Producing Samples

Leaching tests (16 hour 1:5 soil:water extracts using <2mm size sample) have shown that only six of the 62 samples tested had acidic leachates(pH 2.75 - 4.80) indicating an initial acidic response. These samples continued to give an acidic response (pH 3.00-4.75) over the 30 days of simulated weathering.

The six samples identified as giving an acidic response were:

ACID PRODUCING SAMPLES

MRDL LAB. NUMBER	DRILL DEPTH		SEAM OVERBURDEN	pH (16 Hr)	pH (30 days)	NAPP
	FROM	TO				
HOLE NAME : 5000C000						
E94/1436	133.400	133.700	WYNN EF MIDBURDEN	4.20	4.20	3.6
E94/1437	134.900	135.200	WYNN EF INTERBURDEN	4.80	4.20	3.8
HOLE NAME : 6000C000						
E94/1450	44.800	45.300	WYNN EF MIDBURDEN	2.75	3.70	1.7
E94/1451	47.800	48.300	WYNN EF MIDBURDEN	3.65	3.50	4.1
HOLE NAME : 6000D000						
E94/1459	90.000	90.500	WYNN EF MIDBURDEN	3.20	3.60	4.1
E94/1460	92.800	93.200	WYNN I MIDBURDEN	3.40	4.20	2.7

These six samples were the only samples that were found to have a NAPP value greater than zero. These samples had high total sulphur contents (>0.5%) and with NAPP values greater than zero, they can be classified as acid forming or potentially acid forming (Miller and Murray, 1988).

The sulphate and pH results over the period of the weathering test indicated that most of this total sulphur is present as pyritic sulphides and that they are readily oxidised. Oxidisation of pyritic sulphides produces acidic leachates and sulphates. The weathering test results showed that the concentration of sulphate in the 1:5 soil:water extracts remained high over the 30 day period. The pH of the 1:5 soil:water extract over the same period remained low. This indicates that over the entire period of the weathering test pyritic sulphides were continuously oxidising and releasing sulphates and acidic leachates. Towards the end of the weathering tests, sulphate concentrations were generally increasing. Hence, the pH and sulphate results from the weathering tests of the six acid producing samples indicate that there would be a long term acidity problem caused by oxidation of pyritic sulphides.

The pH, sulphate, total sulphur and NAPP values from the leachate and weathering tests for the six samples in the table above, indicate that there may be potential for the material represented by these samples to generate acidic leachate. This should be taken into consideration for the design of the waste rock emplacement.

3.1.2 Slightly Acidic Sample

The 1:5 soil:water extract (16 hours) of sample E94/1428 gave a slightly acidic leachate (pH 6.30).

SLIGHTLY ACIDIC SAMPLE

MRDL LAB. NUMBER	DRILL DEPTH		SEAM OVERBURDEN	pH (16 Hr)	pH (30 days)	NAPP
	FROM	TO				
HOLE NAME : 5000A500						
E94/1428	110.000	110.500	WYNN EF MIDBURDEN	6.30	7.90	-13.4

Over the simulated weathering period of 30 days, the pH of the 1:5 soil:water extract went from neutral to alkaline. Results for the concentration of sulphates in the 1:5 soil:water extract over the weathering period showed that sulphates were leached out over the entire period. This sample also had a high total sulphur content (1.41%). The sample was found to have a high neutralising potential (7.85% carbonate carbon) which produced an alkaline 1:5 soil:water extract over the extended weathering period (30 days).

Because of the initial low pH of sample E94/1428, its high total sulphur percentage and high sulphate ion concentration (which remained high on weathering) it would initially produce an acidic leachate.

The pH, sulphate and total sulphur results for the leachate and weathering tests, for sample E94/1428, indicate that the material represented by this sample there may potentially generate some acidic leachate. Therefore this material should take into consideration in the design of the waste rock emplacement.

The six acid producing samples and E94/1428 will be referred to in this report as the "acid producing samples".

3.1.3 Non-Acid Producing Samples

The pH of the 1:5 soil:water extract, after 16 hours leaching, of the remaining 55 samples (ie. other than the seven acid producing samples) were alkaline. The pH ranged from 8.00 to 10.30. The 1:5 soil:water extracts of these samples after 20 days of simulated weathering had a pH range of 8.55 to 10.25. This indicated that they continued to produce alkaline leachates with extended weathering.

Therefore, from the pH results all of the samples (except for the acid producing samples) showed no acidic response over the entire period of testing. This was reflected in the NAPP values of these samples which were all less than zero, meaning that they were non-acid forming (Miller and Murray, 1988).

3.2 SULPHATE

The major anion in the 1:5 soil:water extracts was found to be sulphate.

According to Charman and Murphy 1991, the "toxicity symptom limit" of sulphate is 3meq/100g water soluble sulphate in a 1:5 soil:water extract (which is equivalent to 6meq/L or 300mg/L for a 20g:100mL 1:5 soil:water extract as used in this study). At this concentration of sulphate, plant growth will be retarded (Charman and Murphy 1991).

3.2.1 Non-Sulphate Toxic Samples

All 55 of the non-acid response samples were found to have sulphate concentrations, in their 1:5 soil:water extracts, below the "toxicity symptom limit" of 6 meq/L, after 10 days of weathering. Therefore all of the non-acid response samples had no sulphate toxicity on weathering. The exception was sample E94/1449.

3.2.2 Sulphate Toxic Samples

The samples with sulphate concentrations of their 1:5 soil:water extracts greater than the toxicity symptom limit after 10 days of weathering, are the seven acid producing samples and E94/1449. It is notable that sample E94/1449 is a rock sample from the WYNN EF MIDBURDEN seam, as are some of the acid-producing samples.

The results of sulphate analysis for the leaching and weathering tests indicate that the material represented by the seven acid producing samples and E94/1449 may have the potential to generate leachate with levels of sulphate ions that are above the desirable level for plant growth (Charman and Murphy). This should be taken into consideration when designing the waste rock emplacement.

3.3 SODICITY

Sodium, potassium, calcium and magnesium constitute the major cations in soil:water extracts from non-acidic coal mine spoil. The concentrations of these cations provide information on;

- the quality of leachate which may drain from the spoil after contact with water, and;
- the suitability of the spoil as a plant-growing medium.

The relative proportions of the cations in the extract are indicative of cation concentrations adsorbed on the exchange complex (silt clay and organic particles), since the adsorbed ions are in equilibrium with the ions in solution. A high level of sodium ions in spoil is of particular concern. The condition where a relatively high proportion of readily soluble sodium is present in spoil is referred to as sodicity. Sodicity leads to clay material being highly dispersed. Overburden containing dispersive clays become puddled and impermeable when wet, and dry to a hard surface. On the other hand, clays contained in spoil with a relatively low proportion of readily available sodium flocculate easily and are more permeable and less prone to erosion.

Sodium Adsorption Ratio (SAR)

The sodicity of the samples was determined by calculating the Sodium Adsorption Ratio (SAR) and then using the relationship between SAR values and sodicity to interpret the SAR values.

The SAR value of an extract is calculated from the concentration of cations in the extract using the equation below (Rayment and Higginson, 1992):

$$SAR = Na^{+} / \sqrt{(Ca^{2+} + Mg^{2+}) / 2}$$

Where Na^{+} , Ca^{2+} and Mg^{2+} are concentrations of the respective ions, expressed as meq/L

The relationship between SAR values and sodicity used by Croft and Associates 1986 (cited in Envirosciences Pty.Ltd 1993) is given below:

SAR<5 - favourable for maintaining soil structures and for avoiding sodium toxicity problems.
SAR 5-15 - unfavourable
SAR > 15 - a serious sodic problem could result if the material is exposed to the surface.

3.3.1 Highly Sodic Samples

The 16 hour 1:5 soil:water leachate of seven samples were found to be highly sodic (SAR > 15). These samples also produced leachates with high sodium ion concentrations (relative to the other cations Magnesium and Calcium). These samples were:

HIGHLY SODIC SAMPLES

MRDL LAB. NUMBER	DRILL DEPTH		SEAM OVERBURDEN	Na (me/L) 16 Hour	SAR		
	FROM	TO			16 Hour	10 Day	20 Day
HOLE NAME : 4000C000							
E94/1405	60.540	60.890	MTA A INTERBURDEN	9.39	23.5	7.9	2.7
HOLE NAME : 4000F000							
E94/1412	60.500	60.800	MTA MIDBURDEN	35.8	23.1	8.0	2.5
E94/1414	74.000	74.400	MTA MIDBURDEN	62.7	42.1	6.3	5.2
E94/1415	90.500	90.827	PFD A MIDBURDEN	23.7	22.3	26.2	6.3
E94/1417	110.000	110.400	PFD A MIDBURDEN	25.7	20.5	-	7.7
E94/1418	134.000	134.500	PFD C MIDBURDEN	18.7	15.6	18.5	4.7
HOLE NAME : 5000C000							
E94/1433	90.000	90.500	BRN A MIDBURDEN	9.78	19.1	8.5	2.7

The above seven samples had a 16 hour 1:5 soil:water extract with an SAR greater than 15. They all had 1:5 soil:water extracts which were "unfavourable" (SAR 6.3-26.2) after 10 days of weathering, and some were "unfavourable" (SAR>5) even after 20 days of weathering.

The toxicity limit of sodium for vegetative growth is 4.34meq/100g (Charman and Murphy, 1991) this is equivalent to 8.68meq/L or 200mg/L for a 20g sample in 100mL water, as used in this study. All of the above seven samples that have been identified as being highly sodic, also have high concentrations of sodium (>8.68meq/L) in their 1:5 soil:water extracts after 16 hours. Even after 20 days of weathering six of the seven samples still have concentrations of sodium that are above 8.68meq/L. The sodium results for these samples support the SAR values.

3.3.2 Slightly Sodic Samples

A further six samples exhibited "unfavourable" sodicity (SAR > 9) and relatively high sodium concentrations (7.52 - 12.2 meq/L) during the leach tests (16 hour 1:5 extracts). These six samples are presented in the table below.

SLIGHTLY / HIGHLY SODIC SAMPLES

MRDL LAB. NUMBER	DRILL DEPTH		SEAM OVERBURDEN	Na (me/L) 16 Hour	SAR		
	FROM	TO			16 Hour	10 Day	20 Day
HOLE NAME : 4000C000							
E94/1404	52.200	52.500	MTA A INTERBURDEN	10.9	9.2	12.5	3.8
HOLE NAME : 4000C000							
E94/1407	88.200	88.500	PFD A INTERBURDEN	13.4	12.1	13.3	6.5
E94/1408	104.000	104.500	VAUX A INTERBURDEN	7.52	9.2	5.5	1.6
HOLE NAME : 4000F000							
E94/1413	68.500	68.800	MTA MIDBURDEN	17.4	14.6	7.6	2.2
E94/1416	99.000	99.400	PFD A MIDBURDEN	12.2	11.7	18.5	6.9
E94/1419	162.000	162.500	PFD C MIDBURDEN	9.57	9.4	8.9	3.4

3.3.3 Sodicity on weathering

The samples identified in 3.3.1 and 3.3.2 as being unfavourably to highly sodic, continued to have an unfavourable to high sodicity after 10-20 days of extended weathering. The SAR values and sodium concentrations on weathering for the unfavourably sodic samples are summarised in the table below.

SAMPLES WITH UNFAVOURABLE SODICITY ON WEATHERING

MRDL LAB NUMBER	16 Hour		5 Day		10 Day		15 Day		20 Day	
	SAR	Na (me/L)	SAR	Na (me/L)	SAR	Na (me/L)	SAR	Na (me/L)	SAR	Na (me/L)
HOLE NAME : 4000C000										
E94/1404	9.2	10.87	5.9	7.83	12.5	3.83	6.8	2.43	3.8	1.22
E94/1405	23.5	9.39	14.3	4.48	7.9	2.48		1.13	2.7	0.78
E94/1406	15.0	14.72	7.2	7.00	13.9	4.96	7.6	2.78	6.0	2.13
E94/1407	12.1	13.35	7.4	7.26	13.3	4.52	9.8	3.00	6.5	1.70
E94/1408	9.2	7.52	6.1	4.83	5.5	2.22	2.1	0.78	1.6	.57
HOLE NAME : 4000F000										
E94/1412	23.1	35.83	21.2	29.43	8.0	3.78	3.0	1.83	2.5	1.17
E94/1413	14.6	17.39	8.8	10.91	7.6	3.09	2.9	1.30	2.2	0.91
E94/1414	42.1	62.70	27.8	43.30	6.3	9.04	14.7	6.30	5.2	2.26
E94/1415	22.3	23.74	12.3	15.17	26.2	9.35	10.5	4.04	6.3	2.35
E94/1416	11.7	12.17	10.6	12.35	18.5	6.43	20.6	7.96	6.9	2.52
E94/1417	20.5	25.70	8.2	10.96	16.8	8.48	15.8	6.00	7.7	3.22
E94/1418	15.6	18.70	11.6	15.39	18.5	7.57	8.8	3.87	4.7	2.00
E94/1419	9.4	9.57	8.0	8.04	8.9	3.39	5.2	2.09	3.4	1.26
HOLE NAME : 5000C000										
E94/1433	19.1	9.78	5.5	7.04	8.5	3.30	4.0	1.52	2.7	1.00

The SAR values indicate that material represented by the seven samples in the table above could cause a serious sodic problem if the material is exposed to the surface according to the classification of SAR values used by Croft and Associates 1986 (cited in Envirosciences Pty.Ltd 1993). The sodium results for the leachate and weathering tests of the seven highly sodic samples indicates that the material represented by these samples may have the potential to generate leachate with sodium ion concentrations above the desirable level for vegetation (according to Charman and Murphy). This should be taken into consideration when designing a waste rock emplacement.

3.3.4 Exchangeable Sodium Percentage (ESP)

Determination of the exchangeable sodium percentage (ESP) gives a measure of the proportion of sodium adsorbed on the exchange complex (SPCC, 1983).

Determination of the ESP value of soils is one of the most widely used tests to assist in the assessment of dispersibility (Charman and Murphy, 1991). The ESP values were calculated from the SAR values using the equation below (after Richards 1969 cited in Envirosciences Pty.Ltd 1993):

$$ESP = \frac{100(-0.0126 + 0.01475 \mathrm{x} SAR)}{1 + (-0.0126 + 0.01475 \mathrm{x} SAR}$$

The implication of ESP values, as given by Croft and Associates, 1986 (cited in Envirosciences Pty.Ltd 1993) are as follows:

ESP > 6 - material prone to clay dispersion and described as sodic.
ESP 15 - 40 - material has adverse effects on plants

ESP is a function of SAR. Hence the ESP values for the 16 hour leachates of the 1:5 extracts were found to support and parallel the SAR values.

The interpretation of data on SAR and ESP has been widely studied in the case of agricultural soils but very little information is available in the case of mine spoils where unweathered rock is exposed to atmospheric conditions (SPCC, 1983). The ESP and SAR may be used as an indication of potential sodium toxicity in plants.

The effect of sodicity on plant establishment should be kept in perspective. In studies on the dispersion characteristics of Permian overburden in Central Queensland, Seedsman and Emerson, 1981 (cited in Envirosciences Pty.Ltd 1993) indicated that mechanical disruption of moist overburden particles is of greater importance in affecting subsequent dispersion than very high ESP levels.

3.5 SALINITY

Salinity is a measure of the total soluble salt concentration in the spoil. Highly saline spoil can have two main consequences:

1) The adverse effect on plant growth and health (leaving the exposed surface more prone to wind and water erosion).
2) The possible impact on the quality of water percolating through the spoil which may have unacceptably high levels of salts and impact on surface and ground waters. (SPCC, 1983)

Saline soils are usually defined as those with an Electrical Conductivity >1500μS/cm for a 1:5 soil:water extract. This is generally accepted as the upper limit of salinity for normal plants (Charman and Murphy 1991).

Plants vary widely in their tolerance of salts in soils, but most pasture species and crop plants will not grow well when salt contents rise above normal levels (Charman and Murphy). High soluble salt contents in soils can reduce plant growth and health, and even result in death of vegetation.

3.5.1 Highly Saline Samples

The samples which had highly saline 1:5 soil:water extracts after 16 hours (EC >1500μS/cm) were the seven acid producing samples.

These samples have previously identified as having potential for generating acidic leachate and leachate with undesirable sulphate concentrations. These factors, in addition to the potential for the samples to produce highly saline leachate, should be taken into consideration for the design of the waste rock emplacement.

3.5.2 Slightly Saline Samples

There were two samples which had 16 hour 1:5 soil:water extracts that had and electrical conductivity less than 1500µS/cm but their salinity values were at a level at which only salt tolerant crops grow and yield satisfactorily (Richards 1954 in Charman and Murphy). These two samples are identified in the table below:

MRDL LAB. NUMBER	DRILL DEPTH		SEAM OVERBURDEN	EC (µS/cm @ 25°C) 16 Hour
	FROM	TO		
HOLE NAME : 4000F000				
E94/1414	74.000	74.400	MTA MIDBURDEN	1299
HOLE NAME : 6000C000				
E94/1449	90.000	90.500	BRN A MIDBURDEN	1328

Sample E94/1414 has been previously identified as producing leachate with sodium concentrations above the "toxicity limit" after 20 days of weathering. Sample E94/1449 has been previously identified as producing a leachate with a sulphate concentration of 664mg/L after 16 hours, which exceeds the sulphate toxicity level for vegetation of 80mg/L.

Weathering tests show that E94/1414 and E94/1449 release soluble salts rapidly

The electrical conductivity of the extract gives an indication of the total soluble salt content in the interstitial water and is therefore an estimate of the quality of potential leachate water and water contained in soil pores and available to plants.

The seven acid producing samples have been previously identified as generating acidic leachate with undesirable sulphate ion concentrations. Sample E94/1414 has been identified as generating leachate on weathering with sodium ion concentrations above the sodium toxicity limit. Sample E94/1449 has been identified as producing leachate with sulphate ion concentrations exceeding the toxicity limit for vegetation. These results, in addition to the salinity results for the leachate tests, should be considered when designing a waste rock emplacement.

The electrical conductivity of the 1:5 extracts of the samples, and the effect of salinity on plant growth, should be taken into consideration when selecting the material for placement as a rooting horizon in the waste rock emplacement.

4.0 WASTE ROCK CHARACTERISTICS

In section 3 of this report samples with potential to produce leachate that is acidic, sodic and saline have been identified and need to be carefully considered in waste rock emplacement design. The remaining samples that through leachate and weathering tests have not shown the potential to generate acidic, sodic or saline leachate have been discussed below.

4.1 BARREN MATERIAL

Material that can be described as "barren" is essentially devoid of sulphur and has a low Acid Neutralising Capacity (Miller and Murray, 1988). The samples that through leachate and weathering tests have not been previously identified as being sodic, saline, sulphate toxic, or acidic, have negligible total sulphur contents and acid neutralising capacity, are presented in the table below. The low sulphur content of these samples indicates that they are not likely to result in any long term acid generation (ie they are non-acid forming). This is supported by the pH results from the weathering tests. The pH values of the 1:5 soil:water extracts of the barren material remained alkaline (pH > 8) over the weathering period. However it is notable that the pH of most of the barren material is outside the desirable pH range for soils, of pH 4-9 (Charman and Murphy, 1991).

BARREN MATERIAL

MRDL LAB NUMBER	DRILL DEPTH		SUPPLIED DEPTH		ROCKTYPE	SEAM INTERBURDEN
	FROM	TO	FROM	TO		
HOLE NAME: 4000F000						
E94/ 1410	17.000	17.500	17.200	17.500	Siltstone	WKH A OVERBURDEN
1411	33.000	33.500	33.200	33.500	Sandstone / Siltstone 70:30	WKH OVERBURDEN
HOLE NAME: 5000A500						
E94/ 1420	13.660	25.190	24.890	25.190	Sandstone Weathered	PFD B OVERBURDEN
1421	40.000	40.500	40.200	40.500	Sandstone	PFD B OVERBURDEN
1422	50.340	51.395	51.095	51.395	Siltstone	PFD B OVERBURDEN
1423	66.979	67.859	67.559	67.859	Siltstone	VAUX E MIDBURDEN
1425	80.485	83.365	83.065	83.365	Sandstone / Siltstone 70:30	BRN B MIDBURDEN
1426	83.365	87.265	86.965	87.265	Siltstone / Sandstone 60:40	BRN B MIDBURDEN
HOLE NAME: 5000C000						
E94/ 1429	19.460	19.760	19.460	19.760	Sandstone	PFD A MIDBURDEN
1430	24.500	25.000	24.700	25.000	Sandstone / Siltstone 70:30	PFD A MIDBURDEN
1434	105.950	106.250	105.950	106.250	Siltstone	BRN B MIDBURDEN
1435	128.500	128.800	128.500	128.800	Sandstone	WYNN EF MIDBURDEN
1438	140.000	140.500	140.200	104.500	Sandstone / Siltstone 70:30	WYNN I MIDBURDEN
1439	152.000	152.299	152.000	152.300	Sandstone / Siltstone 60:40	WYNN I INTERBURDEN
1440	157.200	157.400	157.100	157.400	Siltstone	EDDERTON B MIDBURDEN
HOLE NAME: 5000F000						
E94/ 1441	16.500	17.000	16.700	17.000	Conglomerate/Sandstone 80:20	MTA OVERBURDEN
1442	34.000	34.500	34.200	34.500	Siltstone	MTA OVERBURDEN
1443	42.000	42.500	42.200	42.500	Mudstone	PFD C MIDBURDEN
HOLE NAME: 6000C000						
1447	20.346	20.751	20.451	20.751	Mudstone - Grey, Soft, Fissile	BRN B OVERBURDEN
1448	23.951	25.086	24.786	25.086	Sandstone	BRN B OVERBURDEN
1453	56.047	56.337	56.047	56.337	Sandstone / Siltstone 50:50	EDDERTON MIDBURDEN
HOLE NAME: 6000D000						
E94/ 1454	16.800	17.200	16.900	17.200	Sandstone Weathered	VAUX OVERBURDEN
1455	39.847	40.437	40.137	40.437	Siltstone /Sandstone 80:20	BRN A MIDBURDEN
1456	58.902	60.140	59.840	60.140	Sandstone / Siltstone 80:20	BRN B MIDBURDEN
1457	68.500	69.000	68.700	69.000	Conglomerate / Sandstone 70:30	BAY MIDBURDEN
1458	87.530	87.830	87.530	87.830	Sandstone	WYNN EF MIDBURDEN
1461	100.820	101.200	100.820	101.120	Sandstone	WYNN I MIDBURDEN
1462	114.458	114.990	114.690	114.990	Siltstone	EBBERTON B MIDBURDEN
HOLE NAME: 6000G000						
1464	25.850	26.150	25.850	26.150	Siltstone / Siltstone 60:40	PFD C OVERBURDEN

4.2 MATERIAL IN THE DESIRABLE pH RANGE

From the results of the leachate and weathering tests, some of the samples that represented barren material were found to generate leachate in the desirable pH range of pH 4-9. These samples are identified in the table below.

BARREN MATERIAL IN THE DESIRABLE pH RANGE

MRDL LAB. NUMBER	DRILL DEPTH		SEAM OVERBURDEN	pH Range	
	FROM	TO		(16 Hr)	(30 days)
HOLE NAME : 4000C000					
E94/1403	36.500	37.000	WKH A OVERBURDEN	7.20	8.85
HOLE NAME : 6000C000					
E94/1446	17.195	19.585	BRN B OVERBURDEN	7.00	7.90
E94/1452	55.208	55.406	EDDERTON MIDBURDEN	7.80	8.05
HOLE NAME : 6000G000					
E94/1463	10.500	10.800	PFD C OVERBURDEN	7.45	8.75

The above four materials have an initial neutral pH value and the pH value increases to a maximum of 8.95 on extended weathering, which is within the normal pH range of soils (Charman and Murphy, 1991).

4.3 ACID-NEUTRALISING MATERIAL

From bicarbonate and carbonate carbon results and NAPP calculations, some samples have been identified as having potential acid neutralising properties. These samples are identified in the table below:

SAMPLES WITH ACID NEUTRALISING POTENTIAL

MRDL LAB.	DRILL DEPTH		ROCKTYPE	SEAM INTERBURDEN
NUMBER	FROM	TO		
HOLE NAME : 4000C000				
E94/1404	52.200	52.500	Siltstone	MTA A INTERBURDEN
E94/1406	73.570	73.870	Sandstone / Siltstone 60:40	PFD A INTERBURDEN
E94/1407	88.200	88.500	Sandstone / Siltstone 80:20	PFD A INTERBURDEN
E94/1408	104.000	104.500	Sandstone / Siltstone 90:10	VAUX A INTERBURDEN
E94/1409	122.000	122.500	Sandstone	VAUX A INTERBURDEN
HOLE NAME : 4000F000				
E94/1416	99.000	99.400	Siltstone - Muddy Laminated	PFD A MIDBURDEN
HOLE NAME: 5000A500				
E94/1424	73.369	77.824	Siltstone / Sandstone 60:40	VAUX E MIDBURDEN
E94/1427	105.500	106.000	Sandstone	WYNN EF MIDBURDEN
HOLE NAME: 5000C000				
E94/1431	34.500	35.000	Sandstone	PFD A MIDBURDEN
E94/1432	56.000	56.500	Sandstone / Siltstone 70:30	VAUX A MIDBURDEN
HOLE NAME: 5000F000				
E94/1444	60.000	60.500	Sandstone	PFD C MIDBURDEN

These materials have a high acid neutralising capacity because of their high carbonate carbon content and their high soluble bicarbonate concentration. They have very low electrical conductivity values and total sulphur contents which means that they are unlikely to generate acidic or saline leachate. All these samples exhibit high negative NAPP values. A negative NAPP indicates that there is excess neutralising capacity and that the material is non- acid forming (Miller and Murray 1988).

4.4 BENTONITES

Under our normal testing regime we have identified two of the samples as bentonites as they exhibited typical bentonoic properties during evaluation. The samples were E94/1412 and E94/1414. They were confirmed as being bentonites by X-Ray Diffraction (XRD analysis).

5.0 CONCLUSION

The long term objectives of waste management plans associated with overburden dumps are;
- to ensure a high quality of waters draining from disturbed areas and,
- to successfully establish a self-sustaining vegetation cover.

This report has identified samples that have the potential to produce leachate that is acidic, saline or sodic on weathering. These chemical conditions may have an adverse effect on vegetation growth and water quality draining from a waste rock emplacement. Therefore the overburden and interburden material represented by the samples that were identified as having the potential to produce acidic, saline and sodic leachate, should be managed carefully.

This report has also identified some forty samples that have not shown the potential to produce acidic, saline or sodic leachate. These samples have been characterised in this report as being;

- barren material
- barren material in the desirable pH range
- acid-neutralising material

The geochemical characteristics of the overburden and interburden represented by these forty-four samples may be taken into consideration when designing the waste rock emplacement.

It should be noted that results of the analysis of the samples for the weathering and leaching tests is a "worst case scenario". The waste material used in these tests was crushed to a much smaller sized material(<2mm) than would generally be generated from open cut mining operations (45-120 cm). It is possible that any samples that have been identified as marginally environmentally significant (such as slightly sodic, slightly saline and slightly acidic samples) may have no environmental significance in actual waste dumps. This aspect of the study should be given consideration when formulating and enacting a waste management plan.

The overall results indicate that overburden dumps from any future mining development using current waste management, rehabilitation and revegetation practices will have insignificant environmental effects. The waste management plan will need to take the seven acidic samples into consideration.

REFERENCES

Bradham, W S and F T Caruccio, 1990. **A Comparative Study of Tailings Analysis Using Acid/Base Accounting, Cells, Columns and Soxhlets.** Proceedings of the 1990 Mining and Reclamation Conference and Exhibition, Charleston, West Virginia, April, 1990.

Brady, B. C., J. R. Shaulis and V. W. Skema, 1988. **A Study of Mine Drainage Quality and Prediction Using Overburden Analysis and Paleoenvironmental Reconstructions, Fayette County, Pennsylvania.** Mine Drainage and Surface Mine Reclamation Conference, Pittsburgh Pa, U.S.A., April, 1988.

Carrucio, F.T., 1969. Characterisation of Strip Mine Drainage, in **Ecology and Reclamation of Drastically Disturbed Sites,** Gordon and Breach, pp 193 - 224.

Carrucio, F.T. and R.R. Parizek, 1967. **An Evaluation of Factors Influencing Acid Mine Drainage Production from Various Strata of the Allegheny Group and the Ground-Water Interactions in Selected Areas of Western Pennsylvania,** Coal Research Section, SR-65, Pennsylvania State University.

Charman, P. E. V. and B. W. Murphy. (Eds).1991. **Soils - Their Properties and Management, A Soil Conservation Handbook for New South Wales.** Sydney University Press, South Melbourne, Australia

Envirosciences Pty. Ltd. November 1993. **EIS for Bengalla Coal Mine.**

di Pretoro, R. S. and H. R. Rauch. 1988. **Use of Acid-Base Accounts in Pre-Mining Prediction of Acid Drainage Potential: A New Approach from Northern West Virginia.** Mine Drainage and Surface Mine Reclamation Conference, Pittsburgh Pa, U.S.A., April, 1988.

Erickson P. M. and R. S. Hedlin. 1988. **Evaluation of Overburden Methods as a Means to Predict Post-Mining Coal Mine Drainage Quality.** Mine Drainage and Surface Mine Reclamation Conference, Pittsburgh Pa, U.S.A., April, 1988.

Erickson P. M. and R. S. Hedlin. 1988. **Relationships Between the Initial Geochemistry and Leachate Chemistry of Weathering Overburden Samples.** Mine Drainage and Surface Mine Reclamation Conference, Pittsburgh Pa, U.S.A., April, 1988.

Jackson M. L. 1958. **Soil Chemical Analysis.** Prentice Hall Inc., Sixth Printing, 1970, by the author, Department of Soil Science, University of Wisconsin, Madison, Wis. 53706.

Lappakko, K. 1988. **Prediction of acid Mine Drainage from Duluth Complex Mining Wastes in Northeastern Minnesota**. Mine Drainage and Surface Mine Reclamation Conference, Pittsburgh Pa, U.S.A. , April, 1988.

Miller, S. D. and G. S. Murray, 1988. **Application of Acid-Base Analysis to Wastes from Base Metal and Precious Metal Mines**. Mine Drainage and Surface Mine Reclamation Conference, Pittsburgh Pa, U.S.A. , April, 1988.

Richards. L. A. 1954. **Diagnosis and Improvement of Saline and Alkaline Soils**. USDA Handbook no 60, Washington DC.

Rayment, G. E. and Higginson, F. R. 1992. **Australian Laboratory Handbook of Soil and Water Chemical Methods**. Inkata Press, Melbourne Australia.

Smith, R M, W E Grube, T Arkle and A Sobek, 1974. **Mine Spoil Potentials for Soil and Water Quality**. U. S. EPA Report EPA-670/2-74-070

Sobek, A. A., W. A. Schuller, J. R. Freeman and R. M. Smith. 1978. **Field and Laboratory Methods Applicable to Overburden and Minespoils**. U.S. EPA Report EPA-600/2-78-054

State Pollution Control Commission (SPCC). 1983. **Chemical Characteristics of Overburden from Surface Coal Mines in the Upper Hunter Valley**. Hunter Valley Technical Report No 3, April, 1983.

94019-C4

DEPARTMENT OF MINERAL RESOURCES
NEW SOUTH WALES

MINERAL RESOURCES DEVELOPMENT LABORATORY

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

RESULTS OF ANALYSIS

(TO ACCOMPANY REPORT No R951201A)

Analysis by S. Gillan, D. McKone, R. Mountford, C. Wall and V. Nguyen

12 January 1995

Report No: R951201B

Mineral Resourecs Development Laboratory
PO Box 76, Lidcombe NSW 2141

9646 1644

TABLE OF CONTENTS

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE A-1 (1 OF 2)

MRDL Laboratory Numbers and Field Designations

MRDL LAB NUMBER	DRILL DEPTH		SUPPLIED DEPTH		ROCKTYPE	SEAM INTERBURDEN
	FROM	TO	FROM	TO		
HOLE NAME: 4000C000						
E94/ 1403	36.500	37.000	36.700	37.000	Sandstone / Siltstone 90:10	WKH A OVERBURDEN
1404	52.200	52.500	52.200	52.500	Siltstone	MTA A INTERBURDEN
1405	60.540	60.890	60.590	60.890	Siltstone	MTA A INTERBURDEN
1406	73.570	73.870	73.570	73.870	Sandstone / Siltstone 60:40	PFD A INTERBURDEN
1407	88.200	88.500	88.200	88.500	Sandstone / Siltstone 80:20	PFD A INTERBURDEN
1408	104.000	104.500	104.200	104.500	Sandstone / Siltstone 90:10	VAUX A INTERBURDEN
1409	122.000	122.500	122.300	122.500	Sandstone	VAUX A INTERBURDEN
HOLE NAME: 4000F000						
E94/ 1410	17.000	17.500	17.200	17.500	Siltstone	WKH A OVERBURDEN
1411	33.000	33.500	33.200	33.500	Sandstone / Siltstone 70:30	WKH OVERBURDEN
1412	60.500	60.800	60.500	60.800	Tuff	MTA MIDBURDEN
1413	68.500	68.800	68.500	68.800	Sandstone	MTA MIDBURDEN
1414	74.000	74.400	74.100	74.400	Tuff (Fairford Claystone)	MTA MIDBURDEN
1415	90.500	90.827	90.530	90.830	Sandstone (Silty)	PFD A MIDBURDEN
1416	99.000	99.400	99.100	99.400	Siltstone - Muddy Laminated	PFD A MIDBURDEN
1417	110.000	110.400	110.100	110.400	Sandstone / Siltstone	PFD A MIDBURDEN
1418	134.000	134.500	134.200	134.500	Sandstone / Siltstone 70:30	PFD C MIDBURDEN
1419	162.000	162.500	162.200	162.500	Sandstone / Siltstone 50:50	PFD C MIDBURDEN
HOLE NAME: 5000A500						
E94/ 1420	13.660	25.190	24.890	25.190	Sandstone Weathered	PFD B OVERBURDEN
1421	40.000	40.500	40.200	40.500	Sandstone	PFD B OVERBURDEN
1422	50.340	51.395	51.095	51.395	Siltstone	PFD B OVERBURDEN
1423	66.979	67.859	67.559	67.859	Siltstone	VAUX E MIDBURDEN
1424	73.369	77.824	77.524	77.824	Siltstone / Sandstone 60:40	VAUX E MIDBURDEN
1425	80.485	83.365	83.065	83.365	Sandstone / Siltstone 70:30	BRN B MIDBURDEN
1426	83.365	87.265	86.965	87.265	Siltstone / Sandstone 60:40	BRN B MIDBURDEN
1427	105.500	106.000	105.700	106.000	Sandstone	WYNN EF MIDBURDEN
1428	110.000	110.500	110.200	110.500	Conglomerate	WYNN EF MIDBURDEN
HOLE NAME: 5000C000						
E94/ 1429	19.460	19.760	19.460	19.760	Sandstone	PFD A MIDBURDEN
1430	24.500	25.000	24.700	25.000	Sandstone / Siltstone 70:30	PFD A MIDBURDEN
1431	34.500	35.000	34.700	35.000	Sandstone	PFD A MIDBURDEN
1432	56.000	56.500	56.200	56.500	Sandstone / Siltstone 70:30	VAUX A MIDBURDEN
1433	90.000	90.500	90.200	90.500	Sandstone / Siltstone 90:10	BRN A MIDBURDEN
1434	105.950	106.250	105.950	106.250	Siltstone	BRN B MIDBURDEN
1435	128.500	128.800	128.500	128.800	Sandstone	WYNN EF MIDBURDEN
1436	133.400	133.700	133.400	133.700	Sandstone	WYNN EF MIDBURDEN
1437	134.900	135.200	134.900	135.200	Sandstone	WYNN EF INTERBURDEN
1438	140.000	140.500	140.200	104.500	Sandstone / Siltstone 70:30	WYNN I MIDBURDEN
1439	152.000	152.299	152.000	152.300	Sandstone / Siltstone 60:40	WYNN I INTERBURDEN
1440	157.200	157.400	157.100	157.400	Siltstone	EDDERTON B MIDBURDEN

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE A-1 (2 OF 2)

MRDL Laboratory Numbers and Field Designations

MRDL LAB. NUMBER	DRILL DEPTH		SUPPLIED DEPTH		ROCKTYPE	SEAM INTERBURDEN
	FROM	TO	FROM	TO		
HOLE NAME: 5000F000						
E94/ 1441	16.500	17.000	16.700	17.000	Conglomerate/Sandstone 80:20	MTA OVERBURDEN
1442	34.000	34.500	34.200	34.500	Siltstone	MTA OVERBURDEN
1443	42.000	42.500	42.200	42.500	Mudstone	PFD C MIDBURDEN
1444	60.000	60.500	60.200	60.500	Sandstone	PFD C MIDBURDEN
1445	83.200	83.746	83.446	83.746	Siltstone	PFD C MIDBURDEN
HOLE NAME: 6000C000						
E94/ 1446	17.195	19.585		19.585	Sandstone - Course Weathered	BRN B OVERBURDEN
1447	20.346	20.751	20.451	20.751	Mudstone - Grey, Soft, Fissile	BRN B OVERBURDEN
1448	23.951	25.086	24.786	25.086	Sandstone	BRN B OVERBURDEN
1449	40.068	47.668	41.368	41.668	Sandstone / Conglomerate 80:20	WYNN EF MIDBURDEN
1450	44.800	45.300	45.000	45.300	Sandstone / Conglomerate	WYNN EF MIDBURDEN
1451	47.800	48.300	48.000	48.300	Sandstone / Conglomerate	WYNN EF MIDBURDEN
1452	55.208	55.406	55.208	55.406	Mudstone	EDDERTON MIDBURDEN
1453	56.047	56.337	56.047	56.337	Sandstone / Siltstone 50:50	EDDERTON MIDBURDEN
HOLE NAME: 6000D000						
E94/ 1454	16.800	17.200	16.900	17.200	Sandstone Weathered	VAUX OVERBURDEN
1455	39.847	40.437	40.137	40.437	Siltstone /Sandstone 80:20	BRN A MIDBURDEN
1456	58.902	60.140	59.840	60.140	Sandstone / Siltstone 80:20	BRN B MIDBURDEN
1457	68.500	69.000	68.700	69.000	Conglomerate / Sandstone 70:30	BAY MIDBURDEN
1458	87.530	87.830	87.530	87.830	Sandstone	WYNN EF MIDBURDEN
1459	90.000	90.500	90.200	90.500	Sandstone / Conglomerate 80:20	WYNN EF MIDBURDEN
1460	92.800	93.200	92.900	93.200	Siltstone	WYNN I MIDBURDEN
1461	100.820	101.200	100.820	101.120	Sandstone	WYNN I MIDBURDEN
1462	114.458	114.990	114.690	114.990	Siltstone	EBBERTON B MIDBURDEN
HOLE NAME: 6000G000						
E94/ 1463	10.500	10.800	10.500	10.800	Sandstone / Weathered	PFD C OVERBURDEN
1464	25.850	26.150	25.850	26.150	Siltstone / Siltstone 60:40	PFD C OVERBURDEN

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE A-2 (1 OF 2)

Analysis of Waste Rock Samples

Total Sulphur, Total Carbon, and Crude Nett Acid Producing Potential

MRDL LAB No.	SEAM INTERBURDEN	TOTAL SULPHUR %	TOTAL CARBON %CO_2	CARBONATE CARBON %CO_2	CRUDE NAPP [a] (Equiv. % $CaCO_3$)
E94/1403	WKH A OVERBURDEN	<0.01	7.0	4.1	-9.4
E94/1404	MTA A INTERBURDEN	0.02	11.6	7.4	-16.7
E94/1405	MTA A INTERBURDEN	0.03	22.6	4.2	-9.4
E94/1406	PFD A INTERBURDEN	<0.01	8.4	5.0	-11.3
E94/1407	PFD A INTERBURDEN	<0.01	10.1	8.1	-18.4
E94/1408	VAUX A INTERBURDEN	<0.01	10.0	8.3	-18.8
E94/1409	VAUX A INTERBURDEN	<0.01	19.2	13.6	-30.8
E94/1410	WKH A OVERBURDEN	<0.01	4.2	3.0	-6.9
E94/1411	WKH OVERBURDEN	<0.01	7.5	4.2	-9.5
E94/1412	MTA MIDBURDEN	<0.01	0.5	0.4	-0.9
E94/1413	MTA MIDBURDEN	<0.01	2.2	0.7	-1.7
E94/1414	MTA MIDBURDEN	<0.01	1.1	0.7	-1.6
E94/1415	PFD A MIDBURDEN	0.02	6.1	2.3	-5.1
E94/1416	PFD A MIDBURDEN	0.06	42.8	11.1	-25.1
E94/1417	PFD A MIDBURDEN	<0.01	7.4	2.9	-6.5
E94/1418	PFD C MIDBURDEN	0.01	5.3	2.5	-5.7
E94/1419	PFD C MIDBURDEN	0.01	6.0	3.8	-8.6
E94/1420	PFD B OVERBURDEN	<0.01	3.2	2.9	-6.6
E94/1421	PFD B OVERBURDEN	<0.01	4.6	4.0	-9.0
E94/1422	PFD B OVERBURDEN	0.03	4.8	1.2	-2.5
E94/1423	VAUX E MIDBURDEN	0.04	6.0	1.8	-4.1
E94/1424	VAUX E MIDBURDEN	0.19	11.9	9.0	-19.9
E94/1425	BRN B MIDBURDEN	<0.01	8.2	5.6	-12.7
E94/1426	BRN B MIDBURDEN	<0.01	10.6	5.8	-13.1
E94/1427	WYNN EF MIDBURDEN	<0.01	9.5	9.2	-20.9
E94/1428	WYNN EF MIDBURDEN	1.41	8.8	7.8	-13.4
E94/1429	PFD A MIDBURDEN	0.03	7.2	3.4	-7.6
E94/1430	PFD A MIDBURDEN	<0.01	8.0	4.9	-11.1
E94/1431	PFD A MIDBURDEN	<0.01	16.7	13.4	-30.5
E94/1432	VAUX A MIDBURDEN	<0.01	9.6	5.1	-11.5
E94/1433	BRN A MIDBURDEN	<0.01	6.6	2.9	-6.5
E94/1434	BRN B MIDBURDEN	0.03	11.6	2.9	-6.5
E94/1435	WYNN EF MIDBURDEN	<0.01	1.0	0.5	-1.1
E94/1436	WYNN EF MIDBURDEN	1.34	1.0	0.3	3.6
E94/1437	WYNN EF INTERBURDEN	1.47	1.7	0.4	3.8
E94/1438	WYNN I MIDBURDEN	0.01	5.4	1.1	-2.4
E94/1439	WYNN I INTERBURDEN	0.03	6.7	1.2	-2.5
E94/1440	EDDERTON B MIDBURDEN	0.05	8.4	1.7	-3.7

[a] Nett Acid Producing Potential (NAPP)

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE A-2 (2 OF 2)

Analysis of Waste Rock Samples

Total Sulphur, Total Carbon, and Crude Nett Acid Producing Potential

MRDL LAB No.	SEAM INTERBURDEN	TOTAL SULPHUR %	TOTAL CARBON %CO_2	CARBONATE CARBON %CO_2	CRUDE NAPP [a] (Equiv. % $CaCO_3$)
E94/1441	MTA OVERBURDEN	0.01	5.5	4.3	-9.8
E94/1442	MTA OVERBURDEN	0.03	7.7	1.4	-3.0
E94/1443	PFD C MIDBURDEN	0.02	4.0	0.3	-0.6
E94/1444	PFD C MIDBURDEN	<0.01	8.3	5.3	-11.9
E94/1445	PFD C MIDBURDEN	0.22	52.5	2.9	-5.9
E94/1446	BRN B OVERBURDEN	0.05	0.8	0.2	-0.3
E94/1447	BRN B OVERBURDEN	0.03	6.8	1.0	-2.1
E94/1448	BRN B OVERBURDEN	<0.01	5.6	3.3	-7.6
E94/1449	WYNN EF MIDBURDEN	0.02	4.3	3.0	-6.8
E94/1450	WYNN EF MIDBURDEN	0.55	0.4	0.0	1.7
E94/1451	WYNN EF MIDBURDEN	1.47	1.3	0.2	4.1
E94/1452	EDDERTON MIDBURDEN	0.10	22.4	3.6	-7.8
E94/1453	EDDERTON MIDBURDEN	0.04	11.1	5.3	-11.9
E94/1454	VAUX OVERBURDEN	<0.01	4.9	3.8	-8.7
E94/1455	BRN A MIDBURDEN	0.01	5.8	2.0	-4.4
E94/1456	BRN B MIDBURDEN	<0.01	7.3	2.7	-6.2
E94/1457	BAY MIDBURDEN	<0.01	9.1	1.7	-3.9
E94/1458	WYNN EF MIDBURDEN	0.06	8.7	5.5	-12.3
E94/1459	WYNN EF MIDBURDEN	1.58	2.9	0.3	4.1
E94/1460	WYNN I MIDBURDEN	5.69	24.8	6.6	2.7
E94/1461	WYNN I MIDBURDEN	<0.01	3.0	0.8	-1.7
E94/1462	EBBERTON B MIDBURDEN	0.10	8.1	1.4	-2.8
E94/1463	PFD C OVERBURDEN	<0.01	0.6	0.1	-0.3
E94/1464	PFD C OVERBURDEN	<0.01	11.6	7.3	-16.6

[a] Nett Acid Producing Potential (NAPP)

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE A-3 (1 OF 2)

Sodium Absorption Rate (SAR)
Exchangeable Sodium Percentage (ESP)

1 : 5 Soil:Water Extract After 16 hours leaching @ 22°

MRDL LAB No.	SEAM OVERBURDEN	pH	EC (us/cm)	SOLUBLE CATIONS (meq/L)			SAR	ESP
				Na	Ca	Mg		
E94/1403	WKH A OVERBURDEN	7.20	195	1.7	1.40	3.6	1.10	0.36
E94/1404	MTA A INTERBURDEN	9.50	420	10.9	0.14	2.6	9.23	10.99
E94/1405	MTA A INTERBURDEN	9.85	340	9.4	0.15	0.2	23.51	25.05
E94/1406	PFD A INTERBURDEN	10.05	637	14.7	0.12	1.8	14.99	17.25
E94/1407	PFD A INTERBURDEN	10.30	723	13.3	0.22	2.2	12.08	14.21
E94/1408	VAUX A INTERBURDEN	10.15	569	7.5	0.75	0.6	9.19	10.95
E94/1409	VAUX A INTERBURDEN	10.10	482	7.4	2.20	0.9	5.94	6.97
E94/1410	WKH A OVERBURDEN	9.65	385	6.6	2.15	2.5	4.28	4.82
E94/1411	WKH OVERBURDEN	9.50	229	3.1	1.30	4.0	1.92	1.54
E94/1412	MTA MIDBURDEN	10.20	846	35.8	0.60	4.2	23.14	24.74
E94/1413	MTA MIDBURDEN	10.10	460	17.4	0.21	2.6	14.58	16.84
E94/1414	MTA MIDBURDEN	10.00	1299	62.7	0.65	3.8	42.12	37.84
E94/1415	PFD A MIDBURDEN	10.15	694	23.7	0.04	2.2	22.31	24.04
E94/1416	PFD A MIDBURDEN	10.05	454	12.2	0.03	2.1	11.68	13.77
E94/1417	PFD A MIDBURDEN	10.00	648	25.7	0.18	3.0	20.51	22.47
E94/1418	PFD C MIDBURDEN	10.05	630	18.7	0.08	2.8	15.58	17.84
E94/1419	PFD C MIDBURDEN	9.80	377	9.6	0.11	2.0	9.37	11.16
E94/1420	PFD B OVERBURDEN	9.05	84	0.9	2.10	3.5	0.54	-0.46
E94/1421	PFD B OVERBURDEN	8.65	126	0.6	3.04	6.0	0.29	-0.84
E94/1422	PFD B OVERBURDEN	8.65	136	1.5	1.65	6.3	0.77	-0.13
E94/1423	VAUX E MIDBURDEN	8.95	132	2.8	1.55	3.2	1.83	1.42
E94/1424	VAUX E MIDBURDEN	8.60	236	3.0	1.40	3.1	2.00	1.65
E94/1425	BRN B MIDBURDEN	9.00	194	2.5	1.85	3.0	1.63	1.13
E94/1426	BRN B MIDBURDEN	8.95	163	3.3	1.70	3.5	2.04	1.72
E94/1427	WYNN EF MIDBURDEN	9.10	183	1.2	4.39	3.4	0.60	-0.38
E94/1428	WYNN EF MIDBURDEN	6.30	2340	1.3	34.58	9.2	0.29	-0.84
E94/1429	PFD A MIDBURDEN	9.00	196	3.3	1.10	3.0	2.32	2.12
E94/1430	PFD A MIDBURDEN	9.30	238	4.3	1.00	3.1	2.97	3.02
E94/1431	PFD A MIDBURDEN	9.40	227	2.2	3.49	2.7	1.26	0.59
E94/1432	VAUX A MIDBURDEN	9.45	236	3.3	1.80	2.5	2.24	2.01
E94/1433	BRN A MIDBURDEN	9.90	254	9.8	0.25	0.3	19.08	21.19
E94/1434	BRN B MIDBURDEN	9.50	385	4.6	1.30	2.3	3.44	3.67
E94/1435	WYNN EF MIDBURDEN	9.60	181	1.3	0.29	0.7	1.86	1.46
E94/1436	WYNN EF MIDBURDEN	4.20	3300	0.1	23.90	16.1	0.03	-1.23
E94/1437	WYNN EF INTERBURDEN	4.80	2830	0.2	7.83	10.1	0.06	-1.18
E94/1438	WYNN I MIDBURDEN	9.50	211	2.1	1.10	2.1	1.67	1.20
E94/1439	WYNN I INTERBURDEN	9.35	210	1.8	0.90	2.1	1.50	0.95
E94/1440	EDDERTON B MIDBURDEN	9.40	337	2.7	0.80	1.6	2.52	2.40

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE A-3 (2 OF 2)

Sodium Absorption Rate (SAR)
Exchangeable Sodium Percentage (ESP)

1 : 5 Soil:Water Extract After 16 hours leaching @ 22°

MRDL LAB No.	SEAM OVERBURDEN	pH	EC (us/cm)	SOLUBLE CATIONS (meq/L)			SAR	ESP
				Na	Ca	Mg		
E94/1441	MTA OVERBURDEN	9.30	242	1.3	0.22	0.5	2.10	1.80
E94/1442	MTA OVERBURDEN	9.75	267	2.7	1.65	3.6	1.63	1.14
E94/1443	PFD C MIDBURDEN	9.70	377	4.2	1.85	3.5	2.57	2.47
E94/1444	PFD C MIDBURDEN	10.10	371	3.1	0.80	0.6	3.74	4.09
E94/1445	PFD C MIDBURDEN	7.85	500	3.1	0.32	0.8	4.08	4.54
E94/1446	BRN B OVERBURDEN	7.00	204	0.8	0.20	0.5	1.36	0.75
E94/1447	BRN B OVERBURDEN	8.00	325	0.8	0.35	1.1	0.93	0.11
E94/1448	BRN B OVERBURDEN	8.65	176	1.1	0.40	1.2	1.25	0.58
E94/1449	WYNN EF MIDBURDEN	7.50	1328	1.0	7.14	7.2	0.37	-0.71
E94/1450	WYNN EF MIDBURDEN	2.75	2830	0.1	5.39	10.3	0.02	-1.25
E94/1451	WYNN EF MIDBURDEN	3.65	2660	0.0	7.19	18.3	0.01	-1.26
E94/1452	EDDERTON MIDBURDEN	7.80	328	1.7	0.27	0.6	2.56	2.45
E94/1453	EDDERTON MIDBURDEN	8.10	271	1.3	0.29	0.6	2.00	1.67
E94/1454	VAUX OVERBURDEN	9.15	221	1.4	0.13	0.3	2.85	2.87
E94/1455	BRN A MIDBURDEN	9.70	216	2.1	0.03	0.4	4.67	5.33
E94/1456	BRN B MIDBURDEN	9.70	218	2.1	0.02	0.3	5.58	6.51
E94/1457	BAY MIDBURDEN	8.20	470	1.8	0.75	1.4	1.76	1.32
E94/1458	WYNN EF MIDBURDEN	9.00	382	1.4	0.55	1.2	1.51	0.96
E94/1459	WYNN EF MIDBURDEN	3.20	3150	0.1	5.14	14.1	0.02	-1.25
E94/1460	WYNN I MIDBURDEN	3.40	2330	2.2	4.04	11.9	0.77	-0.13
E94/1461	WYNN I MIDBURDEN	9.50	185	1.4	0.02	0.2	3.89	4.29
E94/1462	EBBERTON B MIDBURDEN	8.00	329	1.8	0.18	0.5	3.17	3.31
E94/1463	PFD C OVERBURDEN	7.45	298	1.8	0.12	0.3	3.91	4.31
E94/1464	PFD C OVERBURDEN	8.70	205	0.7	0.21	0.5	1.18	0.48

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE B-1 (1 OF 2)

16 Hour Leach Tests of Waste Rock Samples

pH, Electrical Conductivity, Sulphate and Chloride Concentration , Equivalent Bicarbonate, and Alkalinity Equivalent Values of 1:5 Soil:Water Extracts After 16 hours leaching @ 22°

MRDL LAB No.	Crude NAPP [a] (Equiv. % $CaCO_3$)	pH	E.C. µS/cm @ 25°	Sulphate Conc. (mg/L)	Chloride Conc. (mg/L)	Equivalent HCO_3^- (mg/L)	Alkalinity Equivalent CaO_3 (mg/L)
E94/1403	-9.4	7.20	195	49	5	42	34
E94/1404	-16.7	9.50	420	44	2	304	249
E94/1405	-9.4	9.85	340	13	3	218	179
E94/1406	-11.3	10.05	637	23	5	453	371
E94/1407	-18.4	10.30	723	14	4	497	408
E94/1408	-18.8	10.15	569	13	3	135	111
E94/1409	-30.8	10.10	482	10	2	377	309
E94/1410	-6.9	9.65	385	8	32	414	339
E94/1411	-9.5	9.50	229	31	4	299	245
E94/1412	-0.9	10.20	846	5	2	94	77
E94/1413	-1.7	10.10	460	15	6	500	410
E94/1414	-1.6	10.00	1299	12	3	275	226
E94/1415	-5.1	10.15	694	24	3	622	510
E94/1416	-25.1	10.05	454	12	5	458	375
E94/1417	-6.5	10.00	648	19	2	266	218
E94/1418	-5.7	10.05	630	28	2	371	304
E94/1419	-8.6	9.80	377	28	3	380	312
E94/1420	-6.6	9.05	84	5	4	216	177
E94/1421	-9.0	8.65	126	22	3	45	37
E94/1422	-2.5	8.65	136	32	3	47	39
E94/1423	-4.1	8.95	132	24	3	34	28
E94/1424	-19.9	8.60	236	41	6	53	43
E94/1425	-12.7	9.00	194	26	4	81	66
E94/1426	-13.1	8.95	163	23	4	86	71
E94/1427	-20.9	9.10	183	29	11	71	59
E94/1428	-13.4	6.30	2340	1550	16	68	55
E94/1429	-7.6	9.00	196	39	5	43	35
E94/1430	-11.1	9.30	238	39	7	68	56
E94/1431	-30.5	9.40	227	20	4	91	74
E94/1432	-11.5	9.45	236	20	2	111	91
E94/1433	-6.5	9.90	254	17	3	222	182
E94/1434	-6.5	9.50	385	98	4	119	97
E94/1435	-1.1	9.60	181	17	17	51	42
E94/1436	3.6	4.20	3300	2350	14	NIL	NIL
E94/1437	3.8	4.80	2830	1970	14	NIL	NIL
E94/1438	-2.4	9.50	211	37	7	86	71
E94/1439	-2.5	9.35	210	46	6	79	65
E94/1440	-3.7	9.40	337	70	4	124	102

[a] Nett Acid Producing Potential (NAPP)

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE B-1 (2 OF 2)

16 Hour Leach Tests of Waste Rock Samples

pH, Electrical Conductivity, Sulphate and Chloride Concentration , Equivalent Bicarbonate, and Alkalinity Equivalent Values of 1:5 Soil:Water Extracts After 16 hours leaching @ 22°

MRDL LAB No.	Crude NAPP [a] (Equiv. % $CaCO_3$)	pH	E.C. µS/cm @ 25°	Sulphate Conc. (mg/L)	Chloride Conc. (mg/L)	Equivalent HCO_3^- (mg/L)	Alkalinity Equivalent CaO_3 (mg/L)
E94/1441	-9.8	9.30	242	32	20	55	45
E94/1442	-3.0	9.75	267	34	11	114	94
E94/1443	-0.6	9.70	377	53	11	153	125
E94/1444	-11.9	10.10	371	13	5	208	171
E94/1445	-5.9	7.85	500	145	9	58	48
E94/1446	-0.3	7.00	204	41	22	10	9
E94/1447	-2.1	8.00	325	91	13	24	20
E94/1448	-7.6	8.65	176	34	7	39	32
E94/1449	-6.8	7.50	1328	664	14	59	49
E94/1450	1.7	2.75	2830	1510	15	NIL	NIL
E94/1451	4.1	3.65	2660	1765	13	NIL	NIL
E94/1452	-7.8	7.80	328	77	19	30	24
E94/1453	-11.9	8.10	271	59	10	47	39
E94/1454	-8.7	9.15	221	10	29	60	49
E94/1455	-4.4	9.70	216	22	4	127	104
E94/1456	-6.2	9.70	218	25	5	111	91
E94/1457	-3.9	8.20	470	152	9	40	33
E94/1458	-12.3	9.00	382	123	7	42	34
E94/1459	4.1	3.20	3150	2205	15	NIL	NIL
E94/1460	2.7	3.40	2330	1360	16	NIL	NIL
E94/1461	-1.7	9.50	185	28	7	66	54
E94/1462	-2.8	8.00	329	94	7	35	29
E94/1463	-0.3	7.45	298	12	71	11	9
E94/1464	-16.6	8.70	205	36	6	60	49

[a] Nett Acid Producing Potential (NAPP)

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE B-2 (1 OF 2)

5 Day Weathering Tests of Waste Rock Samples

pH, Electrical Conductivity, Sulphate and Chloride Concentration , Equivalent Bicarbonate, and Alkalinity Equivalent Values of 1:5 Soil:Water Extracts After 5 Days Weathering @ 40°

MRDL LAB No.	Crude NAPP [a] (Equiv. % $CaCO_3$)	pH	E.C. µS/cm @ 25°	Sulphate Conc. (mg/L)	Chloride Conc. (mg/L)	Equivalent HCO_3^- (mg/L)	Alkalinity Equivalent CaO_3 (mg/L)
E94/1403	-9.4	7.35	250	71	5	46	37
E94/1404	-16.7	9.30	536	39	2	323	265
E94/1405	-9.4	9.75	311	7	4	201	165
E94/1406	-11.3	9.80	567	19	5	355	291
E94/1407	-18.4	9.95	692	11	3	443	363
E94/1408	-18.8	9.80	455	8	3	302	247
E94/1409	-30.8	10.30	465	9	3	427	350
E94/1410	-6.9	9.80	368	7	28	269	221
E94/1411	-9.5	9.30	228	26	4	93	76
E94/1412	-0.9	10.00	864	6	14	400	328
E94/1413	-1.7	9.85	435	14	5	239	196
E94/1414	-1.6	10.00	1075	<1	2	477	391
E94/1415	-5.1	10.00	742	34	3	470	385
E94/1416	-25.1	10.00	388	11	5	263	215
E94/1417	-6.5	10.10	466	15	3	279	229
E94/1418	-5.7	10.10	629	37	2	381	312
E94/1419	-8.6	9.90	371	27	3	218	179
E94/1420	-6.6	9.00	73.1	4	4	34	28
E94/1421	-9.0	8.75	119	22	3	31	25
E94/1422	-2.5	8.60	123	32	3	32	26
E94/1423	-4.1	9.10	103	22	3	33	27
E94/1424	-19.9	8.60	213	45	6	60	49
E94/1425	-12.7	9.00	160	25	4	58	48
E94/1426	-13.1	9.00	137	21	4	45	37
E94/1427	-20.9	9.30	166	25	10	55	45
E94/1428	-13.4	7.70	2600	1605	31	27	22
E94/1429	-7.6	9.20	167	40	5	34	28
E94/1430	-11.1	9.50	199	38	7	58	48
E94/1431	-30.5	9.60	204	18	4	203	166
E94/1432	-11.5	9.70	210	16	3	102	84
E94/1433	-6.5	9.80	298	12	3	180	148
E94/1434	-6.5	9.10	268	82	4	60	49
E94/1435	-1.1	8.60	125	12	16	32	26
E94/1436	3.6	4.40	2275	1735	15	NIL	NIL
E94/1437	3.8	4.35	2220	1720	13	NIL	NIL
E94/1438	-2.4	8.80	137	29	6	36	30
E94/1439	-2.5	8.80	149	45	6	27	22
E94/1440	-3.7	8.80	113	60	3	43	35

[a] Nett Acid Producing Potential (NAPP)

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE B-2 (2 OF 2)

5 Day Weathering Tests of Waste Rock Samples

pH, Electrical Conductivity, Sulphate and Chloride Concentration , Equivalent Bicarbonate, and Alkalinity Equivalent Values of 1:5 Soil:Water Extracts After 5 Days Weathering @ 40°

MRDL LAB No.	Crude NAPP [a] (Equiv. % $CaCO_3$)	pH	E.C. µS/cm @ 25°	Sulphate Conc. (mg/L)	Chloride Conc. (mg/L)	Equivalent HCO_3^- (mg/L)	Alkalinity Equivalent CaO_3 (mg/L)
E94/1441	-9.8	9.30	170	25	17	35	29
E94/1442	-3.0	9.15	174	24	10	58	47
E94/1443	-0.6	9.50	223	39	8	102	83
E94/1444	-11.9	10.10	217	10	5	144	118
E94/1445	-5.9	8.15	313	114	9	23	19
E94/1446	-0.3	7.10	159	38	19	3	3
E94/1447	-2.1	7.65	220	72	11	11	9
E94/1448	-7.6	8.50	110	27	6	18	15
E94/1449	-6.8	7.50	829	440	12	10	8
E94/1450	1.7	3.00	1749	1120	5	NIL	NIL
E94/1451	4.1	3.50	1979	1360	5	NIL	NIL
E94/1452	-7.8	7.50	245	68	18	16	14
E94/1453	-11.9	8.20	174	54	9	11	9
E94/1454	-8.7	9.20	143	7	26	34	28
E94/1455	-4.4	9.80	118	20	4	55	45
E94/1456	-6.2	9.90	107	21	4	38	31
E94/1457	-3.9	7.85	282	107	7	6	5
E94/1458	-12.3	8.60	301	114	6	25	21
E94/1459	4.1	3.40	2093	1515	6	NIL	NIL
E94/1460	2.7	3.90	1156	693	3	NIL	NIL
E94/1461	-1.7	9.15	95	19	6	17	14
E94/1462	-2.8	7.75	223	79	7	8	6
E94/1463	-0.3	7.30	219	5	63	3	2
E94/1464	-16.6	9.00	130	27	5	38	31

[a] Nett Acid Producing Potential (NAPP)

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE B-3 (1 OF 2)

10 Day Weathering Tests of Waste Rock Samples

pH, Electrical Conductivity, Sulphate and Chloride Concentration , Equivalent Bicarbonate, and Alkalinity Equivalent Values of 1:5 Soil:Water Extracts After 10 Days Weathering @ 40°

MRDL LAB No.	Crude NAPP [a] (Equiv. % $CaCO_3$)	pH	E.C. µS/cm @ 25°	Sulphate Conc. (mg/L)	Chloride Conc. (mg/L)	Equivalent HCO_3^- (mg/L)	Alkalinity Equivalent CaO_3 (mg/L)
E94/1403	-9.4	8.10	103	11	4	45	37
E94/1404	-16.7	9.50	275	9	11	181	149
E94/1405	-9.4	10.20	195	3	6	111	91
E94/1406	-11.3	10.25	323	4	9	203	167
E94/1407	-18.4	10.20	407	2	12	256	209
E94/1408	-18.8	9.90	217	2	7	141	116
E94/1409	-30.8	9.60	206	4	<1	144	118
E94/1410	-6.9	10.00	185	1	3	142	116
E94/1411	-9.5	9.30	111	5	5	67	55
E94/1412	-0.9	10.10	228	4	8	133	109
E94/1413	-1.7	10.20	174	4	6	99	81
E94/1414	-1.6	10.15	407	5	9	217	178
E94/1415	-5.1	10.25	340	7	9	246	202
E94/1416	-25.1	10.10	151	2	6	115	94
E94/1417	-6.5	10.50	453	<1	3	285	233
E94/1418	-5.7	10.30	337	<1	3	216	177
E94/1419	-8.6	10.30	230	6	7	132	108
E94/1420	-6.6	9.25	33	1	3	18	14
E94/1421	-9.0	8.75	76	4	5	42	34
E94/1422	-2.5	9.20	42	8	3	22	18
E94/1423	-4.1	9.50	39	7	4	22	18
E94/1424	-19.9	9.30	76	10	2	52	43
E94/1425	-12.7	9.35	65	3	3	35	29
E94/1426	-13.1	9.40	47	2	3	28	23
E94/1427	-20.9	9.40	67	4	3	39	32
E94/1428	-13.4	7.80	1019	502	36	32	26
E94/1429	-7.6	9.65	50	4	2	25	20
E94/1430	-11.1	10.00	80	5	2	48	39
E94/1431	-30.5	9.50	97	2	4	88	72
E94/1432	-11.5	9.65	97	4	4	57	46
E94/1433	-6.5	10.40	180	3	1	110	90
E94/1434	-6.5	9.05	138	27	4	57	47
E94/1435	-1.1	8.85	54	3	2	29	23
E94/1436	3.6	4.75	1360	789	3	NIL	NIL
E94/1437	3.8	4.05	915	475	3	NIL	NIL
E94/1438	-2.4	9.35	78	10	1	40	33
E94/1439	-2.5	8.75	64	11	1	29	24
E94/1440	-3.7	9.05	105	16	1	51	42

[a] Nett Acid Producing Potential (NAPP)

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE B-3 (2 OF 2)

10 Day Weathering Tests of Waste Rock Samples

pH, Electrical Conductivity, Sulphate and Chloride Concentration , Equivalent Bicarbonate, and Alkalinity Equivalent Values of 1:5 Soil:Water Extracts After 10 Days Weathering @ 40°

MRDL LAB No.	Crude NAPP [a] (Equiv. % $CaCO_3$)	pH	E.C. µS/cm @ 25°	Sulphate Conc. (mg/L)	Chloride Conc. (mg/L)	Equivalent HCO_3^- (mg/L)	Alkalinity Equivalent CaO_3 (mg/L)
E94/1441	-9.8	9.50	91	7	2	47	39
E94/1442	-3.0	9.55	83	5	2	51	42
E94/1443	-0.6	9.45	153	8	2	104	85
E94/1444	-11.9	9.80	197	3	1	155	127
E94/1445	-5.9	8.40	142	32	3	48	40
E94/1446	-0.3	7.95	52	13	3	7	6
E94/1447	-2.1	7.95	97	25	2	18	14
E94/1448	-7.6	8.80	55	4	2	26	21
E94/1449	-6.8	7.50	657	319	2	15	12
E94/1450	1.7	3.45	850	387	2	NIL	NIL
E94/1451	4.1	3.45	1088	533	2	NIL	NIL
E94/1452	-7.8	7.85	86	19	3	25	20
E94/1453	-11.9	8.25	79	13	2	29	23
E94/1454	-8.7	9.30	78	2	3	56	46
E94/1455	-4.4	9.45	90	6	1	56	46
E94/1456	-6.2	9.70	87	6	1	56	46
E94/1457	-3.9	8.40	202	66	3	19	15
E94/1458	-12.3	8.75	153	35	2	34	28
E94/1459	4.1	3.60	856	414	2	NIL	NIL
E94/1460	2.7	4.35	1290	723	2	NIL	NIL
E94/1461	-1.7	9.20	69	8	2	37	30
E94/1462	-2.8	8.30	99	29	2	22	18
E94/1463	-0.3	8.20	67	4	12	14	12
E94/1464	-16.6	9.00	82	10	1	54	44

[a] Nett Acid Producing Potential (NAPP)

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE B-4 (1 OF 2)

15 Day Weathering Tests of Waste Rock Samples

pH, Electrical Conductivity, Sulphate and Chloride Concentration , Equivalent Bicarbonate, and Alkalinity Equivalent Values of 1:5 Soil:Water Extracts After 15 Days Weathering @ 40°

MRDL LAB No.	Crude NAPP [a] (Equiv. % $CaCO_3$)	pH	E.C. µS/cm @ 25°	Sulphate Conc. (mg/L)	Chloride Conc. (mg/L)	Equivalent HCO_3^- (mg/L)	Alkalinity Equivalent CaO_3 (mg/L)
E94/1403	-9.4	8.95	47	6	3	29	24
E94/1404	-16.7	9.10	201	4	9	135	111
E94/1405	-9.4	9.75	170	2	7	102	83
E94/1406	-11.3	9.60	253	4	11	165	135
E94/1407	-18.4	9.90	294	2	10	189	155
E94/1408	-18.8	9.65	140	2	6	96	79
E94/1409	-30.8	9.40	112	4	5	90	73
E94/1410	-6.9	9.55	130	3	6	101	83
E94/1411	-9.5	9.30	71	2	5	45	37
E94/1412	-0.9	9.75	152	2	6	91	74
E94/1413	-1.7	9.60	138	3	6	82	68
E94/1414	-1.6	9.85	187	3	10	113	92
E94/1415	-5.1	9.35	255	3	10	180	147
E94/1416	-25.1	9.55	110	2	5	77	63
E94/1417	-6.5	9.95	303	2	10	191	157
E94/1418	-5.7	9.75	261	2	10	172	141
E94/1419	-8.6	10.20	179	3	6	103	85
E94/1420	-6.6	9.05	27	2	4	16	13
E94/1421	-9.0	9.35	44	2	3	26	21
E94/1422	-2.5	8.60	29	6	4	20	16
E94/1423	-4.1	9.15	39	7	5	22	18
E94/1424	-19.9	8.85	66	9	5	39	32
E94/1425	-12.7	9.35	53	4	5	31	25
E94/1426	-13.1	9.45	42	3	5	25	20
E94/1427	-20.9	9.40	53	4	5	35	28
E94/1428	-13.4	8.00	684	305	5	35	28
E94/1429	-7.6	9.35	40	4	4	21	17
E94/1430	-11.1	9.55	68	3	4	42	35
E94/1431	-30.5	9.45	76	3	4	61	50
E94/1432	-11.5	9.55	71	3	5	43	35
E94/1433	-6.5	10.15	155	3	6	93	76
E94/1434	-6.5	9.15	85	6	4	51	41
E94/1435	-1.1	8.40	38	<1	3	23	19
E94/1436	3.6	4.45	480	217	3	NIL	NIL
E94/1437	3.8	4.20	343	142	3	NIL	NIL
E94/1438	-2.4	9.05	58	6	5	34	28
E94/1439	-2.5	9.15	37	7	3	21	17
E94/1440	-3.7	8.95	57	9	4	26	21

[a] Nett Acid Producing Potential (NAPP)

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE B-4 (2 OF 2)

15 Day Weathering Tests of Waste Rock Samples

pH, Electrical Conductivity, Sulphate and Chloride Concentration , Equivalent Bicarbonate, and Alkalinity Equivalent Values of 1:5 Soil:Water Extracts After 15 Days Weathering @ 40°

MRDL LAB No.	Crude NAPP [a] (Equiv. % $CaCO_3$)	pH	E.C. µS/cm @ 25°	Sulphate Conc. (mg/L)	Chloride Conc. (mg/L)	Equivalent HCO_3^- (mg/L)	Alkalinity Equivalent CaO_3 (mg/L)
E94/1441	-9.8	9.35	61	2	4	38	31
E94/1442	-3.0	9.65	52	3	3	35	28
E94/1443	-0.6	9.15	131	7	6	94	77
E94/1444	-11.9	9.55	110	3	5	76	62
E94/1445	-5.9	8.75	81	14	3	38	31
E94/1446	-0.3	8.80	26	6	2	7	6
E94/1447	-2.1	8.65	45	9	2	27	22
E94/1448	-7.6	8.90	39	2	3	23	19
E94/1449	-6.8	7.50	229	80	3	18	15
E94/1450	1.7	3.70	225	67	3	NIL	NIL
E94/1451	4.1	3.50	435	151	3	NIL	NIL
E94/1452	-7.8	8.50	51	9	4	30	24
E94/1453	-11.9	8.60	50	5	3	27	22
E94/1454	-8.7	9.30	51	3	4	38	31
E94/1455	-4.4	9.65	70	4	4	59	49
E94/1456	-6.2	9.65	65	5	4	42	34
E94/1457	-3.9	9.10	67	13	4	28	23
E94/1458	-12.3	8.55	132	33	4	34	28
E94/1459	4.1	3.70	352	125	3	NIL	NIL
E94/1460	2.7	4.40	920	469	3	NIL	NIL
E94/1461	-1.7	9.30	44	4	4	24	20
E94/1462	-2.8	8.60	41	9	4	17	14
E94/1463	-0.3	8.70	25	1	2	13	11
E94/1464	-16.6	9.00	58	5	4	40	33

[a] Nett Acid Producing Potential (NAPP)

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE B-5 (1 OF 2)

20 Day Weathering Tests of Waste Rock Samples

pH, Electrical Conductivity, Sulphate and Chloride Concentration , Equivalent Bicarbonate, and Alkalinity Equivalent Values of 1:5 Soil:Water Extracts After 20 Days Weathering @ 40°

MRDL LAB No.	Crude NAPP [a] (Equiv. % $CaCO_3$)	pH	E.C. µS/cm @ 25°	Sulphate Conc. (mg/L)	Chloride Conc. (mg/L)	Equivalent HCO_3^- (mg/L)	Alkalinity Equivalent CaO_3 (mg/L)
E94/1403	-9.4	8.85	50	5	1	32	26
E94/1404	-16.7	9.90	152	5	1	92	76
E94/1405	-9.4	10.05	117	3	<1	61	50
E94/1406	-11.3	10.20	220	3	<1	131	107
E94/1407	-18.4	9.90	245	3	<1	150	123
E94/1408	-18.8	9.65	99	4	1	67	55
E94/1409	-30.8	9.25	81	5	<1	47	38
E94/1410	-6.9	9.55	98	3	<1	77	63
E94/1411	-9.5	9.25	57	3	<1	37	30
E94/1412	-0.9	9.95	123	3	1	68	55
E94/1413	-1.7	9.90	115	4	<1	63	52
E94/1414	-1.6	10.20	130	2	<1	78	64
E94/1415	-5.1	10.20	174	4	<1	122	100
E94/1416	-25.1	10.10	77	3	<1	67	55
E94/1417	-6.5	10.25	224	4	<1	142	116
E94/1418	-5.7	10.15	191	3	<1	120	98
E94/1419	-8.6	10.20	164	4	<1	95	78
E94/1420	-6.6	8.85	23	2	1	13	11
E94/1421	-9.0	9.35	45	3	1	26	21
E94/1422	-2.5	8.95	21	5	<1	23	18
E94/1423	-4.1	8.55	30	6	5	21	17
E94/1424	-19.9	8.50	63	8	<1	35	28
E94/1425	-12.7	9.00	40	4	4	23	19
E94/1426	-13.1	9.15	41	3	12	23	19
E94/1427	-20.9	9.20	51	3	<1	33	27
E94/1428	-13.4	8.10	545	232	1	30	24
E94/1429	-7.6	9.05	32	7	7	17	14
E94/1430	-11.1	9.40	57	4	2	40	33
E94/1431	-30.5	9.40	68	3	<1	68	56
E94/1432	-11.5	9.20	56	3	1	35	29
E94/1433	-6.5	10.05	141	3	1	79	65
E94/1434	-6.5	8.75	75	7	<1	55	45
E94/1435	-1.1	8.00	35	4	<1	28	23
E94/1436	3.6	4.25	306	121	<1	NIL	NIL
E94/1437	3.8	4.20	266	106	<1	NIL	NIL
E94/1438	-2.4	9.05	49	6	<1	28	23
E94/1439	-2.5	8.90	33	9	<1	22	18
E94/1440	-3.7	9.00	54	8	<1	35	29

[a] Nett Acid Producing Potential (NAPP)

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE B-5 (2 OF 2)

20 Day Weathering Tests of Waste Rock Samples

pH, Electrical Conductivity, Sulphate and Chloride Concentration , Equivalent Bicarbonate, and Alkalinity Equivalent Values of 1:5 Soil:Water Extracts After 20 Days Weathering @ 40°

MRDL LAB No.	Crude NAPP [a] (Equiv. % $CaCO_3$)	pH	E.C. µS/cm @ 25°	Sulphate Conc. (mg/L)	Chloride Conc. (mg/L)	Equivalent HCO_3^- (mg/L)	Alkalinity Equivalent CaO_3 (mg/L)
E94/1441	-9.8	9.35	55	5	<1	35	29
E94/1442	-3.0	9.15	60	6	<1	39	32
E94/1443	-0.6	8.60	127	6	<1	87	72
E94/1444	-11.9	8.95	85	6	<1	56	46
E94/1445	-5.9	8.40	72	12	<1	35	29
E94/1446	-0.3	7.90	23	10	<1	6	5
E94/1447	-2.1	8.15	36	8	<1	21	17
E94/1448	-7.6	8.75	34	5	<1	27	22
E94/1449	-6.8	8.20	120	34	<1	30	25
E94/1450	1.7	3.75	161	44	<1	NIL	NIL
E94/1451	4.1	3.55	344	112	<1	NIL	NIL
E94/1452	-7.8	8.05	43	10	<1	29	24
E94/1453	-11.9	8.55	47	6	<1	28	23
E94/1454	-8.7	9.20	48	4	<1	33	27
E94/1455	-4.4	9.65	66	5	<1	51	41
E94/1456	-6.2	9.65	65	6	<1	39	32
E94/1457	-3.9	9.05	50	7	<1	29	24
E94/1458	-12.3	9.00	114	31	<1	30	25
E94/1459	4.1	3.60	346	115	<1	NIL	NIL
E94/1460	2.7	4.20	829	413	<1	NIL	NIL
E94/1461	-1.7	9.40	42	6	<1	24	20
E94/1462	-2.8	8.80	36	10	<1	14	11
E94/1463	-0.3	8.75	18	3	<1	10	8
E94/1464	-16.6	8.95	56	8	<1	35	29

[a] Nett Acid Producing Potential (NAPP)

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE B-6

30 Day Weathering Tests of Waste Rock Samples

pH, Electrical Conductivity, Sulphate and Chloride Concentration , Equivalent Bicarbonate, and Alkalinity Equivalent Values of 1:5 Soil:Water Extracts After 30 Days Weathering @ 40°

MRDL LAB No.	Crude NAPP [a] (Equiv. % $CaCO_3$)	pH	E.C. µS/cm @ 25°	Sulphate Conc. (mg/L)	Chloride Conc. (mg/L)	Equivalent HCO_3^- (mg/L)	Alkalinity Equivalent CaO_3 (mg/L)
E94/1428	-13.4	7.90	473	192	<1	58	48
E94/1436	3.6	4.20	293	132	1	NIL	NIL
E94/1437	3.8	4.20	256	146	1	NIL	NIL
E94/1443	-0.6	8.40	88	5	1	51	42
E94/1449	-6.8	7.80	102	27	1	25	20
E94/1450	1.7	3.70	126	32	1	NIL	NIL
E94/1451	4.1	3.50	320	134	1	NIL	NIL
E94/1458	-12.3	8.92	96	40	1	27	22
E94/1459	4.1	3.60	320	142	1	NIL	NIL
E94/1460	2.7	4.20	774	492	1	NIL	NIL

[a] Nett Acid Producing Potential (NAPP)

Note: Only the above samples were tested for 30day weathering.

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE C-1 (1 OF 2)

1:5 Soil:Water Extract After 16 hours leaching @ 22°

Calcium, Magnesium and Sodium Values of Extract

MRDL LAB No.	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Calcium (meq/L)	Magnesium (meq/L)	Sodium (meq/L)
E94/1403	28	44	40	1.40	3.62	1.74
E94/1404	2.9	32	250	0.14	2.63	10.9
E94/1405	3.1	2.0	216	0.15	0.16	9.39
E94/1406	2.5	22	339	0.12	1.81	14.7
E94/1407	4.4	27	307	0.22	2.22	13.4
E94/1408	15	7.2	173	0.75	0.59	7.52
E94/1409	44	11	170	2.20	0.90	7.39
E94/1410	43	31	151	2.15	2.55	6.57
E94/1411	26	49	72	1.30	4.03	3.13
E94/1412	12	51	824	0.60	4.19	35.8
E94/1413	4.3	32	400	0.21	2.63	17.4
E94/1414	13	46	1442	0.65	3.78	62.7
E94/1415	0.9	27	546	0.04	2.22	23.7
E94/1416	0.7	26	280	0.03	2.14	12.2
E94/1417	3.6	36	591	0.18	2.96	25.7
E94/1418	1.7	34	430	0.08	2.80	18.7
E94/1419	2.2	24	220	0.11	1.97	9.57
E94/1420	42	43	21	2.10	3.54	0.91
E94/1421	61	73	14	3.04	6.00	0.61
E94/1422	33	76	35	1.65	6.25	1.52
E94/1423	31	39	65	1.55	3.21	2.83
E94/1424	28	38	69	1.40	3.13	3.00
E94/1425	37	36	58	1.85	2.96	2.52
E94/1426	34	43	76	1.70	3.54	3.30
E94/1427	88	41	27	4.39	3.37	1.17
E94/1428	693	112	31	34.6	9.21	1.35
E94/1429	22	36	76	1.10	2.96	3.30
E94/1430	20	38	98	1.00	3.13	4.26
E94/1431	70	33	51	3.49	2.71	2.22
E94/1432	36	31	76	1.80	2.55	3.30
E94/1433	5.1	3.3	225	0.25	0.27	9.78
E94/1434	26	28	106	1.30	2.30	4.61
E94/1435	5.9	8.4	30	0.29	0.69	1.30
E94/1436	479	196	2.8	23.9	16.12	0.12
E94/1437	157	123	4.2	7.83	10.12	0.18
E94/1438	22	26	49	1.10	2.14	2.13
E94/1439	18	25	42	0.90	2.06	1.83
E94/1440	16	19	63	0.80	1.56	2.74

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE C-1 (2 OF 2)

1:5 Soil:Water Extract After 16 hours leaching @ 22°

Calcium, Magnesium and Sodium Values of Extract

MRDL LAB No.	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Calcium (meq/L)	Magnesium (meq/L)	Sodium (meq/L)
E94/1441	4.4	6.1	29	0.22	0.50	1.26
E94/1442	33	44	61	1.65	3.62	2.65
E94/1443	37	43	97	1.85	3.54	4.22
E94/1444	16	7.3	72	0.80	0.60	3.13
E94/1445	6.5	10	71	0.32	0.82	3.09
E94/1446	4.0	6.5	19	0.20	0.53	0.83
E94/1447	7.1	13	18	0.35	1.07	0.78
E94/1448	8.1	15	26	0.40	1.23	1.13
E94/1449	143	88	23	7.14	7.24	1.00
E94/1450	108	125	1.2	5.39	10.3	0.05
E94/1451	144	223	0.8	7.19	18.3	0.03
E94/1452	5.4	7.4	39	0.27	0.61	1.70
E94/1453	5.8	6.8	30	0.29	0.56	1.30
E94/1454	2.6	4.2	32	0.13	0.35	1.39
E94/1455	0.6	4.7	49	0.03	0.39	2.13
E94/1456	0.5	3.1	48	0.02	0.25	2.09
E94/1457	15	17	42	0.75	1.40	1.83
E94/1458	11	14	32	0.55	1.15	1.39
E94/1459	103	172	1.2	5.14	14.1	0.05
E94/1460	81	145	50	4.04	11.9	2.17
E94/1461	0.5	3.0	33	0.02	0.25	1.43
E94/1462	3.7	5.8	42	0.18	0.48	1.83
E94/1463	2.4	3.6	41	0.12	0.30	1.78
E94/1464	4.3	5.8	16	0.21	0.48	0.70

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE C-2 (1 OF 2)

1:5 Soil:Water Extract After 5 Days Weathering @ 40°

Calcium, Magnesium and Sodium Values of Extract

MRDL LAB No.	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Calcium (meq/L)	Magnesium (meq/L)	Sodium (meq/L)
E94/1403	5.1	12	24	0.25	0.99	1.04
E94/1404	0.7	43	180	0.03	3.54	7.83
E94/1405	0.3	2.2	103	0.01	0.18	4.48
E94/1406	16	13	161	0.80	1.07	7.00
E94/1407	1.1	9.4	167	0.05	0.77	7.26
E94/1408	12	7.9	111	0.60	0.65	4.83
E94/1409	30	13	103	1.50	1.07	4.48
E94/1410	44	39	84	2.20	3.21	3.65
E94/1411	9.1	26	41	0.45	2.14	1.78
E94/1412	16	37	677	0.80	3.04	29.4
E94/1413	4.6	35	251	0.23	2.88	10.9
E94/1414	13	51	996	0.65	4.19	43.3
E94/1415	3.1	35	349	0.15	2.88	15.2
E94/1416	3.2	31	284	0.16	2.55	12.4
E94/1417	4.1	41	252	0.20	3.37	11.0
E94/1418	4.7	40	354	0.23	3.29	15.4
E94/1419	4.2	22	185	0.21	1.81	8.04
E94/1420	3.4	5.1	11	0.17	0.42	0.48
E94/1421	2.6	6.5	8.6	0.13	0.53	0.37
E94/1422	1.0	22	17	0.05	1.81	0.74
E94/1423	0.7	19	21	0.03	1.56	0.91
E94/1424	12	17	35	0.60	1.40	1.52
E94/1425	5.5	8.0	25	0.27	0.66	1.09
E94/1426	3.3	9.8	23	0.16	0.81	1.00
E94/1427	3.4	6.6	23	0.17	0.54	1.00
E94/1428	534	88	20	26.7	7.24	0.87
E94/1429	7.7	15	29	0.38	1.23	1.26
E94/1430	11	23	35	0.55	1.89	1.52
E94/1431	42	15	28	2.10	1.23	1.22
E94/1432	9.2	12	35	0.46	0.99	1.52
E94/1433	4.1	37	162	0.20	3.04	7.04
E94/1434	0.4	2.7	75	0.02	0.22	3.26
E94/1435	0.2	2.6	25	0.01	0.21	1.09
E94/1436	315	178	5.9	15.7	14.6	0.26
E94/1437	66	110	9.1	3.29	9.05	0.40
E94/1438	0.4	2.5	31	0.02	0.21	1.35
E94/1439	0.3	2.0	31	0.01	0.16	1.35
E94/1440	0.9	2.9	45	0.04	0.24	1.96

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE C-2 (2 OF 2)

1:5 Soil:Water Extract After 5 Days Weathering @ 40°

Calcium, Magnesium and Sodium Values of Extract

MRDL LAB No.	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Calcium (meq/L)	Magnesium (meq/L)	Sodium (meq/L)
E94/1441	3.4	3.7	23	0.17	0.30	1.00
E94/1442	0.3	11	38	0.01	0.90	1.65
E94/1443	0.9	52	65	0.04	4.28	2.83
E94/1444	0.2	0.5	47	0.01	0.04	2.04
E94/1445	2.4	4.5	54	0.12	0.37	2.35
E94/1446	3.8	5.9	15	0.19	0.49	0.65
E94/1447	5.3	9.9	19	0.26	0.81	0.83
E94/1448	2.9	4.5	11	0.14	0.37	0.48
E94/1449	66	7.6	20	3.29	0.63	0.87
E94/1450	31	103	<0.1	1.55	8.47	<0.01
E94/1451	46	210	0.6	2.30	17.3	0.03
E94/1452	4.9	6.7	32	0.24	0.55	1.39
E94/1453	3.7	4.8	23	0.18	0.39	1.00
E94/1454	2.6	2.7	21	0.13	0.22	0.91
E94/1455	0.5	4.3	28	0.02	0.35	1.22
E94/1456	0.4	3.7	25	0.02	0.30	1.09
E94/1457	6.7	9.1	26	0.33	0.75	1.13
E94/1458	11	13	26	0.55	1.07	1.13
E94/1459	50	143	<0.1	2.50	11.8	<0.01
E94/1460	33	102	24	1.65	8.39	1.04
E94/1461	1.8	5.0	20	0.09	0.41	0.87
E94/1462	3.5	6.2	33	0.17	0.51	1.43
E94/1463	2.5	3.7	35	0.12	0.30	1.52
E94/1464	3.8	4.8	19	0.19	0.39	0.83

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE C-3 (1 OF 2)

1:5 Soil:Water Extract After 10 Days Weathering @ 40°

Calcium, Magnesium and Sodium Values of Extract

MRDL LAB No.	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Calcium (meq/L)	Magnesium (meq/L)	Sodium (meq/L)
E94/1403	3.2	6.5	6.9	0.16	0.53	0.30
E94/1404	0.3	2.1	88	0.01	0.17	3.83
E94/1405	0.3	2.2	57	0.01	0.18	2.48
E94/1406	0.8	2.6	114	0.04	0.21	4.96
E94/1407	1.0	2.2	104	0.05	0.18	4.52
E94/1408	0.6	3.6	51	0.03	0.30	2.22
E94/1409	7.5	3.2	46	0.37	0.26	2.00
E94/1410	1.4	5.5	44	0.07	0.45	1.91
E94/1411	0.4	4.2	17	0.02	0.35	0.74
E94/1412	1.0	4.8	87	0.05	0.39	3.78
E94/1413	0.9	3.5	71	0.04	0.29	3.09
E94/1414	1.7	49	208	0.08	4.03	9.04
E94/1415	0.5	2.8	215	0.02	0.23	9.35
E94/1416	0.4	2.7	148	0.02	0.22	6.43
E94/1417	1.5	5.3	195	0.07	0.44	8.48
E94/1418	0.9	3.5	174	0.04	0.29	7.57
E94/1419	0.7	3.1	78	0.03	0.25	3.39
E94/1420	0.3	3.5	4.0	0.01	0.29	0.17
E94/1421	2.4	5.9	2.6	0.12	0.49	0.11
E94/1422	0.4	3.0	8.6	0.02	0.25	0.37
E94/1423	0.4	2.9	9.7	0.02	0.24	0.42
E94/1424	0.8	3.6	16	0.04	0.30	0.70
E94/1425	0.7	4.8	12	0.03	0.39	0.52
E94/1426	0.6	11	8.7	0.03	0.90	0.38
E94/1427	4.2	4.1	4.4	0.21	0.34	0.19
E94/1428	185	22	4.0	9.23	1.81	0.17
E94/1429	0.3	3.2	11	0.01	0.26	0.48
E94/1430	0.6	3.9	22	0.03	0.32	0.96
E94/1431	8.7	13	12	0.43	1.07	0.52
E94/1432	0.9	12	20	0.04	0.99	0.87
E94/1433	1.0	3.1	76	0.05	0.25	3.30
E94/1434	0.5	2.0	35	0.02	0.16	1.52
E94/1435	0.3	3.1	12	0.01	0.25	0.52
E94/1436	235	69	4.3	11.7	5.67	0.19
E94/1437	87	35	5.1	4.34	2.88	0.22
E94/1438	0.3	5.3	18	0.01	0.44	0.78
E94/1439	0.3	4.7	15	0.01	0.39	0.65
E94/1440	0.4	12	31	0.02	0.99	1.35

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE C-3 (2 OF 2)

1:5 Soil:Water Extract After 10 Days Weathering @ 40°

Calcium, Magnesium and Sodium Values of Extract

MRDL LAB No.	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Calcium (meq/L)	Magnesium (meq/L)	Sodium (meq/L)
E94/1441	3.4	3.0	10	0.17	0.25	0.43
E94/1442	0.6	31	16	0.03	2.55	0.70
E94/1443	1.0	3.8	45	0.05	0.31	1.96
E94/1444	1.0	2.1	38	0.05	0.17	1.65
E94/1445	0.5	5.4	20	0.02	0.44	0.87
E94/1446	1.7	1.8	4.5	0.08	0.15	0.20
E94/1447	2.0	3.4	8.7	0.10	0.28	0.38
E94/1448	2.3	3.0	4.1	0.11	0.25	0.18
E94/1449	78	31	4.5	3.89	2.55	0.20
E94/1450	58	24	0.2	2.89	1.97	0.01
E94/1451	81	58	0.5	4.04	4.77	0.02
E94/1452	0.4	13	12	0.02	1.07	0.52
E94/1453	1.0	4.9	10	0.05	0.40	0.43
E94/1454	2.8	2.9	9.6	0.14	0.24	0.42
E94/1455	0.3	38	17	0.01	3.13	0.74
E94/1456	0.4	2.5	16	0.02	0.21	0.70
E94/1457	7.1	7.0	17	0.35	0.58	0.74
E94/1458	7.3	7.8	8.5	0.36	0.64	0.37
E94/1459	52	38	<0.1	2.59	3.13	<0.01
E94/1460	70	111	22	3.49	9.13	0.96
E94/1461	<0.1	<0.1	14	<0.01	<0.01	0.61
E94/1462	<0.1	0.1	14	<0.01	0.01	0.61
E94/1463	<0.1	<0.1	11	<0.01	<0.01	0.48
E94/1464	0.3	0.6	10	0.01	0.05	0.43

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE C-4 (1 OF 2)

1:5 Soil: Water Extract After 15 Days Weathering @ 40°

Calcium, Magnesium and Sodium Values of Extract

MRDL LAB No.	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Calcium (meq/L)	Magnesium (meq/L)	Sodium (meq/L)
E94/1403	1.6	4.3	2.5	0.08	0.35	0.11
E94/1404	0.1	3.1	56	<0.01	0.25	2.43
E94/1405	<0.1	1.1	26	<0.01	0.09	1.13
E94/1406	0.3	3.1	64	0.01	0.25	2.78
E94/1407	0.6	1.9	69	0.03	0.16	3.00
E94/1408	3.1	1.5	18	0.15	0.12	0.78
E94/1409	7.4	1.9	22	0.37	0.16	0.96
E94/1410	0.8	4.1	18	0.04	0.34	0.78
E94/1411	1.5	4.4	8.4	0.07	0.36	0.37
E94/1412	0.6	8.6	42	0.03	0.71	1.83
E94/1413	0.4	4.6	30	0.02	0.38	1.30
E94/1414	0.6	4.1	145	0.03	0.34	6.30
E94/1415	0.3	3.4	93	0.01	0.28	4.04
E94/1416	0.2	3.5	183	0.01	0.29	7.96
E94/1417	0.5	3.2	138	0.02	0.26	6.00
E94/1418	0.7	4.3	89	0.03	0.35	3.87
E94/1419	0.6	3.5	48	0.03	0.29	2.09
E94/1420	0.5	2.4	1.9	0.02	0.20	0.08
E94/1421	1.5	4	1.0	0.07	0.33	0.04
E94/1422	0.5	3.8	4.5	0.02	0.31	0.20
E94/1423	0.6	3.6	9.8	0.03	0.30	0.43
E94/1424	0.7	2.9	9.5	0.03	0.24	0.41
E94/1425	0.9	2.5	8.7	0.04	0.21	0.38
E94/1426	0.4	1.9	8.2	0.02	0.16	0.36
E94/1427	4.7	3.6	1.5	0.23	0.30	0.07
E94/1428	133	12	1.3	6.64	0.99	0.06
E94/1429	<0.1	3.7	8.3	<0.01	0.30	0.36
E94/1430	0.1	3.7	15	<0.01	0.30	0.65
E94/1431	6.3	4.3	4.6	0.31	0.35	0.20
E94/1432	1.0	2.8	11	0.05	0.23	0.48
E94/1433	0.3	3.3	35	0.01	0.27	1.52
E94/1434	0.6	2.7	21	0.03	0.22	0.91
E94/1435	0.4	1.5	7.3	0.02	0.12	0.32
E94/1436	62	15	2.4	3.09	1.23	0.10
E94/1437	26	13	3.3	1.30	1.07	0.14
E94/1438	0.2	3.3	13	0.01	0.27	0.57
E94/1439	0.2	4.8	9.6	0.01	0.39	0.42
E94/1440	0.8	2.5	12	0.04	0.21	0.52

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE C-4 (2 OF 2)

1:5 Soil:Water Extract After 15 Days Weathering @ 40°

Calcium, Magnesium and Sodium Values of Extract

MRDL LAB No.	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Calcium (meq/L)	Magnesium (meq/L)	Sodium (meq/L)
E94/1441	3.3	3.4	3.7	0.16	0.28	0.16
E94/1442	0.5	3.4	1.3	0.02	0.28	0.06
E94/1443	0.6	3.6	44	0.03	0.30	1.91
E94/1444	4.0	2.0	19	0.20	0.16	0.83
E94/1445	0.4	8.7	13	0.02	0.72	0.57
E94/1446	1.6	1.7	1.9	0.08	0.14	0.08
E94/1447	0.5	2.9	5.6	0.02	0.24	0.24
E94/1448	2.3	3.2	2.2	0.11	0.26	0.10
E94/1449	24	10	1.1	1.20	0.82	0.05
E94/1450	8.7	3.9	0.2	0.43	0.32	0.01
E94/1451	23	17	0.5	1.15	1.40	0.02
E94/1452	0.4	3.9	6.8	0.02	0.32	0.30
E94/1453	1.4	4.6	5.1	0.07	0.38	0.22
E94/1454	3.2	3.3	3.8	0.16	0.27	0.17
E94/1455	0.7	4.5	16	0.03	0.37	0.70
E94/1456	0.2	4.2	16	0.01	0.35	0.70
E94/1457	3.4	3.1	4.5	0.17	0.25	0.20
E94/1458	9.3	7.5	2.8	0.46	0.62	0.12
E94/1459	16	11	0.4	0.80	0.90	0.02
E94/1460	45	82	14	2.25	6.74	0.61
E94/1461	0.4	3.0	8.9	0.02	0.25	0.39
E94/1462	0.6	3.6	6.9	0.03	0.30	0.30
E94/1463	<0.1	4.1	4.8	<0.01	0.34	0.21
E94/1464	2.9	4.2	4.3	0.14	0.35	0.19

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE C-5 (1 OF 2)

1:5 Soil:Water Extract After 20 Days Weathering @ 40°

Calcium, Magnesium and Sodium Values of Extract

MRDL LAB No.	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Calcium (meq/L)	Magnesium (meq/L)	Sodium (meq/L)
E94/1403	1.8	4.8	1.4	0.09	0.39	0.06
E94/1404	0.2	2.4	28	0.01	0.20	1.22
E94/1405	0.2	1.9	18	0.01	0.16	0.78
E94/1406	0.5	2.8	49	0.02	0.23	2.13
E94/1407	1.1	1.0	39	0.05	0.08	1.70
E94/1408	2.7	1.5	13	0.13	0.12	0.57
E94/1409	5.9	1.7	6.2	0.29	0.14	0.27
E94/1410	0.7	5.1	13	0.03	0.42	0.57
E94/1411	1.3	4.4	2.7	0.06	0.36	0.12
E94/1412	0.3	5.0	27	0.01	0.41	1.17
E94/1413	0.4	3.9	21	0.02	0.32	0.91
E94/1414	0.7	4.1	52	0.03	0.34	2.26
E94/1415	0.4	3.1	54	0.02	0.25	2.35
E94/1416	0.5	2.9	58	0.02	0.24	2.52
E94/1417	0.6	3.9	74	0.03	0.32	3.22
E94/1418	0.6	4.1	46	0.03	0.34	2.00
E94/1419	0.6	2.9	29	0.03	0.24	1.26
E94/1420	0.7	2.6	0.8	0.03	0.21	0.03
E94/1421	1.7	3.8	0.5	0.08	0.31	0.02
E94/1422	0.6	2.7	3.2	0.03	0.22	0.14
E94/1423	0.5	2.4	6.7	0.02	0.20	0.29
E94/1424	1.6	8.0	3.9	0.08	0.66	0.17
E94/1425	1.7	2.3	3.8	0.08	0.19	0.17
E94/1426	0.5	1.8	6.0	0.02	0.15	0.26
E94/1427	4.6	3.1	0.4	0.23	0.25	0.02
E94/1428	93	8.2	0.5	4.64	0.67	0.02
E94/1429	0.3	4.4	5.0	0.01	0.36	0.22
E94/1430	0.4	4.6	9.7	0.02	0.38	0.42
E94/1431	6.6	4.2	1.7	0.33	0.35	0.07
E94/1432	1.9	2.9	4.2	0.09	0.24	0.18
E94/1433	0.4	3.1	23	0.02	0.25	1.00
E94/1434	0.7	4.0	34	0.03	0.33	1.48
E94/1435	2.1	2.7	3.7	0.10	0.22	0.16
E94/1436	37	8.5	3.5	1.85	0.70	0.15
E94/1437	17	9.0	2.8	0.85	0.74	0.12
E94/1438	1.7	2.2	12	0.08	0.18	0.52
E94/1439	1.7	2.6	9.7	0.08	0.21	0.42
E94/1440	2.3	3.1	13	0.11	0.25	0.57

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE C-5 (2 OF 2)

1:5 Soil:Water Extract After 20 Days Weathering @ 40°

Calcium, Magnesium and Sodium Values of Extract

MRDL LAB No.	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Calcium (meq/L)	Magnesium (meq/L)	Sodium (meq/L)
E94/1435	2.1	2.7	3.7	0.10	0.22	0.16
E94/1436	37	8.5	3.5	1.85	0.70	0.15
E94/1437	17	9.0	2.8	0.85	0.74	0.12
E94/1438	1.7	2.2	12	0.08	0.18	0.52
E94/1439	1.7	2.6	9.7	0.08	0.21	0.42
E94/1440	2.3	3.1	13	0.11	0.25	0.57
E94/1441	3.9	3.6	1.8	0.19	0.30	0.08
E94/1442	3.7	11	16	0.18	0.90	0.70
E94/1443	3.0	12	26	0.15	0.99	1.13
E94/1444	5.9	2.7	8.5	0.29	0.22	0.37
E94/1445	2.3	3.9	7.5	0.11	0.32	0.33
E94/1446	2.2	2.2	1.1	0.11	0.18	0.05
E94/1447	2.3	11	2.9	0.11	0.90	0.13
E94/1448	3.5	4.0	1.1	0.17	0.33	0.05
E94/1449	12	5.2	0.7	0.60	0.43	0.03
E94/1450	4.6	2.1	0.7	0.23	0.17	0.03
E94/1451	15	9.3	1.2	0.75	0.76	0.05
E94/1452	7.8	7.2	3.7	0.39	0.59	0.16
E94/1453	6.4	5.8	2.8	0.32	0.48	0.12
E94/1454	4.6	4.4	1.9	0.23	0.36	0.08
E94/1455	3.6	12	20	0.18	0.99	0.87
E94/1456	4.0	8.4	16	0.20	0.69	0.70
E94/1457	5.6	4.7	2.5	0.28	0.39	0.11
E94/1458	7.8	7.1	1.4	0.39	0.58	0.06
E94/1459	11	8.1	0.6	0.55	0.67	0.03
E94/1460	36	78	8.7	1.80	6.41	0.38
E94/1461	2.1	3.1	8.4	0.10	0.25	0.37
E94/1462	3.5	5.1	5.5	0.17	0.42	0.24
E94/1463	1.7	2.1	3.2	0.08	0.17	0.14
E94/1464	6.7	4.4	2.2	0.33	0.36	0.10

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE C-6

1:5 Soil:Water Extract After 30 Days Weathering @ 40°

Calcium, Magnesium and Sodium Values of Extract

MRDL LAB No.	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Calcium (meq/L)	Magnesium (meq/L)	Sodium (meq/L)
E94/1428	82	12	0.8	4.09	0.99	0.03
E94/1436	35	7.4	2.8	1.75	0.61	0.12
E94/1437	26	14	1.7	1.30	1.15	0.07
E94/1443	0.8	5.3	13	0.04	0.44	0.57
E94/1449	11	4.9	0.5	0.55	0.40	0.02
E94/1450	5.5	1.6	0.7	0.27	0.13	0.03
E94/1451	18	9.8	0.6	0.90	0.81	0.03
E94/1458	10	7.7	0.9	0.50	0.63	0.04
E94/1459	15	8.6	0.3	0.75	0.71	0.01
E94/1460	40	48	6.7	2.00	3.95	0.29

Note: Only the above samples were tested for 30day weathering.

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE D-1 (1 OF 2)

pH Values of 1:5 Soil:Water Extract After Weathering Tests

MRDL LAB No.	Crude NAPP [a] (Equiv. % $CaCO_3$)	pH after 16 hrs @ 22°	pH after 5 days @ 40°	pH after 10 days @ 40°	pH after 15 days @ 40°	pH after 20 days @ 40°	pH after 30 days @ 40°
E94/1403	-9.4	7.20	7.35	8.10	8.95	8.85	-
E94/1404	-16.7	9.50	9.30	9.50	9.10	9.90	-
E94/1405	-9.4	9.85	9.75	10.20	9.75	10.05	-
E94/1406	-11.3	10.05	9.80	10.25	9.60	10.20	-
E94/1407	-18.4	10.30	9.95	10.20	9.90	9.90	-
E94/1408	-18.8	10.15	9.80	9.90	9.65	9.65	-
E94/1409	-30.8	10.10	10.30	9.60	9.40	9.25	-
E94/1410	-6.9	9.65	9.80	10.00	9.55	9.55	-
E94/1411	-9.5	9.50	9.30	9.30	9.30	9.25	-
E94/1412	-0.9	10.20	10.00	10.10	9.75	9.95	-
E94/1413	-1.7	10.10	9.85	10.20	9.60	9.90	-
E94/1414	-1.6	10.00	10.00	10.15	9.85	10.20	-
E94/1415	-5.1	10.15	10.00	10.25	9.35	10.20	-
E94/1416	-25.1	10.05	10.00	10.10	9.55	10.10	-
E94/1417	-6.5	10.00	10.10	10.50	9.95	10.25	-
E94/1418	-5.7	10.05	10.10	10.30	9.75	10.15	-
E94/1419	-8.6	9.80	9.90	10.30	10.20	10.20	-
E94/1420	-6.6	9.05	9.00	9.25	9.05	8.85	-
E94/1421	-9.0	8.65	8.75	8.75	9.35	9.35	-
E94/1422	-2.5	8.65	8.60	9.20	8.60	8.95	-
E94/1423	-4.1	8.95	9.10	9.50	9.15	8.55	-
E94/1424	-19.9	8.60	8.60	9.30	8.85	8.50	-
E94/1425	-12.7	9.00	9.00	9.35	9.35	9.00	-
E94/1426	-13.1	8.95	9.00	9.40	9.45	9.15	-
E94/1427	-20.9	9.10	9.30	9.40	9.40	9.20	-
E94/1428	-13.4	6.30	7.70	7.80	8.00	8.10	7.90
E94/1429	-7.6	9.00	9.20	9.65	9.35	9.05	-
E94/1430	-11.1	9.30	9.50	10.00	9.55	9.40	-
E94/1431	-30.5	9.40	9.60	9.50	9.45	9.40	-
E94/1432	-11.5	9.45	9.70	9.65	9.55	9.20	-
E94/1433	-6.5	9.90	9.80	10.40	10.15	10.05	-
E94/1434	-6.5	9.50	9.10	9.05	9.15	8.75	-
E94/1435	-1.1	9.60	8.60	8.85	8.40	8.00	-
E94/1436	3.6	4.20	4.40	4.75	4.45	4.25	4.20
E94/1437	3.8	4.80	4.35	4.05	4.20	4.20	4.20
E94/1438	-2.4	9.50	8.80	9.35	9.05	9.05	-
E94/1439	-2.5	9.35	8.80	8.75	9.15	8.90	-
E94/1440	-3.7	9.40	8.80	9.05	8.95	9.00	-

[a] Nett Acid Producing Potential (NAPP)

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE D-1 (2 OF 2)

pH Values of 1:5 Soil:Water After Weathering Tests

MRDL LAB No.	Crude NAPP [a] (Equiv. % $CaCO_3$)	pH after 16 hrs @ 22°	pH after 5 days @ 40°	pH after 10 days @ 40°	pH after 15 days @ 40°	pH after 20 days @ 40°	pH after 30 days @ 40°
E94/1441	-9.8	9.30	9.30	9.50	9.35	9.35	-
E94/1442	-3.0	9.75	9.15	9.55	9.65	9.15	-
E94/1443	-0.6	9.70	9.50	9.45	9.15	8.60	8.40
E94/1444	-11.9	10.10	10.10	9.80	9.55	8.95	
E94/1445	-5.9	7.85	8.15	8.40	8.75	8.40	-
E94/1446	-0.3	7.00	7.10	7.95	8.80	7.90	-
E94/1447	-2.1	8.00	7.65	7.95	8.65	8.15	-
E94/1448	-7.6	8.65	8.50	8.80	8.90	8.75	-
E94/1449	-6.8	7.50	7.50	7.50	7.50	8.20	7.80
E94/1450	1.7	2.75	3.00	3.45	3.70	3.75	3.70
E94/1451	4.1	3.65	3.50	3.45	3.50	3.55	3.50
E94/1452	-7.8	7.80	7.50	7.85	8.50	8.05	-
E94/1453	-11.9	8.10	8.20	8.25	8.60	8.55	-
E94/1454	-8.7	9.15	9.20	9.30	9.30	9.20	-
E94/1455	-4.4	9.70	9.80	9.45	9.65	9.65	-
E94/1456	-6.2	9.70	9.90	9.70	9.65	9.65	-
E94/1457	-3.9	8.20	7.85	8.40	9.10	9.05	-
E94/1458	-12.3	9.00	8.60	8.75	8.55	9.00	8.95
E94/1459	4.1	3.20	3.40	3.60	3.70	3.60	3.60
E94/1460	2.7	3.40	3.90	4.35	4.40	4.20	4.20
E94/1461	-1.7	9.50	9.15	9.20	9.30	9.40	-
E94/1462	-2.8	8.00	7.75	8.30	8.60	8.80	-
E94/1463	-0.3	7.45	7.30	8.20	8.70	8.75	-
E94/1464	-16.6	8.70	9.00	9.00	9.00	8.95	-

[a] Nett Acid Producing Potential (NAPP)

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE D-2 (1 OF 2)

Electrical Conductivity (μS/cm @ 25°) of 1:5 Soil:Water Extract After Weathering Tests

MRDL LAB No.	Crude NAPP [a] (Equiv. % $CaCO_3$)	E.C. after 16 hrs @ 22°	E.C. after 5 days @ 40°	E.C. after 10 days @ 40°	E.C. after 15 days @ 40°	E.C. after 20 days @ 40°	E.C. after 30 days @ 40°
E94/1403	-9.4	195	250	103	47	50	-
E94/1404	-16.7	420	536	275	201	152	-
E94/1405	-9.4	340	311	195	170	117	-
E94/1406	-11.3	637	567	323	253	220	-
E94/1407	-18.4	723	692	407	294	245	-
E94/1408	-18.8	569	455	217	140	99	-
E94/1409	-30.8	482	465	206	112	81	-
E94/1410	-6.9	385	368	185	130	98	-
E94/1411	-9.5	229	228	111	71	57	-
E94/1412	-0.9	846	864	228	152	123	-
E94/1413	-1.7	460	435	174	138	115	-
E94/1414	-1.6	1299	1075	407	187	130	-
E94/1415	-5.1	694	742	340	255	174	-
E94/1416	-25.1	454	388	151	110	77	-
E94/1417	-6.5	648	466	453	303	224	-
E94/1418	-5.7	630	629	337	261	191	-
E94/1419	-8.6	377	371	230	179	164	-
E94/1420	-6.6	84	73.1	33	27	23	-
E94/1421	-9.0	126	119	76	44	45	-
E94/1422	-2.5	136	123	42	29	21	-
E94/1423	-4.1	132	103	39	39	30	-
E94/1424	-19.9	236	213	76	66	63	-
E94/1425	-12.7	194	160	65	53	40	-
E94/1426	-13.1	163	137	47	42	41	-
E94/1427	-20.9	183	166	67	53	51	-
E94/1428	-13.4	2340	2600	1019	684	545	473
E94/1429	-7.6	196	167	50	40	32	-
E94/1430	-11.1	238	199	80	68	57	-
E94/1431	-30.5	227	204	97	76	68	-
E94/1432	-11.5	236	210	97	71	56	-
E94/1433	-6.5	254	298	180	155	141	-
E94/1434	-6.5	385	268	138	85	75	-
E94/1435	-1.1	181	125	54	38	35	-
E94/1436	3.6	3300	2275	1360	480	306	293
E94/1437	3.8	2830	2220	915	343	266	256
E94/1438	-2.4	211	137	78	58	49	-
E94/1439	-2.5	210	149	64	37	33	-
E94/1440	-3.7	337	113	105	57	54	-

[a] Nett Acid Producing Potential (NAPP)

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE D-2 (2 OF 2)

Electrical Conductivity (µS/cm @ 25°) of 1:5 Soil:Water Extract After Weathering Tests

MRDL LAB No.	Crude NAPP [a] (Equiv. % $CaCO_3$)	E.C. after 16 hrs @ 22°	E.C. after 5 days @ 40°	E.C. after 10 days @ 40°	E.C. after 15 days @ 40°	E.C. after 20 days @ 40°	E.C. after 30 days @ 40°
E94/1441	-9.8	242	170	91	61	55	-
E94/1442	-3.0	267	174	83	52	60	-
E94/1443	-0.6	377	223	153	131	127	88
E94/1444	-11.9	371	217	197	110	85	-
E94/1445	-5.9	500	313	142	81	72	-
E94/1446	-0.3	204	159	52	26	23	-
E94/1447	-2.1	325	220	97	45	36	-
E94/1448	-7.6	176	110	55	39	34	-
E94/1449	-6.8	1328	829	657	229	120	102
E94/1450	1.7	2830	1749	850	225	161	126
E94/1451	4.1	2660	1979	1088	435	344	320
E94/1452	-7.8	328	245	86	51	43	-
E94/1453	-11.9	271	174	79	50	47	-
E94/1454	-8.7	221	143	78	51	48	-
E94/1455	-4.4	216	118	90	70	66	-
E94/1456	-6.2	218	107	87	65	65	-
E94/1457	-3.9	470	282	202	67	50	-
E94/1458	-12.3	382	301	153	132	114	96
E94/1459	4.1	3150	2093	856	352	346	320
E94/1460	2.7	2330	1156	1290	920	829	774
E94/1461	-1.7	185	95	69	44	42	-
E94/1462	-2.8	329	223	99	41	36	-
E94/1463	-0.3	298	219	67	25	18	-
E94/1464	-16.6	205	130	82	58	56	-

[a] Nett Acid Producing Potential (NAPP)

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE D-3 (1 OF 2)

Sulphate Concentration Values (mg/Litre) of 1:5 Soil:Water Extract After Weathering Tests

MRDL LAB No.	Crude NAPP [a] (Equiv. % $CaCO_3$)	SO_4^{2-} after 16 hrs @ 22°	SO_4^{2-} after 5 days @ 40°	SO_4^{2-} after 10 days @ 40°	SO_4^{2-} after 15 days @ 40°	SO_4^{2-} after 20 days @ 40°	SO_4^{2-} after 30 days @ 40°
E94/1403	-9.4	49	71	11	6	5	-
E94/1404	-16.7	44	39	9	4	5	-
E94/1405	-9.4	13	7	3	2	3	-
E94/1406	-11.3	23	19	4	4	3	-
E94/1407	-18.4	14	11	2	2	3	-
E94/1408	-18.8	13	8	2	2	4	-
E94/1409	-30.8	10	9	4	4	5	-
E94/1410	-6.9	8	7	1	3	3	-
E94/1411	-9.5	31	26	5	2	3	-
E94/1412	-0.9	5	6	4	2	3	-
E94/1413	-1.7	15	14	4	3	4	-
E94/1414	-1.6	12	<1	5	3	2	-
E94/1415	-5.1	24	34	7	3	4	-
E94/1416	-25.1	12	11	2	2	3	-
E94/1417	-6.5	19	15	<1	2	4	-
E94/1418	-5.7	28	37	<1	2	3	-
E94/1419	-8.6	28	27	6	3	4	-
E94/1420	-6.6	5	4	1	2	2	-
E94/1421	-9.0	22	22	4	2	3	-
E94/1422	-2.5	32	32	8	6	5	-
E94/1423	-4.1	24	22	7	7	6	-
E94/1424	-19.9	41	45	10	9	8	-
E94/1425	-12.7	26	25	3	4	4	-
E94/1426	-13.1	23	21	2	3	3	-
E94/1427	-20.9	29	25	4	4	3	-
E94/1428	-13.4	1550	1605	502	305	232	192
E94/1429	-7.6	39	40	4	4	7	-
E94/1430	-11.1	39	38	5	3	4	-
E94/1431	-30.5	20	18	2	3	3	-
E94/1432	-11.5	20	16	4	3	3	-
E94/1433	-6.5	17	12	3	3	3	-
E94/1434	-6.5	98	82	27	6	7	-
E94/1435	-1.1	17	12	3	<1	4	-
E94/1436	3.6	2350	1735	789	217	121	132
E94/1437	3.8	1970	1720	475	142	106	146
E94/1438	-2.4	37	29	10	6	6	-
E94/1439	-2.5	46	45	11	7	9	-
E94/1440	-3.7	70	60	16	9	8	-

[a] Nett Acid Producing Potential (NAPP)

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE D-3 (2 OF 2)

Sulphate Concentration Values (mg/Litre) of 1:5 Soil:Water Extract After Weathering Tests

MRDL LAB No.	Crude NAPP [a] (Equiv. % $CaCO_3$)	SO_4^{2-} after 16 hrs @ 22°	SO_4^{2-} after 5 days @ 40°	SO_4^{2-} after 10 days @ 40°	SO_4^{2-} after 15 days @ 40°	SO_4^{2-} after 20 days @ 40°	SO_4^{2-} after 30 days @ 40°
E94/1441	-9.8	32	25	7	2	5	-
E94/1442	-3.0	34	24	5	3	6	-
E94/1443	-0.6	53	39	8	7	6	5
E94/1444	-11.9	13	10	3	3	6	-
E94/1445	-5.9	145	114	32	14	12	-
E94/1446	-0.3	41	38	13	6	10	-
E94/1447	-2.1	91	72	25	9	8	-
E94/1448	-7.6	34	27	4	2	5	-
E94/1449	-6.8	664	440	319	80	34	27
E94/1450	1.7	1510	1120	387	67	44	32
E94/1451	4.1	1765	1360	533	151	112	134
E94/1452	-7.8	77	68	19	9	10	-
E94/1453	-11.9	59	54	13	5	6	-
E94/1454	-8.7	10	7	2	3	4	-
E94/1455	-4.4	22	20	6	4	5	-
E94/1456	-6.2	25	21	6	5	6	-
E94/1457	-3.9	152	107	66	13	7	-
E94/1458	-12.3	123	114	35	33	31	40
E94/1459	4.1	2205	1515	414	125	115	142
E94/1460	2.7	1360	693	723	469	413	492
E94/1461	-1.7	28	19	8	4	6	-
E94/1462	-2.8	94	79	29	9	10	-
E94/1463	-0.3	12	5	4	1	3	-
E94/1464	-16.6	36	27	10	5	8	-

[a] Nett Acid Producing Potential (NAPP)

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE D-4 (1 OF 2)

Equivalent Bicarbonate Concentration Values (mg/Litre) of 1:5 Soil:Water Extract After Weathering Tests

MRDL LAB No.	Crude NAPP [a] (Equiv. % $CaCO_3$)	Equivalent HCO_3^- after 16 hrs @ 22°	Equivalent HCO_3^- after 5 days @ 40°	Equivalent HCO_3^- after 10 days @ 40°	Equivalent HCO_3^- after 15 days @ 40°	Equivalent HCO_3^- after 20 days @ 40°	Equivalent HCO_3^- after 30 days @ 40°
E94/1403	-9.4	42	46	45	29	32	-
E94/1404	-16.7	304	323	181	135	92	-
E94/1405	-9.4	218	201	111	102	61	-
E94/1406	-11.3	453	355	203	165	131	-
E94/1407	-18.4	497	443	256	189	150	-
E94/1408	-18.8	135	302	141	96	67	-
E94/1409	-30.8	377	427	144	90	47	-
E94/1410	-6.9	414	269	142	101	77	-
E94/1411	-9.5	299	93	67	45	37	-
E94/1412	-0.9	94	400	133	91	68	-
E94/1413	-1.7	500	239	99	82	63	-
E94/1414	-1.6	275	477	217	113	78	-
E94/1415	-5.1	622	470	246	180	122	-
E94/1416	-25.1	458	263	115	77	67	-
E94/1417	-6.5	266	279	285	191	142	-
E94/1418	-5.7	371	381	216	172	120	-
E94/1419	-8.6	380	218	132	103	95	-
E94/1420	-6.6	216	34	18	16	13	-
E94/1421	-9.0	45	31	42	26	26	-
E94/1422	-2.5	47	32	22	20	23	-
E94/1423	-4.1	34	33	22	22	21	-
E94/1424	-19.9	53	60	52	39	35	-
E94/1425	-12.7	81	58	35	31	23	-
E94/1426	-13.1	86	45	28	25	23	-
E94/1427	-20.9	71	55	39	35	33	-
E94/1428	-13.4	68	27	32	35	30	58
E94/1429	-7.6	43	34	25	21	17	-
E94/1430	-11.1	68	58	48	42	40	-
E94/1431	-30.5	91	203	88	61	68	-
E94/1432	-11.5	111	102	57	43	35	-
E94/1433	-6.5	222	180	110	93	79	-
E94/1434	-6.5	119	60	57	51	55	-
E94/1435	-1.1	51	32	29	23	28	-
E94/1436	3.6	NIL	NIL	NIL	NIL	NIL	NIL
E94/1437	3.8	NIL	NIL	NIL	NIL	NIL	NIL
E94/1438	-2.4	86	36	40	34	28	-
E94/1439	-2.5	79	27	29	21	22	-
E94/1440	-3.7	124	43	51	26	35	-

[a] Nett Acid Producing Potential (NAPP)

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE D-4 (2 OF 2)

Equivalent Bicarbonate Concentration Values (mg/Litre) of 1:5 Soil:Water Extract After Weathering Tests

MRDL LAB No.	Crude NAPP [a] (Equiv. % $CaCO_3$)	Equivalent HCO_3^- after 16 hrs @ 22°	Equivalent HCO_3^- after 5 days @ 40°	Equivalent HCO_3^- after 10 days @ 40°	Equivalent HCO_3^- after 15 days @ 40°	Equivalent HCO_3^- after 20 days @ 40°	Equivalent HCO_3^- after 30 days @ 40°
E94/1441	-9.8	55	35	47	38	35	-
E94/1442	-3.0	114	58	51	35	39	-
E94/1443	-0.6	153	102	104	94	87	51
E94/1444	-11.9	208	144	155	76	56	-
E94/1445	-5.9	58	23	48	38	35	-
E94/1446	-0.3	10	3	7	7	6	-
E94/1447	-2.1	24	11	18	27	21	-
E94/1448	-7.6	39	18	26	23	27	-
E94/1449	-6.8	59	10	15	18	30	25
E94/1450	1.7	NIL	NIL	NIL	NIL	NIL	NIL
E94/1451	4.1	NIL	NIL	NIL	NIL	NIL	NIL
E94/1452	-7.8	30	16	25	30	29	-
E94/1453	-11.9	47	11	29	27	28	-
E94/1454	-8.7	60	34	56	38	33	-
E94/1455	-4.4	127	55	56	59	51	-
E94/1456	-6.2	111	38	56	42	39	-
E94/1457	-3.9	40	6	19	28	29	-
E94/1458	-12.3	42	25	34	34	30	27
E94/1459	4.1	NIL	NIL	NIL	NIL	NIL	NIL
E94/1460	2.7	NIL	NIL	NIL	NIL	NIL	NIL
E94/1461	-1.7	66	17	37	24	24	-
E94/1462	-2.8	35	8	22	17	14	-
E94/1463	-0.3	11	3	14	13	10	-
E94/1464	-16.6	60	38	54	40	35	-

[a] Nett Acid Producing Potential (NAPP)

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE D-5 (1 OF 2)

Alkalinity Equivalent $CaCO_3$ Values (mg/Litre) of 1:5 Soil:Water Extract After Weathering Tests

MRDL LAB No.	Crude NAPP [a] (Equiv. % $CaCO_3$)	Alkalinity Equivalent CaO_3 after 16 hrs @ 22°	Alkalinity Equivalent CaO_3 after 5 days @ 40°	Alkalinity Equivalent CaO_3 after 10 days @ 40°	Alkalinity Equivalent CaO_3 after 15 days @ 40°	Alkalinity Equivalent CaO_3 after 20 days @ 40°	Alkalinity Equivalent CaO_3 after 30 days @ 40°
E94/1403	-9.4	34	37	37	24	26	-
E94/1404	-16.7	249	265	149	111	76	-
E94/1405	-9.4	179	165	91	83	50	-
E94/1406	-11.3	371	291	167	135	107	-
E94/1407	-18.4	408	363	209	155	123	-
E94/1408	-18.8	111	247	116	79	55	-
E94/1409	-30.8	309	350	118	73	38	-
E94/1410	-6.9	339	221	116	83	63	-
E94/1411	-9.5	245	76	55	37	30	-
E94/1412	-0.9	77	328	109	74	55	-
E94/1413	-1.7	410	196	81	68	52	-
E94/1414	-1.6	226	391	178	92	64	-
E94/1415	-5.1	510	385	202	147	100	-
E94/1416	-25.1	375	215	94	63	55	-
E94/1417	-6.5	218	229	233	157	116	-
E94/1418	-5.7	304	312	177	141	98	-
E94/1419	-8.6	312	179	108	85	78	-
E94/1420	-6.6	177	28	14	13	11	-
E94/1421	-9.0	37	25	34	21	21	-
E94/1422	-2.5	39	26	18	16	18	-
E94/1423	-4.1	28	27	18	18	17	-
E94/1424	-19.9	43	49	43	32	28	-
E94/1425	-12.7	66	48	29	25	19	-
E94/1426	-13.1	71	37	23	20	19	-
E94/1427	-20.9	59	45	32	28	27	-
E94/1428	-13.4	55	22	26	28	24	48
E94/1429	-7.6	35	28	20	17	14	-
E94/1430	-11.1	56	48	39	35	33	-
E94/1431	-30.5	74	166	72	50	56	-
E94/1432	-11.5	91	84	46	35	29	-
E94/1433	-6.5	182	148	90	76	65	-
E94/1434	-6.5	97	49	47	41	45	-
E94/1435	-1.1	42	26	23	19	23	-
E94/1436	3.6	NIL	NIL	NIL	NIL	NIL	NIL
E94/1437	3.8	NIL	NIL	NIL	NIL	NIL	NIL
E94/1438	-2.4	71	30	33	28	23	-
E94/1439	-2.5	65	22	24	17	18	-
E94/1440	-3.7	102	35	42	21	29	-

[a] Nett Acid Producing Potential (NAPP)

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE D-5 (2 OF 2)

Alkalinity Equivalent $CaCO_3$ Values (mg/Litre) of 1:5 Soil:Water Extract After Weathering Tests

MRDL LAB No.	Crude NAPP [a] (Equiv. % $CaCO_3$)	Alkalinity Equivalent CaO_3 after 16 hrs @ 22°	Alkalinity Equivalent CaO_3 after 5 days @ 40°	Alkalinity Equivalent CaO_3 after 10 days @ 40°	Alkalinity Equivalent CaO_3 after 15 days @ 40°	Alkalinity Equivalent CaO_3 after 20 days @ 40°	Alkalinity Equivalent CaO_3 after 30 days @ 40°
E94/1441	-9.8	45	29	39	31	29	-
E94/1442	-3.0	94	47	42	28	32	-
E94/1443	-0.6	125	83	85	77	72	42
E94/1444	-11.9	171	118	127	62	46	-
E94/1445	-5.9	48	19	40	31	29	-
E94/1446	-0.3	9	3	6	6	5	-
E94/1447	-2.1	20	9	14	22	17	-
E94/1448	-7.6	32	15	21	19	22	-
E94/1449	-6.8	49	8	12	15	25	20
E94/1450	1.7	NIL	NIL	NIL	NIL	NIL	NIL
E94/1451	4.1	NIL	NIL	NIL	NIL	NIL	NIL
E94/1452	-7.8	24	14	20	24	24	-
E94/1453	-11.9	39	9	23	22	23	-
E94/1454	-8.7	49	28	46	31	27	-
E94/1455	-4.4	104	45	46	49	41	-
E94/1456	-6.2	91	31	46	34	32	-
E94/1457	-3.9	33	5	15	23	24	-
E94/1458	-12.3	34	21	28	28	25	22
E94/1459	4.1	NIL	NIL	NIL	NIL	NIL	NIL
E94/1460	2.7	NIL	NIL	NIL	NIL	NIL	NIL
E94/1461	-1.7	54	14	30	20	20	-
E94/1462	-2.8	29	6	18	14	11	-
E94/1463	-0.3	9	2	12	11	8	-
E94/1464	-16.6	49	31	44	33	29	-

[a] Nett Acid Producing Potential (NAPP)

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE E-1 (1 OF 3)

Calcium Values of 1:5 Soil:Water Extract After Weathering Tests

MRDL LAB No.	Ca after 16 hrs @ 22° (mg/L)	Ca after 5 days @ 40° (mg/L)	Ca after 10 days @ 40° (mg/L)	Ca after 15 days @ 40° (mg/L)	Ca after 20 days @ 40° (mg/L)	Ca after 30 days @ 40° (mg/L)	Ca after 16 hrs @ 22° (meq/L)	Ca after 5 days @ 40° (meq/L)	Ca after 10 days @ 40° (meq/L)	Ca after 15 days @ 40° (meq/L)	Ca after 20 days @ 40° (meq/L)	Ca after 30 days @ 40° (meq/L)
E94/1403	28	5.1	3.2	1.6	1.8	-	1.40	0.25	0.16	0.08	0.09	-
E94/1404	2.9	0.7	0.3	0.1	0.2	-	0.14	0.03	0.01	<0.01	0.01	-
E94/1405	3.1	0.3	0.3	<0.1	0.2	-	0.15	0.01	0.01	<0.01	0.01	-
E94/1406	2.5	16	0.8	0.3	0.5	-	0.12	0.80	0.04	0.01	0.02	-
E94/1407	4.4	1.1	1.0	0.6	1.1	-	0.22	0.05	0.05	0.03	0.05	-
E94/1408	15	12	0.6	3.1	2.7	-	0.75	0.60	0.03	0.15	0.13	-
E94/1409	44	30	7.5	7.4	5.9	-	2.20	1.50	0.37	0.37	0.29	-
E94/1410	43	44	1.4	0.8	0.7	-	2.15	2.20	0.07	0.04	0.03	-
E94/1411	26	9.1	0.4	1.5	1.3	-	1.30	0.45	0.02	0.07	0.06	-
E94/1412	12	16	1.0	0.6	0.3	-	0.60	0.80	0.05	0.03	0.01	-
E94/1413	4.3	4.6	0.9	0.4	0.4	-	0.21	0.23	0.04	0.02	0.02	-
E94/1414	13	13	1.7	0.6	0.7	-	0.65	0.65	0.08	0.03	0.03	-
E94/1415	0.9	3.1	0.5	0.3	0.4	-	0.04	0.15	0.02	0.01	0.02	-
E94/1416	0.7	3.2	0.4	0.2	0.5	-	0.03	0.16	0.02	0.01	0.02	-
E94/1417	3.6	4.1	1.5	0.5	0.6	-	0.18	0.20	0.07	0.02	0.03	-
E94/1418	1.7	4.7	0.9	0.7	0.6	-	0.08	0.23	0.04	0.03	0.03	-
E94/1419	2.2	4.2	0.7	0.6	0.6	-	0.11	0.21	0.03	0.03	0.03	-
E94/1420	42	3.4	0.3	0.5	0.7	-	2.10	0.17	0.01	0.03	0.03	-
E94/1421	61	2.6	2.4	1.5	1.7	-	3.04	0.13	0.12	0.02	0.03	-
E94/1422	33	1.0	0.4	0.5	0.6	-	1.65	0.05	0.02	0.07	0.08	-
E94/1423	31	0.7	0.4	0.6	0.5	-	1.55	0.03	0.02	0.02	0.03	-

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE E-1 (2 OF 3)

Calcium Values of 1:5 Soil:Water Extract After Weathering Tests

MRDL LAB No.	Ca after 16 hrs @ 22° (mg/L)	Ca after 5 days @ 40° (mg/L)	Ca after 10 days @ 40° (mg/L)	Ca after 15 days @ 40° (mg/L)	Ca after 20 days @ 40° (mg/L)	Ca after 30 days @ 40° (mg/L)	Ca after 16 hrs @ 22° (meq/L)	Ca after 5 days @ 40° (meq/L)	Ca after 10 days @ 40° (meq/L)	Ca after 15 days @ 40° (meq/L)	Ca after 20 days @ 40° (meq/L)	Ca after 30 days @ 40° (meq/L)
E94/1424	28	12	0.8	0.7	1.6	-	1.40	0.60	0.04	0.03	0.08	-
E94/1425	37	5.5	0.7	0.9	1.7	-	1.85	0.27	0.03	0.04	0.08	-
E94/1426	34	3.3	0.6	0.4	0.5	-	1.70	0.16	0.03	0.02	0.02	-
E94/1427	88	3.4	4.2	4.7	4.6	-	4.39	0.17	0.21	0.23	0.23	-
E94/1428	693	534	185	133	93	82	34.6	26.7	9.23	6.64	4.64	4.09
E94/1429	22	7.7	0.3	<0.1	0.3	-	1.10	0.38	0.01	<0.01	0.01	-
E94/1430	20	11	0.6	0.1	0.4	-	1.00	0.55	0.03	<0.01	0.02	-
E94/1431	70	42	8.7	6.3	6.6	-	3.49	2.10	0.43	0.31	0.33	-
E94/1432	36	9.2	0.9	1.0	1.9	-	1.80	0.46	0.04	0.05	0.09	-
E94/1433	5.1	4.1	1.0	0.3	0.4	-	0.25	0.20	0.05	0.01	0.02	-
E94/1434	26	0.4	0.5	0.6	0.7	-	1.30	0.02	0.02	0.03	0.03	-
E94/1435	5.9	0.2	0.3	0.4	2.1	-	0.29	0.01	0.01	0.02	0.10	-
E94/1436	479	315	235	62	37	35	23.9	15.7	11.7	3.09	1.85	1.75
E94/1437	157	66	87	26	17	26	7.83	3.29	4.34	1.30	0.85	1.30
E94/1438	22	0.4	0.3	0.2	1.7	-	1.10	0.02	0.01	0.01	0.08	-
E94/1439	18	0.3	0.3	0.2	1.7	-	0.90	0.01	0.01	0.01	0.08	-
E94/1440	16	0.9	0.4	0.8	2.3	-	0.80	0.04	0.02	0.04	0.11	-
E94/1441	4.4	3.4	3.4	3.3	3.9	-	0.22	0.17	0.17	0.16	0.19	-
E94/1442	33	0.3	0.6	0.5	3.7	-	1.65	0.01	0.03	0.02	0.18	-
E94/1443	37	0.9	1.0	0.6	3.0	0.8	1.85	0.04	0.05	0.03	0.15	0.04
E94/1444	16	0.2	1.0	4.0	5.9	-	0.80	0.01	0.05	0.20	0.29	-

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE E-1 (3 OF 3)

Calcium Values of 1:5 Soil:Water Extract After Weathering Tests

MRDL LAB No.	Ca after 16 hrs @ 22° (mg/L)	Ca after 5 days @ 40° (mg/L)	Ca after 10 days @ 40° (mg/L)	Ca after 15 days @ 40° (mg/L)	Ca after 20 days @ 40° (mg/L)	Ca after 30 days @ 40° (mg/L)	Ca after 16 hrs @ 22° (meq/L)	Ca after 5 days @ 40° (meq/L)	Ca after 10 days @ 40° (meq/L)	Ca after 15 days @ 40° (meq/L)	Ca after 20 days @ 40° (meq/L)	Ca after 30 days @ 40° (meq/L)
E94/1445	6.5	2.4	0.5	0.4	2.3	-	0.32	0.12	0.02	0.02	0.11	-
E94/1446	4.0	3.8	1.7	1.6	2.2	-	0.20	0.19	0.08	0.08	0.11	-
E94/1447	7.1	5.3	2.0	0.5	2.3	-	0.35	0.26	0.10	0.02	0.11	-
E94/1448	8.1	2.9	2.3	2.3	3.5	-	0.40	0.14	0.11	0.11	0.17	-
E94/1449	143	66	78	24	12	11	7.14	3.29	3.89	1.20	0.60	0.55
E94/1450	108	31	58	8.7	4.6	5.5	5.39	1.55	2.89	0.43	0.23	0.27
E94/1451	144	46	81	23	15	18	7.19	2.30	4.04	1.15	0.75	0.90
E94/1452	5.4	4.9	0.4	0.4	7.8	-	0.27	0.24	0.02	0.02	0.39	-
E94/1453	5.8	3.7	1.0	1.4	6.4	-	0.29	0.18	0.05	0.07	0.32	-
E94/1454	2.6	2.6	2.8	3.2	4.6	-	0.13	0.13	0.14	0.16	0.23	-
E94/1455	0.6	0.5	0.3	0.7	3.6	-	0.03	0.02	0.01	0.03	0.18	-
E94/1456	0.5	0.4	0.4	0.2	4.0	-	0.02	0.02	0.02	0.01	0.20	-
E94/1457	15	6.7	7.1	3.4	5.6	-	0.75	0.33	0.35	0.17	0.28	-
E94/1458	11	11	7.3	9.3	7.8	10	0.55	0.55	0.36	0.46	0.39	0.50
E94/1459	103	50	52	16	11	15	5.14	2.50	2.59	0.80	0.55	0.75
E94/1460	81	33	70	45	36	40	4.04	1.65	3.49	2.25	1.80	2.00
E94/1461	0.5	1.8	<0.1	0.4	2.1	-	0.02	0.09	<0.01	0.02	0.10	-
E94/1462	3.7	3.5	<0.1	0.6	3.5	-	0.18	0.17	<0.01	0.03	0.17	-
E94/1463	2.4	2.5	<0.1	<0.1	1.7	-	0.12	0.12	<0.01	<0.01	0.08	-
E94/1464	4.3	3.8	0.3	2.9	6.7	-	0.21	0.19	0.01	0.14	0.33	-

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE E-2 (1 OF 3)

Magnesium Values of 1:5 Soil:Water Extract After Weathering Tests

MRDL LAB No.	Mg after 16 hrs @ 22° (mg/L)	Mg after 5 days @ 40° (mg/L)	Mg after 10 days @ 40° (mg/L)	Mg after 15 days @ 40° (mg/L)	Mg after 20 days @ 40° (mg/L)	Mg after 30 days @ 40° (mg/L)	Mg after 16 hrs @ 22° (meq/L)	Mg after 5 days @ 40° (meq/L)	Mg after 10 days @ 40° (meq/L)	Mg after 15 days @ 40° (meq/L)	Mg after 20 days @ 40° (meq/L)	Mg after 30 days @ 40° (meq/L)
E94/1403	44	12	6.5	4.3	4.8	-	3.62	0.99	0.53	0.35	0.39	-
E94/1404	32	43	2.1	3.1	2.4	-	2.63	3.54	0.17	0.25	0.20	-
E94/1405	2.0	2.2	2.2	1.1	1.9	-	0.16	0.18	0.18	0.09	0.16	-
E94/1406	22	13	2.6	3.1	2.8	-	1.81	1.07	0.21	0.25	0.23	-
E94/1407	27	9.4	2.2	1.9	1.0	-	2.22	0.77	0.18	0.16	0.08	-
E94/1408	7.2	7.9	3.6	1.5	1.5	-	0.59	0.65	0.30	0.12	0.12	-
E94/1409	11	13	3.2	1.9	1.7	-	0.90	1.07	0.26	0.16	0.14	-
E94/1410	31	39	5.5	4.1	5.1	-	2.55	3.21	0.45	0.34	0.42	-
E94/1411	49	26	4.2	4.4	4.4	-	4.03	2.14	0.35	0.36	0.36	-
E94/1412	51	37	4.8	8.6	5.0	-	4.19	3.04	0.39	0.71	0.41	-
E94/1413	32	35	3.5	4.6	3.9	-	2.63	2.88	0.29	0.38	0.32	-
E94/1414	46	51	49	4.1	4.1	-	3.78	4.19	4.03	0.34	0.34	-
E94/1415	27	35	2.8	3.4	3.1	-	2.22	2.88	0.23	0.28	0.25	-
E94/1416	26	31	2.7	3.5	2.9	-	2.14	2.55	0.22	0.29	0.24	-
E94/1417	36	41	5.3	3.2	3.9	-	2.96	3.37	0.44	0.26	0.32	-
E94/1418	34	40	3.5	4.3	4.1	-	2.80	3.29	0.29	0.35	0.34	-
E94/1419	24	22	3.1	3.5	2.9	-	1.97	1.81	0.25	0.29	0.24	-
E94/1420	43	5.1	3.5	2.4	2.6	-	3.54	0.42	0.29	0.20	0.21	-
E94/1421	73	6.5	5.9	4	3.8	-	6.00	0.53	0.49	0.33	0.31	-
E94/1422	76	22	3.0	3.8	2.7	-	6.25	1.81	0.25	0.31	0.22	-
E94/1423	39	19	2.9	3.6	2.4	-	3.21	1.56	0.24	0.30	0.20	-

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE E-2 (2 OF 3)

Magnesium Values of 1:5 Soil:Water Extract After Weathering Tests

MRDL LAB No.	Mg after 16 hrs @ 22° (mg/L)	Mg after 5 days @ 40° (mg/L)	Mg after 10 days @ 40° (mg/L)	Mg after 15 days @ 40° (mg/L)	Mg after 20 days @ 40° (mg/L)	Mg after 30 days @ 40° (mg/L)	Mg after 16 hrs @ 22° (meq/L)	Mg after 5 days @ 40° (meq/L)	Mg after 10 days @ 40° (meq/L)	Mg after 15 days @ 40° (meq/L)	Mg after 20 days @ 40° (meq/L)	Mg after 30 days @ 40° (meq/L)
E94/1424	38	17	3.6	2.9	8.0	-	3.13	1.40	0.30	0.24	0.66	-
E94/1425	36	8.0	4.8	2.5	2.3	-	2.96	0.66	0.39	0.21	0.19	-
E94/1426	43	9.8	11	1.9	1.8	-	3.54	0.81	0.90	0.16	0.15	-
E94/1427	41	6.6	4.1	3.6	3.1	-	3.37	0.54	0.34	0.30	0.25	-
E94/1428	112	88	22	12	8.2	12	9.21	7.24	1.81	0.99	0.67	0.99
E94/1429	36	15	3.2	3.7	4.4	-	2.96	1.23	0.26	0.30	0.36	-
E94/1430	38	23	3.9	3.7	4.6	-	3.13	1.89	0.32	0.30	0.38	-
E94/1431	33	15	13	4.3	4.2	-	2.71	1.23	1.07	0.35	0.35	-
E94/1432	31	12	12	2.8	2.9	-	2.55	0.99	0.99	0.23	0.24	-
E94/1433	3.3	37	3.1	3.3	3.1	-	0.27	3.04	0.25	0.27	0.25	-
E94/1434	28	2.7	2.0	2.7	4.0	-	2.30	0.22	0.16	0.22	0.33	-
E94/1435	8.4	2.6	3.1	1.5	2.7	-	0.69	0.21	0.25	0.12	0.22	-
E94/1436	196	178	69	15	8.5	7.4	16.1	14.6	5.67	1.23	0.70	0.61
E94/1437	123	110	35	13	9.0	14	10.1	9.05	2.88	1.07	0.74	1.15
E94/1438	26	2.5	5.3	3.3	2.2	-	2.14	0.21	0.44	0.27	0.18	-
E94/1439	25	2.0	4.7	4.8	2.6	-	2.06	0.16	0.39	0.39	0.21	-
E94/1440	19	2.9	12	2.5	3.1	-	1.56	0.24	0.99	0.21	0.25	-
E94/1441	6.1	3.7	3.0	3.4	3.6	-	0.50	0.30	0.25	0.28	0.30	-
E94/1442	44	11	31	3.4	11	-	3.62	0.90	2.55	0.28	0.90	-
E94/1443	43	52	3.8	3.6	12	5.3	3.54	4.28	0.31	0.30	0.99	0.44
E94/1444	7.3	0.5	2.1	2.0	2.7	-	0.60	0.04	0.17	0.16	0.22	-

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE E-2 (3 OF 3)

Magnesium Values of 1:5 Soil:Water Extract After Weathering Tests

MRDL LAB No.	Mg after 16 hrs @ 22° (mg/L)	Mg after 5 days @ 40° (mg/L)	Mg after 10 days @ 40° (mg/L)	Mg after 15 days @ 40° (mg/L)	Mg after 20 days @ 40° (mg/L)	Mg after 30 days @ 40° (mg/L)	Mg after 16 hrs @ 22° (meq/L)	Mg after 5 days @ 40° (meq/L)	Mg after 10 days @ 40° (meq/L)	Mg after 15 days @ 40° (meq/L)	Mg after 20 days @ 40° (meq/L)	Mg after 30 days @ 40° (meq/L)
E94/1445	10	4.5	5.4	8.7	3.9	-	0.82	0.37	0.44	0.72	0.32	-
E94/1446	6.5	5.9	1.8	1.7	2.2	-	0.53	0.49	0.15	0.14	0.18	-
E94/1447	13	9.9	3.4	2.9	11	-	1.07	0.81	0.28	0.24	0.90	-
E94/1448	15	4.5	3.0	3.2	4.0	-	1.23	0.37	0.25	0.26	0.33	-
E94/1449	88	7.6	31	10	5.2	4.9	7.24	0.63	2.55	0.82	0.43	0.40
E94/1450	125	103	24	3.9	2.1	1.6	10.3	8.47	1.97	0.32	0.17	0.13
E94/1451	223	210	58	17	9.3	9.8	18.3	17.3	4.77	1.40	0.76	0.81
E94/1452	7.4	6.7	13	3.9	7.2	-	0.61	0.55	1.07	0.32	0.59	-
E94/1453	6.8	4.8	4.9	4.6	5.8	-	0.56	0.39	0.40	0.38	0.48	-
E94/1454	4.2	2.7	2.9	3.3	4.4	-	0.35	0.22	0.24	0.27	0.36	-
E94/1455	4.7	4.3	38	4.5	12	-	0.39	0.35	3.13	0.37	0.99	-
E94/1456	3.1	3.7	2.5	4.2	8.4	-	0.25	0.30	0.21	0.35	0.69	-
E94/1457	17	9.1	7.0	3.1	4.7	-	1.40	0.75	0.58	0.25	0.39	-
E94/1458	14	13	7.8	7.5	7.1	7.7	1.15	1.07	0.64	0.62	0.58	0.63
E94/1459	172	143	38	11	8.1	8.6	14.1	11.8	3.13	0.90	0.67	0.71
E94/1460	145	102	111	82	78	48	11.9	8.39	9.13	6.74	6.41	3.95
E94/1461	3.0	5.0	<0.1	3.0	3.1	-	0.25	0.41	<0.01	0.25	0.25	-
E94/1462	5.8	6.2	0.1	3.6	5.1	-	0.48	0.51	0.01	0.30	0.42	-
E94/1463	3.6	3.7	<0.1	4.1	2.1	-	0.30	0.30	<0.01	0.34	0.17	-
E94/1464	5.8	4.8	0.6	4.2	4.4	-	0.48	0.39	0.05	0.35	0.36	-

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE E-3 (1 OF 3)

Sodium Values of 1:5 Soil:Water Extract After Weathering Tests

MRDL LAB No.	Na after 16 hrs @ 22° (mg/L)	Na after 5 days @ 40° (mg/L)	Na after 10 days @ 40° (mg/L)	Na after 15 days @ 40° (mg/L)	Na after 20 days @ 40° (mg/L)	Na after 30 days @ 40° (mg/L)	Na after 16 hrs @ 22° (meq/L)	Na after 5 days @ 40° (meq/L)	Na after 10 days @ 40° (meq/L)	Na after 15 days @ 40° (meq/L)	Na after 20 days @ 40° (meq/L)	Na after 30 days @ 40° (meq/L)
E94/1403	40	24	6.9	2.5	1.4	-	1.74	1.04	0.30	0.11	0.06	-
E94/1404	250	180	88	56	28	-	10.9	7.83	3.83	2.43	1.22	-
E94/1405	216	103	57	26	18	-	9.39	4.48	2.48	1.13	0.78	-
E94/1406	339	161	114	64	49	-	14.7	7.00	4.96	2.78	2.13	-
E94/1407	307	167	104	69	39	-	13.4	7.26	4.52	3.00	1.70	-
E94/1408	173	111	51	18	13	-	7.52	4.83	2.22	0.78	0.57	-
E94/1409	170	103	46	22	6.2	-	7.39	4.48	2.00	0.96	0.27	-
E94/1410	151	84	44	18	13	-	6.57	3.65	1.91	0.78	0.57	-
E94/1411	72	41	17	8.4	2.7	-	3.13	1.78	0.74	0.37	0.12	-
E94/1412	824	677	87	42	27	-	35.8	29.4	3.78	1.83	1.17	-
E94/1413	400	251	71	30	21	-	17.4	10.9	3.09	1.30	0.91	-
E94/1414	1442	996	208	145	52	-	62.7	43.3	9.04	6.30	2.26	-
E94/1415	546	349	215	93	54	-	23.7	15.2	9.35	4.04	2.35	-
E94/1416	280	284	148	183	58	-	12.2	12.4	6.43	7.96	2.52	-
E94/1417	591	252	195	138	74	-	25.7	11.0	8.48	6.00	3.22	-
E94/1418	430	354	174	89	46	-	18.7	15.4	7.57	3.87	2.00	-
E94/1419	220	185	78	48	29	-	9.57	8.04	3.39	2.09	1.26	-
E94/1420	21	11	4.0	1.9	0.8	-	0.91	0.48	0.17	0.08	0.03	-
E94/1421	14	8.6	2.6	1.0	0.5	-	0.61	0.37	0.11	0.04	0.02	-
E94/1422	35	17	8.6	4.5	3.2	-	1.52	0.74	0.37	0.20	0.14	-
E94/1423	65	21	9.7	9.8	6.7	-	2.83	0.91	0.42	0.43	0.29	-

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE E-3 (2 OF 3)

Sodium Values of 1:5 Soil:Water Extract After Weathering Tests

MRDL LAB No.	Na after 16 hrs @ 22° (mg/L)	Na after 5 days @ 40° (mg/L)	Na after 10 days @ 40° (mg/L)	Na after 15 days @ 40° (mg/L)	Na after 20 days @ 40° (mg/L)	Na after 30 days @ 40° (mg/L)	Na after 16 hrs @ 22° (meq/L)	Na after 5 days @ 40° (meq/L)	Na after 10 days @ 40° (meq/L)	Na after 15 days @ 40° (meq/L)	Na after 20 days @ 40° (meq/L)	Na after 30 days @ 40° (meq/L)
E94/1424	69	35	16	9.5	3.9	-	3.00	1.52	0.70	0.41	0.17	-
E94/1425	58	25	12	8.7	3.8	-	2.52	1.09	0.52	0.38	0.17	-
E94/1426	76	23	8.7	8.2	6.0	-	3.30	1.00	0.38	0.36	0.26	-
E94/1427	27	23	4.4	1.5	0.4	-	1.17	1.00	0.19	0.07	0.02	-
E94/1428	31	20	4.0	1.3	0.5	0.8	1.35	0.87	0.17	0.06	0.02	0.03
E94/1429	76	29	11	8.3	5.0	-	3.30	1.26	0.48	0.36	0.22	-
E94/1430	98	35	22	15	9.7	-	4.26	1.52	0.96	0.65	0.42	-
E94/1431	51	28	12	4.6	1.7	-	2.22	1.22	0.52	0.20	0.07	-
E94/1432	76	35	20	11	4.2	-	3.30	1.52	0.87	0.48	0.18	-
E94/1433	225	162	76	35	23	-	9.78	7.04	3.30	1.52	1.00	-
E94/1434	106	75	35	21	34	-	4.61	3.26	1.52	0.91	1.48	-
E94/1435	30	25	12	7.3	3.7	-	1.30	1.09	0.52	0.32	0.16	-
E94/1436	2.8	5.9	4.3	2.4	3.5	2.8	0.12	0.26	0.19	0.10	0.15	0.12
E94/1437	4.2	9.1	5.1	3.3	2.8	1.7	0.18	0.40	0.22	0.14	0.12	0.07
E94/1438	49	31	18	13	12	-	2.13	1.35	0.78	0.57	0.52	-
E94/1439	42	31	15	9.6	9.7	-	1.83	1.35	0.65	0.42	0.42	-
E94/1440	63	45	31	12	13	-	2.74	1.96	1.35	0.52	0.57	-
E94/1441	29	23	10	3.7	1.8	-	1.26	1.00	0.43	0.16	0.08	-
E94/1442	61	38	16	1.3	16	-	2.65	1.65	0.70	0.06	0.70	-
E94/1443	97	65	45	44	26	13	4.22	2.83	1.96	1.91	1.13	0.57
E94/1444	72	47	38	19	8.5	-	3.13	2.04	1.65	0.83	0.37	-

COAL AND ALLIED OPERATIONS PTY LTD
MOUNT PLEASANT PROJECT
COAL AUTHORISATION AREA 459

CHARACTERISATION OF OVERBURDEN AND INTERBURDEN MATERIALS

TABLE E-3 (3 OF 3)

Sodium Values of 1:5 Soil:Water Extract After Weathering Tests

MRDL LAB No.	Na after 16 hrs @ 22° (mg/L)	Na after 5 days @ 40° (mg/L)	Na after 10 days @ 40° (mg/L)	Na after 15 days @ 40° (mg/L)	Na after 20 days @ 40° (mg/L)	Na after 30 days @ 40° (mg/L)	Na after 16 hrs @ 22° (meq/L)	Na after 5 days @ 40° (meq/L)	Na after 10 days @ 40° (meq/L)	Na after 15 days @ 40° (meq/L)	Na after 20 days @ 40° (meq/L)	Na after 30 days @ 40° (meq/L)
E94/1445	71	54	20	13	7.5	-	3.09	2.35	0.87	0.57	0.33	-
E94/1446	19	15	4.5	1.9	1.1	-	0.83	0.65	0.20	0.08	0.05	-
E94/1447	18	19	8.7	5.6	2.9	-	0.78	0.83	0.38	0.24	0.13	-
E94/1448	26	11	4.1	2.2	1.1	-	1.13	0.48	0.18	0.10	0.05	-
E94/1449	23	20	4.5	1.1	0.7	0.5	1.00	0.87	0.20	0.05	0.03	0.02
E94/1450	1.2	<0.1	0.2	0.2	0.7	0.7	0.05	<0.01	0.01	0.01	0.03	0.03
E94/1451	0.8	0.6	0.5	0.5	1.2	0.6	0.03	0.03	0.02	0.02	0.05	0.03
E94/1452	39	32	12	6.8	3.7	-	1.70	1.39	0.52	0.30	0.16	-
E94/1453	30	23	10	5.1	2.8	-	1.30	1.00	0.43	0.22	0.12	-
E94/1454	32	21	9.6	3.8	1.9	-	1.39	0.91	0.42	0.17	0.08	-
E94/1455	49	28	17	16	20	-	2.13	1.22	0.74	0.70	0.87	-
E94/1456	48	25	16	16	16	-	2.09	1.09	0.70	0.70	0.70	-
E94/1457	42	26	17	4.5	2.5	-	1.83	1.13	0.74	0.20	0.11	-
E94/1458	32	26	8.5	2.8	1.4	0.9	1.39	1.13	0.37	0.12	0.06	0.04
E94/1459	1.2	<0.1	<0.1	0.4	0.6	0.3	0.05	<0.01	<0.01	0.02	0.03	0.01
E94/1460	50	24	22	14	8.7	6.7	2.17	1.04	0.96	0.61	0.38	0.29
E94/1461	33	20	14	8.9	8.4	-	1.43	0.87	0.61	0.39	0.37	-
E94/1462	42	33	14	6.9	5.5	-	1.83	1.43	0.61	0.30	0.24	-
E94/1463	41	35	11	4.8	3.2	-	1.78	1.52	0.48	0.21	0.14	-
E94/1464	16	19	10	4.3	2.2	-	0.70	0.83	0.43	0.19	0.10	-

LAND CAPABILITY AND SOIL SURVEY REPORT

2

LAND CAPABILITY AND SOIL SURVEY REPORT

MOUNT PLEASANT PROJECT

February, 1997

Prepared by: VENESS & ASSOCIATES Pty Limited
10 Dutton Crescent
Coffs Harbour 2450
Ph: (066) 52 7692
Fax: (066) 52 8232
A.C.N. 003 419 958

REPORT No. VA 1324/03

TABLE OF CONTENTS

APPENDICES

FIGURES

LAND CAPABILITY AND SOIL SURVEY REPORT

MOUNT PLEASANT PROJECT

1.0 INTRODUCTION

At the request of Coal & Allied Operations Pty Limited, Veness & Associates Pty Limited was contracted to survey the soils within the area covered by the Mount Pleasant Project and to map the soils' suitability for stripping during the mining program in order for a soil stripping map to be formulated. In addition, the pre-mine land capability of the study area was also assessed.

This report records the findings of this survey.

1.1 Brief and Limits of the Study

The area surveyed (hereafter referred to as the study area) consists of approximately 3750 hectares. This area was defined on a map by Coal & Allied and is shown on the soils map appended to this report. It consists of the entire Mount Pleasant Project area, together with the addition of two small catchments in the south-western corner and a short, narrow strip of land measuring approximately 300 metres long and 100 metres wide located between the rail line and the southern boundary of the Bengalla lease area. The study area comprises of predominantly grazing lands with small pockets of arable areas, especially along the eastern boundary.

The brief set for this study was to examine the soils of the study area, and to determine their suitability for stripping and subsequent respreading purposes during the open-cut process. Pre-mine land capability was also to be assessed and recorded.

1.2 Timing of this Study

The fieldwork for this study was undertaken by Veness & Associates over a total of 524 man hours during the periods from 30/05/94 to 30/06/94, on 16/11/94, and from 10/02/97 to 13/02/97. The weather was predominantly fine during these periods except for the last period in February 1997 when the additional areas comprising the two small catchments in the south-western corner and the rail line extension were surveyed.

1.3 Methodology

Aerial photograph interpretation was undertaken over all of the study area using 1:10 000 coloured photographs taken in 1992 and supplied by the client.

Five hundred and ninety seven holes were excavated using a backhoe. These 597 site locations are shown on Figure 1. (Note: Figures do not appear in this report. They have been forwarded to Coal & Allied separately at scales of both 1:10 000 and or 1:4 000). Data was recorded on Stripping Record Sheets for each of the 597 excavated holes. Stripping suitability was determined based on the amalgamation of all the data generated from the above sources. The procedure described by Elliott & Veness (1981) was used in determining stripping suitability. Consequently, the information recorded on the Stripping Record sheets included horizon and depth, structure grade, coherence, mottle, macrostructure, force to disrupt peds, texture, gravel and sand content, pH, salt content (where known through later laboratory analyses) and a recommended stripping depth for each site.

Soils at 145 of these sites were fully described in the field following detailed examination. A coloured photograph of the soil material was taken at most full description pits. The remaining 452 sites were partially described where the soils were examined for consistency within soil mapping units, boundary information and soil characteristics to assess stripping suitability as detailed above.

Apart from these 597 description sites, other observations were made to ensure consistency within soil mapping units.

Mapping technique and soil properties examined are consistent with the specifications determined by the Department of Conservation and Land Management's (CaLM) Soil Conservation Service regarding the undertaking of soil surveys on proposed open-cut coal mine sites. These specifications require a soil profile description to be undertaken for each 25 hectares of study area or new mapping unit (whichever is greater), and observation holes to be dug at a minimum of one every 6.5 hectares to establish consistency within, and boundaries between, soil mapping units. These specifications also call for the soil to be examined to a depth of 2.5 metres on cropping lands. The frequency of soil pits and observation holes undertaken in the study area was compatible with these specifications, as were the depth requirements. These specifications also require that stripping suitability be determined using the criteria of Elliott & Veness (1981).

Soil samples were collected from each soil layer at fifteen of the 145 full description sites generating a total of 54 samples. These samples were analysed in the Veness & Associates laboratory for a range of tests consistent with the CaLM specifications.

The relevant soils information from each full description site was recorded on soil data cards. The cards for each of the 15 sampling sites are included in this report at Appendix 1. The soil properties examined include texture and fabric, structure, consistence, boundary characteristics, colour, pH and classification.

The class name (Northcote et al, 1975), Great Soil Group name and principal profile form (Northcote, 1979) were determined for each soil (where applicable).

Soil pH was determined in the field using Raupach solution. Soil colours were determined using Oyama & Takehara (1970) colour charts. In the soil descriptions, colours refer to the moist soil unless indicated otherwise.

1.4 Report's organisation

This report presents the results of the field descriptions and the laboratory analyses in Section 2. The description of each soil mapping unit is presented in turn. Section 3 discusses the interpretation of the various parameters presented in Section 2 culminating in recommendations for various stripping depths throughout the study area presented in Section 5. Section 6 discusses soil handling strategies. The result of the land capability assessment is presented in Section 4.

2.0 RESULTS

2.1 Soil Descriptions

On the basis of the data generated during the soil survey, the study area is divided into five different soil mapping units. The locations of these soil mapping units, shown in Figure 1, are as follows:

Map Code	Soil Unit
A	- Soil Mapping Unit A (alluvial soils)
B	- Soil Mapping Unit B (soils located on/in drainage flats/drainage lines)
C	- Soil Mapping Unit C (hillslope soils)
D	- Soil Mapping Unit D (sandy hillslope soils)
E	- Soil Mapping Unit E (volcanically derived hillslope soils)

Each of these soil units is described below. Each soil unit description is an amalgamation of all the data recorded within each unit at both the full description sites and the part description sites.

The occurrence of the floodplain (Soil Mapping Unit A) and drainage flat/drainage line (Soil Mapping Unit B) soils is self–explanatory from a geomorphic point of view. The rest of the study area is hillslope soils (ridgeline/hilltop, upper slope, midslope, sideslope, lower slope and footslope). During the fieldwork phase and also during collating the field generated data, it became evident that some of the soils in this large unit could be conveniently subdivided into two specific "subclasses" giving rise to Soil Mapping Unit D (i.e. those hillslope soils which were evidently sandy) and Soil Mapping Unit E (those hillslope soils which are derived from volcanic parent materials). The remaining, and majority, of the hillslope soils which do not fall into either of these two subclasses are mapped as Soil Mapping Unit C (hillslope soils).

The number of sites described for each soil mapping unit is as follows:

Soil Mapping Unit	**No. of full description sites**	**No. of part description sites**	**Total No. of description sites**	**No. of soil sampling sites**
A	7	12	19	1
B	10	9	19	1
C	91	314	405	11
D	32	108	140	1
E	5	9	14	1
TOTAL	145	452	597	

TABLE 1: Number of soil description sites within each soil mapping unit

It should be noted that not all soil layers / horizons described for each soil mapping unit are necessarily present at all sites. This highlights the need to examine a number of soil pits within each unit before a complete understanding of that unit can be gained. The occurrence of each layer at the various description sites can be gauged by examining each unit's soil data cards. Those cards associated with the thirteen sampling sites are presented in Appendix 1.

The description of each soil unit is given as both a "plain English" version which precedes a more detailed "technical" version. The technical soil field description lists the appearance and behaviour of each soil examined during the site visit. The parameters used in this description are mostly self–explanatory except for the following:

> coherence which refers to the structure grade of the soil – the higher the grade the more pedal the soil
>
> consistence is divided into two parts which are separated by a semi–colon within the descriptions. These two parts describe the amount of finger and thumb force required to disrupt peds and the behaviour of that disrupted soil when sheared between the palms of the hands. Together, they reflect on the soil's ped strength, the amount of clay content present and, where applicable, the effects of soil moisture in working the soil

(For a definition of these and other technical terms used in this report, refer to either McDonald et. al. (1990) or Houghton & Charman (1986)).

2.1.1 SOIL MAPPING UNIT A - (Floodplain soils)

2.1.1.1 "Plain English" description

The floodplain soils in this unit are located along a part of the eastern boundary of the study area and in the north–east and south–east corners. The topography in this unit is generally flat, with some dissection by drainage channels and back swamp areas.

These soil materials are characterised by a dark, friable, moderately acid to moderately alkaline clay loam, silty clay loam or light clay which overlies a number of dark–coloured depositional layers, the thickness of which is highly variable. These layers are alkaline clay loams or clays and contain very few small stones.

2.1.1.2 "Technical" description

Great soil group names: none applicable

Northcote codes: Uf 6.11, Uf 6.12, Um 6.23, Um 6.21

Northcote et al (1975) names: non-cracking friable clays with rough ped fabric, shallow friable loams with rough-ped fabric

Field Description

Surface condition: all cultivated or rested; some plough layer, some compaction to 1.5 cm depth, some disturbed by farming practices, otherwise self-mulching; <2% stones occur.

Layer 1 (slightly to moderately moist)

A horizon - always present

12–99 cm thick, pH 5.5–9.5; brownish black (5YR 2/1, 7.5YR 3/2, 10YR 2/2 moist (m)); slightly to moderately sticky light clay with some clay loam, silty clay loam and silty clay; coherent wet and dry; weakly to strongly consistent; moderately to strongly pedal with rough-faced, porous sub-angular blocky peds 10–200 mm breaking to sub-angular blocky and granular peds <2–5 mm diameter; no cutans (clay skins on ped faces); <2% stones occur; roots are few to abundant; no concretions or inclusions; clear, even boundary to layer 2:

Layer 2 (slightly moist)

D1 horizon - always present

15–178 cm thick, pH 6.5–9.5 - brownish black (7.5YR 2/2, 3/2, 10YR 3/2 m) to brown (7.5YR 4/3 m), slightly to moderately sticky clay loam or light medium clay with some silty clay and light clay; coherent wet and dry; weakly to moderately consistent; moderately to strongly pedal with rough-faced, porous, sub-angular blocky peds 20–100 mm breaking to angular and sub-angular blocky peds 2–10 mm diameter; cutans are common at some sites; <2% stones occur; few to many roots are present; clear, even boundary to layer 3:

Layer 3 (slightly moist)

D2 horizon - always present

18–100+ cm thick, pH 7.5–9.5 - brownish black (7.5YR 2/2 m) to brown (7.5YR 4/3, 4/4 m), non-sticky to moderately sticky silty clay and light clay; coherent wet and dry; weakly to strongly consistent; moderately to strongly pedal with smooth- or rough-faced porous sub-angular blocky peds 10–100 mm breaking to angular blocky, sub-angular blocky and granular peds <2–10 mm diameter; few to many cutans may occur; <2%

stones may occur; none to many roots occur; organic charcoal fragments may be present; few scattered to many concentrated soft carbonate nodules may occur; sharp to gradual, even boundary to layer 4:

Layer 4 (dry to moderately moist)

D3 horizon – almost always present above 2.5 m depth, highly variable layer

12–150+ cm thick, pH 8.0–9.5 – dark brown (7.5YR 3/3, 3/4 m) to brown (7.5YR 4/4, 4/6 m), slightly sticky sandy loam, fine sandy clay loam, light clay or light medium clay; coherent wet and dry with some coherent dry, not coherent wet; weakly to strongly consistent; weakly to strongly pedal with earthy, sandy, smooth– or rough–faced porous angular and sub–angular blocky peds 10–200 mm breaking, in the better structured soils, to <2–10 mm diameter; few to many cutans may occur; <2% 2–6 mm sized stones may occur; few to common roots occur; soft carbonate nodules may occur; sharp to diffuse, even boundary to layer 5:

Layer 5 (dry to moderately moist)

D4 horizon – present at depth at some sites

56–126+ cm thick, pH 8.0–9.5 – usually dark brown (7.5YR 3/4 m), slightly sticky clay loam, silty clay, light clay or light medium clay; mostly coherent wet and dry; weakly to strongly consistent; weakly to strongly pedal with smooth– or rough–faced porous sub–angular blocky peds 10–100 mm breaking, in better structured soils, to angular or sub–angular blocky peds <2–10 mm diameter; few to many cutans may occur; up to 10% 2–6 mm stone fragments may occur; no to few roots occur; sharp to diffuse, even boundary to layer 6:

Layer 6 (moderately moist)

D5 horizon – sometimes present at depth

81+ cm thick, pH 9.5 – brown (7.5YR 4/4 m), non–sticky clay loam; coherent wet and dry; weakly consistent; weakly to moderately pedal with earthy and rough–faced porous sub–angular blocky peds 20–100 mm diameter; no cutans; no stones and few roots occur; boundary not reached at depth.

2.1.2 SOIL MAPPING UNIT B – (Drainage flats and drainage lines)

2.1.2.1 "Plain English" description

Soils of the drainage flat / drainage line unit occur mainly adjacent to, and up–catchment of, the floodplains midway along the study area's eastern boundary and in the south–eastern corner. Another main occurrence is along the northern boundary where two tributaries converge at the boundary. There are also isolated pockets of these soils higher up catchment on relatively flat areas where deposition of sediment has occurred.

The soil surface of this unit is generally self–mulching and sometimes stony. The topsoil is a moderately structured, dark brown, sticky clay loam or light clay. It is usually underlain by a weakly structured and sometimes stony bleached sandy clay loam. Topsoil layers are moderately acid to neutral.

The bright brown to reddish brown subsoil is a sticky, sandy clay loam or light to medium clay, with moderate to strong structure. Subsoil layers are slightly acid to slightly alkaline. The subsoil is sometimes underlain by a series of depositional layers which are indicative of the low slope topography of these lower catchment areas. All of these dark layers have few to no stones. They are usually moderately to strongly structured, light clays to fine sandy clay loams.

Occasionally there is a bleached, or almost bleached, weakly structured layer (layer 3) and at some sites there are mottled layers (layers 4, 6, 9 and 10). Soil pH increases with depth, ranging from slightly acid to moderately alkaline.

2.1.2.2 "Technical" description

Great soil group names: solonized brown soils, brown and yellow solodic soils, no names

Northcote codes: Uf 6.11, Uf 6.12, Um 6.23, Gc 2.21, Gn 4.82, Db 3.43, Dy 3.42

Northcote et al (1975) names: non–cracking friable clays, shallow friable loams and structured earths, all with rough–ped fabric, calcareous earths, friable brown and hard pedal mottled–yellow duplex soils

Field Description

Surface condition: mainly self–mulching, with some platy or hard–setting areas; <2% dispersed sub–rounded, sandstone fragments, 2–200 mm in size.

Layer 1 (dry to slightly moist)

A, A1, A11 horizon - always present

4–21 cm thick, pH 5.5–6.0 - dark brown (7.5YR 3/3, 3/4, 10YR 3/4 m) or brown (7.5YR 4/3, 4/4 m), slightly to moderately sticky clay loam, silty clay loam or light clay; coherent wet and dry; weakly to moderately consistent; moderately pedal with rough–faced porous sub–angular blocky peds 10–100 mm breaking to 2–10 mm diameter; nil to few cutans; <2% 2–6 mm sized stones may occur; roots are common to abundant; sharp to clear, wavy boundary to layers 2, 3 or 7:

Layer 2 (slightly moist)

A12 horizon – rarely present

26 cm thick, pH 7.0 – dark brown (7.5YR 3/4 m, 4/3 dry), slightly to moderately sticky clay loam; coherent wet and dry; weakly consistent; strongly pedal with rough–faced porous sub–angular blocky peds 2–10 mm breaking to <2–5 mm diameter; no cutans; no stones; roots are common; gradual wavy boundary to layer 3:

Layer 3 (dry)

A2 horizon – usually present

11–33 cm thick, pH 6.0–7.0 – brown (7.5YR 4/4 m, 6/3 d; 7.5YR 4/3 m, 7/3 d), dull brown (7.5YR 5/3 m, 8/3 d) or orange (7.5YR 6/6 m, 8/3 d), bleached, slightly sticky sandy clay loam or fine sandy clay loam; either coherent wet and dry or coherent dry, not coherent wet; weakly consistent; weakly pedal with earthy or sandy porous sub–angular blocky peds 50–100 mm rarely breaking to 10–20 mm diameter; no cutans; up to 20% 2–20 mm sized sedimentary stones may occur; roots are few to common; clear, even to wavy boundary to layers 4 or 5:

Layer 4 (slightly moist)

B1 horizon – rarely present

26 cm thick, pH 6.0 – bright yellowish brown (10YR 6/6 m), mottled, slightly sticky medium clay; coherent wet and dry; strongly consistent; strongly pedal with smooth–faced dense blocky peds 100–200 mm breaking to 2–5 mm diameter; 2–10% cutans are common; 2–20 mm sized quartz and sandstone fragments may occur; roots are common; gradual wavy boundary to layer 5:

Layer 5 (dry to slightly moist)

B2 horizon – commonly present

21–72+ cm thick, pH 5.5–7.5 – brown (7.5YR 4/4 m), bright brown (7.5YR 5/6 m) or bright reddish brown (5YR 5/6 m), slightly to moderately sticky sandy clay loam , light clay, light medium clay or medium clay; coherent wet and dry; weakly to very strongly consistent; weakly to strongly pedal with smooth–faced dense sub–angular blocky peds 50–200 mm breaking to angular and sub–angular blocky peds <2–5 mm diameter; cutans commonly occur; up to 20% 2–20 mm sized sedimentary stones may occur; roots are few to common; small manganese nodules occasionally occur; clear even boundary to layers 6 or 7:

Layer 6 (slightly moist)

B3 horizon – sometimes present

52+ cm thick, pH 7.0–8.5 – bright reddish brown (2.5YR 5/6 m) or brown (7.5YR 4/4 m), mottled, moderately sticky sandy clay or light clay; coherent wet and dry; strongly to very strongly consistent; moderately to strongly pedal with smooth–faced dense or rough–faced porous sub–angular blocky peds 10–200 mm breaking to 2–10 mm diameter; some cutans may be observed; <2% stones occur; no roots; 2–20% soft carbonate nodules <5 mm in size may occur; boundary not reached at depth

Layer 7 (dry to slightly moist)

D1 horizon – usually present

16–85 cm thick, pH 6.0–7.5 – dark brown (7.5YR 3/3, 3/4 m) or brown (7.5YR 4/4, 4/6 m), slightly to moderately sticky silty clay loam to light clay; coherent wet and dry; very weakly to strongly consistent; moderately pedal with usually rough–faced porous blocky peds 50–200 mm breaking to 2–10 mm diameter; usually no cutans; <2% tiny stones may occur; few to many roots occur; sharp to gradual, even to wavy boundary to layer 8:

Layer 8 (dry to slightly moist)

D2 horizon – usually present

22–100+ cm thick, pH 6.5–9.0 – dark brown (10YR 3/3, 3/4, 7.5YR 3/4 m), or dull brown (7.5YR 5/4 m, 7/3 dry) slightly to moderately sticky fine sandy clay loam or light clay; coherent wet and dry (sometimes coherent dry, not coherent wet); weakly to strongly consistent; weakly to strongly pedal with earthy or rough–faced porous sub–angular blocky peds 10–200 mm breaking to <2–10 mm diameter; nil to few cutans; no stones; few to many roots; sharp to diffuse, even to wavy boundary to layer 9:

Layer 9 (slightly moist)

D3 horizon – sometimes present above 2.5 m depth

30–78+ cm thick, pH 7.0–9.0 – dark brown (7.5YR 3/3 m), brown (7.5YR 4/3, 4/4 m) or dark reddish brown (5YR 4/8 m), sometimes mottled, slightly to moderately sticky light or light medium clay; coherent wet and dry; strongly to very strongly consistent; moderately to strongly pedal with smooth–faced porous or dense blocky peds 50–500 mm breaking to <2–20 mm diameter; cutans are common; no stones; few roots; clear to gradual, even to wavy boundary to layer 10:

Layer 10 (slightly moist)

D4 horizon – sometimes present above 2.5 metre depth

34 cm thick, pH 9.0 – dark brown (10YR 3/4 m, 7.5YR 5/3 d), reddish brown (5YR 4/6 m) mottled grey, or bright reddish brown (5YR 5/6 m) mottled grey, moderately sticky fine sandy clay loam or light clay; coherent wet or dry or coherent dry, not coherent wet; very weakly to strongly consistent; weakly to moderately pedal with earthy porous sub-angular blocky peds <2–50 mm diameter; no cutans; <2% stones; few roots; clear even boundary to layer 11:

Layer 11 (slightly moist)

D5 horizon – occurs at one out of the 8 sites

44+ cm thick, pH 9.5 – brown (7.5YR 4/6 m), slightly moist light clay; coherent wet and dry; very strongly consistent; moderately to strongly pedal with rough-faced porous blocky peds 10–100 mm breaking to <2–10 mm diameter; no cutans; no stones; few roots; boundary not reached at depth.

2.1.3 SOIL MAPPING UNIT C – (Hillslope soils)

2.1.3.1 "Plain English" description

Soils of this unit dominate the study area, supporting a predominantly grazing land use. The soil surface is generally characterised by a thin organic mulch, although some areas are hard-setting where the soil is degraded, and there are occasional areas of surface crusting. Also some areas have platy soil surface due to compaction resulting from stock. Small amounts of stone are often dispersed across the surface.

The well structured topsoil is a dark brown or reddish brown clay loam or light clay which is slightly to moderately acid. This layer is underlain by a brown to reddish brown, sometimes bleached, slightly acid, weakly to moderately structured fine sandy clay loam lower topsoil layer. Stones up to 200 mm diameter are commonly present in this layer.

The subsoil layers are well structured, dark to bright brown / reddish brown, clay to light medium clay. They are slightly acid at the top and increase in alkalinity with depth. Carbonate nodules are common at depth.

This soil unit also predominantly occurs in the two small catchments attached to the south-western corner of the Mount Pleasant Project area. Additionally, this unit is also located along the narrow site of the proposed rail line extension to the south of the Bengalla lease area.

2.1.3.2 "Technical" description

Great soil group names: structured plastic clays, solonized brown soils, red-brown earths, red and yellow solodic soils, solods, red and yellow solonetzic soils, no names

Northcote codes: Uf 6.31, Uf 6.32, Uf 6.34, Gc 2.21, Gc 2.22, Gn 3.11, Gn 3.12, 3.13, Gn 3.14, Gn 3.16, Gn 3.73, Gn 3.86, Gn 4.13, Dr 2.11, Dr 2.13, Dr 2.43, Dr 4.11, Dr 4.12 Dr 4.13, Dr 4.41, Dr 4.42, Dr 4.43, Db 3.12, Dy 2.12, Dy 4.12, Dy 4.13, Dy 4.23, Dy 4.41, Dy 4.42, Dy 4.43

Northcote et al (1975) names: non-cracking friable clays with smooth-ped fabric, calcareous earths, red and yellow smooth-ped earths, red and black rough-ped earths, hard pedal red duplex soils, friable red and brown duplex soils, friable pedal yellow duplex soils, sandy pedal yellow duplex soils, no names

Field Description

Surface condition: usually an organic mulch is present, with some hard-setting areas where the soil is degraded and occasional areas of surface crusting; <2% sub-rounded to angular, weakly weathered petrified wood, ironstone siltstone or claystone rock fragments may occur, 2-200 mm in size.

Layer 1 (dry to moderately moist)

A, A1, A11 horizon - always present

4-28 cm thick, pH 5.5-6.5 - usually dark brown (7.5YR 3/3, 3/4, 10YR 3/3 m) or dark reddish brown (5YR 3/2, 3/3, 3/4 m), slightly to moderately sticky clay loam, silty clay loam, fine sandy clay loam, silty clay or light clay; coherent wet and dry; weakly to strongly consistent; moderately to strongly pedal with rough-faced porous sub-angular blocky peds 10-100 mm breaking to blocky and granular peds <2-10 mm diameter; no cutans; up to 10% rounded to angular, weakly to strongly weathered siltstone, claystone, petrified wood or ironstone fragments 2-200 mm diameter may occur; roots are common to abundant; charcoal fragments may occur; sharp to clear, even to wavy boundary to layers 2, 3, 4 or 5:

Layer 2 (dry)

A12 horizon - rarely present

8-28 cm thick, pH 6.0-8.5 - dark reddish brown (5YR 3/3, 3/4 m) or dark brown (7.5YR 3/4 m), slightly to moderately sticky silty clay loam, fine sandy clay loam or light clay; coherent wet and dry; weakly to moderately consistent; weakly to strongly pedal with earthy or rough-faced porous or dense sub-angular blocky peds 20-100 mm breaking to <2-5 mm diameter; no cutans; <2% stones occur; roots are common to many; small charcoal fragments may occur; clear even to wavy boundary to layers 4 or 5:

Layer 3 (dry to moderately moist)

A2 horizon – commonly present

3–18 cm thick, pH 6.0–7.0 – usually dark brown (7.5YR 3/4 m, 5/4, 6/3, 7/2 d), dark reddish brown (5YR 3/3 m, 5/3, 6/3 d, 5YR 3/6 m, 6/6 d), dull reddish brown (5YR 4/4 m, 6/4 d) or reddish brown (5YR 4/6 m, 5/6, 6/4, 7/4 d), sometimes bleached, slightly sticky fine sandy clay loam; either coherent wet and dry or coherent dry, not coherent wet; weakly to moderately consistent; weakly to moderately pedal with earthy porous sub-angular blocky peds <2–100 mm diameter; no cutans; <2–50% rounded to angular quartz or ironstone fragments up to 200 mm in size may occur; few to many roots; sharp to clear, even to wavy boundary to layers 4 or 5

Layer 4 (dry to moderately moist)

B1 horizon – commonly present

4–53 cm thick, pH 6.0–8.5 – usually dark brown (7.5YR 3/3, 3/4 m), dark reddish brown (5YR 3/3, 3/4, 3/6 m) or dull reddish brown (5YR 4/3, 4/4 m), slightly to moderately sticky silty clay, light clay or light medium clay; coherent wet and dry; moderately to very strongly consistent; moderately to strongly pedal with smooth-faced dense or rough-faced porous sub-angular blocky peds 10–200 mm breaking to angular and sub-angular blocky peds <2–10 mm diameter; few to many cutans; up to 2% rounded to angular sandstone, petrified wood or ironstone fragments up to 60 mm in size may occur; few to many roots occur; clear to gradual, even to wavy boundary to layer 5

Layer 5 (dry to moderately moist)

B2, B21 horizon – always present

13–77+ cm thick, pH 6.5–9.5 – usually bright reddish brown (5YR 5/6, 5/8 m), reddish brown (5YR 4/6, 4/8, 2.5YR 4/6, 4/8 m), dark reddish brown (5YR 3/4, 3/6, 2.5YR 3/6 m) or brown (7.5YR 4/4, 4/6, 10YR 4/4 m), slightly sticky light or light medium clay; coherent wet and dry; moderately to very strongly consistent; moderately to strongly pedal with mainly smooth-faced dense or porous, lenticular, angular blocky and sub-angular blocky peds 10–500 mm breaking to <2–10 mm diameter; common to many cutans; up to 10% rounded to angular, feldspathic sandstone, siltstone, claystone, petrified wood or ironstone fragments up to 60 mm diameter may occur; few to common roots; carbonate nodules commonly occur; small manganese nodules may occur; clear to diffuse, even to irregular boundary to layers 6, 7, 9 or 10:

Layer 6 (slightly moist)

B22 horizon – very rarely present (Site 100)

71 cm thick, pH 9.5 – bright reddish brown (5YR 5/6 m), slightly sticky light clay;

coherent wet and dry; very strongly consistent; moderately to strongly pedal with smooth-faced dense lenticular peds 200–500 mm breaking to angular blocky peds 5–10 mm diameter; many cutans; no stones; no roots; carbonate and manganese occur; diffuse even boundary to layer 7:

Layer 7 (slightly to moderately moist)

B3, B31 horizon – commonly present

9–76 cm thick, pH 8.5–9.5 – usually brown (7.5YR 4/3, 4/4, 4/6, 10YR 4/4, 4/6 m), bright brown (7.5YR 5/6, 5/8 m), yellowish brown (10YR 5/6 m), bright reddish brown (5YR 5/6, 5/8 m), or orange (5YR 6/6, 7.5YR 6/6, 6/8 m), slightly sticky silty clay, light clay or light medium clay; coherent wet and dry; moderately to very strongly consistent; moderately to strongly pedal with smooth-faced porous or dense sub-angular blocky and lenticular peds 100–500 mm breaking to angular and sub-angular blocky peds 2–10 mm diameter; few to many cutans; nil–20% sub-angular and angular, non weathered to strongly weathered feldspathic sandstone, siltstone, claystone, ironstone or petrified wood fragments occur 2–60 mm in size; few to common roots occur; carbonate nodules almost always occur; clear to diffuse, even to wavy boundary to layers 8, 9 or 10:

Layer 8 (moderately moist)

B32 horizon – very rarely present (Site 048)

52+ cm thick, pH 8.5 – reddish brown (2.5YR 4/6 m), slightly sticky light clay; coherent wet and dry; strongly consistent; strongly pedal with smooth-faced porous angular peds 50–200 mm breaking to 2–5 mm diameter; many cutans; <2% small stones occur; few roots; >20% carbonate nodules occur; boundary not reached at depth.

Layer 9 (slightly to moderately moist)

BC horizon – usually present

14–75+ cm thick, pH 9.5 – reddish brown (2.5YR 4/8, 5YR 4/6, 4/8 m), brown (7.5YR 4/6, 10YR 4/4, 4/6 m), dull brown (10YR 5/3, 5/4, 6/3 m), bright brown (7.5YR 5/6, 10YR 5/6 m), dull orange (10YR 6/4 m) or orange (7.5YR 6/6, 10YR 6/6 m), slightly sticky light clay; coherent wet and dry; moderately to very strongly consistent; weakly to strongly pedal with smooth- and rough-faced porous sub-angular blocky peds 50–200 mm breaking to angular and sub-angular blocky peds 2–20 mm diameter; few to common cutans; nil to >90% sub-angular and angular, undisturbed, strongly weathered feldspathic sandstone and claystone fragments may occur, 2–200 mm in size; nil to few roots occur; many carbonate nodules occur at about half the sites; either the boundary is not reached at depth or clear to diffuse, even boundary to layer 10:

Layer 10 (dry to slightly moist)

C horizon – always present but not always reached at depth

Below 24–140 cm depth, pH 9.5–10.0 – bright brown (7.5YR 5/8 m) to orange (7.5YR 6/8 m), strongly weathered, undisturbed feldspathic sandstone, siltstone or claystone ; weakly to moderately fractured; cracks <2 mm; few roots along fracture planes; carbonate nodules may occur in more weathered sites where some weak to moderate pedality is apparent; boundary not reached at depth.

2.1.4 SOIL MAPPING UNIT D - (Sandy hillslope soils)

2.1.4.1 "Plain English" description

These soils occur on sandy parent materials within the large Soil Mapping Unit C. The soil surface is characterised by a thin organic mulch with some loose sandy areas and sometimes up to 50% sandstone fragments. Compaction resulting from grazing stock and farm machinery sometimes occurs as a hardsetting surface soil.

There are two topsoil layers. The first is a dark reddish brown to brown, slightly sticky, slightly to moderately acid light sandy clay loam, loam fine sandy or fine sandy clay loam which is weakly to moderately structured and usually contains little to no stones. The second layer is a less acid, dull reddish brown, bleached, slightly sticky clayey sand, sandy loam or light to fine sandy clay loam. This soil is mainly weakly structured and quite often stony. It grades into weathered sandstone on steep, shallow sites, and into a subsoil layer over most of the unit.

The main subsoil layer is generally more alkaline than overlying horizons, and is characterised by a reddish brown to orange, often sticky, sandy to light medium clay which is reasonably well structured. This layer overlies either similar, deeper subsoil layers or weathered parent material.

2.1.4.2 "Technical" description

Great soil group names: red earths, red and yellow solonetzic soils, red and yellow solodic soils, yellow solods, yellow podzolic soils, no names

Northcote codes: Gn 2.11, Gn 3.18, Dr 1.11, Dr 1.21, Dr 2.43, Dr 4.13, Dr 4.42, Dr 4.43, Dr 5.42, Dy 2.13, Dy 2.43, Dy 4.22, Dy 4.23, Dy 4.41, Dy 4.42, Dy 4.43

Northcote et al (1975) names: red massive earths, red smooth–ped earths, crusty red, friable red, friable mottled–red, hard pedal yellow and sandy pedal yellow duplex soils, no names

Field Description

Surface condition: usually an organic mulch occurs, with some loose sandy areas; in other areas a platy, hardsetting condition occurs as a result of compaction by grazing animals' hooves; rarely a surface crust is observed; up to 50% rounded and sub-rounded sandstone fragments, 2-600 mm in size, may be dispersed across the surface.

Layer 1 (dry)

A1 horizon - always present

4-39 cm thick, pH 5.5-6.0 - usually dark reddish brown (5YR 3/3, 3/4 m), with some dark brown (7.5YR 3/3, 3/4 m), dull reddish brown (5YR 4/4 m) or brown (7.5YR 4/3, 4/4 m), slightly sticky light sandy clay loam, loam fine sandy or fine sandy clay loam; coherent wet and dry; very weakly to moderately consistent; weakly to moderately pedal with earthy or rough-faced porous sub-angular blocky peds 10-100 mm breaking (in the better structured soils) to <2-20 mm diameter; no cutans; mainly <2% stones, but up to 90% rounded and sub-rounded sandstone fragments 2->600 mm in size may occur; roots are common to abundant; <2% charcoal fragments may occur; sharp to clear and even to wavy boundary to layers 2 or 4:

Layer 2 (dry)

A2 horizon - almost always present

3-56 cm thick, pH 5.5-7.0 - usually dull reddish brown (5YR 4/3, 4/4, 5/3, 5/4 m and 5YR 6/3, 6/4, 7/2, 7/3, 7/4, 8/4 d), reddish brown (5YR 4/6, 4/8 m and 5YR 5/4, 6/4, 7/4 d) or bright reddish brown (5YR 5/6 m and 5YR 7/3, 7/4, 8/3, 8/4 d), bleached, slightly sticky clayey sand, sandy loam, light sandy clay loam, loam fine sandy, sandy clay loam or fine sandy clay loam; usually weakly pedal with earthy or sandy, porous, sub-angular blocky peds <2-200 mm diameter; no cutans; up to 90% rounded to sub-angular, reoriented, weathered feldspathic sandstone and ironstone rock fragments, 2-600 mm in size, may occur; few roots; sharp to gradual and even to broken boundary to layers 3, 4 or 8:

Layer 3 (dry to slightly moist)

B1 horizon - rarely present

8-53 cm thick, pH 6.0-7.0 - dark reddish brown (2.5YR 3/6 m) to bright brown 7.5YR 5/6 m), slightly sticky light to light medium clay; coherent wet and dry; weakly to very strongly consistent; moderately to strongly pedal with smooth- and rough-faced porous angular and sub-angular blocky peds 10-200 mm breaking to <2-20 mm diameter; cutans may be present; soil cracks range from <2 mm to 10 mm in width; no stones; roots are few to common; clear to diffuse, even boundary to layer 4:

Layer 4 (dry to slightly moist)

B2 horizon – always present (except in skeletal soils)

6–134+ cm thick, pH 5.5–9.5 – mainly reddish brown (2.5YR 4/6, 4/8, 5YR 4/6, 4/8 m), or bright reddish brown (2.5YR 5/8, 5YR 5/6, 5/8 m) or orange, slightly to moderately sticky sandy clay, light clay or light medium clay; coherent wet and dry; moderately to very strongly consistent; moderately to strongly pedal with rough–faced porous or smooth–faced dense angular and sub–angular blocky peds 10–200 mm breaking to <2–20 mm diameter; cutans are usually present; nil to >90% sub–rounded to angular, strongly weathered feldspathic sandstone, ironstone or siltstone rock fragments, 2–600 mm in size occur; few to common roots occur; charcoal fragments and carbonate nodules are only rarely present; clear to gradual, even to broken boundary to layers 5, 7 or 8:

Layer 5 (dry to moderately moist)

B3, B31 horizon – sometimes present

7–117+ cm thick, pH 5.5–9.5 – reddish brown (2.5YR 4/8, 5YR 4/8 m), bright reddish brown (5YR 5/6, 5/8 m) or orange (5YR 6/8, 7.5YR 6/8 m), sometimes mottled, slightly to moderately sticky sandy clay loam, silty clay, light clay or light medium clay; coherent wet and dry; moderately to very strongly consistent; moderately to strongly pedal with smooth– or rough–faced porous sub–angular blocky peds 50–500 mm breaking to angular and sub–angular blocky peds <2–20 mm diameter; few to many cutans may occur; up to 10% sub–angular and angular, reoriented, weathered feldspathic sandstone or siltstone fragments, up to 200 mm in size, may occur; few roots may occur; >20% soft carbonate nodules usually occur; clear to diffuse, even to irregular boundary to layers 6, 7 or 8:

Layer 6 (dry)

B32 horizon – rarely present

26+ cm thick, pH 7.5 – bright reddish brown (5YR 5/8 m) light clay; coherent wet and dry; very strongly consistent; moderately pedal with rough–faced porous sub–angular blocky peds 200–500 mm breaking to 20–50 mm diameter; few cutans; 2–10% ironstone fragments occur; no roots; boundary not reached at depth

Layer 7 (slightly to moderately moist)

BC horizon – commonly present

9–96+ cm thick, pH 5.5–9.5 – bright reddish brown (5YR 5/8 m) to dull yellow orange (10YR 7/4 m), slightly sticky light to light medium clay; coherent wet and dry; moderately to very strongly consistent; weakly to moderately pedal with earthy, sandy or rough–faced porous sub–angular blocky peds 5–100 mm breaking to <2–10 mm diameter; usually no cutans; cracks <2–10 mm; nil to >90% sub–angular and angular, undisturbed, strongly weathered, 2–200 mm sandstone fragments may occur; few roots may occur; carbonate nodules are commonly present; clear to diffuse, even or broken boundary to layer 8:

Layer 8

C horizon – always present but not always reached at depth

Below 28–96 cm depth, pH 5.5–9.5 – >90% sub-angular and angular, undisturbed, strongly weathered sandstone fragments, 2–>600 mm in size, comprise this layer; few roots may be present on rock fracture faces; boundary not reached at depth.

2.1.5 SOIL MAPPING UNIT E – (Volcanic hillslope soils)

2.1.5.1 "Plain English" description

This soil mapping unit occurs in association with extrusive volcanic dykes and is located in small pockets throughout the study area but generally in the eastern half. A soft surface organic mulch overlies a dark reddish brown, fine sandy clay loam or light clay. This well structured, slightly to moderately acid topsoil layer sometimes overlies a less well structured and more stony, bleached sandy clay loam or light clay lower topsoil layer.

The well structured subsoil layers are slightly to moderately alkaline, dark to reddish brown silty to light medium clays. Alkalinity increases with depth. Carbonate nodules are present at depth.

2.1.5.2 "Technical" description

Great soil group names: structured plastic clays, solonized brown soils, no names

Northcote codes: Uf 6.31, Gc 1.22, Gc 2.22, Dr 4.43

Northcote et al (1975) names: non–cracking friable clays with smooth–ped fabric, calcareous earths, friable red duplex soils

Field Description

Surface condition: soft organic mulch occurs at all sites; nil to 10% rounded to sub-angular, weakly weathered igneous stones, 2–200 mm in size, are dispersed across the ground surface

Layer 1 (dry to slightly moist)

A, A1 horizon - always present

8–16 cm thick, pH 5.5–6.5 - dark reddish brown (5YR 3/3, 3/4 m), very dark reddish brown (5YR 2/4 m) or brownish black (7.5YR 3/2 m), slightly to moderately sticky fine sandy clay loam or light clay; coherent wet and dry; moderately consistent; moderately to strongly pedal with rough–faced porous sub–angular blocky peds 20–200 mm breaking to <2–10 mm diameter; no cutans; cracks up to 10 mm wide; up to 10% rounded to sub–angular, reoriented, weakly weathered igneous rock fragments may occur, 2–200 mm in size; many to abundant roots; sharp even or wavy boundary to layers 2 or 3:

Layer 2 (dry)

A2 horizon - sometimes present

9–15 cm thick, pH 6.0 - dark brown (7.5YR 3/3 m, 7/2 d) or dull reddish brown (5YR 4/4 m, 6/4 d), bleached, slightly sticky sandy clay loam or light clay; coherent wet and dry; weakly to strongly consistent; weakly to moderately pedal with earthy or rough–faced porous sub–angular blocky peds 50–200 mm breaking to 10–50 mm diameter; cracks <2 mm wide; <2%–50% reoriented, weakly weathered igneous rock fragments occur, 2–200 mm in size; few roots; sharp to clear, even to wavy boundary to layer 3:

Layer 3 (dry)

B1 horizon - always present

5–23 cm thick, pH 7.0–8.5 - brownish black (7.5YR 3/2 m) to reddish brown (5YR 4/6 m), slightly to moderately sticky silty clay or light medium clay; coherent wet and dry; moderately to very strongly consistent; moderately to strongly pedal with smooth–faced dense blocky peds 10–500 mm breaking to <2–10 mm diameter; cutans are few to many; soil cracks are <2–10 mm wide; up to 20% reoriented, weakly weathered igneous rock fragments may occur, 2–200 mm in size; few to many roots occur; sharp to gradual, even or wavy boundary to layer 4:

Layer 4 (slightly to moderately moist)

B2 horizon - always present

16–106 cm thick, pH 9.5 - usually reddish brown (2.5YR 4/8, 5YR 4/6, 4/8 m), slightly to moderately sticky silty clay, light clay or light medium clay; coherent wet and dry; moderately to very strongly consistent; moderately to strongly pedal with smooth–faced dense blocky peds 10–500 mm breaking to <2–10 mm diameter; cutans are common; crack width ranges from <2–10 mm; usually 10–20% sub–rounded to angular, reoriented, weakly to strongly weathered igneous rock fragments occur, 2–200 mm in size; few roots; carbonate nodules are usually present; gradual, even to wavy boundary to layers 5 or 6:

Layer 5 (slightly moist)

B3 horizon – sometimes present

23–28 cm thick, pH 9.5 – dull brown (7.5YR 5/4 m) or dull reddish brown (5YR 4/4 m), slightly to moderately sticky silty clay or light clay; coherent wet and dry; strongly to very strongly consistent; moderately to strongly pedal with smooth–faced dense, sub–angular blocky peds 50–200 mm breaking to 2–20 mm diameter; few to common cutans; cracks 2–10 mm wide; up to 50% undisturbed, strongly weathered igneous rock fragments occur, 2–60 mm in size; no roots, carbonate nodules usually occur; clear, irregular boundary to layers 6 or 7:

Layer 6

BC horizon – usually present

46–59+ cm thick, pH 9.5 – orange (5YR 6/8 m) to greyish (as a result of the large amounts of white carbonate), slightly sticky light clay; coherent wet and dry; strongly consistent; moderately pedal with rough–faced porous sub–angular blocky peds 50–100 mm breaking to 10–20 mm diameter; few cutans; <2% stones; no roots; abundant carbonate nodules; boundary not reached at depth

Layer 7

C horizon – always present but not always reached at depth

Below 86–92 cm depth, 50–>90% undisturbed, strongly weathered igneous rock fragments occur, 2–60 mm in size; boundary not reached at depth.

2.2 Soil Laboratory Analyses

Soil samples were collected from each soil layer at fifteen of the full description sites, generating a total of 54 samples. A range of physical and chemical laboratory analyses were undertaken on these samples in the Veness & Associates laboratory where they were analysed for erodibility potential (the laboratory tests undertaken were Particle Size Analysis, Dispersion Percentage and Emerson Aggregate Test), pH and electrical conductivity.

The results of these analyses are presented below.

2.2.1 PHYSICAL ANALYSES

The results of these physical analyses, presented below in Table 2, have been grouped into the five different soil mapping units.

Site	Layer*	Horizon	Depth (cm)	PARTICLE SIZE ANALYSIS (%) Clay	Silt	Fine Sand	Coarse Sand	Gravel	D%	EAT
Soil Mapping Unit A (Floodplain)										
003	1	A	0- 20	24	20	48	8	0	24	3(2)
	2	D1	20- 52	21	18	57	4	0	28	3(3)
	3	D2	52-112	21	23	54	2	0	30	3(3)
	4	D3	112-124	13	5	27	55	0	36	3(1)
	5	D4	124-250+	20	13	57	10	0	52	2(1)
Soil Mapping Unit B (Drainage Flat / Drainage Line)										
001	1	A1	0- 11	17	16	35	23	9	25	8
	2	A2	11- 22	13	12	29	23	23	35	3(2)
	3	B1	22- 58	53	5	19	11	12	77	2(3)
	4	B2	58-130+	35	9	28	18	10	86	1
Soil Mapping Unit C (Hillslope)										
008	1	A	0- 13	26	17	50	3	4	31	8
	2	B2	13- 48	34	7	19	1	39	38	3(4)
	3	B3	48- 67	38	11	29	1	21	40	3(3)
009	1	A	0- 8	31	25	36	5	3	31	8
	2	B2	8- 28	49	16	20	3	12	27	5
	3	B3	28- 50	48	24	15	4	9	27	5
022	1	A	0- 28	38	10	27	4	21	20	8
	2	B2	28- 64	55	11	25	3	6	40	3(3)
	3	B3	64-140	57	13	12	7	11	38	5
041	1	A1	0- 18	26	13	42	10	9	28	8
	2	A2	18- 22	19	13	27	8	33	26	8
	3	B1	22- 40	59	8	24	5	4	29	2(2)
	4	B2	40-105	59	11	23	6	1	69	2(3)
053	1	A	0- 11	17	11	35	9	28	17	8
	2	B11	11- 49	51	7	25	6	11	47	2(2)
	3	B12	49- 64	57	8	22	6	7	42	3(4)
	4	B2	64-131	36	8	42	5	9	44	5
104	1	A	0- 9	14	16	58	9	2	56	8
	2	B2	9- 52	37	16	21	2	24	39	3(4)
	3	B3	52- 74	39	30	16	2	13	24	5
106	1	A	0- 18	19	20	45	13	3	17	8
	2	B1	18- 50	51	10	30	6	3	54	2(2)
	3	B2	50-117	56	9	25	7	3	28	2(1)
115	1	A	0- 5	30	22	42	4	2	9	8
	2	B1	5- 11	36	23	36	3	2	18	8
	3	B2	11- 34	44	18	25	2	11	24	3(3)
	4	B3	34- 61	54	19	22	2	3	24	5

(continued next page)

				PARTICLE SIZE ANALYSIS (%)						
Site	Layer*	Horizon	Depth (cm)	Clay	Silt	Fine Sand	Coarse Sand	Gravel	D%	EAT
Soil Mapping Unit C (Hillslope) [cont'd]										
120	1	A	0- 10	17	15	43	20	5	29	8
	2	B1	10- 17	46	18	22	5	9	38	2(1)
	3	B2	17- 41	54	15	22	3	6	36	2(1)
	4	B3	41- 50	54	26	16	2	2	32	2(1)
134	1	A	0- 13	16	30	49	3	2	17	8
	2	B2	13- 61	53	16	26	1	5	25	2(3)
	3	B3	61- 85	57	21	13	2	7	14	5
139	1	A	0- 14	13	19	58	9	1	14	8
	2	B2	14- 37	48	13	30	5	4	19	2(2)
	3	B3	37- 58	34	24	30	7	5	22	5
Hillslope Mapping Unit D (Hillslope / sandy)										
070	1	A1	0- 17	19	16	49	15	1	28	8
	2	A2	17- 26	20	19	42	17	2	53	2(1)
	3	B1	26- 42	47	10	13	9	5	74	2(2)
	4	B2	42- 64	27	12	14	13	34	45	2(1)
Soil Mapping Unit E (Hillslope / volcanic)										
099	1	A	0- 10	22	16	37	5	20	23	8
	2	B1	10- 15	41	14	30	5	10	30	7
	3	B2	15- 48	56	10	21	3	10	31	7
	4	B3	48- 71	46	10	19	4	21	25	5

* the layer in this table refers to the layer existing at each particular soil site – it does not equate with the layers in the technical description. However, this relationship can be worked out by examining the horizon names in column three above and those in the technical descriptions

TABLE 2: Results of soil laboratory physical analyses

2.2.2 CHEMICAL ANALYSES

As mentioned earlier, pH and electrical conductivity (eC) analyses were undertaken on these samples in the Veness & Associates laboratory and the resulting data is presented in Table 3 below.

Site	Layer*	Horizon	Depth (cm)	pH (1:5) soil:water	eC (1:5) soil:water mS/cm
Soil Mapping Unit A (Floodplain)					
003	1	A	0- 20	8.16	0.10
	2	D1	20- 52	7.73	0.08
	3	D2	52–112	7.89	0.08
	4	D3	112–124	7.94	0.05
	5	D4	124–250+	8.09	0.14

(continued next page)

Site	Layer*	Horizon	Depth (cm)	pH (1:5) soil:water	eC (1:5) soil:water mS/cm
Soil Mapping Unit B (Drainage Flat / Drainage Line)					
001	1	A1	0- 11	6.98	0.08
	2	A2	11- 22	6.36	0.05
	3	B1	22- 58	6.83	0.15
	4	B2	58-130+	8.33	0.58
Soil Mapping Unit C (Hillslope)					
008	1	A	0- 13	6.39	0.06
	2	B2	13- 48	7.75	0.16
	3	B3	48- 67	7.79	0.31
009	1	A	0- 8	6.81	0.08
	2	B2	8- 28	7.49	0.20
	3	B3	28- 50	8.51	0.18
022	1	A	0- 28	8.27	0.17
	2	B2	28- 64	8.00	0.25
	3	B3	64-140	8.51	0.63
041	1	A1	0- 18	6.20	0.09
	2	A2	18- 22	6.51	0.07
	3	B1	22- 40	7.40	0.14
	4	B2	40-105	8.11	0.18
053	1	A	0- 11	6.37	0.09
	2	B11	11- 49	8.38	0.56
	3	B12	49- 64	8.74	0.91
	4	B2	64-131	9.06	1.27
104	1	A	0- 9	6.55	0.06
	2	B2	9- 52	7.97	0.31
	3	B3	52- 74	8.31	0.57
106	1	A	0- 18	6.04	0.07
	2	B1	18- 50	7.86	0.26
	3	B2	50-117	8.21	1.21
115	1	A	0- 5	7.19	0.09
	2	B1	5- 11	6.48	0.07
	3	B2	11- 34	7.81	0.07
	4	B3	34- 61	8.11	0.23
120	1	A	0- 10	6.54	0.09
	2	B1	10- 17	7.61	0.10
	3	B2	17- 41	7.64	0.20
	4	B3	41- 50	8.22	0.51
134	1	A	0- 13	6.94	0.14
	2	B2	13- 61	7.84	0.33
	3	B3	61- 85	8.41	1.08
139	1	A	0- 14	6.44	0.09
	2	B2	14- 37	7.92	0.31
	3	B3	37- 58	8.75	0.39

(continued next page)

Site	Layer*	Horizon	Depth (cm)	pH (1:5) soil:water	eC (1:5) soil:water mS/cm
Hillslope Mapping Unit D (Hillslope / sandy)					
070	1	A1	0- 17	5.99	0.07
	2	A2	17- 26	6.93	0.05
	3	B1	26- 42	8.28	0.15
	4	B2	42- 64	8.09	0.53
Soil Mapping Unit E (Hillslope / volcanic)					
099	1	A	0- 10	7.24	0.11
	2	B1	10- 15	7.93	0.09
	3	B2	15- 48	8.31	0.24
	4	B3	48- 71	8.35	0.23

* the layer in this table refers to the layer existing at each particular soil site - it does not equate with the layers in the technical description. However, this relationship can be worked out by examining the horizon names in column three above and those in the technical descriptions

TABLE 3: Results of soil laboratory chemical analyses

3.0 DISCUSSION OF SOILS

The following section of this report discusses the implications of the above results. This discussion will be organised under the headings of physical attributes, chemical attributes and erosion potential.

3.1 Physical Attributes

The results shown in Table 2 assist in the determination of the degree of erodibility of each of the soil units within the study area. Each of the three physical tests undertaken indicate specific aspects of the soil and its behaviour to erosive forces. When the results of these tests are combined, a good overview of the soil's erodibility is gained.

3.1.1 PARTICLE SIZE ANALYSIS

The Particle Size Analysis test (PSA) proportions the amounts of clay, silt, fine sand, coarse sand and gravel which exist in a given sample, on a percentage basis. Thus, layer 1 at site 001 consists of 17% clay, 16% silt, and so on, including 9% gravel.

The soils in Soil Mapping Unit A are typical floodplain soils, with the majority of material being of the finer fractions included in the clays and silts, with a high fine sand content. No gravels were evident in the samples analysed from site 003. The drainage line / drainage flat soils making up Soil Mapping Unit B are sandy throughout, as are the soils in Soil Mapping Unit D. The hillslope soils of Soil Mapping Unit C are the most commonly occurring soils within the study area. They are mainly clay soils which have a high fine sand content. The clay soils in Soil Mapping Unit E, while having significant proportions of gravel, have little coarse sand but contain reasonable high levels of fine sand.

3.1.2 DISPERSION PERCENTAGE

The Dispersion Percentage (D%) test indicates the proportion of the soil fraction less than 0.005 mm (i.e. the clay and some of the fine silt material) that will disperse on wetting.

An interpretation of the D% values can be based on the following, taken from Hazelton & Murphy (1992):

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

TABLE 4: Interpretation of D% values

It should be noted that the interpretation of these values should also take into account the PSA and EAT data.

A sample which has a very high D% value (e.g. 90%) and a very high clay content (e.g. 45%) would be more dispersive than a sample with the same D% value and a low clay content (e.g. 10%). When the results of the Dispersion % values in Table 2 are read in this context, the soils sampled within the study area range from slight to very high dispersibility. The alluvial soils in Soil Mapping Unit A increase in dispersibility with depth, with the top layers being stable. This pattern is also evident in the soils tested from Soil Mapping Units B and D. The igneous soils in Soil Mapping Unit E are basically stable throughout. There is not such a clear trend in the hillslope soils of Soil Mapping Unit C. While most of the topsoils are stable, some of them are moderately to highly dispersible (sites 008, 009 and 104), while the subsoils range from stable to very high dispersibility.

Thus, from a Dispersion Percentage point of view, the soils in the study area, represented by the results of those tested in Table 2, are considered to be generally stable but have stable to highly dispersible topsoils and stable to very highly dispersible subsoils. The implications of this in a stripping, stockpiling, respreading context would require that some consideration is given to protecting these soils from erosion, primarily through the retention of a vegetative cover.

3.1.3 EMERSON AGGREGATE TEST

The Emerson Aggregate Test (EAT) classifies soil aggregates based on their coherence when immersed in water. As stated in Houghton & Charman (1986), this test uses natural peds, with the first separation being based on slaking. Those aggregates that do not slake are placed in class 7 if they swell and class 8 if they do not. Of those which do slake, those which show complete soil dispersion are placed in class 1 and those showing only partial dispersion are placed in class 2. Those showing no dispersion are remoulded and reimmersed in water. Aggregates which disperse after remoulding are placed in class 3 and those which do not are further separated by the presence or absence of carbonate or gypsum. Those with carbonate or gypsum fall into class 4 while those without are made up into a 1:5 soil:water suspension and shaken. Those soils which then show dispersion are placed in class 5 and those which show flocculation fall into class 6. Classes 2 and 3 are further subdivided into four subclasses with an increasing tendency to disperse with an increase in numerical value. The degree of stability of soils increases from class 1 through to class 8, with classes 1 and 2 generally being considered to be unstable, class 3 generally considered to be stable while classes 4 to 8 are considered to be stable. (Charman, 1978).

The relationship between the EAT class and soil structural stability or soil dispersibility is shown below in Table 5, taken from Hazelton & Murphy (1992).

Emerson Aggregate Classes	Dispersion Rating
1, 2(4) and 2(3)	Very High
2(2)	High
2(1)	High to Moderate
3(4) and 3(3)	Moderate
3(2), 3(1) and 5	Slight
6, 7, 8	Negligible

TABLE 5: Interpretation of EAT classes

As shown in Table 2, the EAT values for the samples tested are usually consistent with the Dispersion Percentage results. The surface topsoil layers are stable, having an EAT class 8 rating (the exception being site 003 with a slightly dispersible Class 3(2) rating), while the lower layers are more dispersive with various class ratings ranging from Class 1 to Class 7. Consequently, while the surface layers are considered to be stable, the lower B horizons have a stable to slight to very high dispersive rating.

3.2 Chemical Attributes

This section will deal only with the chemical attributes of pH and electrical conductivity, the values of which are presented above in Table 3.

3.2.1 pH

The pH value, which is technically the negative common logarithm of the hydrogen ion (H^+) concentration in a solution, indicates the nutrient availability and plant growth environment of a soil, especially if extremes exist. An acceptable pH range of soil material is between 4.0 and 8.5.

On this basis, all of the soils tested in the laboratory on samples collected in the study area have acceptable pH levels for agronomic purposes except for the deeper subsoil layers at site 009 and 053. In contrast, the pH values recorded in the field at most of the 509 sites show a greater variation, especially for the deeper subsoil layers when values of 9.0 or 9.5 were often recorded. This variation has been noted in the soil descriptions in Section 2 above and is taken into account when assessing the stripping suitability of the soils later in Section 5.

3.2.2 ELECTRICAL CONDUCTIVITY

One of the conventional ways to estimate soil salinity is to determine electrical conductivity on a 1:5 soil:water suspension. The Veness & Associates laboratory uses this method. Published data on the salt tolerance of agricultural crops often refer to the electrical conductivity of the saturation extract (ECe). The electrical conductivity of the 1:5 soil:water suspension (eC) can be converted to an approximate value of the ECe, if soil texture is known, by multiplying by the appropriate factor from Table 6.

SOIL TEXTURE	MULTIPLICATION FACTOR
loamy sand, clayey sand	25
sandy loam, fine sandy loam, light sandy clay loam	20
loam, loam fine sandy, silt loam, sandy clay loam	15
clay loam, silty clay loam, fine sandy clay loam	12.5
sandy clay, silty clay, light clay	10
light medium clay	9
medium clay	7.5
heavy clay	6

TABLE 6: Multiplication factors for converting eC (1:5) to an approximate value of ECe (after Abbott, 1987)

The values obtained in Table 6 can be used to calculate the ECe values from Table 3.

Site	Layer	Horizon	Depth (cm)	Texture	eC (1:5) soil:water mS/cm	Multiplication factor	ECe (calculated)
Soil Mapping Unit A (Floodplain)							
003	1	A	0- 20	LC	0.10	10	1.0
	2	D1	20- 52	CL	0.08	12.5	1.0
	3	D2	52-112	CL	0.08	12.5	1.0
	4	D3	112-124	SL	0.05	20	1.0
	5	D4	124-250+	SL	0.14	20	2.8
Soil Mapping Unit B (Drainage Flat / Drainage Line)							
001	1	A1	0- 11	CL	0.08	12.5	1.0
	2	A2	11- 22	SCL	0.05	15	0.75
	3	B1	22- 58	MC	0.15	7.5	1.125
	4	B2	58-130+	MC	0.58	7.5	4.35
Soil Mapping Unit C (Hillslope)							
008	1	A	0- 13	CL	0.06	12.5	0.75
	2	B2	13- 48	LMC	0.16	9	1.44
	3	B3	48- 67	LMC	0.31	9	2.79

(continued next page)

Site	Layer	Horizon	Depth (cm)	Texture	eC (1:5) soil:water mS/cm	Multiplication factor	ECe (calculated)
Soil Mapping Unit C (Hillslope) [cont'd]							
009	1	A	0- 8	LC	0.08	10	0.8
	2	B2	8- 28	LMC	0.20	9	1.8
	3	B3	28- 50	LMC	0.18	9	1.62
022	1	A	0- 28	LMC	0.17	9	1.53
	2	B2	28- 64	LMC	0.25	9	2.25
	3	B3	64-140	LMC	0.63	9	5.67
041	1	A1	0- 18	CL	0.09	12.5	1.125
	2	A2	18- 22	SiCL	0.07	12.5	0.875
	3	B1	22- 40	LMC	0.14	9	1.26
	4	B2	40-105	LMC	0.18	9	1.62
053	1	A	0- 11	FSCL	0.09	12.5	1.125
	2	B11	11- 49	LMC	0.56	9	5.04
	3	B12	49- 64	LMC	0.91	9	8.19
	4	B2	64-131	LC	1.27	10	12.7
104	1	A	0- 9	FSCL	0.06	12.5	0.75
	2	B2	9- 52	LC	0.31	10	3.1
	3	B3	52- 74	LC	0.57	10	5.7
106	1	A	0- 18	SiCL	0.07	12.5	0.875
	2	B1	18- 50	LC	0.26	10	2.6
	3	B2	50-117	LC	1.21	10	12.1
115	1	A	0- 5	SiC	0.09	10	0.9
	2	B1	5- 11	LC	0.07	10	0.7
	3	B2	11- 34	LC	0.07	10	0.7
	4	B3	34- 61	LC	0.23	10	2.3
120	1	A	0- 10	SiCL	0.09	12.5	1.125
	2	B1	10- 17	SiC	0.10	10	1.0
	3	B2	17- 41	SiC	0.20	10	2.0
	4	B3	41- 50	SiC	0.51	10	5.1
134	1	A	0- 13	CL	0.14	12.5	1.75
	2	B2	13- 61	LMC	0.33	9	2.97
	3	B3	61- 85	LMC	1.08	9	9.72
139	1	A	0- 14	FSCL	0.09	12.5	1.125
	2	B2	14- 37	LMC	0.31	9	2.79
	3	B3	37- 58	LMC	0.39	9	3.51
Hillslope Mapping Unit D (Hillslope / sandy)							
070	1	A1	0- 17	FSCL	0.07	12.5	0.875
	2	A2	17- 26	SCL$^-$	0.05	20	1.0
	3	B1	26- 42	LMC	0.15	9	1.35
	4	B2	42- 64	LMC	0.53	9	7.47

(continued next page)

Site	Layer	Horizon	Depth (cm)	Texture	eC (1:5) soil:water mS/cm	Multiplication factor	ECe (calculated)
Soil Mapping Unit E (Hillslope / volcanic)							
099	1	A	0- 10	SiCL	0.11	12.5	1.375
	2	B1	10- 15	SiC	0.09	10	0.9
	3	B2	15- 48	SiC	0.24	10	2.4
	4	B3	48- 71	SiC	0.23	10	2.3

* the layer in this table refers to the layer existing at each particular soil site - it does not equate with the layers in the technical description. However, this relationship can be worked out by examining the horizon names in column three above and those under 'Occurrence' in the technical descriptions

TABLE 7: Calculated ECe values

When the eC 1:5 soil:water suspension method is used, the cut-off for suspect / saline soils is usually around the 0.4 value. When the ECe saturation extract method is used, saline soils are deemed to occur when the value of 4.0 is reached. The samples exceeding eC values of 0.4 also exceed ECe values 4.0. The ECe values are a more relevant way to assess agronomic potential.

The range of ECe values for the samples tested range from 0.7 to 12.7. Based on the cut-off for vegetative response being 4.0, none of the topsoils in the study area are considered to be too saline to be used in the mining rehabilitation program. However, high values exceeding ECe values of 4.0 are recorded in the subsoil layers at site 053 as well as in the deeper subsoil layer at sites 001, 022, 104, 106, 120 and 070.

3.3 Erosion Potential

The discussion in Section 3.1 above concluded that the study area's soils are currently predominantly stable but have a moderate to high to very high erosion potential. However, the simplest way to objectively determine the erosion potential of the study area's soils is to determine their erosion hazard. Erosion hazard is determined by the susceptibility of a parcel of land to the prevailing agents of erosion. It is dependent on a combination of climate, landform, soil, land use and land management factors. The qualitative categories of erosion hazard used are low, moderate, high, very high and extreme.

As defined by Houghton & Charman (1986), extreme erosion hazard implies that erosion will occur to such an extent that it will be normally uneconomic to address satisfactorily. Very high erosion hazard implies significant erosion occurring during and after development, even with intensive soil conservation measures. High erosion hazard implies significant erosion during development, with short-term erosion controlled by simple soil conservation measures but long-term erosion control requiring intensive measures. Moderate erosion hazard implies that significant erosion may occur during development, but short– and long–term erosion problems can be avoided by adopting appropriate soil conservation measures during development. Low erosion hazard results in no appreciable erosion during or after development.

Given that the proposed development in the case of the Mount Pleasant Project study area is open–cut mining, the above definition is somewhat inappropriate.

3.4 SOILOSS Program

An alternative method of examining the erosion hazard of the study area's soils is based on a technique which uses a computer program, SOILOSS (Rosewell & Edwards, 1988), to generate predicted soil loss values as an indicator of erosion hazard. SOILOSS is based on the Universal Soil Loss Equation or USLE (Wischmeier & Smith, 1978):

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

where

A	is the average annual soil loss (t/ha)
R	is the rainfall erosivity factor
K	is the soil erodibility factor
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 factors

Erosivity is the "potential ability to cause erosion" (Houghton & Charman, 1986) and is commonly referred to in respect of rainfall. The erosivity of the study area, prepared from data contained within Australian Rainfall and Runoff (Pilgrim, 1987) according to the method of Rosewell & Turner (1992) was determined.

The SOILOSS program calculates a value for the 'K' factor, as well as determining soil loss in tonnes/hectare/year. (It ought to be appreciated that the use of USLE technology does not fit fully comfortably with Australian conditions. Therefore, the values produced through SOILOSS are indicative only.)

One of the key factor inputs, soil erodibility (K), can be determined from laboratory data (soil particle size analysis, organic matter) and structure and profile permeability. SOILOSS has a subroutine to calculate K from these inputs. (While organic matter was not determined for the study area's soils, the 'default' value used in SOILOSS is 3% for topsoil and 1% for subsoils. The 'K' value for each sampled soil, calculated by the SOILOSS program, is presented below in Table 8. The erodibility rating is also given in each case. (Erodibility is determined as: <0.02 low; 0.02 – 0.04 moderate; >0.04 high.)

Site	Layer	Topsoil 'K' / Rating	Layer	Subsoil 'K' / Rating	Whole Soil Average 'K'	Unit Erodibility rating
Soil Mapping Unit A (Floodplain)						
003	1 (A)	.041 / HIGH	2 (D1)	.051 / HIGH		
			3 (D2)	.049 / HIGH		
			4 (D3)	.019 / LOW		
			5 (D4)	.046 / HIGH	**.041**	**HIGH**
Soil Mapping Unit B (Drainage Flat / Drainage Line)						
001	1 (A1)	.029 / MOD	3 (B1)	.022 / MOD		
	2 (A2)	.037 / MOD	4 (B2)	.028 / MOD	**.029**	**MODERATE**
Soil Mapping Unit C (Hillslope)						
008	1 (A)	.036 / MOD	2 (B2)	.023 / MOD		
			3 (B3)	.033 / MOD	.031	
009	1 (A)	.029 / MOD	2 (B2)	.024 / MOD		
			3 (B3)	.034 / MOD	.029	
022	1 (A)	.020 / LOW	2 (B2)	.021 / MOD		
			3 (B3)	.021 / MOD	.021	
041	1 (A1)	.030 / MOD	3 (B1)	.022 / MOD		
	2 (A2)	.037 / MOD	4 (B2)	.015 / LOW	.026	
053	1 (A)	.030 / MOD	2 (B11)	.021 / MOD		
			3 (B12)	.019 / LOW		
			4 (B2)	.038 / MOD	.027	
104	1 (A)	.045 / HIGH	2 (B2)	.023 / MOD		
			3 (B3)	.039 / MOD	.036	
106	1 (A)	.038 / MOD	2 (B1)	.021 / MOD		
			3 (B2)	.014 / LOW	.024	
115	1 (A)	.024 / MOD	2 (B1)	.026 / MOD		
			3 (B2)	.014 / LOW		
			4 (B3)	.010 / LOW	.019	
120	1 (A)	.032 / MOD	2 (B1)	.020 / LOW		
			3 (B2)	.016 / LOW		
			4 (B3)	.019 / LOW	.022	
134	1 (A)	.049 / HIGH	2 (B2)	.017 / LOW		
			3 (B3)	.014 / LOW	.027	
139	1 (A)	.047 / HIGH	2 (B2)	.019 / LOW		
			3 (B3)	.032 / MOD	.033	
					.027	**MODERATE**

(continued next page)

Site	Layer	Topsoil 'K' / Rating	Layer	Subsoil 'K' / Rating	Whole Soil Average 'K'	Unit Erodibility rating
Hillslope Mapping Unit D (Hillslope / sandy)						
070	1 (A1)	.025 / MOD	3 (B1)	.022 / MOD		
	2 (A2)	.043 / HIGH	4 (B2)	.029 / MOD	.030	MODERATE
Soil Mapping Unit E (Hillslope / volcanic)						
099	1 (A)	.026 / MOD	2 (B1)	.027 / MOD		
			3 (B2)	.013 / LOW		
			4 (B3)	.015 / LOW	.020	MODERATE

TABLE 8: Erodibility (K) values and erodibility ratings for the study area's soils using SOILOSS

The exercise in averaging the 'K' values in Table 8, to arrive at a whole soil average 'K', is justifiably open to criticism. However, it ought to be appreciated that this was done in order to arrive at some indication of how erodible each soil type is. Therefore, the values of the whole soil average are indicative only and are not to be taken as being prescriptive.

As can be seen from the data in Table 8, the soils situated at the sites tested have predominantly a moderate erodibility. This is somewhat a more severe rating on the study area's erosion potential when compared with the conclusions reached in Section 3 above. However, for reasons explained below, these SOILOSS results may be misleading.

The difficulty in using the SOILOSS program to assess the erodibility of the study area's soils is evident when the results presented in Table 8 above are compared with the results of the Dispersion Percentage and Emerson Aggregate Test in Section 3.1 above. Soil layers which, in Table 8 have a moderate or even high erodibility, have a contradictory EAT Class 8 value. This is the case with each surface layer tested for all of the fifteen sampling sites. Similar, but not so striking examples, are found throughout the various layers analysed in the laboratory. Some of the inherent problems associated with the SOILOSS program stem from that program's specific applicability to cropping situations. Consequently, the determination of such aspects as soil structure and permeability are not fully adaptable to the study area's soils. (For example, the four choices for structure relate specifically to a fine tilth resulting from frequent surface preparations for cropping land uses. They do not aptly allow for the structure found within the study area's soils).

Given this, the question can be validly asked at this stage as to why this SOILOSS program was used in the assessment of the study area's soils. The answer lies in the interests of objectivity. The opinion offered in respect of the stability of the study area's soils in Section 3.1 above is subjectively based on the authors' experience and expertise, especially that related to the interpretation of laboratory data. As the SOILOSS program has been developed by the government agency responsible for soil conservation in NSW, and widely used by that organisation for similar assessment, it was considered proper that a similar exercise ought to be repeated here. However, in light of the laboratory analysis results presented above, and given the constraints of using the USLE based SOILOSS program under Australian conditions, it is suggested that the results in Table 8 above are indicative only and should be over–ridden by results presented earlier in Section 3.

Nonetheless, regardless of which method is deemed to be the more suitable, appropriate measures are needed to minimise any detrimental impact on the soil material which is to be stripped to be used in the rehabilitation process. These measures relate to both the soil's suitability for stripping purposes and the methods in which the actual soil material is handled. These two aspects are discussed later in this report in Sections 5 and 6 respectively.

4.0 LAND CAPABILITY

4.1 Methodology

Land capability is defined by the NSW Soil Conservation Service (Houghton & Charman, 1986) as "the ability of land to accept a type and intensity of use permanently, or for specified periods under specific management, without permanent damage. It 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... Land capability involves consideration of:

- the various land resource attributes
- the production to be obtained from the land
- the activities or inputs required to achieve that production
- the risks of damage to the land .. resulting from those activities
- the inter-relations of the above"

Based on this concept, a system of land capability classification was developed in the United States and modified to suit local conditions by the Soil Conservation Service of NSW. This classification system is based on an assessment of the biophysical characteristics of the land, the extent to which these will limit a particular type of land use, and the current technology that is available for the management of that land.

The method takes into account a range of factors including the local climate, soils, geology, geomorphology, soil erosion, topography and the effects of past land uses. The classification does not necessarily reflect the existing land uses, rather it indicates the potential of the land for such uses as crop production, pasture improvement and grazing.

This system has been fully described by Emery (undated). A summary table from Emery's article, which defines each of the eight classes, together with interpretations and implications of each class, is included in this report at Appendix 2. As can be seen from this table, the classification has an hierarchical sequence, ranging from Class I land with the greatest potential for agricultural or pastoral use, to Class VIII which is entirely unsuitable for either.

The study area was mapped on a two metre contour map at a scale of 1:4000, to determine the pre-mine rural land capability, according to the system used by the Soil Conservation Service. This map is presented as Figure 2.

4.2 Land Capability Classification of the Study area

Consistent with the table presented in Appendix 2, the study area has been classified into various land capability ratings. Figure 2 shows that each of the first seven land capability classes are found to exist within the study area. The alluvial flats located along parts of the eastern boundary and in the south eastern corner of the study area are classified as

Class I lands. Usually associated with these are the adjoining steeper (but nonetheless low sloped) lands that have been mapped as Class II lands. Pockets of Class III lands occur in the north, east and south–east of the study area. Class IV lands are usually associated with the flatter ridgetops, less steep slopes which do not have soils capable of supporting regular cultivation, and sandier flow line situations. Class V predominates the study area and is found throughout. Pockets of Class VI land occur mainly in the north–west sector of the study area. Isolated, small areas of Class VII lands are usually associated with rocky knobs, ridgelines, etc where the skeletal soil is quite shallow or non existent.

The NSW Soil Conservation Service (SCS) has previously mapped the land capability of all of the area covered by the Muswellbrook 1:100 000 topographic sheet (see Oakley, 1982) which includes all of the study area. This SCS study was undertaken at a scale of 1:100 000. While there is a basic agreement between the two studies in respect of the Class I and II lands, this current Veness & Associates (V&A) study, which was undertaken at a scale of 1:4 000, delineates the occurrence of various classifications at a far greater frequency. This is what would normally be expected given the different scales of the two studies.

However, there is another, less easily explained difference. The SCS map shows Class III lands occurring over much of the eastern half of the study area. The V&A study is in disagreement with this result. Class III lands, by definition, are suitable for regular cultivation. Emery (undated) defines lands suitable for regular cultivation by stating: "Soils must be able to sustain at least two successive seasonal or annual tillage phases for crop production, in which the tilled layer is inverted or shattered, without producing either a significant increase in soil erosion susceptibility, or a significant deterioration in soil structure." For reasons primarily related to soil depth and structure, the V&A land capability study has mapped these areas as either Class IV or Class V. Because of the shallow soils, these lands would not support regular cultivation and are consequently not Class III lands. It is assumed that the SCS study primarily mapped land capability on slope gradient rather than including soil factors. Certainly, this 1:100 000 SCS study would not have had the benefit of the closer soils scrutiny that the 1:4 000 V&A study enjoyed.

After the V&A land capability study maps were drafted, the data was transferred to the single 1:10 000 map sheet to assist the easier presentation of this information in the EIS document. During this process, trade–offs and compromises were made which are more in fitting with the 1:10 000 scale. For example, where small areas of a particular land capability may appear on the 1:4 000 map sheets, they would be a meaningless "blob" on the smaller scale map. Likewise, where areas of a similar land capability existed in close proximity to each other on the 1:4 000 map, they were often joined up on the smaller scale 1:10 000 map. Consequently, there is some variation in the final tabulated results. This variation refers predominantly to Classes IV and V.

The tabulated data, which includes the SCS study, is presented below.

Land	SCS study (1:100 000)		V&A study (1:4 000)		EIS study (1:10 000)	
Class	ha.	% of area	ha.	% of area	ha.	% of area
I	105	2.8	99	2.6	103	2.7
II	29	0.8	52	1.4	43	1.1
III	1249	33.3	47	1.3	41	1.1
IV	166	4.4	940	25.0	1192	31.8
V	2090	55.7	2508	66.8	2264	60.3
VI	114	3.0	74	2.0	104	2.8
VII	-	-	33	0.9	6	0.2

TABLE 9: Land Capability of the Study Area

5.0 STRIPPING SUITABILITY

The method developed by Elliott & Veness (1981) has been used to determine stripping suitability of the various soil materials found during this survey. The key from this method is presented in Appendix 3 of this report. Basically, this method recognises that not all soil material available for topdressing disturbed areas is suitable for agricultural use. Physically, such material may be too weakly structured, too poorly drained, or too sandy or too gravelly to support vegetation. Elliott and Veness found the physical soil properties used to separate suitable and unsuitable materials to be soil structure, macrostructure, coherence, texture and the force necessary to disrupt peds.

The study area's soils have been examined in the field and assessed in the laboratory. When the Elliott and Veness method is applied to these soils, the following stripping recommendations can be made, primarily for topsoiling usage. It ought to be appreciated that the Elliott and Veness key has been designed specifically for the Upper Hunter coalfields soils to determine topdressing suitability. Consequently, judgements have been made by the authors, based on their experience and expertise, which sometimes results in an over-riding of the key's determination, thereby making the stripping suitability assessment more applicable to the study area especially in respect of subsoil materials.

It should be further appreciated that the soil descriptions in Section 2.1 are generalised descriptions which present ranges of data rather than a series of site specific combinations. Likewise, the stripping recommendations below are similarly generalised. However, the stripping map has been compiled by taking into consideration the more detailed data available on a site specific basis and as such is the more reliable indicator of stripping depths to be adopted.

The stripping recommendations refer to the suitability of the soil material to be stripped for use as topsoil, unless otherwise stated. Subsoil stripping is only considered for arable lands (i.e. where the land capability is either Class I, II or III).

5.1 Soil Mapping Unit A - (Floodplain soils)

5.1.1 STRIPPING RECOMMENDATIONS

Layer 1 - A horizon

This layer is always present and most of it is generally suitable for topsoil material. This layer in the north-east and south-east corners of the study area can be stripped to 60 cm for topsoil and in the middle of the eastern boundary this layer can be stripped to 50 cm for topsoil material. There is an occurrence (site 043) in the south-east corner where it is only 34 cm thick and is underlain by unsuitable material. None of this layer around site 075 is suitable for topsoil material due to the high pH values. Where this layer is not stripped for topsoil, it can be stripped for subsoil reserves.

Stripping Recommendation: strip some (generally the top 40 - 60 cm as topsoil)
strip the remainder as subsoil

Layer 2 - D1 horizon

Similar to layer 1 above, some of this layer is suitable for topsoil stripping while the remainder is suitable for subsoil. It is primarily a function of pH which excludes some of this material from topsoil suitability.

Stripping Recommendation: strip some for topsoil; strip the remainder for subsoil reserves

Layer 3 - D2 horizon

This layer is also similar to layer 1 although the pH values here are generally high. Some of this layer is suitable for topsoil stripping while the remainder of this layer is suitable for subsoil stripping purposes.

Stripping Recommendation: strip some for topsoil; strip the remainder for subsoil reserves

Layer 4 - D3 horizon

This layer is always present at depth. While some of it may be suitable for topsoil purposes, its location at depth makes it impractical to selectively strip. Consequently, this layer is suitable only for subsoil stripping.

Stripping Recommendation: strip nil for topsoil; strip all for subsoil

Layer 5 - D4 horizon

This layer is sometimes present at depth. Like layer 4, some of this layer may be suitable for topsoil purposes, but its location at depth makes it impractical to selectively strip. Therefore, this layer is suitable only for subsoil stripping.

Stripping Recommendation: strip nil for topsoil; strip all for subsoil

Layer 6 - D5 horizon

This layer which is sometimes present at depth is not suitable for topsoil purposes because of its high pH values. It is however suitable for subsoil stripping.

Stripping Recommendation: strip nil for topsoil; all of this layer can be stripped for subsoil

5.1.2 SOIL MAPPING UNIT A STRIPPING SUMMARY

Approximately the top half metre of most of this soil mapping unit is suitable for topsoil stripping purposes, while all of the remaining soil materials down to at least 2.5 metres are suitable to be stripped for subsoil purposes.

5.2 Soil Mapping Unit B - (Drainage flat / drainage line soils)

5.2.1 STRIPPING RECOMMENDATIONS

Layer 1 - A, A1, A11 horizon

The surface layer of this soil mapping unit is always suitable for topsoil stripping with the only exception being a small pocket to the north of site 008 where the force to disrupt peds is too high to be suitable. In some instances, especially where only 10 cm is the recommended stripping depth, care needs to be exercised so as not to disturb the soil's structure too much. This may require the use of machinery other than scrapers in the stripping process.

Stripping Recommendation: strip all (usually 4 - 21 cm thick)

Layer 2 - A12 horizon

While this layer is rarely present, it can be stripped for topsoil purposes.

Stripping Recommendation: strip all (26 cm thick)

Layer 3 - A2 horizon

This layer is usually present but is not suitable for topsoil stripping. It is too weakly structured, erodible and often stony. Its hardsetting characteristics makes it unsuitable for germinating plants.

Stripping Recommendation: strip nil

Layer 4 - B1 horizon

While this layer is rarely present, it is not suitable for stripping. It is mottled, has a strong pedality with a corresponding large macrostructure and the force to disrupt peds is not compatible with rehabilitation requirements.

Stripping Recommendation: strip nil

Layer 5 - B2 horizon

This clay subsoil layer has a large macrostructure which makes it unsuitable for stripping purposes. It is also often strongly structured, with an unacceptably high force to disrupt peds and is often stony.

Stripping Recommendation: strip nil

Layer 6 - B3 horizon

This mottled subsoil layer is unsuitable for stripping purposes. Additionally, it has a too large macrostructure.

Stripping Recommendation: strip nil

Layer 7 - D1 horizon

This layer, which is 19 - 85 cm thick, is sometimes located immediately beneath layer 1. It is this combination which results in the deeper stripping depths within Soil Mapping Unit B.

Stripping Recommendation: strip some for topsoil

Layer 8 - D2 horizon

This layer which is usually present is unsuitable for stripping. Its consistence is often not suitable, as is its macrostructure and force to disrupt peds.

Stripping Recommendation: strip nil

Layer 9 - D3 horizon

This layer has too large a macrostructure to be suitable for stripping. In addition, its pH values are often too high for agronomic purposes.

Stripping Recommendation: strip nil

Layer 10 - D4 horizon

This layer occurs only at one site but has unsuitably high pH and soil structure characteristics.

Stripping recommendation: strip nil

Layer 11 - D5 horizon

Like layer 10 above, this layer occurs only at one site but has unsuitably high pH and soil structure characteristics.

Stripping recommendation: strip nil

5.2.2 SOIL MAPPING UNIT B STRIPPING SUMMARY

Except for a small pocket north of site 008, the surface layer of this soil mapping unit is always suitable for topsoil stripping but to various depths. The depth of stripping is generally 20 cm but, depending on site specific soil characteristics, this stripping depth can range from the surface 10 cm to as deep as 70 cm. The soil at depth below any surface strippable material is not recommended to be stripped because of detrimental values relating to soil pH, structure and force to disrupt peds.

5.3 Soil Mapping Unit C - (Hillslope soils)

5.3.1 STRIPPING RECOMMENDATIONS

Layer 1 - A, A1, A11 horizon

This layer can be stripped throughout this soil mapping unit unless it is either too thin (i.e. less than 100 mm thick without another (layer 2) layer of strippable material beneath it) or too rocky. This limitation is usually associated with ridgeline situations.

Stripping Recommendation: strip all (usually 4 - 28 cm thick) unless this layer is too thin or too rocky

Layer 2 - A12 horizon

This layer, which is rarely present, is suitable for topsoiling purposes.

Stripping Recommendation: strip all (occurs 8 - 28 cm thick)

Layer 3 - A2 horizon

This commonly occurring layer is not suitable for topsoil stripping due to its weak structure, its sand and gravel content and it erodible nature and hardsetting characteristics.

Stripping Recommendation: strip nil

Layer 4 - B1 horizon

This strongly structured soil has an unsuitably large macrostructure and strong force to disrupt peds making this layer unsuitable for topsoil stripping.

Stripping Recommendation: strip nil

Layer 5 - B2, B21 horizon

Like layer 4, this strongly structured main subsoil layer has an unsuitably very large macrostructure and strong force to disrupt peds making this material unsuitable for topsoil stripping.

Stripping Recommendation: strip nil

Layer 6 - B22 horizon

This rarely present layer has too large a macrostructure and strong force to disrupt peds making it unsuitable for topsoil stripping.

Stripping Recommendation: strip nil

Layer 7 - B3, B31 horizon

This commonly occurring layer, like layer 6 above, has too large a macrostructure and strong force to disrupt peds making it unsuitable for topsoil stripping.

Stripping Recommendation: strip nil

Layer 8 - B32 horizon

This strongly pedal layer sometimes has an unsuitable macrostructure and an unsuitably high force to disrupt peds making it unsuitable for topsoil stripping.

Stripping Recommendation: strip nil

Layer 9 - BC horizon

Apart from an unsuitable macrostructure and force to disrupt peds, this layer has an unacceptably high pH value for topsoiling stripping purposes.

Stripping recommendation: strip nil

5.3.2 SOIL MAPPING UNIT C STRIPPING SUMMARY

Basically, the surface soil material in this unit can be stripped for topsoil purposes down to the pale coloured A2 horizon or, if the A2 is not present, down to the brighter coloured subsoil clay layer.

5.4 Soil Mapping Unit D - (Sandy hillslope soils)

5.4.1 STRIPPING RECOMMENDATIONS

Layer 1 - A1 horizon

This surface layer is usually suitable for stripping, depending on its thickness, the degree of sandiness and surface rock at specific sites. Because of its fragile structure, this soil needs to be stripped with care. Often it is the organic root matter that permits this soil to be deemed suitable.

Stripping Recommendation: strip sometimes with care (occurs 4 – 39 cm thick)

Layer 2 - A2 horizon

This layer is not suitable for stripping due to its unsuitable texture, usually weak pedality and the high degree of stone content.

Stripping recommendation: strip nil

Layer 3 - B1 horizon

This rarely present upper subsoil layer is sometimes suitable for stripping but, given that it always occurs beneath the unsuitable A2 layer, it is not feasible to strip.

Stripping recommendation: strip nil

Layer 4 - B2 horizon

This main subsoil layer is always present except where skeletal soils occur. It is unsuitable for stripping because of its strong force to disrupt peds, its usual large macrostructure and its usual high stone content. Sometimes, its pH level is too high to be suitable.

Stripping Recommendation: strip nil

Layer 5 - B3, B31 horizon

This sometimes present layer is sometimes mottled and has unsuitable macrostructure and strong force to disrupt peds. Its pH levels are sometimes unsuitable.

Stripping Recommendation: strip nil

Layer 6 - B32 horizon

This rarely present layer has unsuitable macrostructure. It is not suitable for topsoil stripping purposes.

Stripping Recommendation: strip nil

Layer 7 - BC horizon

This commonly occurring layer is unsuitable for stripping primarily due to its usually high pH levels.

Stripping Recommendation: strip nil

5.4.2 SOIL MAPPING UNIT D STRIPPING SUMMARY

Only the surface layer in this soil mapping unit is suitable for stripping for topsoiling purposes. The depth of the material to be stripped is usually 100 mm with occasional pockets to 200 mm. There are a number of instances where, because of the shallow depth of the surface layer, the high sand and gravel content or the sandy texture, this layer is not suitable for stripping.

5.5 Soil Mapping Unit E - (Volcanic hillslope soils)

5.5.1 STRIPPING RECOMMENDATIONS

Layer 1 - A, A1 horizon

This surface layer is usually suitable for topsoil stripping.

Stripping Recommendation: strip all (occurs 8 - 16 cm thick)

Layer 2 - A2 horizon

This layer is not suitable for stripping purposes because of its combination of sandiness, gravel content and large macrostructure, together with its tendency to set hard on the surface.

Stripping Recommendation: strip nil

Layer 3 - B1 horizon

This strongly pedal subsoil layer usually has unsuitable macrostructure and strong force to disrupt peds, making it unsuitable for topsoil stripping purposes.

Stripping Recommendation: strip nil

Layer 4 - B2 horizon

This layer's high pH value makes it unsuitable for topsoil stripping. Additionally, like layer 3 above, this layer also usually has unsuitable macrostructure and force to disrupt peds characteristics.

Stripping Recommendation: strip nil

Layer 5 - B3 horizon

This layer is unsuitable for topsoil stripping purposes for the same reasons given for layer 4 above.

Stripping Recommendation: strip nil

Layer 6 - BC horizon

This layer is unsuitable for topsoil stripping purposes for the same reasons given for layer 4 above.

Stripping Recommendation: strip nil

5.5.2 SOIL MAPPING UNIT E STRIPPING SUMMARY

The surface layer of this soil mapping unit is suitable for topsoil stripping, usually to a depth of 100 mm but sometimes to a depth of 200 mm. In specific situations, the surface layer is unsuitable for stripping, due to its shallow nature or its high gravel / rock content.

5.6 Soil Stripping Map and Volumes

Recommended stripping depths for the study area have been plotted on to the 1:4 000 soil stripping map accompanying this report. This stripping map is presented as Figure 3.

Subsoil stripping has only been recommended to take place on arable lands covered by Class I, II or III land capability (see Section 4). The remainder of the study area, under a grazing capability, has stripping recommendations for topsoil only.

The strippable topsoil and subsoil volumes, according to Figure 3, are presented below in Table 10. Note that this table, and the discussion following in Section 5.7 only relate to the main Mount Pleasant Project area – the topsoil stripping volumes for the two small additional catchments in the south-western corner and the rail line area to the south of the Bengalla lease area are specifically excluded from these calculations.

TOPSOIL				**SUBSOIL**			
Depth (cm)	**Thickness (m)**	**Area (ha)**	**Strippable Volume (m^3)**	**Depth (cm)**	**Thickness (m)**	**Area (ha)**	**Strippable Volume (m^3)**
0 - 10	0.1	2568	2568000	0 - 75	0.75	6	45000
0 - 20	0.2	395	790000	0 - 250	2.5	5	125000
0 - 30	0.3	92	276000	10 - 140	1.3	4	52000
0 - 40	0.4	20	80000	20 - 50	0.3	5	15000
0 - 50	0.5	16	80000	20 - 75	0.55	3	16500
0 - 60	0.6	112	672000	30 - 50	0.2	3	6000
0 - 70	0.7	6	42000	30 - 75	0.45	31	139500
				30 - 100	0.7	3	21000
				40 - 250	2.1	4	84000
				50 - 250	2.0	14	280000
				60 - 250	1.9	114	2166000
	Total strippable topsoil		**4508000m^3**		**Total strippable subsoil**		**2950000m^3**

TABLE 10: Volumes of strippable soil material

5.7 Respreading of Stripped Soil Material

Rehabilitation requirements call for the spreading of topsoil, or other suitable topdressing, on lands with an other than arable pre-mine land capability (i.e. Classes IV – VII), while arable lands (Classes I – III) require the reconstruction of a complete soil profile. The depth of this reconstructed profile should be sufficiently deep enough to contain a topsoil layer capable of supporting farming practices (i.e. in excess of 0.3 metres) placed over a subsoil layer. A minimum total reconstructed depth ought to be in the order of 1.5 metres.

An examination of the area covered by Class I, II and III lands in Table 9 shows a total of 198 hectares requiring profile reconstruction (based on the assumption that the whole of the study area will be disturbed through open-cut mining. While this assumption is obviously incorrect, it presents the "worst case scenario" in respect of the effect of mining on the study area's soil resource where 198 hectares require profile reconstruction for the re-establishment of cropping capability and the remaining 3102 hectares in the study area requiring topsoil only replacement for the re-establishment of grazing capability.)

Given the topsoil and subsoil stripping reserves of 4,508,000 m^3 and 2,950,000 m^3 respectively (from Table 10 above), an appropriate distribution of this resource in the rehabilitation program could be:

Grazing lands:

Topsoil resource required to spread 100 mm during rehabilitation process
= area X 0.1 m
= 31,020,000 m^2 X 0.1
= 3,102,000 m^3

Arable lands:

Topsoil resource available = 4,508,000 m^3 - 3,102,000 m^3 = 1,406,000 m^3

Topsoil horizon thickness available

$$= \frac{1,406,000 \text{ m}^3}{1,980,000 \text{ m}^2} = 0.71 \text{ metres}$$

Subsoil horizon thickness available

$$= \frac{2,950,000 \text{ m}^3}{1,980,000 \text{ m}^2} = 1.49 \text{ metres}$$

Based on these calculations, there would be sufficient soil resources to meet the required topsoil and subsoil demands of any rehabilitation program associated with the proposed open-cut project within the study area.

The above distribution example is based on the "worst case scenario" where the entire lease area is disturbed. Obviously, this will not be the case and consequently, the depth of the reconstructed soil profile will not be the same as that presented in this example.

While grazing lands ought to have a minimum 100 mm of topsoil respread on the reformed surface, the depth of reconstructed soil profile (i.e. a topsoil over a subsoil) on reconstituted arable lands will need to be sufficient to support a cropping land use. To this end it is recommended that a minimum 300 mm of topsoil should be replaced over a minimum 1200 mm subsoil. Based on the average pre-mine thickness of these horizons, as shown in Table 10, the attainment of such a profile reconstruction will be viable.

Obviously, if arable lands are disturbed, the better topsoil material resulting from the stripping of these lands should be used to rehabilitate lands to a similar land capability. In other words, the pre–mine arable soils should be used to re–establish rehabilitated post–mine arable lands while the soils from pre–mine grazing lands can be used to re–establish post–mine grazing lands.

6.0 SOIL HANDLING STRATEGIES

On the assumption that the study area may be subjected to open–cut mining, recommendations are made in this report concerning the stripping, stockpiling and respreading of the various soil materials. These recommendations are made basically on the results of the soil survey.

6.1 Review of Existing Technology and Practices

When topsoil material is stripped during open–cut mining operations, a decline in soil structure usually occurs, according to Elliott & Veness (1985), who saw a main reason for this being related to working the soil material at unfavourable moisture conditions. Hunter & Currie (1956) also noted a soil structural decline, attributing it not only to moisture conditions, but also to the effect of mixing soil layers and a subsequent loss of organic matter.

The adverse effects of compaction during the earthmoving process have also been noted (see for example, McQueen & Ross, 1982).

6.2 Stockpiling of Soil Material

During topsoil stockpiling operations, many soil properties may be adversely affected. Dougall (1950) noted that the changes occurring to the soil material included a breakdown in soil aggregates, disruption to the soil's internal drainage pattern and an apparent loss of fertility resulting from these, and other, physical and chemical changes. Elliott & Veness (1985) concluded that the quality of stockpiled topsoil can improve over time, especially in the top 60 centimetres of the stockpile, while Jenkin et al. (1987) found that the adverse effects appear comparable to those which may result from normal agricultural practices and are generally similarly reversible.

6.3 Recommendations

6.3.1 STRIPPING AND STOCKPILING METHODS

Some of the soil materials within the study area, especially those occurring within Soil Mapping Unit D, are generally sandy and have a corresponding fragile soil structure. Consequently, if these materials are to be of use during the rehabilitation program, they must be handled with extreme care – that is, the fragile peds should not be broken down to single grain entities during material handling. The less number of times the strippable material is handled, the better.

While it could sometimes be appropriate, topsoil stripping with a scraper in this material is not the favoured method. Truck and shovel or excavator stripping would be more appropriate as these operations would inflict less damage on the soil's structure during transportation, dumping, reclaiming and respreading operations. A further method of stripping could involve windrowing the topsoil material by dozer.

Elsewhere throughout the study area, conventional scraper techniques would be appropriate during stripping operations.

All stockpiled material should be left in a "rough surface" finish as any attempt to smooth off the final surface will inflict an unnecessary mechanical working on the soil. Likewise, any stockpiles formed by pushing topsoil from haul roads, stockpile pads, borrow pits, etc should also be left in a "rough" condition.

6.3.2 STOCKPILE HEIGHT AND LOCATION

If stockpiled soil material is to remain healthy through the retention of biological activity, the ideal maximum height of stockpiles should be approximately 0.6 to 1 metre. However, given some of the physical restraints of the site and the method of operation, stockpiled soil material should be viable if the individual stockpiles do not exceed two to three metres in height.

Stockpile location should capitalise on surface topography to avoid the occurrence of overland and/or concentrated surface flows from directly impacting on stockpiled material. Therefore, stockpiles should be located on crests or within level areas where there would be no detrimental effects experienced from surface flows. Where this is not possible, adequate protection will need to be given to the stockpiles in the form of protective contour or graded banks constructed immediately above the stockpile locations.

6.3.3 EROSION CONTROL MEASURES

Once they are grassed up, the outside batters of the stockpiles should not erode as a result of rainfall on them. However, as discussed above in Section 6.3.2, protective earthworks, in the form of contour or graded banks, may be necessary to negate the impact of surface flows on the outside batter toes of the stockpiles.

Stockpiled soil material should be grassed as soon as practicable to assist in the control of erosion from both water and wind related processes.

7.0 CONCLUSION

The various soils within the study area have been examined and described. Five main soil mapping units have been delineated. The soils' erosion potential has been assessed and discussed. It has been found that, while the soils throughout the study area are currently stable, they nonetheless have a moderate to very high erodibility rating. This conclusion is consistent with both the laboratory analyses results and the calculations undertaken through the SOILOSS program.

The pH and eC values of the study area's soils have been discussed. The soils tested generally have suitable levels for rehabilitation purposes but can sometimes have pH levels which are considered to be too high for agronomic purposes.

Pre-mine land capability of the study area has been assessed and mapped. Generally, this results in classifications which support predominantly grazing with some significant arable areas mainly occurring in the eastern section of the study area.

Stripping suitability of the soils throughout the study area has been determined. It is discussed in the report and presented graphically on the accompanying soil stripping map. Sufficient reserves of both suitable topsoil and subsoil material are available to assist the successful rehabilitation of any lands which may be disturbed through open-cut mining within the study area.

J.A. Veness R.A. Veness

(Directors)
VENESS & ASSOCIATES Pty Limited
26th February, 1997

REFERENCES

Abbott, T.S. (Ed.) (1987) Soil Testing Service – Methods and Interpretation Department of Agriculture of NSW, Rydalmere

Charman, P.E.V. (1978) Soils of New South Wales – Their Characterisation, Classification and Conservation Soil Conservation Service of NSW Technical Handbook No. 1

Charman, P.E.V. & Murphy, B.W. (1991) Soils – Their Properties and Management A Soil Conservation Handbook for New South Wales Sydney University Press

Dougall, B.M. (1950) The effects of open–cut coal mining on agricultural land. Jnl. Sci. Fd. Agric. 11:225–229

Dyson, J.D.,Elliott, G.L., Reynolds, K.C., Dight, D.C.G. & Hill, M.J. (1987) Coal Mine Rehabilitation End of grant report – Final report January 1987. NSW Coal Association

Elliott, G.L. & Veness, R.A. (1981) Selection of topdressing material for rehabilitation of disturbed areas in the Hunter Valley *Jnl. Soil Cons. N.S.W.* 37:37–40

Elliott, G.L. & Veness, J.A. (1985) Some effects of stockpiling topsoil *Jnl. Soil Cons. N.S.W.* 41:6–11

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

Hazelton, P.A. & Murphy, B.W. (Eds.) (1992) What Do All The Numbers Mean? A Guide for the Interpretation of Soil Test Results. Department of Conservation and Land Management (incorporating the Soil Conservation Service of NSW), Sydney

Houghton, P.D. & Charman, P.E.V. (1986) Glossary of Terms used in Soil Conservation Soil Conservation Service of NSW

Hunter, F & Currie, J.A. (1956) Structural changes during bulk soil storage Jnl. Soil Sci. 7:75–80

Jenkin, J.F., Elliott, G.L. & Veness, J.A. (1987) Soil stockpiling, profile reconstruction and crop growth on reconstituted soils: Dartbrook, Hunter Valley, NSW. Australian Mining Industry Council Proceedings of Environmental Workshop, Adelaide

King, D.P. (1993) Soil Landscapes of the Wallerawang 1:100 000 Sheet. NSW Soil Conservation Service

McDonald, R.C., Isbell, R.F., Speight, J.G., Walker, J. & Hopkins, M.S. (1990) Australian Soil and Land Survey Field Handbook 2nd edition Inkata Press, Melbourne

McQueen, D.J. & Ross, C.W. (1982) Effects of stockpiling topsoils associated with opencast mining – II Physical properties. N.Z. Jnl. Sci. 25:295–302

Northcote, K.H. (1979) A Factual Key for the Recognition of Australian Soils CSIRO Rellim Publications, Adelaide

Northcote, K.H., Hubble, G.D., Isbell, R.F., Thompson, C.H. & Bettanay, E. (1975) A Description of Australian Soils CSIRO Wilke & Co Ltd, Clayton, Victoria

Oakley, W.C.L. (1982) Land Capability of the 1:100 000 Muswellbrook Sheet. NSW Soil Conservation Service

Oyama, M. & Takehara, H. (1970) Revised Standard Soil Colour Charts Ministry of Agriculture and Forestry, Japan

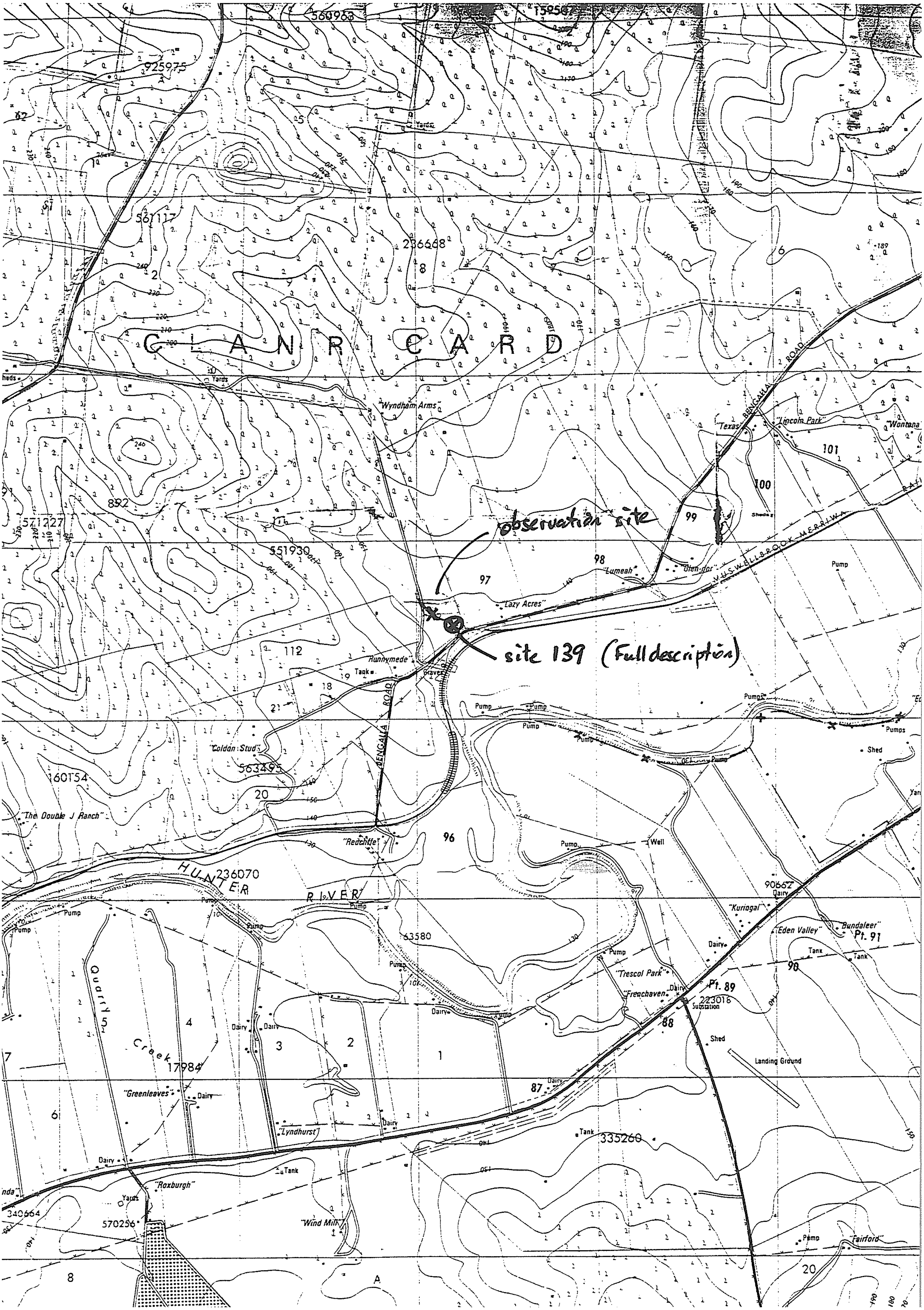
Pilgrim, D.H. (Ed.) (1987) Australian Rainfall and Runoff. A guide to flood estimation. Institute of Engineers, Canberra

Rosewell, C.J. (1993) SOILOSS: a program to assist in the selection of management practices to reduce erosion. Department of Conservation and Land Management, Gunnedah. Technical Handbook No. 11. 2nd edition

Rosewell, C.J. & Edwards, K. (1988) SOILOSS. A program to assist in the selection of management practices to reduce erosion. Soil Conservation Service of New South Wales. Technical Handbook No. 11

Rosewell, C.J. & Turner, J.B. (1992) Rainfall erosivity in New South Wales. Department of Conservation and Land Management, Technical Report No. 20, Sydney

Wischmeier, W.H. & Smith, D.D. (1978) Predicting rainfall erosion losses - a guide to conservation planning. Agricultural Handbook 537, United States Department of Agriculture, Washington, D.C.



observation site

site 139 (Full description)

VENESS & ASSOCIATES PTY LIMITED
Environmental and Natural Resource Consultants 1324 Mt. Pleasant

Unit A SITE No. 003 cont.

cf. 210

Location: ° ' "
Latitude __°__'__" S
Longitude ___°__'__" E

Uf 6.11

Photo

Record Type	Same as Site No	Total No. of Layers
0 0 0 4		

	Layer No	Horizon	Lower Average Depth (m)	Dominant Colour (Munsell Code) Moist	V/C	Dry	Mottle Primary Colour	Tone	Contrast	%	Mottle Secondary Colour	Tone	Contrast	%	Moisture	pH	Ag NO3	Sample
1	1	A	.20	7.5 YR 3/2	1	/								5	M	6.5		1
2	2	D1	.52	7.5 YR 3/2	1	/									M	7.0		1
3	3	D2	1.12	7.5 YR 3/3		/									S	8.5		1
4	4	D3	1.24	7.5 YR 3/3		/									D	8.0		1
5	5	D4	+2.50	7.5 YR 3/4		/									D	8.5		1
~~6~~	~~6~~	~~D5~~		/		/												

CODES		
Colour	Red	R
	Orange	O
	Brown	B
	Yellow	Y
	Grey	G
	Gley	L
Tone	Pale	P
	Dark	D
Contrast	Faint	F
	Distinct	D
	Prominent	P
Moisture	Dry	D
	S Moist	S
	M Moist	M
	Wet	W
Ag NO3	-ve test	N
	+ve test	P
Sample	not taken	O
	taken	1

Floodplain, Gabery

SURFACE CONDITION
Crust –
Hard set –
Not hard set ☒ plough layer

BOUNDARY DISTINCTNESS (1 2 3 4 5 6)
- HA01 None
- HA02 Sharp (<20 mm)
- HA03 Clear (20-50 mm)
- HA04 Gradual (50-100 mm)
- HA05 Diffuse (>100 mm)

SHAPE
- HB01 Even
- HB02 Wavy
- HB03 Irregular
- HB04 Broken

TEXTURE SAND FRACTION
- FA01 Fine
- FA02 Coarse

GRADE
- PG01 Sand
- PG02 Loamy Sand
- PG03 Clayey Sand
- PC01 Sandy Loam
- PC02 Fine Sandy Loam
- PC03 Light Sandy Clay Loam
- PD01 Loam
- PD02 Loam, Fine Sandy
- PD03 Silt Loam
- PD04 Sandy Clay Loam
- PE01 Clay Loam
- PE02 Silty Clay Loam
- PE03 Fine Sandy Clay Loam
- PF01 Sandy Clay
- PF02 Silty Clay
- PF03 Light Clay
- PF04 Light Medium Clay
- PG01 Medium Clay
- PG02 Heavy Clay

PLASTICITY TYPE
- QA01 Super Plastic
- QA02 Normal Plastic
- QA03 Subplastic
- QA04 Strongly Subplastic

STICKINESS
- QF01 Non-sticky
- QF02 Slightly Sticky
- QF03 Moderately Sticky
- QF04 Very Sticky

WATER-TABLE
- SA01 None
- SA02 Seasonal
- SA03 Permanent
- SA04 Perched

CONSISTENCE DISRUPTIVE TEST

Coherent wet-dry - 1,2,3
Coherent dry, not wet - 4,5

- TA01 Very Weak Force
- TA02 Weak Force
- TA03 Moderate Force
- TA04 Strong Force
- TA05 Very Strong Force

SHEARING TEST
- TB01 Brittle
- TB02 Crumbly
- TB03 No Change
- TB04 Labile
- TB05 Plastic

STRUCTURE GRADE
- UA01 Apedal Single Grained
- UA02 Apedal Massive
- UA03 Weak Pedality
- UA04 Moderate Pedality
- UA05 Strong Pedality

PED SIZE (Primary UB01–UB09, Secondary UC01–UC09)
- <2 mm
- 2-5 mm
- 5-10 mm
- 10-20 mm
- 20-50 mm
- 50-100 mm
- 100-200 mm
- 200-500 mm
- >500 mm

PED SHAPE (Primary UD01–UD10, Secondary UE01–UE10)
- Platy
- Lenticular
- Prismatic
- Columnar
- Angular Blocky
- Sub-ang. Blocky
- Polyhedral
- Round
- Granular
- Crumb

FABRIC
- UF01 Earthy
- UF02 Sandy
- UF03 Smooth-faced Peds
- UF04 Rough-faced Peds

CUTANS
- UG01 None
- UG02 Few (<10%)
- UG03 Common (10-50%)
- UG04 Many (> 50%)

PED POROSITY
- UH01 Porous
- UH02 Dense

CRACK SIZE
- UI01 <2mm
- UI02 2-5 mm
- UI03 5-10mm
- UI04 10-20mm
- UI05 >20mm

STONES AMOUNT OF STONES
- VA01 None
- VA02 <2 %
- VA03 2-10 %
- VA04 10-20 %
- VA05 20-50 %
- VA06 50-90 %
- VA07 >90 %

SHAPE
- VB01 Rounded
- VB02 Sub-rounded
- VB03 Sub-angular
- VB04 Angular

STONE DISTRIBUTION
- VC01 Reoriented
- VC02 Undisturbed
- VC03 Stratified
- VC04 Dispersed

STONE SIZE
- VD01 2-6 mm
- VD02 6-20 mm
- VD03 20-60 mm
- VD04 60-200 mm
- VD05 200-600 mm
- VD06 >600 mm

STONE WEATHERING
- VE01 Non-weathered
- VE02 Weakly Weathered
- VE03 Strongly Weathered

STONE LITHOLOGY
- VF01 Not Identified
- VF02 Quartz
- VF03 Sedimentary
- VF04 Metamorphic
- VF05 Igneous

ROOTS AMOUNT
- WA01 None
- WA02 Few
- WA03 Common
- WA04 Many
- WA05 Abundant

ROOT DISTRIBUTION
- WB01 In-ped
- WB02 Ex-ped

PANS
- XA01 No Pans
- XA02 Carbonate
- XA03 Silica
- XA04 Humus & Iron Oxide
- XA05 Sesquioxide
- XA06 Clay
- XA07 Cultivation

CHARACTER
- XB01 Continuous
- XB02 Discontinuous
- XB03 Convoluted Pans
- XB04 Weakly Cemented
- XB05 Strongly Cemented

CONCRETIONS & INCLUSIONS
- XF01 None
- XF02 Carbonate
- XF03 Gypsum
- XF04 Iron
- XF05 Manganese
- XF06 Organic/Charcoal
- XF07 Other

FORM
- XG01 Diffuse
- XG02 Soft Nodules
- XG03 Hard Nodules
- XG04 Crystals

AMOUNT
- XH01 <2 %
- XH02 2-20%
- XH03 >20%

SIZE
- XI01 <5 mm
- XI02 5-15 mm
- XI03 >15 mm

VENESS & ASSOCIATES PTY LIMITED
Environmental and Natural Resource Consultants 1324 Mt. Pleasant

Unit B SITE No. 001 cont.

cf 203

Location: ° ' "
Latitude __°__'__" S
Longitude ___°__'__" E

Dy 3.42

Photo

Record Type	Same as Site No	Total No. of Layers
0 0 0 4		

	Layer No	Horizon	Lower Average Depth (m)	Dominant Colour (Munsell Code) Moist	V/C	Dry	Mottle Primary Colour	Tone	Contrast	%	Mottle Secondary Colour	Tone	Contrast	%	Moisture	pH	Ag NO3	Sample
1	1	A1	.11	7.5 YR 3/3		/									D	6.0		1
3	2	A2	.32	7.5 YR 5/3		8/3									D	6.0		1
4	3	B1	.58	10 YR 6/6	4	/	G	P	D	20					S	6.0		1
5	4	B2	+1.30	5 YR 5/6	4	/									S	7.5		1
	5			/		/												
	6			/		/												

CODES		
Colour	Red	R
	Orange	O
	Brown	B
	Yellow	Y
	Grey	G
	Gley	L
Tone	Pale	P
	Dark	D
Contrast	Faint	F
	Distinct	D
	Prominent	P
Moisture	Dry	D
	S Moist	S
	M Moist	M
	Wet	W
Ag NO3	-ve test	N
	+ve test	P
Sample	not taken	O
	taken	1

Drainage line / footslope

SURFACE CONDITION
Crust –
Hard set ☒
Not hard set –

BOUNDARY DISTINCTNESS (1 2 3 4 5 6)
- HA01 None
- HA02 Sharp (<20 mm)
- HA03 Clear (20-50 mm)
- HA04 Gradual (50-100 mm)
- HA05 Diffuse (>100 mm)

SHAPE
- HB01 Even
- HB02 Wavy
- HB03 Irregular
- HB04 Broken

TEXTURE SAND FRACTION
- FA01 Fine
- FA02 Coarse

GRADE
- PG01 Sand
- PG02 Loamy Sand
- PG03 Clayey Sand
- PC01 Sandy Loam
- PC02 Fine Sandy Loam
- PC03 Light Sandy Clay Loam
- PD01 Loam
- PD02 Loam, Fine Sandy
- PD03 Silt Loam
- PD04 Sandy Clay Loam
- PE01 Clay Loam
- PE02 Silty Clay Loam
- PE03 Fine Sandy Clay Loam
- PF01 Sandy Clay
- PF02 Silty Clay
- PF03 Light Clay
- PF04 Light Medium Clay
- PG01 Medium Clay
- PG02 Heavy Clay

PLASTICITY TYPE
- QA01 Super Plastic
- QA02 Normal Plastic
- QA03 Subplastic
- QA04 Strongly Subplastic

STICKINESS
- QF01 Non-sticky
- QF02 Slightly Sticky
- QF03 Moderately Sticky
- QF04 Very Sticky

WATER-TABLE
- SA01 None
- SA02 Seasonal
- SA03 Permanent
- SA04 Perched

CONSISTENCE DISRUPTIVE TEST

Coherent, wet-dry - 1,3,4
Coherent dry, not wet - 2

- TA01 Very Weak Force
- TA02 Weak Force
- TA03 Moderate Force
- TA04 Strong Force
- TA05 Very Strong Force

SHEARING TEST
- TB01 Brittle
- TB02 Crumbly
- TB03 No Change
- TB04 Labile
- TB05 Plastic

STRUCTURE GRADE
- UA01 Apedal Single Grained
- UA02 Apedal Massive
- UA03 Weak Pedality
- UA04 Moderate Pedality
- UA05 Strong Pedality

PED SIZE (Primary UB01–UB09, Secondary UC01–UC09)
- <2 mm
- 2-5 mm
- 5-10 mm
- 10-20 mm
- 20-50 mm
- 50-100 mm
- 100-200 mm
- 200-500 mm
- >500 mm

PED SHAPE (Primary UD01–UD10, Secondary UE01–UE10)
- Platy
- Lenticular
- Prismatic
- Columnar
- Angular Blocky
- Sub-ang. Blocky
- Polyhedral
- Round
- Granular
- Crumb

FABRIC
- UF01 Earthy
- UF02 Sandy
- UF03 Smooth-faced Peds
- UF04 Rough-faced Peds

CUTANS
- UG01 None
- UG02 Few (<10%)
- UG03 Common (10-50%)
- UG04 Many (> 50%)

PED POROSITY
- UH01 Porous
- UH02 Dense

CRACK SIZE
- UI01 <2mm
- UI02 2-5 mm
- UI03 5-10mm
- UI04 10-20mm
- UI05 >20mm

STONES AMOUNT OF STONES
- VA01 None
- VA02 <2 %
- VA03 2-10 %
- VA04 10-20 %
- VA05 20-50 %
- VA06 50-90 %
- VA07 >90 %

SHAPE
- VB01 Rounded
- VB02 Sub-rounded
- VB03 Sub-angular
- VB04 Angular

STONE DISTRIBUTION
- VC01 Reoriented
- VC02 Undisturbed
- VC03 Stratified
- VC04 Dispersed

STONE SIZE
- VD01 2-6 mm
- VD02 6-20 mm
- VD03 20-60 mm
- VD04 60-200 mm
- VD05 200-600 mm
- VD06 >600 mm

STONE WEATHERING
- VE01 Non-weathered
- VE02 Weakly Weathered
- VE03 Strongly Weathered

STONE LITHOLOGY
- VF01 Not Identified
- VF02 Quartz
- VF03 Sedimentary
- VF04 Metamorphic
- VF05 Igneous

ROOTS AMOUNT
- WA01 None
- WA02 Few
- WA03 Common
- WA04 Many
- WA05 Abundant

ROOT DISTRIBUTION
- WB01 In-ped
- WB02 Ex-ped

PANS
- XA01 No Pans
- XA02 Carbonate
- XA03 Silica
- XA04 Humus & Iron Oxide
- XA05 Sesquioxide
- XA06 Clay
- XA07 Cultivation

CHARACTER
- XB01 Continuous
- XB02 Discontinuous
- XB03 Convoluted Pans
- XB04 Weakly Cemented
- XB05 Strongly Cemented

CONCRETIONS & INCLUSIONS
- XF01 None
- XF02 Carbonate
- XF03 Gypsum
- XF04 Iron
- XF05 Manganese
- XF06 Organic/Charcoal
- XF07 Other

FORM
- XG01 Diffuse
- XG02 Soft Nodules
- XG03 Hard Nodules
- XG04 Crystals

AMOUNT
- XH01 <2 %
- XH02 2-20%
- XH03 >20%

SIZE
- XI01 <5 mm
- XI02 5-15 mm
- XI03 >15 mm

VENESS & ASSOCIATES PTY LIMITED
Environmental and Natural Resource Consultants

1324 Mt. Pleasant

Unit C SITE No. 008 cont.

cf 229

Dr 4.13

Record Type	Same as Site No	Total No. of Layers
0 0 0 4		

Location: ° ' "
Latitude __ ° __ ' __ " S
Longitude __ ° __ ' __ " E

Photo

	Layer No	Horizon	Lower Average Depth (m)	Dominant Colour (Munsell Code) Moist	V/C	Dry	Mottle Primary Colour	Tone	Contrast	%	Mottle Secondary Colour	Tone	Contrast	%	Moisture	pH	Ag NO3	Sample
1	1	A	.13	5YR 2/3		/									D	6.0		1
5	2	B2	.48	5YR 3/6		/									S	7.0		1
7	3	B3	.67	5YR 5/6		/									S	8.5		1
10	4	C	.	/		/										.		
	5		.	/		/										.		
	6		.	/		/										.		

CODES		
Colour	Red	R
	Orange	O
	Brown	B
	Yellow	Y
	Grey	G
	Gley	L
Tone	Pale	P
	Dark	D
Contrast	Faint	F
	Distinct	D
	Prominent	P
Moisture	Dry	D
	S Moist	S
	M Moist	M
	Wet	W
Ag NO3	-ve test	N
	+ve test	P
Sample	Not taken	O
	Taken	

Midslope

SURFACE CONDITION

Crust ☒ none.
Hard set
Not hard set ☒

BOUNDARY
DISTINCTNESS
NA01 None
NA02 Sharp (<20 mm)
NA03 Clear (20-50 mm)
NA04 Gradual (50-100 mm)
NA05 Diffuse (>100 mm)
SHAPE
NB01 Even
NB02 Wavy
NB03 Irregular
NB04 Broken

TEXTURE
SAND FRACTION
FA01 Fine
FA02 Coarse
GRADE
PB01 Sand
PB02 Loamy Sand
PB03 Clayey Sand
~~PC01 Sandy Loam~~
PC02 Fine Sandy Loam
PC03 Light Sandy Clay Loam
PD01 Loam
PD02 Loam, Fine Sandy
PD03 Silt Loam
PD04 Sandy Clay Loam
PE01 Clay Loam
PE02 Silty Clay Loam
PE03 Fine Sandy Clay Loam
PF01 Sandy Clay
PF02 Silty Clay
PF03 Light Clay
PF04 Light Medium Clay
PG01 Medium Clay
PG02 Heavy Clay

PLASTICITY TYPE
QA01 Super Plastic
QA02 Normal Plastic
QA03 Subplastic
QA04 Strongly Subplastic

STICKINESS
QF01 Non-sticky
QF02 Slightly Sticky
QF03 Moderately Sticky
QF04 Very Sticky

WATER-TABLE
SA01 None
SA02 Seasonal
SA03 Permanent
SA04 Perched

CONSISTENCE
DISRUPTIVE TEST
COHERENCE All wet·dry
TA01 Very Weak Force
TA02 Weak Force
TA03 Moderate Force
TA04 Strong Force
TA05 Very Strong Force
SHEARING TEST
TB01 Brittle
TB02 Crumbly
TB03 No Change
TB04 Labile
TB05 Plastic

STRUCTURE
GRADE
UA01 Apedal Single Grained
UA02 Apedal Massive
UA03 Weak Pedality
UA04 Moderate Pedality
UA05 Strong Pedality

PED SIZE

Primary		Secondary
UB01	< 2 mm	UC01
UB02	2-5 mm	UC02
UB03	5-10 mm	UC03
UB04	10-20 mm	UC04
UB05	20-50 mm	UC05
UB06	50-100 mm	UC06
UB07	100-200 mm	UC07
UB08	200-500 mm	UC08
UB09	>500 mm	UC09

PED SHAPE

Primary		Secondary
UD01	Platy	UE01
UD02	Lenticular	UE02
UD03	Prismatic	UE03
UD04	Columnar	UE04
UD05	Angular Blocky	UE05
UD06	Sub-ang Blocky	UE06
UD07	Polyhedral	UE07
UD08	Round	UE08
UD09	Granular	UE09
UD10	Crumb	UE10

FABRIC
UF01 Earthy
UF02 Sandy
UF03 Smooth-faced Peds
UF04 Rough-faced Peds
CUTANS
UG01 None
UG02 Few (<10%)
UG03 Common (10-50%)
UG04 Many (> 50%)
PED POROSITY
UH01 Porous
UH02 Dense

CRACK SIZE
UI01 <2mm
UI02 2-5 mm
UI03 5-10mm
UI04 10-20mm
UI05 >20mm

STONES
AMOUNT OF STONES
VA01 None
VA02 <2 %
VA03 2-10 %
VA04 10-20 %
VA05 20-50 %
VA06 50-90 %
VA07 >90 %
SHAPE
VB01 Rounded
VB02 Sub-rounded
VB03 Sub-angular
VB04 Angular
STONE DISTRIBUTION
VC01 Reoriented
VC02 Undisturbed
VC03 Stratified
VC04 Dispersed

STONE SIZE
VD01 2-6 mm
VD02 6-20 mm
VD03 20-60 mm
VD04 60-200 mm
VD05 200-600 mm
VD06 >600 mm
STONE WEATHERING
VE01 Non-weathered
VE02 Weakly Weathered
VE03 Strongly Weathered
STONE LITHOLOGY
VF01 Not Identified
VF02 Quartz
VF03 Sedimentary
VF04 Metamorphic
VF05 Igneous

ROOTS
AMOUNT
WA01 None
WA02 Few
WA03 Common
WA04 Many
WA05 Abundant
ROOT DISTRIBUTION
WB01 In-ped
WB02 Ex-ped

PANS
XA01 No Pans
XA02 Carbonate
XA03 Silica
XA04 Humus & Iron Oxide
XA05 Sesquioxide
XA06 Clay
XA07 Cultivation
CHARACTER
XB01 Continuous
XB02 Discontinuous
XB03 Convoluted Pans
XB04 Weakly Cemented
XB05 Strongly Cemented

CONCRETIONS & INCLUSIONS
XF01 None
XF02 Carbonate
XF03 Gypsum
XF04 Iron
XF05 Manganese
XF06 Organic/Charcoal
XF07 Other
FORM
XG01 Diffuse
XG02 Soft Nodules
XG03 Hard Nodules
XG04 Crystals
AMOUNT
XH01 <2 %
XH02 2-20%
XH03 >20%
SIZE
XI01 <5 mm
XI02 5-15 mm
XI03 >15 mm

VENESS & ASSOCIATES PTY LIMITED
Environmental and Natural Resource Consultants

1324 Mt. Pleasant

Unit C SITE No. 009 cont.

cf 235

Uf 6.31

Record Type	Same as Site No	Total No. of Layers
0 0 0 4		

Location: ° ' "
Latitude __ ° __ ' __ " S
Longitude __ ° __ ' __ " E

Photo

	Layer No	Horizon	Lower Average Depth (m)	Dominant Colour (Munsell Code) Moist	V/C	Dry	Mottle Primary Colour	Tone	Contrast	%	Mottle Secondary Colour	Tone	Contrast	%	Moisture	pH	Ag NO3	Sample
1	1	A	.08	5MR 3/3		/									D	5.5		1
5	2	B2	.28	5MR 4/6		/									S	7.6		1
7	3	B3	.50	7.5YR 6/4		/									M	8.5		1
10	4	C	+ .70	/		/										.		
	5		.	/		/										.		
	6		.	/		/										.		

CODES		
Colour	Red	R
	Orange	O
	Brown	B
	Yellow	Y
	Grey	G
	Gley	L
Tone	Pale	P
	Dark	D
Contrast	Faint	F
	Distinct	D
	Prominent	P
Moisture	Dry	D
	S Moist	S
	M Moist	M
	Wet	W
Ag NO3	-ve test	N
	+ve test	P
Sample	Not taken	O
	Taken	

Hilltop

SURFACE CONDITION

Crust ☒ some
Hard set
Not hard set ☒

BOUNDARY
DISTINCTNESS
NA01 None
NA02 Sharp (<20 mm)
NA03 Clear (20-50 mm)
NA04 Gradual (50-100 mm)
NA05 Diffuse (>100 mm)
SHAPE
NB01 Even
NB02 Wavy
NB03 Irregular
NB04 Broken

TEXTURE
SAND FRACTION
FA01 Fine
FA02 Coarse
GRADE
PB01 Sand
PB02 Loamy Sand
PB03 Clayey Sand
~~PC01 Sandy Loam~~
PC02 Fine Sandy Loam
PC03 Light Sandy Clay Loam
PD01 Loam
PD02 Loam, Fine Sandy
PD03 Silt Loam
PD04 Sandy Clay Loam
PE01 Clay Loam
PE02 Silty Clay Loam
PE03 Fine Sandy Clay Loam
PF01 Sandy Clay
PF02 Silty Clay
PF03 Light Clay
PF04 Light Medium Clay
PG01 Medium Clay
PG02 Heavy Clay

PLASTICITY TYPE
QA01 Super Plastic
QA02 Normal Plastic
QA03 Subplastic
QA04 Strongly Subplastic

STICKINESS
QF01 Non-sticky
QF02 Slightly Sticky
QF03 Moderately Sticky
QF04 Very Sticky

WATER-TABLE
SA01 None
SA02 Seasonal
SA03 Permanent
SA04 Perched

CONSISTENCE
DISRUPTIVE TEST
COHERENCE All wet·dry
TA01 Very Weak Force
TA02 Weak Force
TA03 Moderate Force
TA04 Strong Force
TA05 Very Strong Force
SHEARING TEST
TB01 Brittle
TB02 Crumbly
TB03 No Change
TB04 Labile
TB05 Plastic

STRUCTURE
GRADE
UA01 Apedal Single Grained
UA02 Apedal Massive
UA03 Weak Pedality
UA04 Moderate Pedality
UA05 Strong Pedality

PED SIZE

Primary		Secondary
UB01	< 2 mm	UC01
UB02	2-5 mm	UC02
UB03	5-10 mm	UC03
UB04	10-20 mm	UC04
UB05	20-50 mm	UC05
UB06	50-100 mm	UC06
UB07	100-200 mm	UC07
UB08	200-500 mm	UC08
UB09	>500 mm	UC09

PED SHAPE

Primary		Secondary
UD01	Platy	UE01
UD02	Lenticular	UE02
UD03	Prismatic	UE03
UD04	Columnar	UE04
UD05	Angular Blocky	UE05
UD06	Sub-ang Blocky	UE06
UD07	Polyhedral	UE07
UD08	Round	UE08
UD09	Granular	UE09
UD10	Crumb	UE10

FABRIC
UF01 Earthy
UF02 Sandy
UF03 Smooth-faced Peds
UF04 Rough-faced Peds
CUTANS
UG01 None
UG02 Few (<10%)
UG03 Common (10-50%)
UG04 Many (> 50%)
PED POROSITY
UH01 Porous
UH02 Dense

CRACK SIZE
UI01 <2mm
UI02 2-5 mm
UI03 5-10mm
UI04 10-20mm
UI05 >20mm

STONES
AMOUNT OF STONES
VA01 None
VA02 <2 %
VA03 2-10 %
VA04 10-20 %
VA05 20-50 %
VA06 50-90 %
VA07 >90 %
SHAPE
VB01 Rounded
VB02 Sub-rounded
VB03 Sub-angular
VB04 Angular
STONE DISTRIBUTION
VC01 Reoriented
VC02 Undisturbed
VC03 Stratified
VC04 Dispersed

STONE SIZE
VD01 2-6 mm
VD02 6-20 mm
VD03 20-60 mm
VD04 60-200 mm
VD05 200-600 mm
VD06 >600 mm
STONE WEATHERING
VE01 Non-weathered
VE02 Weakly Weathered
VE03 Strongly Weathered
STONE LITHOLOGY
VF01 Not Identified
VF02 Quartz
VF03 Sedimentary
VF04 Metamorphic
VF05 Igneous

ROOTS
AMOUNT
WA01 None
WA02 Few
WA03 Common
WA04 Many
WA05 Abundant
ROOT DISTRIBUTION
WB01 In-ped
WB02 Ex-ped

PANS
XA01 No Pans
XA02 Carbonate
XA03 Silica
XA04 Humus & Iron Oxide
XA05 Sesquioxide
XA06 Clay
XA07 Cultivation
CHARACTER
XB01 Continuous
XB02 Discontinuous
XB03 Convoluted Pans
XB04 Weakly Cemented
XB05 Strongly Cemented

CONCRETIONS & INCLUSIONS
XF01 None
XF02 Carbonate
XF03 Gypsum
XF04 Iron
XF05 Manganese
XF06 Organic/Charcoal
XF07 Other
FORM
XG01 Diffuse
XG02 Soft Nodules
XG03 Hard Nodules
XG04 Crystals
AMOUNT
XH01 <2 %
XH02 2-20%
XH03 >20%
SIZE
XI01 <5 mm
XI02 5-15 mm
XI03 >15 mm

VENESS & ASSOCIATES PTY LIMITED
Environmental and Natural Resource Consultants 1324 Mt. Pleasant

Unit C SITE No. 022 cont.

cf. 290

Location: 0, ' "
Latitude ___,___'___" S
Longitude ___,___'___" E Photo

Uf 6.32

Record Type	Same as Site No	Total No. of Layers
0 0 0 4		

	Layer No	Horizon	Lower Average Depth (m)	Moist			V/C	Dry			Mottle Primary Colour	Tone	Contrast	%	Mottle Secondary Colour	Tone	Contrast	%	Moisture	pH	Ag NO3	Sample
1	1	A	.28	10	YR	3/2				/										8.0		1
5	2	B2	.64	7.5	YR	1/1	1			/										9.5		1
7	3	B3	1.40	10	YR	4/3				/	O	D	D	15						9.5		1
10	4	C				/				/										10.0		
	5					/				/												
	6					/				/												

CODES		
Colour	Red	R
	Orange	O
	Brown	B
	Yellow	Y
	Grey	G
	Grey	L
Tone	Pale	P
	Dark	D
Contrast	Faint	F
	Distinct	D
	Prominent	P
Moisture	Dry	D
	S Moist	S
	M Moist	M
	Wet	W
Ag No3	-ve test	N
	+ve test	P
Sample	not taken	O
	taken	.

SURFACE CONDITION

Crust –
Hard set –
Not hard set X

BOUNDARY

DISTINCTNESS

	1	2	3	4	5	6	
NA01							None
NA02	X	X					Sharp (<20 mm)
NA03							Clear (20-50 mm)
NA04							Gradual (50-100 mm)
NA05			X				Diffuse (>100 mm)

SHAPE

	1	2	3	4	5	6	
NB01							Even
NB02	X		X				Wavy
NB03		X					Irregular
NB04							Broken

TEXTURE

SAND FRACTION

	1	2	3	4	5	6	
FA01	X	X	X				Fine
FA02							Coarse

GRADE

	1	2	3	4	5	6	
PB01							Sand
PB02							Loamy Sand
PB03							Clayey Sand
PC01							Sandy Loam
PC02							Fine Sandy Loam
PC03							Light Sandy Clay Loam
PD01							Loam
PD02							Loam, Fine Sandy
PD03							Silt Loam
PD04							Sandy Clay Loam
PE01							Clay Loam
PE02							Silty Clay Loam
PE03							Fine Sandy Clay Loam
PF01							Sandy Clay
PF02							Silty Clay
PF03							Light Clay
PF04	X	X	X				Light Medium Clay
PG01							Medium Clay
PG02							Heavy Clay

PLASTICITY TYPE

	1	2	3	4	5	6	
QA01							Super Plastic
QA02	X	X	X				Normal Plastic
QA03							Subplastic
QA04							Strongly Subplastic

STICKINESS

	1	2	3	4	5	6	
QF01			X				Non-sticky
QF02	X	X	X				Slightly Sticky
QF03							Moderately Sticky
QF04							Very Sticky

WATER-TABLE

	1	2	3	4	5	6	
SA01							None
SA02							Seasonal
SA03							Permanent
SA04							Perched

CONSISTENCE

COHERENCE
Wet + dry - all

DISRUPTIVE TEST

	1	2	3	4	5	6	
TA01							Very Weak Force
TA02							Weak Force
TA03							Moderate Force
TA04			X				Strong Force
TA05	X	X					Very Strong Force

SHEARING TEST

	1	2	3	4	5	6	
TB01							Brittle
TB02			X				Crumbly
TB03	X	X					No Change
TB04			X				Labile
TB05							Plastic

STRUCTURE

GRADE

	1	2	3	4	5	6	
UA01							Apedal Single Grained
UA02							Apedal Massive
UA03							Weak Pedality
UA04			X				Moderate Pedality
UA05	X	X					Strong Pedality

PED SIZE

Primary	1	2	3	4	5	6		Secondary	1	2	3	4	5	6
UB01							<2 mm	UC01	X					
UB02							2-5 mm	UC02	X	X				
UB03							5-10 mm	UC03			X			
UB04							10-20 mm	UC04						
UB05	X						20-50 mm	UC05						
UB06	X						50-100 mm	UC06						
UB07		X		X			100-200 mm	UC07						
UB08			X				200-500 mm	UC08						
UB09							>500 mm	UC09						

PED SHAPE

Primary	1	2	3	4	5	6		Secondary	1	2	3	4	5	6
UD01							Platy	UE01						
UD02		X	X	X			Lenticular	UE02		X	X			
UD03							Prismatic	UE03						
UD04							Columnar	UE04						
UD05							Angular Blocky	UE05		X	X			
UD06	X						Sub-ang. Blocky	UE06	X					
UD07							Polyhedral	UE07						
UD08							Round	UE08						
UD09							Granular	UE09	X					
UD10							Crumb	UE10						

FABRIC

	1	2	3	4	5	6	
UF01							Earthy
UF02							Sandy
UF03		X	X				Smooth-faced Peds
UF04	X						Rough-faced Peds

CUTANS

	1	2	3	4	5	6	
UG01	X						None
UG02							Few (<10%)
UG03							Common (10-50%)
UG04		X	X				Many (> 50%)

PED POROSITY

	1	2	3	4	5	6	
UH01	X						Porous
UH02		X	X				Dense

CRACK SIZE

	1	2	3	4	5	6	
UI01	X			X			<2mm
UI02		X					2-5 mm
UI03		X	X				5-10mm
UI04							10-20mm
UI05							>20mm

STONES

AMOUNT OF STONES

	0	1	2	3	4	5	6	
VA01								None
VA02								<2 %
VA03		X	X	X				2-10 %
VA04								10-20 %
VA05								20-50 %
VA06								50-90 %
VA07					X			>90 %

SHAPE

	0	1	2	3	4	5	6	
VB01								Rounded
VB02					X			Sub-rounded
VB03		X	X	X	X			Sub-angular
VB04		X	X	X	X			Angular

STONE DISTRIBUTION

	0	1	2	3	4	5	6	
VC01		X	X	X				Fragmented
VC02					X			Undisturbed
VC03								Stratified
VC04								Dispersed

STONE SIZE

	0	1	2	3	4	5	6	
VD01		X	X	X	X			2-6 mm
VD02		X	X	X				6-20 mm
VD03		X						20-60 mm
VD04		X			X			60-200 mm
VD05								200-600 mm
VD06								>600 mm

STONE WEATHERING

	0	1	2	3	4	5	6	
VE01		X	X	X				Non-weathered
VE02					X			Weakly Weathered
VE03					X			Strongly Weathered

STONE LITHOLOGY

	0	1	2	3	4	5	6	
VF01								Not Identified
VF02								Quartz
VF03		X	X	X	X			Sedimentary
VF04								Metamorphic
VF05								Igneous

ironstone L1,2,3,4
sst L4

ROOTS

AMOUNT

	1	2	3	4	5	6	
WA01							None
WA02							Few
WA03							Common
WA04							Many
WA05							Abundant

Much bioturbation

ROOT DISTRIBUTION

	1	2	3	4	5	6	
WB01							In-ped
WB02							Ex-ped

PANS

	1	2	3	4	5	6	
XA01							No Pans
XA02							Carbonate
XA03							Silica
XA04							Humus & Iron Oxide
XA05							Sesquioxide
XA06							Clay
XA07							Cultivation

CHARACTER

	1	2	3	4	5	6	
XB01							Continuous
XB02							Discontinuous
XB03							Convoluted Pans
XB04							Weakly Cemented
XB05							Strongly Cemented

CONCRETIONS & INCLUSIONS

	1	2	3	4	5	6	
XF01							None
XF02		X	X	X			Carbonate
XF03							Gypsum
XF04							Iron
XF05							Manganese
XF06							Organic/Charcoal
XF07							Other

FORM

	1	2	3	4	5	6	
XG01							Diffuse
XG02		X	X	X			Soft Nodules
XG03							Hard Nodules
XG04							Crystals

AMOUNT

	1	2	3	4	5	6	
XH01		X					<2 %
XH02							2-20%
XH03			X	X			>20%

SIZE

	1	2	3	4	5	6	
XI01		X					<5 mm
XI02		X	X				5-15 mm
XI03				X			>15 mm

VENESS & ASSOCIATES PTY LIMITED
Environmental and Natural Resource Consultants 1324 Mt. Pleasant

Unit E SITE No. 041 cont.

cf 354

Location: 0, ' "
Latitude ___,___'___" S
Longitude ___,___'___" E

Dr 2.43

Record Type	Same as Site No	Total No. of Layers
0 0 0 4		

	Layer No	Horizon	Lower Average Depth (m)	Moist			V/C	Dry			Mottle Primary Colour	Tone	Contrast	%	Mottle Secondary Colour	Tone	Contrast	%	Moisture	pH	Ag NO3	Sample
1	1	A1	.18	5	YR	3/3				/									D	5.5		1
3	2	A2	.22	5	YR	3/3		5	YR	5/3									DS	6.0		1
4	3	B1	.40	5	YR	3/4				/									S	6.5		1
5	4	B2	1.05	5	YR	4/8				/									S	9.5		1
10	5	C				/				/												
	6					/				/												

CODES		
Colour	Red	R
	Orange	O
	Brown	B
	Yellow	Y
	Grey	G
	Grey	L
Tone	Pale	P
	Dark	D
Contrast	Faint	F
	Distinct	D
	Prominent	P
Moisture	Dry	D
	S Moist	S
	M Moist	M
	Wet	W
Ag No3	-ve test	N
	+ve test	P
Sample	not taken	O
	taken	.

SURFACE CONDITION

Midslope

Crust –
Hard set X ✓
Not hard set X

BOUNDARY

DISTINCTNESS

	1	2	3	4	5	6	
NA01							None
NA02							Sharp (<20 mm)
NA03	X	X	X				Clear (20-50 mm)
NA04							Gradual (50-100 mm)
NA05				X			Diffuse (>100 mm)

SHAPE

	1	2	3	4	5	6	
NB01							Even
NB02	X	X	X				Wavy
NB03							Irregular
NB04							Broken

TEXTURE

SAND FRACTION

	1	2	3	4	5	6	
FA01	X	X	X	X			Fine
FA02							Coarse

GRADE

	1	2	3	4	5	6	
PB01							Sand
PB02							Loamy Sand
PB03							Clayey Sand
PC01							Sandy Loam
PC02							Fine Sandy Loam
PC03							Light Sandy Clay Loam
PD01							Loam
PD02							Loam, Fine Sandy
PD03							Silt Loam
PD04							Sandy Clay Loam
PE01	X						Clay Loam
PE02		X					Silty Clay Loam
PE03							Fine Sandy Clay Loam
PF01							Sandy Clay
PF02							Silty Clay
PF03							Light Clay
PF04			X	X			Light Medium Clay
PG01							Medium Clay
PG02							Heavy Clay

PLASTICITY TYPE

	1	2	3	4	5	6	
QA01							Super Plastic
QA02	X	X	X	X			Normal Plastic
QA03							Subplastic
QA04							Strongly Subplastic

STICKINESS

	1	2	3	4	5	6	
QF01							Non-sticky
QF02	X		X	X			Slightly Sticky
QF03		X					Moderately Sticky
QF04							Very Sticky

WATER-TABLE

	1	2	3	4	5	6	
SA01							None
SA02							Seasonal
SA03							Permanent
SA04							Perched

CONSISTENCE

COHERENCE
Wet + dry - all

DISRUPTIVE TEST

	1	2	3	4	5	6	
TA01							Very Weak Force
TA02							Weak Force
TA03	X	X					Moderate Force
TA04	X		X	X			Strong Force
TA05			X	X			Very Strong Force

SHEARING TEST

	1	2	3	4	5	6	
TB01							Brittle
TB02	X	X					Crumbly
TB03	X		X	X			No Change
TB04							Labile
TB05							Plastic

STRUCTURE

GRADE

	1	2	3	4	5	6	
UA01							Apedal Single Grained
UA02							Apedal Massive
UA03							Weak Pedality
UA04	X	X	X	X			Moderate Pedality
UA05				X			Strong Pedality

PED SIZE

Primary	1	2	3	4	5	6		Secondary	1	2	3	4	5	6
UB01							<2 mm	UC01						
UB02							2-5 mm	UC02	X					
UB03							5-10 mm	UC03	X			X		
UB04		X					10-20 mm	UC04	X		X			
UB05							20-50 mm	UC05						
UB06	X						50-100 mm	UC06						
UB07			X				100-200 mm	UC07						
UB08				X			200-500 mm	UC08						
UB09							>500 mm	UC09						

PED SHAPE

Primary	1	2	3	4	5	6		Secondary	1	2	3	4	5	6
UD01							Platy	UE01						
UD02							Lenticular	UE02						
UD03							Prismatic	UE03						
UD04							Columnar	UE04						
UD05							Angular Blocky	UE05			X	X		
UD06	X	X	X	X			Sub-ang. Blocky	UE06	X					
UD07							Polyhedral	UE07						
UD08							Round	UE08						
UD09							Granular	UE09						
UD10							Crumb	UE10						

FABRIC

	1	2	3	4	5	6	
UF01		X					Earthy
UF02							Sandy
UF03			X	X			Smooth-faced Peds
UF04	X	X					Rough-faced Peds

CUTANS

	1	2	3	4	5	6	
UG01	X	X					None
UG02							Few (<10%)
UG03							Common (10-50%)
UG04			X	X			Many (> 50%)

PED POROSITY

	1	2	3	4	5	6	
UH01	X	X					Porous
UH02			X	X			Dense

CRACK SIZE

	1	2	3	4	5	6	
UI01	X			X			<2mm
UI02		X					2-5 mm
UI03			X				5-10mm
UI04							10-20mm
UI05							>20mm

STONES

AMOUNT OF STONES

	0	1	2	3	4	5	6	
VA01								None
VA02	X							<2 %
VA03		X		X	X			2-10 %
VA04			X					10-20 %
VA05								20-50 %
VA06								50-90 %
VA07						X		>90 %

SHAPE

	0	1	2	3	4	5	6	
VB01		X	X	X	X			Rounded
VB02		X	X	X	X			Sub-rounded
VB03		X	X	X	X			Sub-angular
VB04						X		Angular

STONE DISTRIBUTION

	0	1	2	3	4	5	6	
VC01		X	X	X	X			Fragmented
VC02						X		Undisturbed
VC03								Stratified
VC04	X							Dispersed

STONE SIZE

	0	1	2	3	4	5	6	
VD01		X	X	X	X	X		2-6 mm
VD02		X	X	X	X	X		6-20 mm
VD03						X		20-60 mm
VD04								60-200 mm
VD05								200-600 mm
VD06								>600 mm

STONE WEATHERING

	0	1	2	3	4	5	6	
VE01								Non-weathered
VE02								Weakly Weathered
VE03						X		Strongly Weathered

STONE LITHOLOGY

	0	1	2	3	4	5	6	
VF01								Not Identified
VF02								Quartz
VF03						X		Sedimentary
VF04								Metamorphic
VF05								Igneous

ROOTS

AMOUNT

	1	2	3	4	5	6	
WA01							None
WA02							Few
WA03							Common
WA04							Many
WA05							Abundant

ROOT DISTRIBUTION

	1	2	3	4	5	6	
WB01							In-ped
WB02							Ex-ped

PANS

	1	2	3	4	5	6	
XA01							No Pans
XA02							Carbonate
XA03							Silica
XA04							Humus & Iron Oxide
XA05							Sesquioxide
XA06							Clay
XA07							Cultivation

CHARACTER

	1	2	3	4	5	6	
XB01							Continuous
XB02							Discontinuous
XB03							Convoluted Pans
XB04							Weakly Cemented
XB05							Strongly Cemented

CONCRETIONS & INCLUSIONS

	1	2	3	4	5	6	
XF01							None
XF02				X			Carbonate below 65cm
XF03							Gypsum
XF04							Iron
XF05							Manganese
XF06							Organic/Charcoal
XF07							Other

FORM

	1	2	3	4	5	6	
XG01							Diffuse
XG02					X		Soft Nodules
XG03					X		Hard Nodules
XG04							Crystals

AMOUNT

	1	2	3	4	5	6	
XH01							<2 %
XH02					X		2-20%
XH03							>20%

SIZE

	1	2	3	4	5	6	
XI01					X		<5 mm
XI02					X		5-15 mm
XI03							>15 mm

VENESS & ASSOCIATES PTY LIMITED
Environmental and Natural Resource Consultants

Unit G SITE No. 053

cf. 392

Gc 2.22

Location: ° ' "
Latitude __ ° __ ' __ " S
Longitude __ ° __ ' __ " E

Record Type	Same as Site No	Total No. of Layers
0 0 0 4 1		

	Layer No	Horizon	Lower Average Depth (m)	Dominant Colour (Munsell Code) Moist	V/C	Dry	Mottle Primary Colour	Tone	Contrast	%	Mottle Secondary Colour	Tone	Contrast	%	Moisture	pH	Ag NO$_3$	Sample
1	1	A	.11	7.5 YR 3/3		/									D	5.5		1
4	2	B1	.58	7.5 YR 4/4		/									M	9.5		1
5	3	B2	1.31	5 YR 5/8		/									M	9.5		1
9	4	BC	1.60			/									M	9.5		
	5					/												
	6					/												

CODES
Colour: Red R, Orange O, Brown B, Yellow Y, Grey G, Gley
Abundance: Few F, Many M
Contrast: Faint F, Distinct D, Prominent P
Moisture: Dry D, S Moist S, M Moist M, Wet W
AgNO$_3$: -ve test N, +ve test P
Sample: Not taken O, Taken

SURFACE CONDITION
Crust ☐
Hard set ☐
Not hard set ☒ mulch

lowerslope

BOUNDARY DISTINCTNESS
NA01 None
NA02 Sharp (<20 mm)
NA03 Clear (20-50 mm)
NA04 Gradual (50-100 mm)
NA05 Diffuse (>100 mm)

SHAPE
NE01 Even
NE02 Wavy
NE03 Irregular
NE04 Broken

TEXTURE
SAND FRACTION
FA01 Fine
FA02 Coarse

GRADE
FG01 Sand
FG02 Loamy Sand
FG03 Clayey Sand
FC01 Sandy Loam
FC02 Fine Sandy Loam
FC03 Light Sandy Clay Loam
FD01 Loam
FD02 Loam, Fine Sandy
FD03 Silt Loam
FD04 Sandy Clay Loam
FE01 Clay Loam
FE02 Silty Clay Loam
FE03 Fine Sandy Clay Loam
FF01 Sandy Clay
FF02 Silty Clay
FF03 Light Clay
FF04 Light Medium Clay
FG01 Medium Clay
FG02 Heavy Clay

PLASTICITY TYPE
QA01 Super Plastic
QA02 Normal Plastic
QA03 Subplastic
QA04 Strongly Subplastic

STICKINESS
QF01 Non-sticky
QF02 Slightly Sticky
QF03 Moderately Sticky
QF04 Very Sticky

WATER-TABLE
SA01 None
SA02 Seasonal
SA03 Permanent
SA04 Perched

CONSISTENCE
DISRUPTIVE TEST
TA01 Very Weak Force
TA02 Weak Force
TA03 Moderate Force
TA04 Strong Force
TA05 Very Strong Force

COHERENCE
wet/dry-all

SHEARING TEST
TB01 Brittle
TB02 Crumbly
TB03 No Change
TB04 Labile
TB05 Plastic

STRUCTURE
GRADE
UA01 Apedal Single Grained
UA02 Apedal Massive
UA03 Weak Pedality
UA04 Moderate Pedality
UA05 Strong Pedality

PED SIZE
Primary UB01–UB09 / Secondary UC01–UC09
<2 mm
2-5 mm
5-10 mm
10-20 mm
20-50 mm
50-100 mm
100-200 mm
200-500 mm
>500 mm

PED SHAPE
Primary UD01–UD10 / Secondary UE01–UE10
Platy
Lenticular
Prismatic
Columnar
Angular Blocky
Sub-ang. Blocky
Polyhedral
Round
Granular
Crumb

FABRIC
UF01 Earthy
UF02 Sandy
UF03 Smooth-faced Peds
UF04 Rough-faced Peds

CUTANS
UG01 None
UG02 Few (<10%)
UG03 Common (10-50%)
UG04 Many (> 50%)

PED POROSITY
UH01 Porous
UH02 Dense

CRACK SIZE
UI01 <2mm
UI02 2-5 mm
UI03 5-10mm
UI04 10-20mm
UI05 >20mm

STONES
AMOUNT OF STONES
VA01 None
VA02 <2 %
VA03 2-10 %
VA04 10-20 %
VA05 20-50 %
VA06 50-90 %
VA07 >90 %

SHAPE
VB01 Rounded
VB02 Sub-rounded
VB03 Sub-angular
VB04 Angular

STONE DISTRIBUTION
VC01 Reoriented
VC02 Undisturbed
VC03 Stratified
VC04 Dispersed

STONE SIZE
VD01 2-6 mm
VD02 6-20 mm
VD03 20-60 mm
VD04 60-200 mm
VD05 200-600 mm
VD06 >600 mm

STONE WEATHERING
VE01 Non-weathered
VE02 Weakly Weathered
VE03 Strongly Weathered

STONE LITHOLOGY
VF01 Not Identified
VF02 Quartz
VF03 Sedimentary ironstone
VF04 Metamorphic
VF05 Igneous

ROOTS
AMOUNT
WA01 None
WA02 Few
WA03 Common
WA04 Many
WA05 Abundant

BIOTURBATION

ROOT DISTRIBUTION
WB01 In-ped
WB02 Ex-ped

PANS
XA01 No Pans
XA02 Carbonate
XA03 Silica
XA04 Humus & Iron Oxide
XA05 Sesquioxide
XA06 Clay
XA07 Cultivation

CHARACTER
XB01 Continuous
XB02 Discontinuous
XB03 Convoluted Pans
XB04 Weakly Cemented
XB05 Strongly Cemented

CONCRETIONS & INCLUSIONS
XF01 None
XF02 Carbonate ↓58
XF03 Gypsum
XF04 Iron
XF05 Manganese
XF06 Organic/Charcoal
XF07 Other

FORM
XG01 Diffuse
XG02 Soft Nodules
XG03 Hard Nodules
XG04 Crystals

AMOUNT
XH01 <2 %
XH02 2-20%
XH03 >20%

SIZE
XI01 <5 mm
XI02 5-15 mm
XI03 >15 mm

VENESS & ASSOCIATES PTY LIMITED
Environmental and Natural Resource Consultants

1324 Mt. Pleasant

Unit C SITE No. 104 cont.

cf 620

Gc 2.22

Location: ° ' "
Latitude __ ° __ ' __ " S
Longitude __ ° __ ' __ " E

Record Type	Same as Site No	Total No. of Layers
0 0 0 4		

	Layer No	Horizon	Lower Average Depth (m)	Dominant Colour (Munsell Code) Moist	V/C	Dry	Mottle Primary Colour	Tone	Contrast	%	Mottle Secondary Colour	Tone	Contrast	%	Moisture	pH	Ag NO$_3$	Sample
1	1	A	.09	5 YR 4/4		/									M	6.5		
5	2	B2	.52	5 YR 5/8		/									S	9.0		
7	3	B3	.74	7.5 YR 6/8		/									SM	9.5		
9	4	BC	.98			/									M	9.5		
10	5	C	+1.30			/									SM	9.5		
	6					/												

CODES
Colour: Red R, Orange O, Brown B, Yellow Y, Grey G, Gley
Abundance: Few F, Many M
Contrast: Faint F, Distinct D, Prominent P
Moisture: Dry D, S Moist S, M Moist M, Wet W
AgNO$_3$: -ve test N, +ve test P
Sample: Not taken O, Taken

SURFACE CONDITION
Crust ☐
Hard set ☐
Not hard set ☒

Ridgeline + upperslope section

BOUNDARY DISTINCTNESS
NA01 None
NA02 Sharp (<20 mm)
NA03 Clear (20-50 mm)
NA04 Gradual (50-100 mm)
NA05 Diffuse (>100 mm)

SHAPE
NE01 Even
NE02 Wavy
NE03 Irregular
NE04 Broken

TEXTURE
SAND FRACTION
FA01 Fine
FA02 Coarse

GRADE
FG01 Sand
FG02 Loamy Sand
FG03 Clayey Sand
FC01 Sandy Loam
FC02 Fine Sandy Loam
FC03 Light Sandy Clay Loam
FD01 Loam
FD02 Loam, Fine Sandy
FD03 Silt Loam
FD04 Sandy Clay Loam
FE01 Clay Loam
FE02 Silty Clay Loam
FE03 Fine Sandy Clay Loam
FF01 Sandy Clay
FF02 Silty Clay
FF03 Light Clay
FF04 Light Medium Clay
FG01 Medium Clay
FG02 Heavy Clay

PLASTICITY TYPE
QA01 Super Plastic
QA02 Normal Plastic
QA03 Subplastic
QA04 Strongly Subplastic

STICKINESS
QF01 Non-sticky
QF02 Slightly Sticky
QF03 Moderately Sticky
QF04 Very Sticky

WATER-TABLE
SA01 None
SA02 Seasonal
SA03 Permanent
SA04 Perched

CONSISTENCE
DISRUPTIVE TEST
TA01 Very Weak Force
TA02 Weak Force
TA03 Moderate Force
TA04 Strong Force
TA05 Very Strong Force

COHERENCE
wet-dry-all

SHEARING TEST
TB01 Brittle
TB02 Crumbly
TB03 No Change
TB04 Labile
TB05 Plastic

STRUCTURE
GRADE
UA01 Apedal Single Grained
UA02 Apedal Massive
UA03 Weak Pedality
UA04 Moderate Pedality
UA05 Strong Pedality

PED SIZE
Primary UB01–UB09 / Secondary UC01–UC09
<2 mm
2-5 mm
5-10 mm
10-20 mm
20-50 mm
50-100 mm
100-200 mm
200-500 mm
>500 mm

PED SHAPE
Primary UD01–UD10 / Secondary UE01–UE10
Platy
Lenticular
Prismatic
Columnar
Angular Blocky
Sub-ang. Blocky
Polyhedral
Round
Granular
Crumb

FABRIC
UF01 Earthy
UF02 Sandy
UF03 Smooth-faced Peds
UF04 Rough-faced Peds

CUTANS
UG01 None
UG02 Few (<10%)
UG03 Common (10-50%)
UG04 Many (> 50%)

PED POROSITY
UH01 Porous
UH02 Dense

CRACK SIZE
UI01 <2mm
UI02 2-5 mm
UI03 5-10mm
UI04 10-20mm
UI05 >20mm

STONES
AMOUNT OF STONES
VA01 None
VA02 <2 %
VA03 2-10 %
VA04 10-20 %
VA05 20-50 %
VA06 50-90 %
VA07 >90 %

SHAPE
VB01 Rounded
VB02 Sub-rounded
VB03 Sub-angular
VB04 Angular

STONE DISTRIBUTION
VC01 Reoriented
VC02 Undisturbed
VC03 Stratified
VC04 Dispersed

STONE SIZE
VD01 2-6 mm
VD02 6-20 mm
VD03 20-60 mm
VD04 60-200 mm
VD05 200-600 mm
VD06 >600 mm

STONE WEATHERING
VE01 Non-weathered
VE02 Weakly Weathered
VE03 Strongly Weathered

STONE LITHOLOGY
VF01 Not Identified
VF02 Quartz
VF03 Sedimentary
VF04 Metamorphic
VF05 Igneous

ROOTS
AMOUNT
WA01 None
WA02 Few
WA03 Common
WA04 Many
WA05 Abundant

ROOT DISTRIBUTION
WB01 In-ped
WB02 Ex-ped

PANS
XA01 No Pans
XA02 Carbonate
XA03 Silica
XA04 Humus & Iron Oxide
XA05 Sesquioxide
XA06 Clay
XA07 Cultivation

CHARACTER
XB01 Continuous
XB02 Discontinuous
XB03 Convoluted Pans
XB04 Weakly Cemented
XB05 Strongly Cemented

CONCRETIONS & INCLUSIONS
XF01 None
XF02 Carbonate
XF03 Gypsum
XF04 Iron
XF05 Manganese
XF06 Organic/Charcoal
XF07 Other

FORM
XG01 Diffuse
XG02 Soft Nodules
XG03 Hard Nodules
XG04 Crystals

AMOUNT
XH01 <2 %
XH02 2-20%
XH03 >20%

SIZE
XI01 <5 mm
XI02 5-15 mm
XI03 >15 mm

VENESS & ASSOCIATES PTY LIMITED
Environmental and Natural Resource Consultants 1324 Mt. Pleasant

Unit C SITE No. 106 cont.

cf. 635

Location: ° ' "
Latitude __ ° __ ' __ " S
Longitude __ ° __ ' __ " E

Gc 2-21

Record Type	Same as Site No	Total No. of Layers
0 0 0 4		

	Layer Status			Dominant Colour (Munsell Code)							Mottle Characteristics								Tests			
	Layer No	Horizon	Lower Average Depth (m)	Moist			V/C	Dry			Primary Colour	Tone	Contrast	%	Secondary Colour	Tone	Contrast	%	Moisture	pH	Ag NO3	Sample
1	1	A	.18	5	YR	2/3				/									S	6.0		1
4	2	B1	.38	5	YR	4/4				/									S	9.0		1
5	3	B2	1.17	5	YR	3/6				/									M	9.5		1
9	4	BC	+1.30	5	YR	4/6				/									M-S	9.5		
	5					/				/												
	6					/				/												

CODES		
Colour	Red	R
	Orange	O
	Brown	B
	Yellow	Y
	Grey	G
	Gley	L
Tone	Pale	P
	Dark	D
Contrast	Faint	F
	Distinct	D
	Prominent	P
Moisture	Dry	D
	S Moist	S
	M Moist	M
	Wet	W
Ag NO3	-ve test	N
	+ve test	P
Sample	Not taken	O
	Taken	

SURFACE CONDITION

Crust –
Hard set –
Not hard set ☒

Upperslope

BOUNDARY
DISTINCTNESS (1 2 3 4 5 6)
- NA01 None
- NA02 Sharp (<20 mm)
- NA03 Clear (20-50 mm)
- NA04 Gradual (50-100 mm)
- NA05 Diffuse (>100 mm)

SHAPE
- NB01 Even
- NB02 Wavy
- NB03 Irregular
- NB04 Broken

TEXTURE
SAND FRACTION
- FA01 Fine
- FA02 Coarse

GRADE
- PG01 Sand
- PG02 Loamy Sand
- PG03 Clayey Sand
- PC01 Sandy Loam
- PC02 Fine Sandy Loam
- PC03 Light Sandy Clay Loam
- PD01 Loam
- PD02 Loam, Fine Sandy
- PD03 Silt Loam
- PD04 Sandy Clay Loam
- PE01 Clay Loam
- PE02 Silty Clay Loam
- PE03 Fine Sandy Clay Loam
- PF01 Sandy Clay
- PF02 Silty Clay
- PF03 Light Clay
- PF04 Light Medium Clay
- PG01 Medium Clay
- PG02 Heavy Clay

PLASTICITY TYPE
- QA01 Super Plastic
- QA02 Normal Plastic
- QA03 Subplastic
- QA04 Strongly Subplastic

STICKINESS
- QF01 Non-sticky
- QF02 Slightly Sticky
- QF03 Moderately Sticky
- QF04 Very Sticky

WATER-TABLE
- SA01 None
- SA02 Seasonal
- SA03 Permanent
- SA04 Perched

CONSISTENCE
DISRUPTIVE TEST

COHERENCE wet-dry all

- TA01 Very Weak Force
- TA02 Weak Force
- TA03 Moderate Force
- TA04 Strong Force
- TA05 Very Strong Force

SHEARING TEST
- TB01 Brittle
- TB02 Crumbly
- TB03 No Change
- TB04 Labile
- TB05 Plastic

STRUCTURE
GRADE
- UA01 Apedal Single Grained
- UA02 Apedal Massive
- UA03 Weak Pedality
- UA04 Moderate Pedality
- UA05 Strong Pedality

PED SIZE

Primary		Secondary
UB01	<2 mm	UC01
UB02	2-5 mm	UC02
UB03	5-10 mm	UC03
UB04	10-20 mm	UC04
UB05	20-50 mm	UC05
UB06	50-100 mm	UC06
UB07	100-200 mm	UC07
UB08	200-500 mm	UC08
UB09	>500 mm	UC09

PED SHAPE

Primary		Secondary
UD01	Platy	UE01
UD02	Lenticular	UE02
UD03	Prismatic	UE03
UD04	Columnar	UE04
UD05	Angular Blocky	UE05
UD06	Sub-ang Blocky	UE06
UD07	Polyhedral	UE07
UD08	Round	UE08
UD09	Granular	UE09
UD10	Crumb	UE10

FABRIC
- UF01 Earthy
- UF02 Sandy
- UF03 Smooth-faced Peds
- UF04 Rough-faced Peds

CUTANS
- UG01 None
- UG02 Few (<10%)
- UG03 Common (10-50%)
- UG04 Many (> 50%)

PED POROSITY
- UH01 Porous
- UH02 Dense

CRACK SIZE
- UI01 <2mm
- UI02 2-5 mm
- UI03 5-10mm
- UI04 10-20mm
- UI05 >20mm

STONES
AMOUNT OF STONES
- VA01 None
- VA02 <2 %
- VA03 2-10 %
- VA04 10-20 %
- VA05 20-40 %
- VA06 50-90 %
- VA07 >90 %

SHAPE
- VB01 Rounded
- VB02 Sub-rounded
- VB03 Sub-angular
- VB04 Angular

STONE DISTRIBUTION
- VC01 Reoriented
- VC02 Undisturbed
- VC03 Stratified
- VC04 Dispersed

STONE SIZE
- VD01 2-6 mm
- VD02 6-20 mm
- VD03 20-60 mm
- VD04 60-200 mm
- VD05 200-600 mm
- VD06 >600 mm

STONE WEATHERING
- VE01 Non-weathered
- VE02 Weakly Weathered
- VE03 Strongly Weathered

STONE LITHOLOGY
- VF01 Not Identified
- VF02 Quartz
- VF03 Sedimentary
- VF04 Metamorphic
- VF05 Igneous

ROOTS
AMOUNT
- WA01 None
- WA02 Few
- WA03 Common
- WA04 Many
- WA05 Abundant

ROOT DISTRIBUTION
- WB01 In-ped
- WB02 Ex-ped

PANS
- XA01 No Pans
- XA02 Carbonate
- XA03 Silica
- XA04 Humus & Iron Oxide
- XA05 Sesquioxide
- XA06 Clay
- XA07 Cultivation

CHARACTER
- XB01 Continuous
- XB02 Discontinuous
- XB03 Convoluted Pans
- XB04 Weakly Cemented
- XB05 Strongly Cemented

CONCRETIONS & INCLUSIONS
- XF01 None
- XF02 Carbonate 53↓
- XF03 Gypsum
- XF04 Iron
- XF05 Manganese
- XF06 Organic/Charcoal
- XF07 Other

FORM
- XG01 Diffuse
- XG02 Soft Nodules – CaCO3
- XG03 Hard Nodules Mn
- XG04 Crystals

AMOUNT
- XH01 <2 %
- XH02 2-20% CaCO3
- XH03 >20% Mn

SIZE
- XI01 <5 mm Mn
- XI02 5-15 mm } CaCO3
- XI03 >15 mm

VENESS & ASSOCIATES PTY LIMITED
Environmental and Natural Resource Consultants 1324 Mt. Pleasant

Unit C SITE No. 115 cont.

cf 671

Location: ° ' "
Latitude __ ° __ ' __ " S
Longitude __ ° __ ' __ " E

Uf 6.31

Record Type	Same as Site No	Total No. of Layers
0 0 0 4		

	Layer Status			Dominant Colour (Munsell Code)							Mottle Characteristics								Tests			
	Layer No	Horizon	Lower Average Depth (m)	Moist			V/C	Dry			Primary Colour	Tone	Contrast	%	Secondary Colour	Tone	Contrast	%	Moisture	pH	Ag NO3	Sample
1	1	A	.05	7.5	YR	3/3				/									D	6.6		1
4	2	B1	.11	7.5	YR	3/4				/									D	6.5		1
5	3	B2	.34	7.5	YR	4/4				/									S	7.5		1
7	4	B3	.61	7.5	YR	5/4				/									S-M	9.0		1
9	5	BC	.99	10	YR	5/4				/									S-M	9.5		
10	6	C				/				/												

CODES		
Colour	Red	R
	Orange	O
	Brown	B
	Yellow	Y
	Grey	G
	Gley	L
Tone	Pale	P
	Dark	D
Contrast	Faint	F
	Distinct	D
	Prominent	P
Moisture	Dry	D
	S Moist	S
	M Moist	M
	Wet	W
Ag NO3	-ve test	N
	+ve test	P
Sample	Not taken	O
	Taken	

SURFACE CONDITION

Crust –
Hard set ☒ degraded
Not hard set –

Upperslope

BOUNDARY
DISTINCTNESS (1 2 3 4 5 6)
- NA01 None
- NA02 Sharp (<20 mm)
- NA03 Clear (20-50 mm)
- NA04 Gradual (50-100 mm)
- NA05 Diffuse (>100 mm)

SHAPE
- NB01 Even
- NB02 Wavy
- NB03 Irregular
- NB04 Broken

TEXTURE
SAND FRACTION
- FA01 Fine
- FA02 Coarse

GRADE
- PG01 Sand
- PG02 Loamy Sand
- PG03 Clayey Sand
- PC01 Sandy Loam
- PC02 Fine Sandy Loam
- PC03 Light Sandy Clay Loam
- PD01 Loam
- PD02 Loam, Fine Sandy
- PD03 Silt Loam
- PD04 Sandy Clay Loam
- PE01 Clay Loam
- PE02 Silty Clay Loam
- PE03 Fine Sandy Clay Loam
- PF01 Sandy Clay
- PF02 Silty Clay
- PF03 Light Clay
- PF04 Light Medium Clay
- PG01 Medium Clay
- PG02 Heavy Clay

PLASTICITY TYPE
- QA01 Super Plastic
- QA02 Normal Plastic
- QA03 Subplastic
- QA04 Strongly Subplastic

STICKINESS
- QF01 Non-sticky
- QF02 Slightly Sticky
- QF03 Moderately Sticky
- QF04 Very Sticky

WATER-TABLE
- SA01 None
- SA02 Seasonal
- SA03 Permanent
- SA04 Perched

CONSISTENCE
DISRUPTIVE TEST

COHERENCE Wet + dry - all

- TA01 Very Weak Force
- TA02 Weak Force
- TA03 Moderate Force
- TA04 Strong Force
- TA05 Very Strong Force

SHEARING TEST
- TB01 Brittle
- TB02 Crumbly
- TB03 No Change
- TB04 Labile
- TB05 Plastic

STRUCTURE
GRADE
- UA01 Apedal Single Grained
- UA02 Apedal Massive
- UA03 Weak Pedality
- UA04 Moderate Pedality
- UA05 Strong Pedality

PED SIZE

Primary		Secondary
UB01	<2 mm	UC01
UB02	2-5 mm	UC02
UB03	5-10 mm	UC03
UB04	10-20 mm	UC04
UB05	20-50 mm	UC05
UB06	50-100 mm	UC06
UB07	100-200 mm	UC07
UB08	200-500 mm	UC08
UB09	>500 mm	UC09

PED SHAPE

Primary		Secondary
UD01	Platy	UE01
UD02	Lenticular	UE02
UD03	Prismatic	UE03
UD04	Columnar	UE04
UD05	Angular Blocky	UE05
UD06	Sub-ang Blocky	UE06
UD07	Polyhedral	UE07
UD08	Round	UE08
UD09	Granular	UE09
UD10	Crumb	UE10

FABRIC
- UF01 Earthy
- UF02 Sandy
- UF03 Smooth-faced Peds
- UF04 Rough-faced Peds

CUTANS
- UG01 None
- UG02 Few (<10%)
- UG03 Common (10-50%)
- UG04 Many (> 50%)

PED POROSITY
- UH01 Porous
- UH02 Dense

CRACK SIZE
- UI01 <2mm
- UI02 2-5 mm
- UI03 5-10mm
- UI04 10-20mm
- UI05 >20mm

STONES
AMOUNT OF STONES
- VA01 None
- VA02 <2 %
- VA03 2-10 %
- VA04 10-20 %
- VA05 20-40 %
- VA06 50-90 %
- VA07 >90 %

SHAPE
- VB01 Rounded
- VB02 Sub-rounded
- VB03 Sub-angular
- VB04 Angular

STONE DISTRIBUTION
- VC01 Reoriented
- VC02 Undisturbed
- VC03 Stratified
- VC04 Dispersed

STONE SIZE
- VD01 2-6 mm
- VD02 6-20 mm
- VD03 20-60 mm
- VD04 60-200 mm
- VD05 200-600 mm
- VD06 >600 mm

STONE WEATHERING
- VE01 Non-weathered
- VE02 Weakly Weathered
- VE03 Strongly Weathered

STONE LITHOLOGY
- VF01 Not Identified
- VF02 Quartz
- VF03 Sedimentary petrified wood
- VF04 Metamorphic
- VF05 Igneous

ROOTS
AMOUNT
- WA01 None
- WA02 Few
- WA03 Common
- WA04 Many
- WA05 Abundant

ROOT DISTRIBUTION
- WB01 In-ped
- WB02 Ex-ped

PANS
- XA01 No Pans
- XA02 Carbonate
- XA03 Silica
- XA04 Humus & Iron Oxide
- XA05 Sesquioxide
- XA06 Clay
- XA07 Cultivation

CHARACTER
- XB01 Continuous
- XB02 Discontinuous
- XB03 Convoluted Pans
- XB04 Weakly Cemented
- XB05 Strongly Cemented

CONCRETIONS & INCLUSIONS
- XF01 None
- XF02 Carbonate
- XF03 Gypsum
- XF04 Iron
- XF05 Manganese
- XF06 Organic/Charcoal
- XF07 Other

FORM
- XG01 Diffuse
- XG02 Soft Nodules
- XG03 Hard Nodules
- XG04 Crystals

AMOUNT
- XH01 <2 %
- XH02 2-20%
- XH03 >20%

SIZE
- XI01 <5 mm
- XI02 5-15 mm
- XI03 >15 mm

VENESS & ASSOCIATES PTY LIMITED
Environmental and Natural Resource Consultants

1324 Mt. Pleasant

Unit C SITE No. 120 cont.

cf 109

Gc 2·21

Location: ° ' "
Latitude __ ° __ ' __ " S
Longitude __ ° __ ' __ " E

Photo

Record Type	Same as Site No	Total No. of Layers
0004		

	Layer No	Horizon	Lower Average Depth (m)	Moist	V/C	Dry	Mottle Primary Colour	Tone	Contrast	%	Mottle Secondary Colour	Tone	Contrast	%	Moisture	pH	AgNO3	Sample
1	1	A	.10	5 YR 3/3		/									D	6.0		
4	2	B1	.17	5 YR 4/4		/									D	6.5		
5	3	B2	.41	5 YR 4/6		/									S	8.5		
7	4	B3	.50	10 YR 5/6		/									S	9.5		
9	5	BC	.80	10 YR 5/6 + 4/6 + 5/4 r 8/4 (CaCO3)											S	9.5		
10	6	C	+1.00			/												

CODES		
Colour	Red	R
	Orange	O
	Brown	B
	Yellow	Y
	Grey	G
	Gley	L
Tone	Pale	P
	Dark	D
Contrast	Faint	F
	Distinct	D
	Prominent	P
Moisture	Dry	D
	S Moist	S
	M Moist	M
	Wet	W
AgNO3	-ve test	N
	+ve test	P
Sample	Not taken	O
	Taken	

Midslope - steepish North-facing, drier

SURFACE CONDITION

Crust —
Hard set —
Not hard set —

BOUNDARY

DISTINCTNESS

	1	2	3	4	5	6	
NA01							None
NA02							Sharp (<20 mm)
NA03	☒	☒					Clear (20-50 mm)
NA04			☒	☒			Gradual (50-100 mm)
NA05					☒		Diffuse (>100 mm)

SHAPE

	1	2	3	4	5	6	
NB01							Even
NB02	☒	☒		☒			Wavy
NB03			☒		☒		Irregular
NB04							Broken

TEXTURE

SAND FRACTION

	1	2	3	4	5	6	
FA01	☒						Fine
FA02							Coarse

GRADE

	1	2	3	4	5	6	
PB01							Sand
PB02							Loamy Sand
PB03							Clayey Sand
PC01							Sandy Loam
PC02							Fine Sandy Loam
PC03							Light Sandy Clay Loam
PD01							Loam
PD02							Loam, Fine Sandy
PD03							Silt Loam
PD04							Sandy Clay Loam
PE01							Clay Loam
PE02	☒						Silty Clay Loam
PE03	☒						Fine Sandy Clay Loam
PF01							Sandy Clay
PF02		☒	☒	☒			Silty Clay
PF03							Light Clay
PF04							Light Medium Clay
PG01							Medium Clay
PG02							Heavy Clay

PLASTICITY TYPE

	1	2	3	4	5	6	
QA01							Super Plastic
QA02	☒	☒	☒	☒			Normal Plastic
QA03							Subplastic
QA04							Strongly Subplastic

STICKINESS

	1	2	3	4	5	6	
QF01							Non-sticky
QF02	☒	☒	☒	☒			Slightly Sticky
QF03	☒			☒			Moderately Sticky
QF04							Very Sticky

WATER-TABLE

	1	2	3	4	5	6	
SA01							None
SA02							Seasonal
SA03							Permanent
SA04							Perched

CONSISTENCE

Coherent wet + dry all

DISRUPTIVE TEST

	1	2	3	4	5	6	
TA01							Very Weak Force
TA02							Weak Force
TA03	☒						Moderate Force
TA04					☒		Strong Force
TA05		☒	☒	☒			Very Strong Force

SHEARING TEST

	1	2	3	4	5	6	
TB01							Brittle
TB02	☒				☒		Crumbly
TB03		☒	☒	☒			No Change
TB04							Labile
TB05							Plastic

STRUCTURE

GRADE

	1	2	3	4	5	6	
UA01							Apedal Single Grained
UA02							Apedal Massive
UA03							Weak Pedality
UA04	☒						Moderate Pedality
UA05		☒	☒	☒	☒		Strong Pedality

PED SIZE

Primary	1	2	3	4	5	6		Secondary	1	2	3	4	5	6
UB01							<2 mm	UC01						
UB02							2-5 mm	UC02			☒	☒	☒	
UB03							5-10 mm	UC03		☒				
UB04							10-20 mm	UC04	☒					
UB05							20-50 mm	UC05						
UB06	☒				☒		50-100 mm	UC06						
UB07		☒	☒	☒			100-200 mm	UC07						
UB08							200-500 mm	UC08						
UB09							>500 mm	UC09						

PED SHAPE

Primary	1	2	3	4	5	6		Secondary	1	2	3	4	5	6
UD01							Platy	UE01						
UD02							Lenticular	UE02						
UD03							Prismatic	UE03						
UD04							Columnar	UE04						
UD05							Angular Blocky	UE05				☒	☒	
UD06	☒	☒	☒	☒	☒		Sub-ang. Blocky	UE06	☒				☒	
UD07							Polyhedral	UE07						
UD08							Round	UE08						
UD09							Granular	UE09						
UD10							Crumb	UE10						

FABRIC

	1	2	3	4	5	6	
UF01							Earthy
UF02							Sandy
UF03		☒	☒	☒			Smooth-faced Peds
UF04	☒				☒		Rough-faced Peds

CUTANS

	1	2	3	4	5	6	
UG01	☒						None
UG02					☒		Few (<10%)
UG03		☒	☒	☒			Common (10-50%)
UG04							Many (> 50%)

PED POROSITY

	1	2	3	4	5	6	
UH01	☒				☒		Porous
UH02		☒	☒	☒			Dense

CRACK SIZE

	1	2	3	4	5	6	
UI01	☒	☒	☒	☒	☒		<2mm
UI02		☒	☒				2-5 mm
UI03							5-10mm
UI04							10-20mm
UI05							>20mm

STONES

AMOUNT OF STONES

	0	1	2	3	4	5	6	
VA01	☒	☒	☒					None
VA02				☒				<2 %
VA03					☒			2-10 %
VA04								10-20 %
VA05								20-50 %
VA06						☒		50-90 %
VA07							☒	>90 %

SHAPE

	0	1	2	3	4	5	6	
VB01								Rounded
VB02								Sub-rounded
VB03					☒	☒		Sub-angular
VB04					☒	☒	☒	Angular

STONE DISTRIBUTION

	0	1	2	3	4	5	6	
VC01					☒			Reoriented
VC02						☒	☒	Undisturbed
VC03								Stratified
VC04								Dispersed

STONE SIZE

	0	1	2	3	4	5	6	
VD01					☒	☒		2-6 mm
VD02					☒	☒		6-20 mm
VD03					☒	☒		20-60 mm
VD04								60-200 mm
VD05								200-600 mm
VD06								>600 mm

STONE WEATHERING

	0	1	2	3	4	5	6	
VE01								Non-weathered
VE02								Weakly Weathered
VE03					☒	☒	☒	Strongly Weathered

STONE LITHOLOGY

	0	1	2	3	4	5	6	
VF01								Not Identified
VF02								Quartz
VF03					☒	☒	☒	Sedimentary
VF04								Metamorphic
VF05								Igneous

ROOTS

AMOUNT

	1	2	3	4	5	6	
WA01							None
WA02				☒	☒		Few
WA03		☒	☒				Common
WA04	☒						Many
WA05							Abundant

ROOT DISTRIBUTION

	1	2	3	4	5	6	
WB01	☒						In-ped
WB02		☒	☒	☒			Ex-ped

PANS

	1	2	3	4	5	6	
XA01							No Pans
XA02							Carbonate
XA03							Silica
XA04							Humus & Iron Oxide
XA05							Sesquioxide
XA06							Clay
XA07							Cultivation

CHARACTER

	1	2	3	4	5	6	
XB01							Continuous
XB02							Discontinuous
XB03							Convoluted Pans
XB04							Weakly Cemented
XB05							Strongly Cemented

CONCRETIONS & INCLUSIONS

	1	2	3	4	5	6	
XF01	☒	☒	☒				None
XF02				☒	☒		Carbonate ↓50
XF03							Gypsum
XF04							Iron
XF05							Manganese
XF06							Organic/Charcoal
XF07							Other

FORM

	1	2	3	4	5	6	
XG01							Diffuse
XG02							Soft Nodules
XG03							Hard Nodules
XG04							Crystals

AMOUNT

	1	2	3	4	5	6	
XH01							<2 %
XH02							2-20 %
XH03							>20 %

SIZE

	1	2	3	4	5	6	
XI01							<5 mm
XI02							5-15 mm
XI03							>15 mm

VENESS & ASSOCIATES PTY LIMITED
Environmental and Natural Resource Consultants

1324 Mt. Pleasant

Unit E **SITE No.** 099 **cont.**

cf 591

Gc 1·22

Location: ° ' "
Latitude __ ° __ ' __ " S
Longitude __ ° __ ' __ " E

Record Type	Same as Site No	Total No. of Layers
0 0 0 4		

	Layer No	Horizon	Lower Average Depth (m)	Moist	V/C	Dry	Primary Colour	Primary Tone	Primary Contrast	Primary %	Secondary Colour	Secondary Tone	Secondary Contrast	Secondary %	Moisture	pH	Ag NO3	Sample
1	1	A	.10	5 YR 2/4												6.5		1
3	2	B1	.15	5 YR 3/4												8.5		1
4	3	B2	.48	5 YR 4/6											SM	9.5		1
5	4	B3	.71	5 YR 4/4												9.5		1
6	5	BC	+1.30	[illegible] with much carbonate												9.5		
	6																	

CODES
- Colour: Red R; Orange O; Brown B; Yellow Y; Grey G; Gley L
- Tone: Pale P; Dark D
- Contrast: Faint F; Distinct D; Prominent P
- Moisture: Dry D; S Moist S; M Moist M; Wet W
- Ag NO3: -ve test N; +ve test P
- Sample: Not taken O; taken

SURFACE CONDITION
Crust –
Hard set –
Not hard set ☒ Mulch

BOUNDARY
DISTINCTNESS 1 2 3 4 5 6
NA01 None
NA02 Sharp (<20 mm)
NA03 Clear (20-50 mm)
NA04 Gradual (50-100 mm)
NA05 Diffuse (>100 mm)
SHAPE
NB01 Even
NB02 Wavy
NB03 Irregular
NB04 Broken

TEXTURE
SAND FRACTION
FA01 Fine
FA02 Coarse
GRADE
PB01 Sand
PB02 Loamy Sand
PB03 Clayey Sand
PC01 Sandy Loam
PC02 Fine Sandy Loam
PC03 Light Sandy Clay Loam
PD01 Loam
PD02 Loam, Fine Sandy
PD03 Silt Loam
PD04 Sandy Clay Loam
PE01 Clay Loam
PE02 Silty Clay Loam
PE03 Fine Sandy Clay Loam
PF01 Sandy Clay
PF02 Silty Clay
PF03 Light Clay
PF04 Light Medium Clay
PG01 Medium Clay
PG02 Heavy Clay

PLASTICITY TYPE
QA01 Super Plastic
QA02 Normal Plastic
QA03 Subplastic
QA04 Strongly Subplastic

STICKINESS
QF01 Non-sticky
QF02 Slightly Sticky
QF03 Moderately Sticky
QF04 Very Sticky

WATER-TABLE
SA01 None
SA02 Seasonal
SA03 Permanent
SA04 Perched

CONSISTENCE
DISRUPTIVE TEST
COHERENCE wet [illegible] well
TA01 Very Weak Force
TA02 Weak Force
TA03 Moderate Force
TA04 Strong Force
TA05 Very Strong Force
SHEARING TEST
TB01 Brittle
TB02 Crumbly
TB03 No Change
TB04 Labile
TB05 Plastic

STRUCTURE
GRADE 1 2 3 4 5 6
UA01 Apedal Single Grained
UA02 Apedal Massive
UA03 Weak Pedality
UA04 Moderate Pedality
UA05 Strong Pedality
PED SIZE (Primary UB01–UB09, Secondary UC01–UC09)
<2 mm
2-5 mm
5-10 mm
10-20 mm
20-50 mm
50-100 mm
100-200 mm
200-500 mm
>500 mm
PED SHAPE (Primary UD01–UD10, Secondary UE01–UE10)
Platy
Lenticular
Prismatic
Columnar
Angular Blocky
Sub-ang Blocky
Polyhedral
Round
Granular
Crumb
FABRIC
UF01 Earthy
UF02 Sandy
UF03 Smooth-faced Peds
UF04 Rough-faced Peds
CUTANS
UG01 None
UG02 Few (<10%)
UG03 Common (10-50%)
UG04 Many (> 50%)
PED POROSITY
UH01 Porous
UH02 Dense
CRACK SIZE
UI01 <2mm
UI02 2-5 mm
UI03 5-10mm
UI04 10-20mm
UI05 >20mm

STONES
AMOUNT OF STONES 0 1 2 3 4 5 6
VA01 None
VA02 <2 %
VA03 2-10 %
VA04 10-20 %
VA05 20-50 %
VA06 50-90 %
VA07 >90 %
SHAPE
VB01 Rounded
VB02 Sub-rounded
VB03 Sub-angular
VB04 Angular
STONE DISTRIBUTION
VC01 Reorientated
VC02 Undisturbed
VC03 Stratified
VC04 Dispersed

STONE SIZE
VD01 2-6 mm
VD02 6-20 mm
VD03 20-60 mm
VD04 60-200 mm
VD05 200-600 mm
VD06 >600 mm
STONE WEATHERING
VE01 Non-weathered
VE02 Weakly Weathered
VE03 Strongly Weathered
STONE LITHOLOGY
VF01 Not Identified
VF02 Quartz
VF03 Sedimentary
VF04 Metamorphic
VF05 Igneous

ROOTS
AMOUNT
WA01 None
WA02 Few
WA03 Common
WA04 Many
WA05 Abundant
ROOT DISTRIBUTION
WB01 In-ped
WB02 Ex-ped

PANS
XA01 No Pans
XA02 Carbonate
XA03 Silica
XA04 Humus & Iron Oxide
XA05 Sesquioxide
XA06 Clay
XA07 Cultivation
CHARACTER
XB01 Continuous
XB02 Discontinuous
XB03 Convoluted Pans
XB04 Weakly Cemented
XB05 Strongly Cemented

CONCRETIONS & INCLUSIONS
XF01 None
XF02 Carbonate @ 38cm ↓
XF03 Gypsum
XF04 Iron
XF05 Manganese
XF06 Organic/Charcoal
XF07 Other
FORM
XG01 Diffuse
XG02 Soft Nodules
XG03 Hard Nodules
XG04 Crystals
AMOUNT
XH01 <2 %
XH02 2-20%
XH03 >20%
SIZE
XI01 <5 mm
XI02 5-15 mm
XI03 >15 mm

VENESS & ASSOCIATES PTY LIMITED
Environmental and Natural Resource Consultants

1324 Mt. Pleasant

Unit D **SITE No.** 070 **cont.**

Cf 468

Dy 4·23

Location: ° ' "
Latitude __ ° __ ' __ " S
Longitude __ ° __ ' __ " E

Record Type	Same as Site No	Total No. of Layers
0 0 0 4		

	Layer No	Horizon	Lower Average Depth (m)	Moist	V/C	Dry	Primary Colour	Primary Tone	Primary Contrast	Primary %	Secondary Colour	Secondary Tone	Secondary Contrast	Secondary %	Moisture	pH	Ag NO3	Sample
1	1	A1	.17	7.5 YR 4/2												6.		1
2	2	A2	.26	7.5 YR 5/3		7.5 YR 6/2										7.		1
3	3	B1	.42	7.5 YR 5/4												7.		1
4	4	B2	.64	10 YR 6/6												9.5		1
7	5	BC	+1.60	10 YR 7/4												9.5		
	6																	

CODES
- Colour: Red R; Orange O; Brown B; Yellow Y; Grey G; Gley L
- Tone: Pale P; Dark D
- Contrast: Faint F; Distinct D; Prominent P
- Moisture: Dry D; S Moist S; M Moist M; Wet W
- Ag NO3: -ve test N; +ve test P
- Sample: Not taken O; taken

SURFACE CONDITION
Crust –
Hard set –
Not hard set ☒

Midslope

BOUNDARY
DISTINCTNESS 1 2 3 4 5 6
NA01 None
NA02 Sharp (<20 mm)
NA03 Clear (20-50 mm)
NA04 Gradual (50-100 mm)
NA05 Diffuse (>100 mm)
SHAPE
NB01 Even
NB02 Wavy
NB03 Irregular
NB04 Broken

TEXTURE
SAND FRACTION
FA01 Fine
FA02 Coarse
GRADE
PB01 Sand
PB02 Loamy Sand
PB03 Clayey Sand
PC01 Sandy Loam
PC02 Fine Sandy Loam
PC03 Light Sandy Clay Loam
PD01 Loam
PD02 Loam, Fine Sandy
PD03 Silt Loam
PD04 Sandy Clay Loam
PE01 Clay Loam
PE02 Silty Clay Loam
PE03 Fine Sandy Clay Loam
PF01 Sandy Clay
PF02 Silty Clay
PF03 Light Clay
PF04 Light Medium Clay
PG01 Medium Clay
PG02 Heavy Clay

PLASTICITY TYPE
QA01 Super Plastic
QA02 Normal Plastic
QA03 Subplastic
QA04 Strongly Subplastic

STICKINESS
QF01 Non-sticky
QF02 Slightly Sticky
QF03 Moderately Sticky
QF04 Very Sticky

WATER-TABLE
SA01 None
SA02 Seasonal
SA03 Permanent
SA04 Perched

CONSISTENCE
DISRUPTIVE TEST
COHERENCE [illegible] dry - well
TA01 Very Weak Force
TA02 Weak Force
TA03 Moderate Force
TA04 Strong Force
TA05 Very Strong Force
SHEARING TEST
TB01 Brittle
TB02 Crumbly
TB03 No Change
TB04 Labile
TB05 Plastic

STRUCTURE
GRADE 1 2 3 4 5 6
UA01 Apedal Single Grained
UA02 Apedal Massive
UA03 Weak Pedality
UA04 Moderate Pedality
UA05 Strong Pedality
PED SIZE (Primary UB01–UB09, Secondary UC01–UC09)
<2 mm
2-5 mm
5-10 mm
10-20 mm
20-50 mm
50-100 mm
100-200 mm
200-500 mm
>500 mm
PED SHAPE (Primary UD01–UD10, Secondary UE01–UE10)
Platy
Lenticular
Prismatic
Columnar
Angular Blocky
Sub-ang Blocky
Polyhedral
Round
Granular
Crumb
FABRIC
UF01 Earthy
UF02 Sandy
UF03 Smooth-faced Peds
UF04 Rough-faced Peds
CUTANS
UG01 None
UG02 Few (<10%)
UG03 Common (10-50%)
UG04 Many (> 50%)
PED POROSITY
UH01 Porous
UH02 Dense
rake ripped
CRACK SIZE
UI01 <2mm
UI02 2-5 mm
UI03 5-10mm
UI04 10-20mm
UI05 >20mm

STONES
AMOUNT OF STONES 0 1 2 3 4 5 6
VA01 None
VA02 <2 %
VA03 2-10 %
VA04 10-20 %
VA05 20-50 %
VA06 50-90 %
VA07 >90 %
SHAPE
VB01 Rounded
VB02 Sub-rounded
VB03 Sub-angular
VB04 Angular
STONE DISTRIBUTION
VC01 Reorientated
VC02 Undisturbed
VC03 Stratified
VC04 Dispersed

STONE SIZE
VD01 2-6 mm
VD02 6-20 mm
VD03 20-60 mm
VD04 60-200 mm
VD05 200-600 mm
VD06 >600 mm
STONE WEATHERING
VE01 Non-weathered
VE02 Weakly Weathered
VE03 Strongly Weathered
STONE LITHOLOGY
VF01 Not Identified
VF02 Quartz
VF03 Sedimentary
VF04 Metamorphic
VF05 Igneous

claystone in bottom

ROOTS
AMOUNT
WA01 None
WA02 Few
WA03 Common
WA04 Many
WA05 Abundant
ROOT DISTRIBUTION
WB01 In-ped
WB02 Ex-ped

PANS
XA01 No Pans
XA02 Carbonate
XA03 Silica
XA04 Humus & Iron Oxide
XA05 Sesquioxide
XA06 Clay
XA07 Cultivation
CHARACTER
XB01 Continuous
XB02 Discontinuous
XB03 Convoluted Pans
XB04 Weakly Cemented
XB05 Strongly Cemented

CONCRETIONS & INCLUSIONS
XF01 None
XF02 Carbonate
XF03 Gypsum
XF04 Iron
XF05 Manganese
XF06 Organic/Charcoal
XF07 Other
FORM
XG01 Diffuse
XG02 Soft Nodules
XG03 Hard Nodules
XG04 Crystals
AMOUNT
XH01 <2 %
XH02 2-20%
XH03 >20%
SIZE
XI01 <5 mm
XI02 5-15 mm
XI03 >15 mm

VENESS & ASSOCIATES PTY LIMITED
Environmental and Natural Resource Consultants 2037 Mt. Pleasant

SITE No. 134 1008

Dr 4·13

Record Type	Same as Site No	Total No. of Layers
0 3 0 4		

Layer No	Horizon	Lower Average Depth (m)	Dominant Colour (Munsell Code) Moist	V/C	Dry	Mottle Primary Colour	Tone	Contrast	%	Mottle Secondary Colour	Tone	Contrast	%	Tests Moisture	pH	Au NO3	Sample	
1	A	·13	5 YR 44		/									S	6·0		1	·18
2	B2	·61	5 YR 46		/									M	8·5		1	
3	B3	·85	7 YR 66		/									S	9·5		1	
4	BC	1·03			/										·			
5	C	·			/										·			
6		·			/										·			

CODES		
Colour	Red	R
	Orange	O
	Brown	B
	Yellow	Y
	Grey	G
	Gley	[illegible]
Tone	Pale	P
	Dark	D
Contrast	Faint	F
	Distinct	D
	Prominent	P
Moisture	Dry	D
	S Moist	S
	M Moist	M
	Wet	W
Au NO3	+ve test	+
	-ve test	-
Sample	not taken	O
	taken	·

Lowerslope, end of ridgeline
Moderate grade
20

Dr 4·13

SURFACE CONDITION
Crust —
Hard set —
Not hard set —

BOUNDARY
DISTINCTNESS

	1	2	3	4	5	6	
NA01							None
NA02							Sharp (<20 mm)
NA03	X						Clear (20-50 mm)
NA04		X					Gradual (50-100 mm)
NA05		X	X				Diffuse (>100 mm)

SHAPE

	1	2	3	4	5	6	
NB01		X					Even
NB02	X						Wavy
NB03							Irregular
NB04							Broken

TEXTURE
SAND FRACTION

	1	2	3	4	5	6	
FA01	—	—	—				Fine
FA02							Coarse

GRADE

	1	2	3	4	5	6	
FB01							Sand
FB02							Loamy Sand
FB03							Clayey Sand
FC01							Sandy Loam
FC02							Fine Sandy Loam
FC03							Light Sandy Clay Loam
FD01							Loam
FD02							Loam, Fine Sandy
FD03							Silt Loam
FD04							Sandy Clay Loam
FE01	X						Clay Loam
FE02							Silty Clay Loam
FE03							Fine Sandy Clay Loam
FF01							Sandy Clay
FF02							Silty Clay
FF03							Light Clay
FF04		X	X				Light Medium Clay
FG01							Medium Clay
FG02							Heavy Clay

PLASTICITY TYPE

	1	2	3	4	5	6	
QA01							Super Plastic
QA02	—	—					Normal Plastic
QA03							Subplastic
QA04							Strongly Subplastic

STICKINESS

	1	2	3	4	5	6	
QF01							Non-sticky
QF02	—	—	—				Slightly Sticky
QF03							Moderately Sticky
QF04							Very Sticky

WATER-TABLE

	1	2	3	4	5	6	
SA01	—	—	—				None
SA02							Seasonal
SA03							Permanent
SA04							Perched

CONSISTENCE
DISRUPTIVE TEST

	1	2	3	4	5	6	
TA01							Very Weak
TA02							Weak
TA03	X	X	X				Moderate
TA04							Strong
TA05							Very Strong

COHERENCE

1	2	3	4	5	6
X					
X	X	X			

SHEARING TEST

	1	2	3	4	5	6	
TB01							Brittle
TB02	X		X				Crumbly
TB03			X				No Change
TB04		X					Loose
TB05							Plastic

STRUCTURE
GRADE

	1	2	3	4	5	6	
UA01							Apedal Single Grained
UA02							Apedal Massive
UA03							Weak Pedality
UA04			X				Moderate Pedality
UA05	X	X					Strong Pedality

PED SIZES

Primary	1	2	3	4	5	6		Secondary	1	2	3	4	5	6
UB01							< 2 mm	UC01						
UB02							2-5 mm	UC02	X	X				
UB03							5-10 mm	UC03			X			
UB04							10-20 mm	UC04						
UB05							20-50 mm	UC05						
UB06	X			X			50-100 mm	UC06						
UB07			X				100-200 mm	UC07						
UB08		X					200-500 mm	UC08						
UB09							>500 mm	UC09						

PED SHAPE

Primary	1	2	3	4	5	6		Secondary	1	2	3	4	5	6
UD01							Platy	UE01						
UD02							Lenticular	UE02						
UD03							Prismatic	UE03						
UD04							Columnar	UE04						
UD05							Angular Blocky	UE05			X			
UD06	X	X	X				Sub-ang. Blocky	UE06	X	X				
UD07							Polyhedral	UE07						
UD08							Round	UE08						
UD09							Granular	UE09						
UD10							Crumb	UE10						

FABRIC

	1	2	3	4	5	6	
UF01							Earthy
UF02							Sandy
UF03		X					Smooth-faced Peds
UF04	X		X				Rough-faced Peds

CUTANS

	1	2	3	4	5	6	
UG01	X						None
UG02			X				Few (<10%)
UG03		X					Common (10-50%)
UG04							Many (> 50%)

PED POROSITY

	1	2	3	4	5	6	
UH01	X	X					Porous
UH02							Dense

CRACK SIZE

	1	2	3	4	5	6	
UI01	—	—	—	—			<2mm
UI02							2-5 mm
UI03							5-10mm
UI04							10-20mm
UI05							> 20mm

STONES
AMOUNT OF STONES

	0	1	2	3	4	5	6	
VA01								None
VA02	X	X	X	X				<2 %
VA03								2-10 %
VA04								10-20 %
VA05								20-50 %
VA06								50-90 %
VA07								>90 %

SHAPE

	0	1	2	3	4	5	6	
VB01								Rounded
VB02								Sub-rounded
VB03								Sub-angular
VB04								Angular

STONE DISTRIBUTION

	0	1	2	3	4	5	6	
VC01								Reoriented
VC02								Undisturbed
VC03								Stratified
VC04								Dispersed

STONE SIZE

	0	1	2	3	4	5	6	
VD01								2-6 mm
VD02								6-20 mm
VD03								20-60 mm
VD04								60-200 mm
VD05								200-600 mm
VD06								>600 mm

STONE WEATHERING

	0	1	2	3	4	5	6	
VE01								Non-weathered
VE02								Weakly Weathered
VE03								Strongly Weathered

STONE LITHOLOGY

	0	1	2	3	4	5	6	
VF01								Not Identified
VF02								Quartz
VF03								Sedimentary
VF04								Metamorphic
VF05								Igneous

ROOTS
AMOUNT

	1	2	3	4	5	6	
WA01							None
WA02			X				Few
WA03		X					Common
WA04	X						Many
WA05							Abundant

BIOTURBATION

1	2	3	4	5	6

ROOT DISTRIBUTION

	1	2	3	4	5	6	
WB01							In-ped
WB02							Ex-ped

PANS

	1	2	3	4	5	6	
XA01	—	—	—				No Pans
XA02							Carbonate
XA03							Silica
XA04							Humus & Iron Oxide
XA05							Sesquioxides
XA06							Clay
XA07							Cultivation

CHARACTER

	1	2	3	4	5	6	
XB01							Continuous
XB02							Discontinuous
XB03							Convoluted Pans
XB04							Weakly Cemented
XB05							Strongly Cemented

CONCRETIONS & INCLUSIONS

	1	2	3	4	5	6	
XF01	X	X					None
XF02			X				Carbonate
XF03							Gypsum
XF04							Iron
XF05							Manganese
XF06							Organic/Charcoal
XF07							Other

66↓

FORM

	1	2	3	4	5	6	
XG01							Diffuse
XG02							Soft Nodules
XG03							Hard Nodules
XG04							Crystals

AMOUNT

	1	2	3	4	5	6	
XH01							<2 %
XH02							2-20%
XH03							>20%

SIZE

	1	2	3	4	5	6	
XI01							<5 mm
XI02							5-15 mm
XI03							>15 mm

VENESS & ASSOCIATES PTY LIMITED
Environmental and Natural Resource Consultants 2037 Mt. Pleasant

SITE No.	139

Record Type	Same as Site No	Total No. of Layers
0 3 0 4		

20

Layer No	Horizon	Lower Average Depth (m)	Dominant Colour (Munsell Code) Moist	V/C	Dry	Mottle Primary Colour	Tone	Contrast	%	Mottle Secondary Colour	Tone	Contrast	%	Tests Moisture	pH	Au NO3	Sample
1	A	·14	7·5 YR 3 3		/									S	6·0		1
2	B2	·37	5 YR 4 8		/									M	8·0		1
3	B3	·58	7·5 YR 5 6		/									S	9·5		1
4	BC	·73			/												
5	C	·			/												
6		·			/												

CODES		
Colour	Red	
	Orange	O
	Brown	
	Yellow	
	Grey	G
	[illegible]	
Tone	Pale	
	Dark	D
Contrast	Faint	
	Distinct	D
	Prominent	
Moisture	Dry	D
	S Moist	S
	M Moist	M
	Wet	W
Au NO3	[illegible]	
	[illegible]	
Sample	Not Taken	0
	Taken	

Gc 2.21

SURFACE CONDITION

Crust —
Hard set X
Not hard set —

Lowerslope in casuarines, near Brookfield Homestead

Top of B2 ~~domed~~, 8-6cm ~~across~~ & very tough

BOUNDARY
DISTINCTNESS

	1	2	3	4	5	6	
NA01							None
NA02							Sharp (<20 mm)
NA03	X						Clear (20-50 mm)
NA04		X					Gradual (50-100 mm)
NA05			X				Diffuse (>100 mm)

SHAPE

	1	2	3	4	5	6	
NB01							Even
NB02	X	X					Wavy
NB03							Irregular
NB04							Broken

TEXTURE
SAND FRACTION

	1	2	3	4	5	6	
FA01	—	—					Fine
FA02							Coarse

GRADE

	1	2	3	4	5	6	
PB01							Sand
PB02							Loamy Sand
PB03							Clayey Sand
PC01							Sandy Loam
PC02							Fine Sandy Loam
PC03							Light Sandy Clay Loam
PD01							Loam
PD02							Loam, Fine Sandy
PD03							Silt Loam
PD04							Sandy Clay Loam
PE01							Clay Loam
PE02							Silty Clay Loam
PE03	X						Fine Sandy Clay Loam
PF01							Sandy Clay
PF02							Silty Clay
PF03							Light Clay
PF04		X	X				Light Medium Clay
PG01							Medium Clay
PG02							Heavy Clay

PLASTICITY TYPE

	1	2	3	4	5	6	
QA01							Super Plastic
QA02	—	—					Normal Plastic
QA03							Subplastic
QA04							Strongly Subplastic

STICKINESS

	1	2	3	4	5	6	
QF01							Non-sticky
QF02	X	X	X				Slightly Sticky
QF03							Moderately Sticky
QF04							Very Sticky

WATER-TABLE

	1	2	3	4	5	6	
SA01	—	—	—				None
SA02							Seasonal
SA03							Permanent
SA04							Perched

CONSISTENCE
DISRUPTIVE TEST

	1	2	3	4	5	6		COHERENCE 1	2	3	4	5	6
TA01							Very Weak						
TA02							Weak						
TA03	X	X	X				Moderate	X					
TA04							Strong		X	X			
TA05							Very Strong						

SHEARING TEST

	1	2	3	4	5	6	
TB01							Brittle
TB02	X		X				Crumbly
TB03							No Change
TB04		X					Loose
TB05							Plastic

STRUCTURE
GRADE

	1	2	3	4	5	6	
UA01							Apedal Single Grained
UA02							Apedal Massive
UA03							Weak Pedality
UA04	X						Moderate Pedality
UA05		X	X				Strong Pedality

PED SIZE

Primary	1	2	3	4	5	6		Secondary	1	2	3	4	5	6
UB01							<2 mm	UC01						
UB02							2-5 mm	UC02		X	X			
UB03							5-10 mm	UC03	X	X	X			
UB04							10-20 mm	UC04	X					
UB05							20-50 mm	UC05						
UB06	X						50-100 mm	UC06						
UB07			X				100-200 mm	UC07						
UB08		X					200-500 mm	UC08						
UB09							>500 mm	UC09						

PED SHAPE

Primary	1	2	3	4	5	6		Secondary	1	2	3	4	5	6
UD01							Platy	UE01						
UD02							Lenticular	UE02						
UD03							Prismatic	UE03						
UD04							Columnar	UE04						
UD05							Angular Blocky	UE05		X	X			
UD06	X	X	X				Sub-ang. Blocky	UE06	X	X				
UD07							Polyhedral	UE07						
UD08							Round	UE08						
UD09							Granular	UE09						
UD10							Crumb	UE10						

FABRIC

	1	2	3	4	5	6	
UF01							Earthy
UF02							Sandy
UF03		X	X				Smooth-faced Peds
UF04	X						Rough-faced Peds

CUTANS

	1	2	3	4	5	6	
UG01	X						None
UG02							Few (<10%)
UG03			X				Common (10-50%)
UG04		X					Many (> 50%)

PED POROSITY

	1	2	3	4	5	6	
UH01	X	X	X				Porous
UH02							Dense

CRACK SIZE

	1	2	3	4	5	6	
UI01	—	—	—				<2mm
UI02							2-5 mm
UI03							5-10mm
UI04							10-20mm
UI05							>20mm

STONES
AMOUNT OF STONES

	0	1	2	3	4	5	6	
VA01	X	X						None
VA02			X					<2 %
VA03				X				2-10 %
VA04								10-20 %
VA05								20-50 %
VA06								50-90 %
VA07								>90 %

SHAPE

	0	1	2	3	4	5	6	
VB01								Rounded
VB02								Sub-rounded
VB03				X				Sub-angular
VB04				X				Angular

STONE DISTRIBUTION

	0	1	2	3	4	5	6	
VC01				X				Aggregated
VC02								Unaggregated
VC03								Stratified
VC04								Dispersed

STONE SIZE

	0	1	2	3	4	5	6	
VD01				X				2-6 mm
VD02								6-20 mm
VD03								20-60 mm
VD04								60-200 mm
VD05								200-600 mm
VD06								>600 mm

STONE WEATHERING

	0	1	2	3	4	5	6	
VE01				X				Non-weathered
VE02				X				Weakly Weathered
VE03				X				Strongly Weathered

STONE LITHOLOGY

	0	1	2	3	4	5	6	
VF01								Not Identified
VF02				X				Quartz
VF03				X				Sedimentary Grey claystone.
VF04								Metamorphic
VF05								Igneous

ROOTS
AMOUNT

	1	2	3	4	5	6	
WA01							None
WA02		X	X				Few
WA03							Common
WA04	X						Many
WA05							Abundant

BIOTURBATION

1	2	3	4	5	6

ROOT DISTRIBUTION

	1	2	3	4	5	6	
WB01	X						In-ped
WB02		X	X				Ex-ped

PANS

	1	2	3	4	5	6	
XA01	—	—	—				No Pans
XA02							Carbonate
XA03							Silica
XA04							Humus & Iron Oxide
XA05							Sesquioxide
XA06							Clay
XA07							Cultivation

CHARACTER

	1	2	3	4	5	6	
XB01							Continuous
XB02							Discontinuous
XB03							Conformable Pans
XB04							Weakly Cemented
XB05							Strongly Cemented

CONCRETIONS & INCLUSIONS

	1	2	3	4	5	6	
XF01	X	X					None
XF02			X				Carbonate 48↓
XF03							Gypsum
XF04							Iron
XF05							Manganese
XF06							Organic/Charcoal
XF07							Other

FORM

	1	2	3	4	5	6	
XG01							Diffuse
XG02							Soft Nodules
XG03							Hard Nodules
XG04							Crystals

AMOUNT

	1	2	3	4	5	6	
XH01							<2 %
XH02							2-20%
XH03							>20%

SIZE

	1	2	3	4	5	6	
XI01							<5 mm
XI02							5-15 mm
XI03							>15 mm

APPENDIX 2

Land Capability Classification

(after Emery [undated])

LAND CLASSIFICATION AND SOIL CONSERVATION PRACTICES				INTERPRETATIONS AND IMPLICATIONS
SUITABLE FOR REGULAR CULTIVATION		I	No special soil conservation works or practices.	Land suitable for a wide variety of uses. Where soils are fertile, this is land with the highest potential for agriculture, and may be cultivated for vegetable and fruit production, cereal and other grain crops, energy crops, fodder and forage crops, and sugar cane in specific areas. Includes "prime agricultural land".
		II	Soil conservation practices such as strip cropping, conservation tillage and adequate crop rotation.	Usually gently sloping land suitable for a wide variety of agricultural uses. Has a high potential for production of crops on fertile soils similar to Class I, but increasing limitations to production due to site conditions. Includes "prime agricultural land".
		III	Structural soil conservation works such as graded banks, waterways and diversion banks, together with soil conservation practices such as conservation tillage and adequate crop rotation.	Sloping land suitable for cropping on a rotational basis. Generally used for the production of the same type of crops as listed for Class I, although productivity will vary depending upon soil fertility. Individual yields may be the same as for Classes I and II, but increasing restrictions due to the erosion hazard will reduce the total yield over time. Soil erosion problems are often severe. Generally fair to good agricultural land.
SUITABLE FOR GRAZING	Occasional Cultivation	IV	Soil conservation practices such as pasture improvement, stock control, application of fertilizer and minimal cultivation for the establishment or re-establishment of permanent pasture.	Land not suitable for cultivation on a regular basis owing to limitations of slope gradient, soil erosion, shallowness or rockiness, climate, or a combination of these factors. Comprises the better classes of grazing land of the State and can be cultivated for an occasional crop, particularly a fodder crop, or for pasture renewal. Not suited to the range of agricultural uses listed for Classes I to III. If used for "hobby farms", adequate provision should be made for water supply, effluent disposal and selection of safe building sites and access roads.
		V	Structural soil conservation works such as absorption banks, diversion banks and contour ripping, together with the practices as in Class IV.	Land not suitable for cultivation on a regular basis owing to considerable limitations of slope gradient, soil erosion, shallowness or rockiness, climate, or a combination of these factors. Soil erosion problems are often severe. Production is generally lower than for grazing lands in Class IV. Can be cultivated for an occasional crop, particularly a fodder crop or for pasture renewal. Not suited to the range of agricultural uses listed for Classes I to III. If used for "hobby farms" adequate provision should be made for water supply, effluent disposal, and selection of safe building sites and access roads.
	No Cultivation	VI	Soil conservation practices including limitation of stock, broadcasting of seed and fertilizer, prevention of fire and destruction of vermin. May include some isolated structural works.	Productivity will vary due to the soil depth and the soil fertility. Comprises the less productive grazing lands. If used for "hobby farms", adequate provision should be made for water supply, effluent disposal, and selection of safe building sites and access roads.
OTHER		VII	Land best protected by green timber.	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. Destruction of trees is not generally recommended, but partial clearing for grazing purposes under strict management controls can be practised on small areas of low erosion hazard. Where clearing of these lands has occurred in the past, unstable soil and terrain sites should be returned to timber cover.
		VIII	Cliffs, lakes or swamps and other lands unsuitable for agricultural and pastoral production.	Land unusable for agricultural or pastoral uses. Recommended uses are those compatible with the preservation of the natural vegetation, namely: water supply catchments, wildlife refuges, national and state parks, and scenic areas.
		U	Urban areas	
		M	Mining and quarrying areas.	

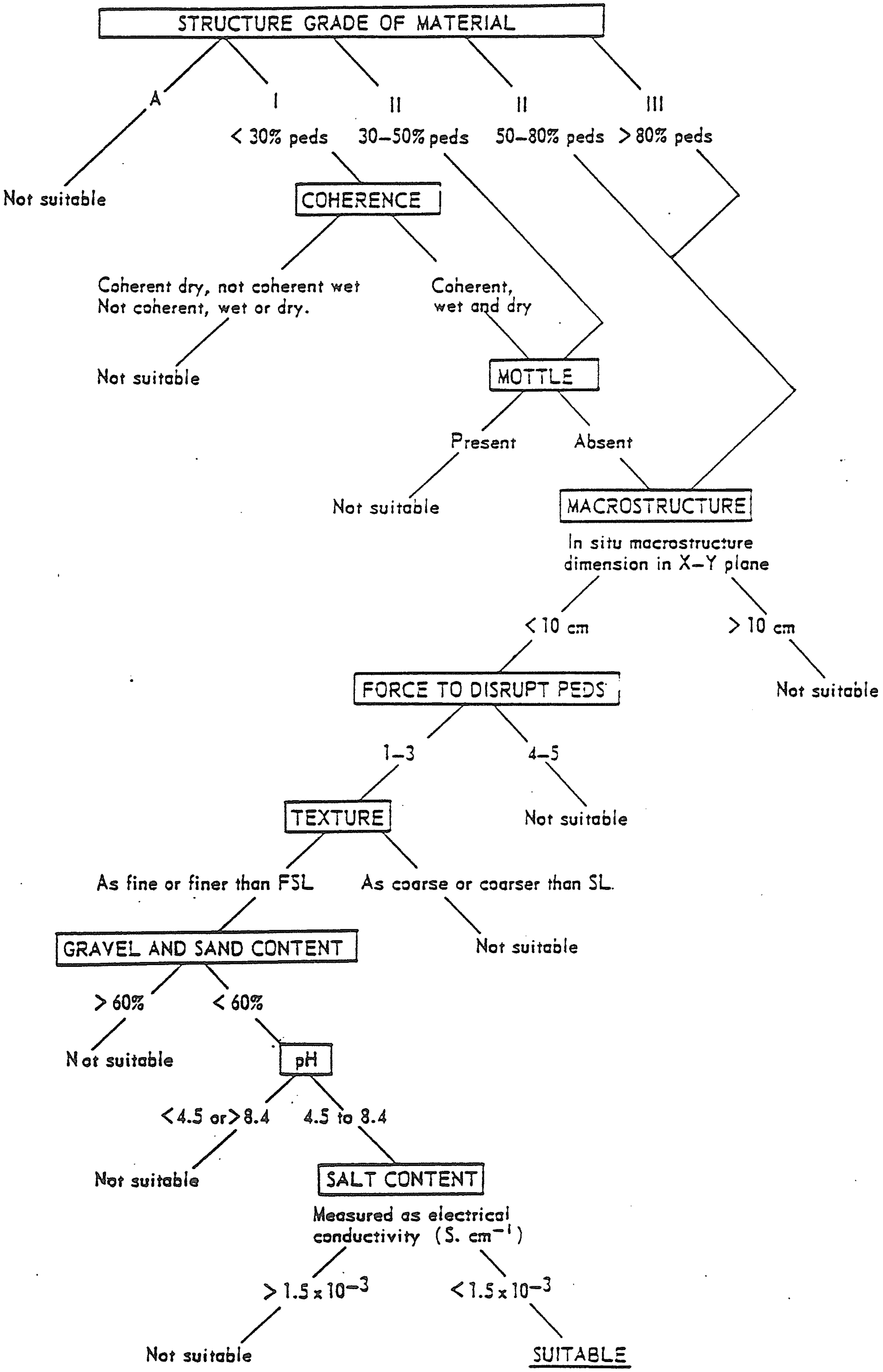
CLASS SUBSCRIPTS	SPECIAL USES
c	Terrain developed for a specific crop (capability class range IV to VII) as a result of the combination of particular soil, terrain, climatic and economic conditions. The class includes such crops as grapes, bananas, avocados and pineapples.
d	Terrain developed for intensive agricultural production and associated with flood irrigation. The class includes land developed for cotton and rice production.

APPENDIX 3

Topsoil Stripping Suitability Key

(after Elliott & Veness, 1981)

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



MT PLEASANT MINE EIS

Supplementary Soil Survey

Report

For:
COAL & ALLIED OPERATIONS PTY LIMITED

MARCH 1996
94019/SOILS

Report No. 94019/SOILS

Approved by: *Robert McCotter*
Position: Project Director
Signed:
Date: *4 September, 1997*

ERM Mitchell McCotter Quality System

TABLE OF CONTENTS

1

INTRODUCTION

1.1 SCOPE OF SURVEY AND REPORT

ERM Mitchell McCotter were commissioned by Coal & Allied Operations Pty Ltd to undertake a soil survey of part of the Mount Pleasant Project site. The area surveyed comprised the proposed north-west out-of-pit emplacement, which covers an area of approximately 250 hectares. A land capability study and soil survey report for the remainder of the site was undertaken by Veness and Associates (1994). The ERM Mitchell McCotter survey was an extension of this previous work.

Much of the generic discussion contained in the Veness and Associates report has not been duplicated here. References are made to the relevant sections of the Veness and Associates report for further information and this should be read in conjunction with this report.

1.2 SURVEY METHODOLOGY

The methodology for the ERM Mitchell McCotter survey was consistent with that of the Veness and Associates survey. This included adopting the procedure described by Elliott and Veness (1981) for assessing stripping suitability and the specifications described by the Department of Land and Water Conservation for soil surveys on proposed open-cut coal mine sites. These methodologies are described in the Veness and Associates report.

Backhoe pits were excavated at 10 locations and full profile descriptions recorded at nine of these. Due to inclement weather the final pit was not described, however there was a high degree of consistency amongst the remaining profiles allowing extrapolation of the results. In addition to the full profile descriptions, observation holes were hand augered at 15 locations

2

SOIL INVESTIGATION RESULTS

2.1 SOIL DESCRIPTIONS

The following section provides a description of the soil types of the investigation area. The soil types encountered during the investigations were similar to those mapped by Veness and Associates (1994). The results generally correspond with those of Mapping Unit C (Hillslope Soils) from the Veness and Associates report. The reporting format adopted here is similar to that used in the Veness and Associates report enabling ready comparison.

2.1.1 *Plain English Description*

Three soil types were recognised during the investigations - Red-brown Earths (Db1.13), Structured Plastic Clays (Uf6.12) and Leached Clays (Uf4.42). Within these soil types there was a high degree of consistency between individual profiles. *Table 2.1* lists the soil types at sites for which full profile descriptions were made.

Table 2.1 SOIL TYPES

Profile Number	Northcote Code[1]	Great Soil Group
1	Db1.13	Red-brown Earth
2	Db1.13	Red-brown Earth
3	Db1.13	Red-brown Earth
4	Db1.13	Red-brown Earth
5	Uf6.12	Structured Plastic Clays
6	Uf6.12	Structured Plastic Clays
7	Uf4.42	Leached Clays
8	Uf6.12	Structured Plastic Clays
9	Uf6.12	Structured Plastic Clays

Note: 1. Northcote (1979)

The topsoil is a well structured, friable, dark brown to very dark brown clay loam to light clay. The pH of this layer ranges from slightly acid to slightly alkaline. Occasionally a lower topsoil layer of light clay is present (usually in the Structured Plastic Clays). This layer is dark brown, moderately structured and slightly to moderately alkaline.

The subsoil layers are well structured light to light medium clays. Colour ranges from dark brown through to yellowish brown in the Red-brown Earths and from dark yellowish brown to light olive brown in the Structured Clay profiles. pH ranges from slightly to moderately alkaline with increasing alkalinity at depth.

2.1.2 *Technical Description*

i. Layer 1

A, A1, A11 horizon - always present

8-38 cm thick, pH 6.2-8.5 - black (10YR 2/1) to dark brown (10YR 2/2, 3/2, 3/3, 7.5YR 2.5/2, 3/3), clay loam or light clay; coherent wet and dry; moderately to strongly consistent; moderately to strongly pedal with rough-faced peds 50-100 mm breaking to porous granular peds 5-10 mm diameter; roots are common to abundant; charcoal fragments are frequently present; sharp to clear boundary to lower layers.

ii. Layer 2

A12 horizon - present in Structured Plastic Clays

15-28 cm thick, pH 7.8-8.6 - dark brown (7.5YR 3/3) to dark yellowish brown (10YR 3/4), light clay; coherent wet and dry; moderately consistent; moderately pedal with blocky peds 20-100 mm breaking to sub angular blocky peds 5-20 mm diameter; roots are common; charcoal fragments are common; clear boundary to lower layers.

iii. Layer 3

B1 horizon - always present

17-60 cm thick, pH 7.1-9.2 - dark brown (10YR 3/3, 10YR 3/4), dark reddish brown (5YR 3/4), strong brown (7.5YR 4/6) or olive brown (2.5YR 3/3, 4/3, 4/4), light clay to light medium clay; coherent wet and dry; moderately to very strongly consistent; strongly pedal with dense smooth-faced peds 50-200 mm breaking to angular blocky peds 5-20 mm diameter; few roots; gradual boundary to lower layers.

iv. Layer 4

B2 horizon - usually present

15-50 cm thick, pH 8.4-8.8 - dark yellowish brown (10YR 4/4), strong brown (7.5YR 5/6) or light olive brown (2.5YR 5/4, 5/6); light to light medium clay; coherent wet and dry; strongly to very strongly consistent; moderately to strongly pedal with smooth-faced, sub-angular blocky peds 50-250 mm breaking to blocky 5-20 mm diameter; roots rare; diffuse boundary to lower layers.

v. Layer 5

B3 horizon - usually present in Red-brown Earths

55-65 cm thick, pH 8.5-9.5 - yellowish brown (10YR 5/6) or dark olive brown (2.5Y 3/3); light to light medium clay; coherent wet and dry; very strongly consistent; strongly pedal with smooth-faced peds 100-400 mm breaking to angular and sub-angular blocky peds 10-20 mm diameter; roots absent.

2.2 SOIL LABORATORY ANALYSES AND INTERPRETATION

A total of 21 samples were sent to the Department of Land and Water Conservation laboratory at Scone for analysis. Physical and chemical analyses were undertaken including particle size analysis, dispersion percentage, Emerson aggregate test, pH and electrical conductivity.

A more detailed discussion of the various analyses is provided in the Veness and Associates report.

2.2.1 *Physical Analyses*

The results of the soil physical analyses are presented in *Table 2.2* and discussed below.

i. Particle Size Analysis

The particle size analysis results show that these soils have high clay contents particularly in the subsoils. Silt and fine sand contents are variable, with the topsoils having a relatively high fine sand percentage. There is very little coarse sand and gravel within these profiles.

Table 2.2 RESULTS OF SOIL PHYSICAL ANALYSES

Site	Layer	Horizon	Depth(cm)	Particle Size Analysis (%)					D %	EAT
				Clay	Silt	Fine Sand	Coarse Sand	Gravel		
1	1	A	0 - 11	39	22	29	10	0	28	8/3(1)
	2	B1	11 - 45	64	20	13	3	<1	41	3(2)
	3	B2	45 - 65	56	26	12	5	1	37	4
	4	B3	65 - 120	45	40	13	2	<1	28	4
2	2	B1	10 - 40	55	20	21	4	<1	32	4
	3	B2	40 - 55	54	26	19	1	0	31	4
3	1	A	0 - 10	28	25	32	15	<1	31	3(1)
	2	B1	10 - 40	56	18	15	11	0	55	3(2)
	3	B2	40 - 65	55	16	16	13	<1	36	4
	4	B3	65 - 110	66	15	11	7	1	29	3(1)
4	1	A	0 - 12	40	23	23	13	1	29	8/3(1)
	2	B1	12 - 40	60	23	12	5	<1	25	5
5	2	A12	18 - 40	65	21	10	4	<1	26	3(1)
	3	B1	40 - 120	39	29	26	5	1	27	4
7	1	A11	0 - 8	51	19	23	7	0	27	8/3(1)
	2	A12	8 - 55	64	16	13	6	1	22	4
	3	B1	55 - 115	58	22	15	5	<1	43	4
8	1	A	0 - 38	72	16	7	5	0	16	4
	2	B1	38 - 55	68	17	8	7	<1	22	4
9	2	B11	14 - 55	62	27	3	7	1	21	4
	3	B12	55 - 90	64	21	7	6	2	35	4

D% - Dispersion Percentage

EAT - Emerson Aggregate Test

ii. Dispersion Percentage

Table 2.3 provides an interpretation of dispersion percentage values. Based on this interpretation and the results shown in *Table 2.2* the soil materials of the investigation area are slightly to moderately dispersible. However, the majority of the soil materials have high clay percentages, suggesting that erosion control techniques will need to be used during stripping and handling operations.

Table 2.3 INTERPRETATION OF DISPERSION PERCENTAGE VALUES

Dispersion Percentage	Dispersion Rating
less than 6	Negligible
6 - 30	Slight
30 - 50	Moderate
50 - 65	High
greater than 65	Very High

Source: Hazelton and Murphy (1992)

iii. Emerson Aggregate Test

The Emerson Aggregate Test (EAT) results in *Table 2.2,* based on the interpretation shown in *Table 2.4,* indicate that all soil materials have a slight dispersion rating.

Table 2.4 INTERPRETATION OF EAT CLASSES

EAT Class	Dispersion Rating
6,7,8	Negligible
3(2), 3(1), 4 and 5	Slight
3(4) and 3(3)	Moderate
2(1)	Moderate to High
2(2)	High
1, 2(4) and 2(3)	Very High

Source: Hazelton and Murphy (1992)

2.2.2 *Chemical Analyses*

Table 2.5 shows the results of the soil chemical analyses, namely pH and electrical conductivity. The results for electrical conductivity refer to the saturation extract (ECe). These have been calculated from the 1:5 soil:water suspension (EC) results provided by the laboratory as per the method described in the Veness and Associates report.

i. pH

The pH results from *Table 2.5* range form 6.2 to 9.2, with most of the subsoils having values greater than 8.5. A pH range of between 4.0 and 8.5 is generally considered suitable for plant growth. Based on this assumption, the majority of the topsoils would be suitable for plant growth while the majority of subsoils would be unsuitable.

Table 2.5 RESULTS OF SOIL CHEMICAL ANALYSES

Site	Layer	Horizon	Depth(cm)	pH (1:5, soil:water)	ECe (mS/cm)
1	1	A	0 - 11	6.2	0.875
	2	B1	11 - 45	7.5	0.6
	3	B2	45 - 65	8.8	1.8
	4	B3	65 - 120	8.9	7.2
2	2	B1	10 - 40	8.5	1.4
	3	B2	40 - 55	8.4	1.2
3	1	A	0 - 10	6.3	0.25
	2	B1	10 - 40	7.1	1.0
	3	B2	40 - 65	8.8	4.8
	4	B3	65 - 110	8.7	8.73
4	1	A	0 - 12	6.7	1.25
	2	B1	12 - 40	7.7	0.6
5	2	A12	18 - 40	7.8	0.7
	3	B1	40 - 120	8.9	4.3
7	1	A11	0 - 8	7.3	1.3
	2	A12	8 - 55	8.6	1.4
	3	B1	55 - 115	9.2	4.8
8	1	A	0 - 38	8.5	2.2
	2	B1	38 - 55	8.8	3.9
9	2	B11	14 - 55	8.8	1.6
	3	B12	55 - 90	8.8	7.8

ii. Electrical Conductivity

As discussed in the Veness and Associates report, a conductivity value of 4.0 (based on the saturation extract) is the cut-off point for saline soils. Conductivity values above this figure would have an impact on plant growth and the suitability of the soils for rehabilitation purposes. The values shown in *Table 2.5* show considerable variation between the topsoils and subsoils. All of the topsoil samples have conductivity values below 4.0 as do some of the subsoils. However, many of the subsoils (particularly at depth) would be considered too saline for vegetation growth and would not be suitable for rehabilitation purposes.

2.3 EROSION POTENTIAL

The erosion potential of the soils was assessed based on the results of dispersion percentage and Emerson aggregate test as discussed above. These results suggest that the soils of the investigation area are predominantly stable but have a moderate to high erosion potential based on the dispersion percentage results and the high clay content.

The SOILOSS Program (Rosewell, 1993) was used to assess the erosion hazard of the soils, based on the calculation of the K factor as discussed in the Veness and Associates report. These results are given in *Table 2.6*. The results indicate that the soils have a low to moderate erodibility rating. This is consistent with the results obtained by Veness and Associates for their Soil Mapping Unit C.

Table 2.6 ERODIBILITY (K) VALUES AND RATINGS

Site	Layer	Topsoil K/ Rating	Layer	Subsoil K/ Rating	Whole Soil Average K
1	1 (A)	0.027/MOD	2 (B1)	0.012/LOW	
			3 (B2)	0.016/LOW	
			4 (B3)	0.030/MOD	0.021/MOD
2			2 (B1)	0.017/LOW	
			3 (B2)	0.020/MOD	0.019/LOW
3	1 (A)	0.033/MOD	2 (B1)	0.014/LOW	
			3 (B2)	0.014/LOW	
			4 (B3)	0.009/LOW	0.018/LOW
4	1 (A)	0.020/MOD	2 (B1)	0.014/LOW	0.017/LOW
5	2 (A12)	0.012/LOW	3 (B1)	0.031/MOD	0.022/MOD
7	1 (A11)	0.017/LOW	3 (B1)	0.016/LOW	0.014/LOW
	2 (A12)	0.010/LOW			
8	1 (A)	0.007/LOW	2 (B1)	0.009/LOW	0.008/LOW
9			2 (B11)	0.012/LOW	
			3 (B12)	0.011/LOW	0.012/LOW

3

LAND CAPABILITY

3.1 METHODOLOGY

A land capability assessment of the investigation area was undertaken using the methodology described by Emery (undated). The basis of this methodology is discussed further in the Veness and Associates report.

4

STRIPPING SUITABILITY

4.1 METHODOLOGY

The suitability of the soils of the investigation area for stripping was assessed using the methodology described in Elliott and Veness (1981). This methodology is described further in the Veness and Associates report and the key to the method is included as an Appendix therein.

4.2 STRIPPING RECOMMENDATIONS

Following field assessment and laboratory analysis, the soils of the investigation area were assessed for their stripping suitability based on the Elliott and Veness (1981) method. The results are given below.

4.2.1 *Layer 1 - A, A1, A11 Horizon*

This layer can be stripped throughout the investigation area. However, it should be noted that this horizon is generally only 10 to 15 centimetres thick. Care should be taken when stripping this material as it is frequently underlain by unsuitable material.

The recommendation is to strip all of this layer to a depth of 15 centimetres unless it can be demonstrated that greater depths exist over large areas.

4.2.2 *Layer 2 - A12 Horizon*

This layer which is present only within the Structured Plastic Clay profiles is unsuitable for stripping due to an unsuitably large macrostructure and high alkalinity.

The recommendation is to strip nil.

4.2.3 *Layer 3 - B1 Horizon*

This layer is unsuitable for topsoil stripping due to an unsuitably large macrostructure and strong force required to disrupt peds.

The recommendation is to strip nil.

4.2.4 *Layer 4 - B2 Horizon*

This layer is unsuitable for topsoil stripping due to an unsuitably large macrostructure and strong force required to disrupt peds.

The recommendation is to strip nil.

4.2.5 *Layer 5 - B3 Horizon*

This layer is unsuitable for topsoil stripping due to an unsuitably large macrostructure and strong force required to disrupt peds.

The recommendation is to strip nil.

4.3 STRIPPING SUMMARY

The majority of soil materials encountered within the investigation area are unsuitable for topsoil stripping purposes. The upper topsoil is suitable for stripping, however due to its inconsistent depth across the area, it is recommended that it only be stripped to a maximum depth of 10 centimetres.

4.4 SOIL STRIPPING MAP AND VOLUMES

Given that only the upper topsoil unit in the investigation area is suitable for stripping a soil stripping map has not been included. The available topsoil resource from the investigation area (based on a uniform depth of 10 centimetres and an area of 110 hectares) would be 110,000 cubic metres.

4.5 SOIL HANDLING STRATEGIES

Refer to the Veness and Associates report for soil handling strategies.

REFERENCES

Elliott, G.L. and Veness, R.A. (1981)
Selection of topdressing material for rehabilitation of disturbed areas in the Hunter Valley. *Jnl. Soil Cons. NSW*, 37:37-40.

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

Hazelton, P.A. and Murphy, B.W. (1992)
What Do All The Numbers Mean? A Guide for the Interpretation of Soil Test Results. Department of Conservation and Land Management.

Northcote, K.H. (1979)
A Factual Key for the Recognition of Australian Soils. CSIRO Rellim Publications, Adelaide.

Rosewell, C.J. (1993)
SOILOSS - A Program to Assist in the Selection of Management Practices to Reduce Erosion. Department of Conservation and Land Management.

Veness and Associates (1992)
Land Capability and Soil Survey Report - Mount Pleasant Project.

WATER MANAGEMENT STUDIES

3

Mt Pleasant Water Management Studies

Coal & Allied Operations Pty Limited

PPK Environment & Infrastructure Pty Ltd

9 Blaxland Road
Rhodes NSW 2138
PO Box 248
Concord West NSW 2138
Australia

Telephone + 61 2 9743 0333
Facsimile: + 61 2 9736 1568

August, 1997 RevD
58E047B PR_0230

ACN 078 004 798

A NATA Certified Quality Company

Contents

Contents (continued)

List of Figures

Appendices

Executive Summary

Groundwater and surface water management studies have been conducted for the Mt. Pleasant Authorisation. The studies have included extensive drilling, sampling, testing and monitoring of the groundwater environment and detailed assessment and computer simulation modelling of proposed groundwater and surface water management scenarios.

Groundwater studies have included insitu testing of coal seams and interburden at more than 20 bore locations using injection, pump out and packer test methodologies. Results of drilling and testing confirm the presence of 2 basic aquifer regimes - the hardrock coal measures (including the shallow weathered zone) and the alluvium overlying the coal measures and hosting the Hunter River.

Within the hardrock aquifer system the coal seams act as the main water transmission zones albeit at very low rates of flow. Interburden materials comprising mostly sandstones and siltstones, indicate extremely low permeabilities with certain test zones indicating the potential to hydraulically isolate formations. The shallow weathered zone acts as a thin aquifer system providing a conduit for rainfall recharge to the deeper coal measures. The alluvium in contrast to the coal measures, is a highly transmissive aquifer system comprised of gravels, sands and silts, hydraulically coupled to the Hunter River and other drainages. The alluvium acts as a major groundwater storage system being recharged by the river during periods of high river flow, and discharging to the river (via bank seepage) during periods of low flow.

Water qualities within the coal measures are generally poor with salinities ranging from 2000 mg/L to more than 4000 mg/L. Water qualities within the alluvium are variable. Near the river, salinity is reduced and the water quality is consistent with river water quality. In areas closer to the hills and areas where the alluvium permeability is reduced through the presence of silts, salinity is generally observed to increase. Where upward leakage from the coal measures is prevalent, it is likely that localised water quality will be impaired. Water qualities measured in 3 observation bores constructed within the alluvium vary from 485 mg/L to 587 mg/L while DLWC records indicate salinities as high as 1300 mg/L.

Monitoring of groundwater levels over a period of more than 2 years in test bores within the coal measures and in 3 observation bores constructed in the alluvial lands, indicates groundwater movements broadly correlating to rainfall or lack thereof. The extended drought period during 1992-1995 resulted in a steady decline in aquifer pressures measured at coal measures bores but generally stable or weakly declining levels in the alluvium.

The water table geometry supports a regional aquifer flow regime consistent with topography. Pressure gradients developed in the coal measures support an easterly flow direction towards the alluvium while groundwater levels within the alluvium support a downstream flow regime consistent with the direction of flow in the Hunter River. The elevated pressures within the coal measures suggest the potential for upward leakage beneath alluvium.

In order to understand the many complex groundwater flow processes which evolve during mining and to develop estimates of mine pit inflows, two computer based simulation models have been developed - a two layered regional model and a vertical section model. These models necessarily simplify the geological system based upon the available data base. In order to ensure findings are broadly acceptable for planning purposes, a conservative approach has been in-built in both models.

Computer simulation of regional effects arising from mine pit developments indicate pit seepage rates rising from zero at the commencement of mining to approximately 1.9 ML/day at year 21 (maximum extent of pit development). When the cumulative effects of mining operations at Bengalla and Dartbrook mines are introduced, the pit seepage rate at year 21 is observed to reduce to approximately 1.6 ML/day. The predicted rates of influx are in a range consistent with seepage rates at other mine locations and generally reflect the very low permeabilities prevailing within the coal measures. Vertical (sectional) model simulations suggest a lower pit influx of 1.2 ML/day.

Pit development will ultimately depressurise coal measures aquifers to a depth of more than 100 metres and potentially lead to a reversal of aquifer pressures beneath alluvial areas immediately east of the Mt. Pleasant Authorisation and west of the Hunter River. The change in aquifer pressures will initiate a reversal of flow beneath the alluvium and groundwater may leak from the alluvium to the coal measures. The rate of leakage is calculated to be of the order of 0.1 litres per square metre of alluvium per day and will be virtually imperceptible since rates of flow within the alluvium are orders of magnitude higher - replacement of the low loss rates will be rapid.

On the cessation of mining, flow reversals are predicted to occur when final void water levels achieve an elevation higher than the elevation of the groundwater table in the alluvium. At this time groundwater will again leak upwards from the coal measures to the alluvium. However the rate of upward leakage is predicted to be substantially lower than the pre mining situation since aquifer pressures in the coal measures will never be restored to their original levels.

Mine development will affect 30 to 70% of the drainage catchments on the eastern side of the Authorisation. Rainfall runoff within the affected areas will be directed to the mine water management system while runoff outside the affected areas will be diverted around the mining operations via engineered diversion dams and channels, ultimately discharging into the natural drainages. Surface water runoff estimations within the affected areas have been calculated using a catchment simulation model based on daily rainfall records and daily soil moisture accounting. Parameters applied to the model have been derived from calibration of other catchments in the region, and from runoff monitoring and measurement at other mine site operations. While such parameters may not concisely reflect the future runoff regime at Mt. Pleasant, the estimations are considered to be sufficiently accurate for planning purposes.

Development of the fine rejects area to the west of Mt. Pleasant will result in loss of catchment runoff over the mine life. Within the north western sub catchment, approximately 43% loss of runoff (measured at the confluence with Sandy Creek) will occur during years 1 to 9 reducing to 34% during the years 10 through 20. In the southern sub catchment, 30 % loss of runoff will occur during the final years of mining. In the greater Sandy Creek catchment above the confluence with the southern sub catchment, approximately 3.6% loss of runoff will occur during the mine life. Seepage from beneath the rejects impoundments will be at a very low rate due to the low permeability of tailings. Seepage will migrate westward within coal measures for the first few years of mine development. Seepage pathways will be altered to an easterly direction as the mine pit is developed. Within 5 years most subsurface flow will be directly towards the pits and will remain that way for more than 80 years. Observation bores will be installed downstream of the emplacement area and regular monitoring will be conducted. Any suspected leakage will be contained by construction of interception trenches, equipping bores as pumping-capture wells, or selective grouting of any conduit structures. Groundwater quality within the catchment will not be impaired.

Comprehensive mine water management simulations have been conducted on a daily accounting basis and have included provisions for the coal preparation plant, dust suppression and truck washdown together with minor provisions. A number of storage volumes have been tested against variable rainfall histories extracted from the 100 year rainfall record, to determine a target storage range and design storage volume based on containment of runoff from all catchments. The rainfall histories have included both an extreme drought period and an extreme wet period to explore storage responses. Findings clearly indicate a water deficit and hence a need to draw make up water from the Hunter River. Water will be drawn as a licensed allocation.

Storage requirements for mine water are estimated to be 1000ML to 2000ML. This storage volume may result in a need for mine water to be released from time to time depending upon climatic conditions during the 20 year mine life and the storage immediately prior to the onset of rainfall. The probability of mine water releases falls within the 6% opportunity window for releases during periods of flood flow in the Hunter River in accordance with the Hunter Salinity Trading Scheme.

Sustainable Development

The groundwater and surface water studies conducted at Mt. Pleasant have been designed to address the principles of ecologically sustainable development as outlined in the EP&A Act. Two principles are relevant to the groundwater and surface management strategies and potential impacts arising therefrom. These are *the precautionary principle* and *the principle of intergenerational equity*.

The Precautionary Principle

In relation to the precautionary principle, detailed studies have been conducted to identify and predict the impacts arising from the proposed mine operations on the water regimes.

Groundwater impacts relate almost entirely to depressurisation of the hardrock coal measures aquifers. Such depressurisation will affect borehole water supplies constructed in coal measures in proximity to the mine. Water levels in these boreholes will decline steadily over the mine life and will not recover. Where economic loss of yield is demonstrated, water supplies will be replaced either by deepening or replacement of bores, or by provision of alternative sources of water in accordance with Coal & Allied Water Policy for Mt. Pleasant. Bores and groundwater resources within the alluvial lands immediately east of the Authorisation, will be generally unaffected.

Potential groundwater impacts have been identified within the western fine rejects catchment. Calculations indicate any deep seepage of rejects leachate is likely to adopt an easterly flow direction and emanate as highwall seepage within the developing mine pit. The leachate is expected to be benign in respect of trace elements but potentially elevated in salts although the salinity will fall over a period of time as leaching and flushing occurs within the emplacement structures. As a precautionary measure, observation bores will be constructed in the western catchment and equipped when necessary to act as pumping bores to attract seepage and return pumped waters to the mine water system.

In relation to surface water impacts, all rainfall and runoff waters falling in disturbed areas will be directed to, and contained within the mine water management system. Water within this system will exhibit increased salt content and will be used for dust suppression, coal washery, fire hazard control and other usages. Development of the mine will reduce runoff in local drainages until such time as lands are rehabilitated and the runoff redirected back to these drainages. Existing dams located on affected drainages will lose recharge capacity; where economic loss of yield is demonstrated, an alternative supply will be developed in accordance with the Water Policy for Mt. Pleasant.

A detailed water management simulation of the future mine developments using sophisticated computer based techniques has demonstrated that the mine will operate with a deficit in supply. Make up water will need to be drawn from the Hunter River at a declining rate from 9.4 ML/day at the commencement of mining, to approximately 7.5 ML/day during years 20 and 21. Water may be drawn from the Hunter River under DLWC licence conditions. Such draw off will not affect regulated flows in the river.

Intergenerational Equity

The principle of intergenerational equity requires that the health, diversity and productivity of the environment is maintained or enhanced for future generations. Since all areas of mining will be rehabilitated, there are no identifiable surface drainage impacts which would substantially affect intergenerational equity.

Groundwater seepage into the mine pit(s) will depressurise coal measures over the life of the mine site. During this period, it is possible that certain areas of the alluvium adjacent to the Hunter River which might presently be subject to upward migration of saline groundwater from the coal measures, could undergo a reversal of hydraulic gradients and improved quality groundwaters will result. Subsequent to mining and after a period of recovery of groundwater pressures, hydraulic gradients may again reverse and saline pockets may recur. While it is unlikely that groundwater levels in mined hardrock areas will ever return to pre mining levels due to replacement of hardrock with spoils, there is opportunity for marginally increased salt levels in spoils materials though the processes of leaching.

Seepage from spoils to areas beyond the proposed pits (via migration within coal seams) has the potential to affect water quality in localised areas within the alluvium. However calculations indicate that any seepage and impact on alluvial floodplain water quality would be an exceptionally slow process that would be largely mitigated by reduced flow rates from the coal measures and dilution effects within the floodplain.

In addition seepage from the western fine rejects emplacements has the potential to migrate regionally within the deeper coal seams. However, calculations indicate seepage will be directed towards the mine pit and subsequent void. Carefully designed capping will ensure minimal percolation and leaching of salts contained within the emplacements.

In order to ensure correctness in these estimations, a long term programme of spoils and fines rejects leachate monitoring will be initiated. The findings from this programme will be compared with long term research efforts at other mine site locations and if any abnormal impacts can be identified, mitigative measures will be introduced.

1. Introduction

Coal & Allied Operations Pty Limited are intending to seek consent for the mining of coal resources within Authorisation No. A459 near the township of Muswellbrook in the Upper Hunter Valley. It is proposed to mine up to 10.5 Mtpa of run of mine (ROM) coal over a period of 21 years. Mining will commence from the eastern side of the Authorisation and progress westward as two main pits. Each pit is designed to proceed down dip for a distance of between 2 and 3 kilometres. In addition, one smaller pit will be developed to exploit localised shallow coal resources.

Overburden will be progressively removed by a truck and shovel operation, and a dragline, with spoils transported to selected areas up dip of mining operations. During the course of mine development, up to 160 metres of overburden and coal will be removed to access the Edderton seam. The deep and extensive development of the pits is expected to initiate seepage infiltration from surrounding hardrock aquifers and possibly from adjacent alluvium. Potential impact of mining both on aquifer systems contained within the hardrock strata and more distant alluvium during and subsequent to mining, warrants consideration especially in regard to rates of groundwater influx and potential changes to groundwater levels regionally.

In July 1993, Mackie Martin & Associates - PPK (MMA-PPK) groundwater engineers and environmental scientists, were commissioned to undertake a preliminary investigation to identify and characterise hydrogeological issues pertaining to the Authorisation and the surrounding region. Accordingly a drilling and monitoring programme was implemented and carried out from late 1993 through to the end of 1994. In August 1994, Rust PPK (formerly MMA-PPK) was further commissioned to undertake a more detailed hydrogeological study to assess the groundwater and surface hydrology and to determine the likely impacts of mine development on the region. Rust PPK changed its name to PPK Environment and Infrastructure Pty Ltd on 1 July 1997.

The contained report provides results of field measurements, data analyses, monitoring and evolution of computer based numerical models to simulate groundwater impacts for the area of proposed mining and related operations, and regionally. In addition, surface water management studies have been conducted to assess the mine water budgets and water storage requirements having regard for changing surface catchments and variable climatic conditions.

2. Location and Water Resources

The proposed mine site is located a few kilometres northwest of Muswellbrook. The eastern boundary of the Authorisation is in close proximity to alluvial lands (floodplain) adjoining the Hunter River as shown on Figure 1. The floodplain area in turn extends over a width of 1.5 to 2 kilometres and flanks the river along most of its length. Nearest open cut coal mining operations are located on the south side of the river and include the Drayton and Bayswater open cut pits. Bengalla Coal Mine (Authorisation A439) is located immediately south of the proposed mine area, while the underground Dartbrook Coal operations are located to the north of the area. The proposed Kayuga Open Cut coal mine is located within Authorisation A256 immediately north of A439.

The surrounding countryside offers high topographic relief while the floodplain area is flat lying with minor incised drainage's as indicated by the topographic contours shown on Figure 2. Nine drainage catchments can be identified within the Authorisation, the eastern most 6 catchments draining eastward or north eastward onto the floodplain (Figure 2). The south western catchments drain southward into Bengalla Authorisation while the large north western catchment drains to the northeast through Kayuga Authorisation A256 to the alluvial lands.

The floodplain area has high agricultural value, and has been actively farmed since early settlement. Irrigation is practised via direct river water pumping or pumping from shallow bores installed in the alluvium. Figure 3 shows land ownership details.

2.1 Available Information and Previous Studies

The geology of the region has been mapped by the NSW Department of Mineral Resources and can be referenced on the 1:25,000 Muswellbrook Geological Map Sheet (9033-II-N), and the 1:100,000 Hunter Coalfield Regional Geology Sheet (9033).

Data relating to the distribution, hydraulic properties and water chemistry of the hardrock and alluvial floodplain aquifers has been obtained from resource exploration conducted by Coal & Allied Operations Pty Limited and from additional drilling and testing undertaken in the course of hydrogeological investigations.

The subsurface geology in the adjacent Bengalla Lease has been interpreted by Bengalla Mining Company Pty Limited (Envirosciences 1993) from a combination of core logging and aerial photographic analysis. The hydrogeology of the Bengalla lease has been investigated by Mackie Martin Associates (1993).

The Department of Land & Water Conservation (DLWC) retains information on private registered bores in New South Wales, including the date of bore completion, drillers lithological logs, depth to the static water level, bore yields and casing details. All available drilling records for registered bores in the vicinity of Mt. Pleasant have been obtained and are summarised in Appendix A - Boremaster Registered Borehole Data. DLWC also retains hydrographic data for the Hunter River together with river salinity information from 1972 to 1990, and has been monitoring groundwater levels in several bores on the floodplain at six monthly intervals since 1970.

2.2 Rainfall and Evaporation

An analysis of rainfall and evaporation has been carried out in order to incorporate rainfall contributions in the regional hydrologic and hydrogeologic water balance. Long term continuous rainfall data has been recorded by the Bureau of Meteorology at Muswellbrook (High School) from 1870-1994. This record set while extensive, is discontinuous. A representative continuous record set has been established for analytical purposes, by including Aberdeen Post Office data. The nearest representative evaporation records have been obtained from the Scone Research Service Centre for the period 1973-1994. Summary statistics of monthly rainfall at Muswellbrook and mean daily pan evaporation are shown in Table 1.

The records for nearly 120 years of rainfall have been processed to generate the historical record in Figure 4. Five and ten year moving averages have been calculated and plotted. These longer term averages characterise periods when recharge to the regional aquifer systems is likely to have varied from mean value. Reduced recharge and falling water tables probably occurred during the periods 1875 to 1890 and from 1935 to 1950 - periods which coincided with extreme drought conditions. In contrast, rising water tables probably occurred during the periods 1888 to 1894 and 1947 to 1952, and during the 1955 flood period.

In general, the region has summer dominated rainfall with the highest monthly rainfalls occurring between December and February. The period of the highest surface evaporation also occurs in the summer months from November to January. In the cooler months of April to September, rainfall and evaporation levels are much lower.

Statistically dry (10 percentile) years occurred during 1935 and 1944 while the driest 3 year period occurred between 1939 and 1941 (average 369 mm). Wet (90 percentile) years occurred during 1889 and 1978 and the wettest 3 year period on record occurred between 1947 and 1949 (average 1010 mm).

Table 1: Summary of Rainfall and Evaporation Data

Month	Mean Rainfall (mm)	Mean No. of Rain Days	Pan Evaporation (mm)
January	71.2	7	217
February	63	6	175
March	52.8	6	155
April	44.7	6	105
May	42.2	7	67
June	49.8	8	49
July	45.3	7	57
August	39.8	7	84
September	40.6	6	116
October	48.4	7	154
November	52.7	7	184
December	65.6	7	227
Totals	**616.1**	**81**	**1590**

Calculated from Muswellbrook rainfall data.

2.3 River Flow and Alluvial Storage

Regional rainfall acts to recharge both hardrock coal measures and the alluvial land areas. However, the most important source of water for direct recharge to the alluvium and underlying hardrock formations is the Hunter River. Exchange of waters between the river and the alluvium represents a dynamic system - during periods of high river flow, river water recharges the alluvial aquifer system and groundwater levels rise within the floodplain. When river levels fall, groundwater gradients are reversed and seepage occurs from the alluvium to the river until an equilibrated state is achieved between alluvium outflow and the prevailing river level.

Materials within the river bed itself are variable but comprise mostly sands, gravels and silts in discrete layers and in braids and stringers. Alluvial flats adjacent to the river are typical floodplain sediments with distinct gravel bands and silty levee bank deposits. Investigative drilling has confirmed the presence of sufficiently permeable alluvium to provide efficient hydraulic coupling between the river bed deposits and the deeper alluvium and underlying coal measures although at some locations, the presence of clay layers may impede the transfer of water.

Flow within the Hunter River has been analysed by MMA-PPK (1994). More than 24 years of historical daily flow data from the Hunter River gauging station at Muswellbrook (Station No. 210002) have been processed to generate the flow duration curves shown in Figure 5. Reference to this plot indicates average flows at Muswellbrook are of the order of 350 ML/day with low river flows (less than 70 ML/day) occurring for less than 5% of the recording period. High flows above

600 ML/day as defined by the Hunter Salinity Trading Scheme (HSTS) occur less than 20% of the monitoring period while flood flows above 2000 ML/day occur less than 6% of the period. Flows at the downstream Singleton gauging location reflect contributions from the Goulburn River and other minor tributaries with flood flows above 10000 ML/day (HSTS) occurring less than 5% of the monitoring period.

Fluctuation of alluvial floodplain groundwater levels in response to rainfall and river levels has been monitored in certain local boreholes. Appendix B provides summary hydrographs for registered bores B34015, B33610 and B37964 monitored by DLWC since 1961. In addition, hydrographic data for 3 monitoring bores in the alluvial lands established as part of the current investigation, are also presented in Appendix B together with the recorded rainfall for the period of monitoring. Reference to these plots shows elevated groundwater levels correlate to periods of high rainfall and increased river levels.

Hydrographic monitoring data has been collected from hardrock monitor bores by PPK (formerly Rust PPK) during the course of the current hydrogeological study, and graphical plots are provided in Appendix B. Inspection of these plots shows correlation to rainfall in coal measures bores but some, notably 5500D000 and 4500F000 indicate anti correlation - water levels fall following receipt of high rainfall. Falling water levels are generally apparent throughout the dry/drought period of 1993 to 1995.

3. Hydrogeology

The regional hydrogeology can be broadly classified in terms of two distinct regimes; the consolidated hardrocks of mostly Permian Age (230 to 280 million years), and the unconsolidated alluvium of Quaternary to Recent Age (less than 1.8 million years). The hardrock regime may in turn be sub classified as either the very shallow weathered hardrock aquifer (exposed to rainfall recharge) or the deeper coal measures.

The Mount Pleasant Authorisation is located in an area underlain by hardrock Permian Wittingham Coal measures of the Singleton Supergroup. Lithologies within this Group comprise mostly sandstones, siltstones and coal measures with minor conglomerates and tuffs. Coal seams amenable to open cut mining occur in 8 correlated seams and include the Upper Piercefield (Warkworth) Seam to the lowermost Edderton Seam. The base of the Edderton Seam is intended to form the floor in the two main pits. A deeper seam - the Edenglassie Seam is generally too deep to mine by open cut methods and is the only seam with sufficient thickness to warrant underground mining. Figure 6 illustrates the subcrop geology within the area of interest showing coal seam subcrop at the base of weathering. Figure 6 also shows the areal extent of alluvium, and the location of an inferred dyke. Figure 7 shows a typical east-west cross section with a number of coal seams and splits indicated.

As part of hydrogeological studies, both alluvium and hardrock environments have been subjected to field testing in order to assign representative aquifer pressures and hydraulic properties for the purpose of impact assessment. A number of boreholes have been drilled and tested in the alluvial lands and in the hardrock environments, while many existing resource holes within the area have been used for bulk formation tests and for water table monitoring. Graphical completion logs for drilled boreholes are provided in Appendix C.

3.1 Hardrock Aquifers

The coal seams are recognised as the main aquifer zones within the coal measures, providing storage and transmission within cleats and joints. Groundwater is also stored and transmitted within the interburden zones comprising sandstones and siltstones however low permeabilities and porosities generally ensure extremely low rates of transmission. Indeed, the interburden zones more often act as aquicludes effectively impeding or isolating vertical exchange of groundwaters.

Water level/pressure measurement and aquifer testing within the coal measures supports a complex assemblage of differing hydrogeologic units with variable hydraulic properties and variable pore water pressures. Like other areas within the Upper Hunter Coalfields, the groundwater levels in boreholes tend to indicate a groundwater pressure distribution with a geometry similar to the prevailing topography ie. high water levels/pressures are recorded in areas of increased elevation and low water levels are recorded downslope. The measurable difference in aquifer pressures supports a flow regime with groundwater migrating from the coal measures towards the Hunter River; upward seepage is inferred beneath the alluvial areas.

Hydraulic testing of the coal measures has comprised injection, slug and packer type testing to establish representative bulk transmission characteristics (Appendix D). Results of these test procedures indicate a permeability (hydraulic conductivity) range from less than 0.0001 m/day to 0.84 m/day the lower value reflecting unjointed formation. A median value of 0.044 m/day has been determined for slug test procedures, 0.00575 for packer testing and a global median of .0195 for all tests. Weighting to remove the more extreme values provides a value of 0.015 m/day. Discrete unjointed core samples of typical interburden sandstones and siltstones at other locations in the region are known to generate very low permeabilities (less than 1 x 10^{-5} m/day).

3.2 Alluvial Aquifers

Quaternary to Recent alluvium comprises most of the floodplain area. The alluvial material offers significantly increased groundwater storage when compared to the hardrock aquifers through more favourable interstitial porosity; gravel zones are known to be capable of providing the highest storage and permeability. On a local scale the floodplain alluvium is probably more complex with braids and channels showing different degrees of hydraulic connectivity and many likely to be discontinuous with reworked gravels and silts imparting a measure of anisotropy. On a more regional scale the alluvium acts as off river storage with rainfall recharge and river inflow/outflow acting as a continuum. During periods of heavy rainfall, infiltration rates will increase significantly and runoff will be low. The occurrence of active recharge is supported by an absence of drainage channels across the floodplain - hillslope runoff from smaller catchments tends to dissipate or seep downwards rapidly. With the onset of high river levels following rainfall, leakage from the Hunter River occurs into aquifer sands and gravel, and water tables in the aquifer rise, especially in areas adjacent to the river. This situation is reversed during dry periods when river levels fall below groundwater levels and accessions occur from the aquifer to the river.

Testing at 3 bore locations has indicated a permeability range of 8.8 to 33.2 m/day with an average 20.3 m/day. Values at other locations are often higher than 40 m/day with some locations being more than 70 m/day in clean gravels. A value of 30 m/day is considered representative of alluvial materials nearer the main river channel where an increased number of water bores and wells are located.

3.3 Regional Water Table

The geometry of the regional water table or aquifer pressure distribution provides important information relating to the direction of groundwater movement and to the distribution of permeabilities and aquifer recharge and discharge areas. In order to generate a representative aquifer pressure distribution, water levels have been measured by dipper apparatus at 23 piezometers and open holes in the hardrock aquifers and a number of locations in the alluvium to the east. Level data in the current study is consistent with data obtained in the MMA (1993) Bengalla groundwater study. Where nested piezometers are installed in hardrock boreholes, water pressures have been observed to differ as a function of depth. Most nested piezometers also showed some difference in relative change in water level over time. This vertical variability in water level was noted during packer testing.

Figure 8 shows a piezometric surface generated from both DLWC and current study data. Elevated water levels/pressures occur in the west of the Authorisation, and lower pressures occur eastward and within the alluvium. Hydraulic grades in coal measures are .015 to .025. Within the alluvium, hydraulic grades are much shallower due to the relatively high transmissivity and permeability of alluvial material which permit rapid dissipation of aquifer pressures (0.005). Contours, within the alluvium reflect a stronger influence of downstream sub surface flow.

The higher aquifer pressures within the coal measures and the regional gradients towards the alluvium imply that a 'driving' pressure force groundwater movement towards the Hunter River as shown by the inferred groundwater flow streamlines. Hence it is likely that beneath the river alluvium, groundwater seeps naturally from the coal measures, upwards into the alluvium. This upward seepage may influence water quality due to increased salinity in coal seams. Indeed, the seepage most likely contributes to the variable and often poor groundwater quality observed in some alluvial areas - especially in locations more distant from the river.

Hydraulic coupling between hardrock and alluvial materials beneath the floodplain is expected to be efficient but the rate of exchange of waters will be extremely low due to the relatively impermeable hardrock lithologies which underlie the alluvium. Sub cropping coal seams beneath the river may provide improved exchange rates although ultimately, subsurface seepage will be constrained by the permeability/transmissivity of deeper coal measures. The presence of faults or dykes extending from the hardrock areas to areas beneath the alluvium, could provide localised transmission pathways in both the vertical and horizontal planes.

3.4 Regional Water Quality

Groundwater samples have been collected at 8 bores - 5 in the coal measures and 3 in the alluvium, and ionic speciation undertaken in order to characterise the groundwaters. Mean concentrations for major ions are summarised in the following Table 2 based on averaging of samples throughout the area (Appendix E). Quality parameters pH and total dissolved solids (TDS and EC) have also been measured at selected piezometer locations over a 30 month period in order to assess variability and possible influences from rainfall infiltration. Coal measures groundwaters indicate a water with an electrical conductivity (EC) range of 386 to 7280 uS/cm (weighted averages of numerous sampling events). Alluvium water quality at the 3 installed monitoring locations ranges from 667 to 744 uS/cm.

pH values tend to be closely grouped while EC values show high variance for all samples - see Appendix E - Chemical Analysis and Field Chemistry.

Results of laboratory ionic speciation have been plotted on Figure 9 - a trilinear facies diagram. Reference to Figure 9 shows the lower left triangular field of major cations as percentage milli equivalents (of total cations), and the lower right triangular field of anions as percentage milli equivalents (of total anions). Sample points plotted in these fields have been projected onto the central diamond field which permits an assessment of regional water character or the presence of different aquifers and possible mixing pathways.

Alluvium sample points in the trilinear plot (MPBH1, 2, and 3) tend to be grouped in the centre of the cation field indicating no dominant species. The anion field shows a grouping of data well within the bicarbonate type waters with weak sulphates evident. Central diamond field plotting maintains this spread of data supporting a bicarbonate water with low salinity (recent recharge).

Waters from the coal measures show increased primary salinity with grouping towards the sodium (cation) species and chloride (anion) species. Central field plotting confirms a primary salinity in coal measures waters with a possible mixing, particularly at Borehole 5000 A500.

Table 2: Typical Water Quality Parameters

Sample Source	pH	TDS (mg/L)	Ca (mg/l)	Mg (mg/l)	K (mg/l)	Na (mg/l)	HCO_3	Cl (mg/l)	SO_4 (mg/l)
Alluv.sed.	7.2	380	77.3	43.0	1.4	40.7	286.7	43.3	27.0
Coal Meas.	7.0	2440	65.0	114.7	10.6	736.0	1056.0	746.0	87.8

3.5 Pit Hydrogeology

Proposed mining operations are scheduled to commence in the eastern part of the Authorisation and extend westward and down dip as indicated by the pit development plan shown on Figure 10. The floor of the mine will equate to the base of the Edderton Seam. Structure contours for the base of this unit are given on Figure 11 which reflects a westerly to north westerly dip of approximately 5° but with a notable plateauing near the central western perimeter.

During mining operations, the high wall will progressively expose all coal seams to gravity drainage. These seams are expected to exhibit high anisotropy with respect to permeability, the vertical permeability being orders of magnitude lower than the horizontal permeability. Seeps will occur along those horizons offering a high impedance to vertically downward drainage and complex interburden leakage is expected to develop. Where vertical discontinuities occur, locally enhanced permeability may result, and transmission pathways could be established between otherwise hydraulically isolated layers. Seepage flows are likely to emanate at these locations also. Similarly, the presence of dykes could influence the prevailing water table.

Mine pit development will initially induce localised depressurisation of the coal measures and ultimately, a regional depressurisation. Hydraulic grades during the life of the mine will be inward towards the pits. With a steady depletion of pressures, it is possible that existing boreholes in proximity to the mine site could exhibit declining water levels and loss of supply.

4. Computer Simulation of Mining

The application of computer based numerical models to problem solving in groundwater engineering provides a powerful tool for the rationalisation of spatially and temporally varying field conditions. The modelling process is a technique for simulating groundwater aquifers by a system of mathematical equations for water flow through porous media. The process requires definition of the aquifer system in respect of the following:

- aquifer geometry including lateral and depth extent,
- aquifer hydraulic properties - permeability, porosity, leakage between layers etc.,
- regional pressure distributions or fluxes including rainfall recharge, throughflows and outflows.

In the present study, a finite element approach (AQUIFEMN - Townley, 1990) has been utilised as this method offers a high level of flexibility in simulating complex geometry relating to stratigraphy, alluvial extent and mine pit development. The method requires dividing the overall area of interest (domain) into triangular elements defined by nodal points at the element vertices. The number of elements defined in a model grid is determined by the spatial variations occurring in aquifer properties and the expected hydraulic gradients developed in the course of modelling. Competition between accuracy and computability can restrict the overall number of elements chosen and consequently the fineness of the elemental grid is varied.

Due to the complex nature of the hydrogeological environment in the current study area and in particular the multi layered nature of the coal measures, a number of separate models have been developed to assess the groundwater impacts of the proposed mine development. A vertical cross sectional model has been developed to allow consideration of the vertical component of the groundwater flow, while a regional plan model has been developed to simulate the horizontal component of groundwater flow and the more regional impacts due to mining. In addition a layered strip model based on finite difference methods (MODFLOW) has been adopted for assessment of the waste reject storage facility

4.1 Vertical Model Computer Simulation

A vertical cross sectional model has been designed to simulate vertical groundwater movements in the multi layered aquifer system present in the coal measures. The model takes into account the hydraulic properties of individual layers within the hardrock environment, while also simulating groundwater interaction between the alluvial and hardrock environments. The model also permits the introduction of anisotropy in the vertical plane. That is, vertical and horizontal permeabilities can be prescribed thus permitting a more accurate simulation of vertical exchange of groundwaters than can be achieved in a horizontal type model (Section 4.6). Conceptually, the model section has been located along a groundwater streamline represented by a 1m thick vertical slice through the hardrock and alluvial environments.

The cross-sectional grid comprises 2954 triangular elements defined by 1558 nodal points as shown in Figure 12. Elements have been carefully located according to the lithologies of the hardrock aquifer so as to allow incorporation of different representative hydraulic properties of the coal seams and interburden into the model. The cross sectional model grid extends along the 1432000N (ISG) line which roughly bisects the Authorisation from a groundwater divide located to the west, through to the Hunter River in the east. Figure 7 provides a generalised schematic showing model conceptualisation.

4.2 Boundary Conditions - Vertical Model

Boundary conditions are those conditions applied to a model which govern the groundwater flows generated through pit excavations or pumping. These boundaries generally take the form of defined aquifer water pressures, defined pit elevations and/or defined fluxes or seepage rates.

Nodes along the western edge of the model have been assigned as constant heads varying from 230 mAHD at the surface to 226 mAHD at the base of the model thus generating a pressure difference of 4 metres between surficial and deep aquifers. These values are based on field measurements of the aquifer water levels. Nodes along the eastern and lower boundaries of the model have been treated as no-flow boundaries implying that flow cannot enter the model along these boundaries. Nodes along the upper boundary (which correspond with the water table) have been assigned as constant heads over the river area. Nodes along the upper boundary west of the alluvium have been simulated as a low or zero flux boundary as a means of examining the contributions arising from rainfall recharge. Steady state impact assessments have been conducted assuming no rainfall in order to consider alluvium recharge contributions in isolation.

4.3 Aquifer Properties - Vertical Model

The finite element grid has been designed so that each row of elements of the grid represents either a coal seam(s) or a section of interburden (sandstone or siltstone). Hydraulic properties have been assigned for each element in the model and include horizontal and vertical hydraulic conductivity (permeability) and storativity.

Hydraulic conductivity values have been based on field testing and an assessment of the lithologic data. In some cases a row of elements represents a combination of coal seams and interburden, and the hydraulic conductivity of these elements has been calculated as a thickness weighted average of the individual lithologic units. Table 3 provides a summary of horizontal permeabilities assigned to the various lithologies. Anisotropy has been introduced in both the alluvium and the hardrock aquifer to account for likely preferential flow. Vertical hydraulic conductivity in each element has been assigned 2 orders of magnitude less than the horizontal conductivity.

Table 3: Range of Hydraulic Conductivities Assigned to Lithologic Units

Lithologic Unit	Horizontal Permeability (m/d)	Lithologic Description
Alluvium	30 - 100	river alluvium
Interburden - 1	0.0002 - 0.001	interburden
Warkworth	0.012 - 0.05	coal
Interburden - 2	0.0002 - 0.001	interburden
Mt. Arthur	0.012 - 0.05	coal
Interburden - 3	0.0002 - 0.001	interburden
Piercefield	0.012 - 0.05	coal
Interburden - 4	0.0002 - 0.001	interburden
Vaux	0.015 - 0.06	coal
Interburden -5	0.0005 - 0.002	interburden
Broonie	0.0025 - 0.01	coal
Interburden - 6	0.0002 - 0.001	interburden
Bayswater- Wynn	0.007 - 0.03	coal
Interburden - 7	0.0007 - 0.003	interburden
Wynn - Edderton	0.015 - 0.03	coal
Interburden - 8	0.001 - 0.004	interburden
Edderton	0.001 - 0.004	coal
Interburden - 9	0.001 - 0.004	interburden
Clanricard-Bengalla-Edenglassie	0.001 - 0.004	coal /interburden

4.4 Vertical Model Calibration

The calibration of a numerical model is a tuning process which requires adjustment of model variables to achieve an empirical matching between model response and measured field conditions. The input of high quality data should resolve to a model of acceptable accuracy and relatively straight forward calibration. Input parameters such as aquifer permeabilities and storativities are subject to adjustment.

The calibration process has involved generation of a steady state solution as a function of hydraulic conductivity and anisotropy, and comparison of simulated and measured aquifer pressures. The model has been calibrated against measured hydraulic gradients in both the horizontal and vertical directions. Only limited information is available on the vertical hydraulic gradients and the data show that these gradients are quite variable over the investigation area with a large gradient evident between bores completed in the shallow siltstone/sandstone and bores completed within deeper coal measures. It is likely that the very high groundwater heads associated with the shallow bores indicate the presence of a perched groundwater system. Highly impermeable interburden units such as claystones, siltstones and highly cemented sandstones at shallow depths may also act as an impedance to vertically downward movement of groundwater thus causing groundwater perching. The vertical gradient suggests a downward migration of water towards the base of the aquifer however, this migration seepage or flux is very small relative to horizontal groundwater fluxes.

The cross-sectional model has been adjusted to reflect composite groundwater levels which include data from shallow bores. The vertical gradients predicted by the model and shown in Figure 13 are of the order of 2 to 5 metres with downward flow predicted. This gradient is consistent with measured vertical gradients deeper in the aquifer and below the perched groundwater system. For example, there is a 4.2 m head difference at location 3500E000 between the Piercefield and Vaux coal seams and a 1 metre gradient at location 6500F500 between the Wynn and Edderton coal seams.

The horizontal gradients computed by the model compare favourably with the regional gradients; an absolute error of the order of 12% has been calculated. This is considered reasonable given the uncertainty in some aquifer parameters. Horizontal gradients deeper in the aquifer are over estimated by the model by approximately 15% to 30%, compared with limited field measurements, the variability being attributed to localised geological complexities.

The net water balance for the cross section obtained from the calibrated vertical model, assuming similar flow conditions prevail over a north/south distance of 6 kms, is as follows:

Model Influx:

Hardrock boundary inflows:	108 kL/day

Balanced by:

Upward leakage to alluvium:	108 kL/day

This balance implies for an average alluvial plain width of say 500 metres (west of the river), the upward leakage flux from the coal measures is 108 kL/day or approximately 0.04 L/day per square metre of alluvium.

4.5 Pit Inflows - Vertical Model

The vertical model has been used in a predictive capacity to determine the impact of mine development and likely pit inflows.

Inflows have been estimated using a steady state simulation with maintenance of a shallow groundwater table - considered to provide the worst case scenario (shallow aquifer zones within the coal measures will invariably dewater thus resulting in an overall reduced availability of groundwater for seepage). Seepage from the pit faces will be initiated from Year 1 rising steadily to maximum seepage rates in Years 15 to 20 for the deepest pit development. The rate of seepage has been estimated for a 20 year mine cut with the pit extending downwards to the Edderton Coal Seam at approximately 160 metres below ground level. Figure 14 shows steady state groundwater contours for the 20 year mine development - the pit clearly impacts groundwater levels within the hardrock aquifer. Figure 15 provides a summary plot showing the expected distribution of seepage across specific coal seams within a model pit.

When factored out to the exposed 'length of mine pit' in a north-south, the approximate net model water balance for the steady state 20 year mine development is as follows:

Model Influx:

Boundary inflows:	450 kL/day
Alluvial seepage (downwards):	810 kL/day

Balanced by:

Pit Seepage:	1260 kL/day

The contribution to downward seepage from the alluvium (assuming a 500 metre floodplain width west of the river), is calculated to be of the order of 0.1 litres per day per square metre of alluvium which will generally be satisfied by river recharge and rainfall.

4.6 Regional Simulation Model

A regional horizontal (plan) model has been developed to assess the horizontal component of groundwater flow on a regional scale and to evaluate the possible groundwater impacts on both hardrock and alluvial aquifers in the area. The plan model grid comprises 1847 triangular elements defined by 943 nodes as shown in Figure 16. Elements have been carefully located over the mine pits with fine elements aligned along high wall stripping zones and the pit floors at locations equating to 5 year intervals.

Reference to Figure 16 shows the western boundary of the model grid is located approximately 12.5 km west of Muswellbrook, and follows the south-westerly draining Sandy Creek to a point about 15 km west south-west of Muswellbrook. The southern and eastern model boundaries correspond to the eastern extent of the Hunter River alluvium, which is traced north beyond the township of Aberdeen. The northern boundary of the model corresponds to Moobie Creek.

The plan model has been treated as a two layer case with the first or upper layer representing the hardrock aquifer above the Edenglassie coal seam and the second or lower layer representing the hardrock aquifer below the Edenglassie seam to a nominal depth of - 200m AHD. This configuration of layers provides a numerically stable model. The alluvium aquifer has been treated as a transmissive region in the upper layer with direct leakages to/from the Hunter River and hydraulic coupling to the lower layer allowing groundwater to exchange between alluvium and the lower model (hardrock) layer but at a rate governed by the transmission capacity of the hardrocks and the leakage capacity of intervening layers.

4.7 Boundary Conditions - Plan Model

Northern and southern boundaries of the plan model have been treated as no flow boundaries. Nodes along the western perimeter (Sandy Creek) have been assigned as rising water table nodes which only permit flow out of the aquifer if the water table rises to a level greater than the base of the creek. All nodes along the Hunter River have been set as fixed water level nodes consistent with measured river water levels.

Flow into mining operations has been assessed by defining certain model node points at expected pit excavation levels and allowing the model to calculate the groundwater influx at these points.

4.8 Aquifer Properties - Plan Model

Hydraulic properties for the plan model have been assigned for each element. These properties include permeability (hydraulic conductivity), confined storativity, specific yield, anisotropy and leakage factors. The bulk hydraulic conductivity or permeability for each layer has been calculated as the thickness weighted average of permeabilities of individual lithologic units determined from field hydraulic test data. A regionally weighted bulk permeability value of 0.015 m/day has been used for the hardrock aquifer and a value of 30 m/day has been used for the alluvium. Unconfined storages (specific yield) of 0.0001 and 0.15 have been used for the hardrock and alluvial aquifers respectively. Leakage factors (permeability divided by thickness of a leaky layer) have been set at 0.005 to .0001 /day between the alluvium and hardrock, and at 0.0001 /day between the two hardrock layers.

4.9 Rainfall Infiltration

The regional water table within the coal measures is sustained ultimately by rainfall infiltrating over a very long period of time. The volume of rainfall infiltrating to the groundwater system is a function of surface geology, topography, evapotranspiration, soil type and many other factors. The accurate calculation of infiltration requires long term monitoring of the various components. In the absence of this data estimates of recharge can be initially determined from annual rainfall and historical assessment at other mine sites.

The simulated groundwater levels for the plan model were found to be sensitive to rainfall recharge rates - expected recharge rates were derived in the course of calibrating the model. The rate was varied to maintain a steady state calibration over most of the area of interest with a maximum of 1% of rainfall as recharge on the hardrock aquifer (6.2 mm/yr) between 6% and 20% of rainfall recharging the alluvial aquifer (37 to 120 mm/yr). Alluvium recharge rates are considered to be conservative since they do not include provision for hillslope drainage runoff recharge in low lying areas.

4.10 Plan Model Calibration

Layer 1 of the plan model has been calibrated against water levels from monitoring bores screened deeper in the hardrock aquifer and water levels from bores completed within the alluvium by adjusting rainfall infiltration. Calibration of water levels in layer 2 was not possible since there are no groundwater monitoring bores completed below the Edenglassie coal seam. However, bores completed at multiple depths above the Edenglassie show only small differences in water levels (2 to 5 metres) which are negligible in relation to horizontal gradients. Therefore it is assumed that water levels in the lower layer (layer 2) are similar to the upper layer.

Figure 17 provides a simulated water table for the upper model layer. Comparison of this water table geometry with the field measured water table shown on Figure 8 indicates broad agreement of hydraulic gradients within most of the Authorisation area. The modelled hydraulic gradients are noted to be less steep in the western part of the area. In the alluvial land areas, the location of the 130m, 140m and 150m contours are approximately correct however it is acknowledged that alluvium water levels continually change due to rainfall and river recharge. In the absence of extensive regional data, the comparable water table trends and flow directions, together with assigned hydraulic properties based upon field measurements, are considered acceptable conditions for undertaking impact assessments.

4.11 Predicted Pit Inflows - Plan Model

Expected pit inflows using the plan model, have been assessed for the 5, 10, 15 and 20 year development scenarios. Sensitivity analyses have also been conducted to assess the overall effect of uncertainty in properties assignment.

Groundwater levels from the steady state calibration were used as the initial conditions for all simulations relating to mine pit development. Computer modelling of aquifer pressures in response to pit development was then undertaken on a stepwise basis commencing at day 1 and proceeding through the entire mine development at time increments increasing from 0.1 days to more than 30 days until 21 years of mining operations had been simulated. The resulting impacts on the aquifer systems are represented in Appendix F.

Figure 18 shows the 20 year groundwater contours for the upper layer. Contouring of aquifer pressures indicates a marked depressurisation to 90 mAHD in the north pit and 100 mAHD in the south pit with depressurisation in the coal seams extending westward more than 5 kilometres to Sandy Creek. No significant depressurisation is evident within the alluvial lands although some depressurisation might occur in areas where alluvial materials are isolated from the main alluvial lands but perhaps directly connected to subsurface coal measures.

Table 4 summarises estimated pit influx. Pit seepages rise to 1.8 ML/day by 20 years and 1.9 ML/day for the final year of development. These rates assume low wall spoils are emplaced with an overall bulk permeability greater than 1 m/day which would allow rapid drainage down dip from beneath the spoils to the pit areas. If spoils emplacement results in a lower permeability (eg. below 1 m/day) then pit seepage rates are expected to peak at about 1.6 ML/day as storage is accumulated in spoils.

Predicted seepages are consistent with the range of seepages encountered at other mine sites in the Upper Hunter based on pit size and depth; seepages will be primarily confined to the more permeable coal seams as indicated by the vertical section model (Section 4.1). Pit seepages through the siltstone and sandstone interburden will be restricted to joints and fractures and will be negligible.

Table 4: Estimated Pit Influxes From Plan Model Simulations

Mine Development Stage	Pit Seepage (ML/day)
0	0
2	0.2
5	0.6
10	1.2
15	1.5
20	1.8
21	1.9 approx

The presence of dykes or faults may lead to compartmentalisation and a reduction in overall pit seepage. A dyke trending north northwest has been identified on the western boundary of the pit development. Displacement along this feature may have juxtaposed some horizons however the overall impact of this feature is not expected to lead to increased rates of pit influx. Indeed, operations at the adjacent Bengalla Mine would result in premature depressurisation along the dyke. A number of faults have also been inferred in the eastern part of the Authorisation trending approximately east southeast. These faults may persist further eastward beneath the alluvium and could act to conduit groundwaters into the developing pits. Early indication of flow potential can be gained by continued measurement of the aquifer pressures in existing or strategic monitoring bores. Flows from such structures while not expected to be significant can be carefully managed through grouting technologies to ensure seepages are impeded.

4.12 Sensitivity Analysis

Sensitivity analyses have been conducted using the plan model by incorporating extreme values of permeability from a bulk value of 0.005 m/day to 0.03 m/day. Simulations for the mine life have been completed and the resulting pit influx rates determined. Resulting rates of seepage are indicated on Figure 19 together with the expected solution domain incorporating results of simulations.

Reference to Figure 19 shows pit seepages ranging from zero to about 0.8 ML/day over the first 10 years of mining and achieving a maximum inflow of 1.2 to 2.4 ML/day after 20-21 years although a reduction in the rate of influx is expected due to impedance of flow within spoils.

4.13 Final Void Water Table Recovery

On cessation of mining, the pit or void will continue to attract seepage from the surrounding coal measures. The void will fill and the rate of seepage will steadily decline as the system approaches an equilibrated state between depletion of storage within the surrounding coal measures, seepage from spoils and rainfall recharge.

An estimate of the rate of recovery of water levels has been made by changing element properties in pit spoil areas to a higher permeability and porosity - 1 m/day and 15% respectively. Figure 20 indicates the regional water table 20 years after mining has ceased - an inward hydraulic grade towards the pit remains evident. Figure 21 provides a hydrographic plot of the long term recovery at in the central part of the authorisation. Predicted recovery occurs at a more rapid rate over the early years immediately following closure, followed by a very long period of recovery with more than 80 years required to return to levels equivalent to river and alluvium levels. Contributions to void recovery will come from rainfall recharge and alluvium (river bed) leakage. The recovered (equilibrated) void water levels in the north and south pits are predicted to be between 150 mAHD and 170 mAHD depending upon the bulk permeability characteristics of emplaced spoils within the pit areas.

4.14 Aquifer Cumulative Depressurisation

Cumulative aquifer depressurisation impacts will result from mining operations conducted at Bengalla mine site to the south of Mt. Pleasant Authorisation, and Dartbrook mine site to the north. These mining operations will induce an accelerated depressurisation of the hardrock coal measures thereby resulting in lower rates of pit inflow at Mt. Pleasant.

Rates of inflow to the north and south pits (Mt. Pleasant) have been estimated by including both Bengalla and Dartbrook operations in the regional aquifer simulation model. Pit depths for Bengalla, and underground operations at Dartbrook have been approximated from available data. The following Table 5 indicates likely inflows to Mt. Pleasant operations at the different stages of development. Results indicate a reduction in pit seepage rates (from a non cumulative estimate) of the order of 22%. If Kayuga Open Cut operations proceed, the cumulative effects from this site will be negligible since pit excavations (at Kayuga) will only be conducted at relatively shallow depths to the base of the Kayuga Seam.

Cumulative depressurisation is expected to be regionally more extensive with reversals of aquifer pressures beneath the alluvial areas east of the Authorisation occurring within the first 10 years of development. Rates of seepage to/from the alluvium are not expected to differ from estimates given in Sections 4.5 since the pit geometry and depressurised floor surface remain the same. However, remote pockets of alluvium could hypothetically be subjected to loss of water table if such areas are not hydraulically connected to the main river alluvium but are connected to zones having direct connection to coal measures. Such areas have not been identified to date.

Table 5: Summary of Expected Seepages for Cumulative Flows

Model Abstractions	Pit Development Stage				
	Year 0 (ML/day)	Year 5 (ML/day)	Year 10 (ML/day)	Year 15 (ML/day)	Year 20 (ML/day)
Pit seepage without cumulative effects	0	0.60	1.20	1.50	1.80
Pit seepage with cumulative effects	0	0.45	0.97	1.21	1.55

4.15 Groundwater Water Quality During Mining

The quality of natural groundwater emanating as seepage from exposed coal seams in the pits, is calculated to have a mean salinity of approximately 2440 mg/L based on sampling of aquifer waters (Appendix E). If regional sampling from seams at Bengalla (EIS) is included, the mean salinity is calculated to be 2800 mg/L with a pH of approximately 7.3. The groundwater is classed as non potable and marginally useful for stock water supply. Pumped pit waters will be retained entirely within the mine water system and utilised in coal washing and other site operations. In addition to seepage waters, a contribution to pit influx will derive from the in pit spoils. This influx is expected to be at a relatively low seepage rate and governed largely by rainfall infiltration in rehabilitated areas. The salinity of the spoils seepage water will be controlled by the amount of salt available to be remobilised in spoils, and the leaching efficiency of the spoils.

Chemical characterisation of the spoil material has been undertaken by the Department of Mineral Resources Development Laboratory (Mountford and Wall, 1995), on behalf of Coal & Allied Operations. Sixty two samples of midburden and interburden material were subjected to various tests including leach tests and weathering tests. Leach tests were undertaken on -2mm crushed samples using 1:5 sample: water extracts agitated for 16 hours, and analysed for electrical conductivity (EC), pH, sulphate, chloride and cation concentrations, equivalent bicarbonate, and alkalinity. Weathering tests at 40°C were also undertaken on all samples for periods of 5, 10, 15, and 20 days, with 10 of the sample tests being continued to 30 days. Leachates from each sample were analysed at the end of each test period for EC, pH, sulphate, chloride and cation concentrations, equivalent bicarbonate, and alkalinity. Of the sixty two samples tested, most produced a weakly saline leachate and only 7 were found to be acid producing.

A leachable salt load (LSL) for specific interburden samples has been calculated by projecting weathering tests to equilibrated values (generally within 100 days). This load has subsequently been factored back to an equivalent load based upon a nominal spoil particle size distribution incorporating block material to more than 1 metre diameter - emplaced spoils will not release the same salt load as -2mm crushed laboratory samples. The calculated LSL has the potential to be leached over a long period of time.

In respect of acid forming characteristics, seven samples of midburden and interburden material from the Wynn Seam were found to offer some potential. However calculations suggest dilutions and neutralisation are likely to negate such potential. Spoils from the Wynn Seam will therefore be selectively emplaced to ensure they are exposed to the neutralising capacity of adjacent formations thereby mitigating acid generating potential.

Table 6 provides an estimate of the spoils volumes together with the calculated LSL. As noted, laboratory testing has produced LSL under extreme conditions. These conditions (flood compaction, 40°C, continuous stirring and decanting) will not be replicated under field conditions. During mining spoils will not be saturated; the spoils water levels will be maintained close to the pit floor level since mining will be conducted in a down dip direction conducive to spoils drainage. Instead, the spoils will only be subjected to occasional wetting fronts which may percolate downwards following wet periods. The rate of recharge through the emplaced spoils has been estimated at less than 3% of annual average - less than 31mm per annum is therefore predicted to migrate downwards. This volume is very low and unlikely to saturate or leach the spoils in a significant way.

During mining and for a very long period following mining, an inward hydraulic gradient will persist towards the pit areas (see Figures 20 and 21 showing pit recovery). Only when pit water levels recover to an elevation above alluvium and river water levels, will a gradient reversal occur and regional flow re-established. However, groundwater pressures within the coal measures will never return to pressures measured prior to mining (current pressures). Instead, the recovered levels will generate a gradient approximately half that of the present gradient.

Table 6: Estimated Spoils Volumes and Leachable Salt Loads

Lithology	Waste tonnage (M Tonnes)	Waste volumes (Mm^3)	LSL (Kg/m^3)	Leachable Salt (tonnes)
Warkworth overburden	272	143	0.4	57,200
Mt. Arthur midburden	181	95	1.14	108,300
Piercefield overburden	354	186	0.13	24,180
Piercefield A midburden	293	154	1.38	212,520
Piercefield C midburden	286	150	1.37	205,500
Vaux A midburden	116	61	0.38	23,180
Vaux E midburden	40	21	0.19	3,990
Broonie B overburden	76	40	0.21	8,400
Broonie A midburden	53	28	0.77	21,560
Broonie B midburden	35	18	0.50	9,000
Bayswater midburden	32	17	0.48	8,160
Wynn EF midburden	30	16	0.23	3,680
Wynn I midburden	56	29	0.31	8,990
Edderton midburden	9	5	0.38	1,900
Totals	**1833**	**963**		**696,560**

Estimates of the leachable salt load and expected porosity of spoils have been calculated for the re-established regional gradient. Assuming a maximum leachable spoils volume of 963 x 10^6 m^3, a bulk pore space of 15% and a leachable salt load of 696.5 tonnes, the calculated instantaneous concentration of leachate is 4836 mg/L. The current regional mean estimate for coal measures water quality is 2440 mg/L, hence the calculated instantaneous increase in salinity within the final void and spoils is approximately double the present value. However, the long term hydraulic grade between the mine void and the alluvial lands - Hunter River is approximately half that of the present grade. Based on standard equations for advective flow, the long term flow rate towards the alluvium will be approximately half that of the current rate, and hence salt load transfers are not expected to change significantly. Indeed, since the spoils are unlikely to fully saturate, and since leaching efficiency is unlikely to be 100%, the salt load transfer may be less than the current transfer rate.

5. Coal Rejects Storage Facility

Fine waste rejects will be potentially emplaced in two catchment areas located immediately west of the Authorisation and extending over an area of more than 3 sq. kms (CMPS&F, 1997). The design of the emplacements provides for sequential filling of 9 storages in two drainages over the mine life as shown on Figure 22. The northern catchment will be utilised for most of the mine life while the southern catchment will provide additional capacity if needed. The materials deposited will comprise a mixed coarse and fine rejects which will provide a stable landform for reclamation and rehabilitation. The progressive development of storages will consume drainage catchment and reduce natural runoff.

5.1 Loss of Catchment Runoff

The western catchments comprise areas of 4.20 sq.kms (420 ha) and 4.89 sq.kms (489 ha) for the northern and southern catchments respectively. These two catchments flow into Sandy Creek, which drains a much larger area of 35.6 sq.km above the confluence with the northern catchment. Simulated runoff and annual yield from both catchments has been estimated using a soil moisture accounting model as described in Appendix G and applying the 100 year rainfall record for Muswellbrook (daily rainfall and runoff simulation). Calculated runoff characteristics are summarised in the following Table 7 together with recently measured water quality specified as salinity in EC units. The runoff is an estimate based upon use of the runoff model in other regional catchments which have been gauged by DLWC over a period of time. For the areas to the confluence with Sandy Creek, catchment runoff represents 10.7% of rainfall in median rainfall years, more than 27% in the more extreme wet years (90 percentile wet) and less than 7.8% in dry years.

Table 7: Western Catchment Runoff Estimates

Catchment	Area (sq.Km)	Average Yield (ML/annum)	Water Quality (uS/cm)	Water Quality (mg/L)
Northern (total)	4.20	280	2180	1410
Southern (total)	4.89	326	3780	2450
Northern (active rejects emp.)	1.75 max	122	na	
Southern (active rejects emp.)	1.46	98	na	
Sandy Creek (above conf.)	35.6	2373	2100	1360

Note: Water quality in mg/L calculated from EC * 0.65

Construction of the fine rejects impoundments will reduce natural runoff since runoff within and adjacent to the impoundments will be redirected into the mine water system. Loss of runoff has been calculated from the parameters given in Table 7. Emplacement in the northern catchment will be undertaken in two stages. The first will comprise construction of storages 1, 2 and 3 with an environmental dam (ED1) located at storage 4. This arrangement will prevail for approximately 9 years and will consume about 1.75 sq.km. of the northern catchment. The loss of runoff within the entire northern catchment is calculated to be 122 ML/annum or 43%. Following year 9 it is expected that most of this area will be rehabilitated and the runoff restored to the natural drainage. However the area below Storage 4 and above environmental dam 2 (ED2) will then be consumed until year 21, resulting in a loss of approximately 97 ML or 34% of the catchment. After year 21, full runoff will be restored as the remaining emplacements are rehabilitated. Similar calculations indicate the southern catchment will endure loss of about 98 ML or 30% of flow during the last years of mining.

Loss of flow contributions to Sandy Creek have been calculated as approximately 3.6% for the median flow condition within the entire Sandy Creek catchment above the southern catchment (C2) confluence.

Water quality monitoring data for each catchment (C1 and C2) suggests variable salinity from the catchment head to the confluence as measured in farm dams and localised creek pools. The loss of runoff is not expected to significantly change creek water quality however dams in catchment C1 and C2 will not receive the benefit of full runoff. Where this occurs (dams located on the central drainage), water quality can be expected to deteriorate following some storm events as a result of reduced dilution effects within the dams.

Implications for water quality change in Sandy Creek due to loss of runoff, have been assessed. A measured salinity above the confluences of C1 and C2 with Sandy Creek indicates a water quality of approximately 2100 uS/cm or 1360 mg/L. Based on contributions from catchments C1 and C2 at the calculated annul median flow rate (Table 7), a water quality estimate of approximately 1484 mg/L should prevail below the confluences. If the component of flow attributed to loss of catchment in C1 is redirected to the mine water system then the resulting water quality in Sandy Creek has been calculated at 1487 mg/L. A change of 3 mg/L is considered negligible and hence loss of runoff is not expected to significantly change water quality in Sandy Creek.

5.2 Sub Surface Seepage from Impoundments

Fines rejects impoundments will comprise fine clayey materials, fine coaly shales with some sand and occasional fine pyrites. The fine rejects will be pumped to the emplacement storage and allowed to beach out towards the impoundment wall. The wall will be constructed of coarse reject material transported to the site and placed to provide a stable structure. The wall will act to both contain fine rejects and to permit filtration and decanting of surplus water which will migrate down the valley drainage (surface seepage) to an environmental dam where collection will be pumped back to the mine water system for re-use (CMPS&F, 1997). Since the mine water system will operate with a significant deficit at most times (see Section 6.3 below), the baseline quality of the water will reflect a low salinity initially - make up water from the Hunter River. After passing through the washery, water quality will have a slightly increased salinity which will be further increased as fines are pumped to the emplacement area through agitation and mixing. The impoundments have the potential to generate additional salinity and certain trace elements through the leaching process.

A profile of the expected leachate chemistry has been developed partly from interburden leachate and weathering tests (DMR, 1996) and partly from experience with washery rejects at a number of other locations (pers.com. EGi, 1997). Leachate salinity is expected to lie between the limits indicated in Figure 23 and to exhibit a reduction in time as water migrates/leaches downward through the impoundment. A significant reduction of 50% in salinity is expected with leaching of the equivalent of 1 pore volume while 2 to 5 pore volumes will reduce salinity to background levels. It is therefore expected that all fines rejects storages will tend towards a benign condition in the long term. The speed with which this occurs will depend upon the insitu permeability of materials and the capacity for leakage from the storage base. The leaching process will commence from the first emplacement and continue as rejects consume each storage.

Emplacement will create a potential for subsurface migration of leachate in coal measures beneath the storages. The likely seepage rates and potential impacts on the local groundwater system have been assessed using a 3 dimensional strip type computer model aligned down the northern valley axis, this being the larger of the emplacement areas. The analytical technique used, permits estimation of the likely subsurface flow paths and flow rates down the valley. To facilitate development of the model, geological inspections were conducted in both the northern and southern emplacement areas in order to identify lithologies and structural aspects. Lau (1977) reports the most common outcrop as sandstone which is underlain by laminites, shales, conglomerates and coal seams; jointing (near vertical) is evident at a number of locations in two dominant directions - easterly and north northeasterly with a weaker north west direction. Figure 24 provides an approximate cross section down the northern valley based upon extensive drilling and sampling to the east, and drilling at bore location ARHTVD12. The section indicates a gently westward dipping sequence dominated by sandstones and siltstones at shallow depths with a distinct shale horizon at 20 to 30 metres depth (increasing depth westward). These units suggest potential for subsurface flow within the sandstones and isolation of deeper flow by the shale zone depending upon prevailing permeabilities.

Core permeability testing of sandstones and siltstones at other locations in the Upper Hunter indicates permeability values generally less than 10^{-5} m/day with subsurface flows controlled mainly by jointing. This tendency is reflected in hydraulic testing within the Mt. Pleasant authorisation, at Bengalla to the south and at Kayuga to the north. Shales are noted to be less prone to joint controlled permeability which may influence the occurrence of springs. Lau (1997) reports springs were also evident in a number of drainages following heavy rains in March 1997. Plotting of locations suggest they broadly equate to the base of the shallow sandstone member. Inspections during April 1997 showed all had dried over a 5 week period without rainfall.

Development of the computer simulation model has included 6 layers the uppermost 5 being 30m thick and the deepest layer 6 extending to about RL-20m. Each layer dips westward in a similar way to observed conditions. Assigned parameters for each layer are given in Appendix H. At the western limit of the strip model, the elevation of Sandy Creek has been adopted while the eastern limit has been aligned with the groundwater divide beneath Mt. Pleasant. Sandy Creek water levels have remained fixed in time but the water table beneath Mt. Pleasant has been permitted to decline based on the predicted depressurisation of the coal measures regionally (see Section

4.11). Model simulations have been conducted with rejects emplacements located progressively down hill to the west. Seepage rates and flow directions have been calculated. Table 8 summarises results at different stages of development while Appendix H contains plots of localised hydraulic gradients and flows.

Consideration of findings indicates an expected seepage from beneath the emplacement storages of 0.07 L/day per m^2 depending upon final storage height and the insitu permeability of contained fines (assumed to be 0.0001 m/day). The seepage will initially migrate westward towards Sandy Creek following flow pathways which attain considerable depth and rise only in the vicinity of Sandy Creek. However, seeped water is unlikely to physically reach Sandy Creek since development of the mine pit will extend aquifer depressurisation westward beneath the emplacement areas and induce subsurface flows eastward towards the pit. Numerical simulation indicates leachate seepage flows will be reversed towards the mine pits within 2 to 5 years of mining. The reversal of flow and depressurised condition will prevail for more than 80 years and ensure containment of most seeped waters.

Capping and closure of the storage emplacements provides for a drainage layer and top soiling to inhibit infiltration of water and generation of leachate. Calculations indicate that a rehabilitated land surface will permit on average, less than 5% of annual rainfall to infiltrate.

Table 8: Summary Seepage Rates and Water Quality for Rejects Emplacement Area

Year	Active Storages	Estimated Seepage (kL/day)	Leachate Quality (mg/L)	Comment
2	1	11	<5000	Deep flow towards Sandy Ck initially
5	2	<27	<5000	Deep flow predominantly towards pit
10	4	<63	<5000	Deep flow predominantly towards pit
20	8 or 9	<107	<5000	Deep flow predominantly towards pit
80	none	<100	<4000	Deep flow predominantly towards pit

6. Water Management Strategy

Water management studies have been conducted to develop an overall water management plan having regard for surface and groundwater within the Authorisation and in the rejects storage facility. The water management and runoff control strategy for the proposed mine operations has been designed to address key aspects including:

- Conveyance of clean runoff from undisturbed areas around existing and proposed mining operations to discharge into natural drainages;
- Control and management of stormwater and groundwater collected in the open-cut pits to maintain efficient operating conditions;
- Harvesting, storage and treatment of runoff waters to provide an operational water supply for dust suppression, coal washery and other usages;
- Supply of make up water from the Hunter River on a needs basis;
- Release of surplus waters to the Hunter River in compliance with the Hunter Salinity Trading Scheme.

A water management simulation model has been developed to assist in the evaluation of likely catchment yields and to assess storage needs and storage management. The computer based model is a conjunctive scheme utilising techniques developed by Pitman (1973) for catchment simulation and subsequently refined to account for mine water management. The model incorporates a rainfall/runoff simulation, accumulation of runoff and flows in assigned storages, depletion of storages through water usage, and transfer of water between storages.

Fundamentally, the model balances the water budget for nominated mine catchments in variable time steps with a maximum daily increment. Daily rainfall data is the main input and when a rain-day occurs, the duration and temporal distribution of the rainfall is estimated by a predetermined relationship. Calculations are then allowed to proceed at one-hour intervals through a process of disaggregation of the daily rainfall thus ensuring a more realistic simulation of rain days and the prevailing soil moisture conditions which govern runoff.

6.1 Catchment Areas

Catchments which contribute to surface runoffs have been identified within and outside the mining area. These catchments are based upon a generalised subdivision of topography, soil type, and absorptivity. To account for the changing mining sequence, catchment areas within the mine lease have been estimated and incorporated in the mine water management model. Adopted catchment types and characteristics are indicated in the following Table 9.

Table 9: Catchment Types used in Runoff Simulation

Code	Catchment Types	Catchment Characteristics
PA	pit areas	compacted base with high runoff characteristics
PS	prestrip areas	disturbed rock and soil with low and high absorptivity
US	unshaped spoils	poorly sorted interburden material - high absorptivity
RH	rehabilitated areas	shaped and grassed - higher runoff initially
DA	developed areas	generally hardstand with high runoff
UD	undisturbed catchments	pastoral land with developed soil profile
SP	stockpile	high absorption and high impervious portion of catchment

Undisturbed catchments have been simulated using calibrated parameters from other regional catchments which have been gauged over a period of time by DLWC. These gauged catchments include Glennies Creek, Yorks Creek, Saddlers Creek and others which have similar features to the Mt. Pleasant area.

The catchment runoff module of the water management model incorporates parameters which characterise catchments in terms of interception storage, hardrock exposure, soil moisture storage, capacity to infiltrate rainfall, deep percolation capacity, etc. These parameters have been assigned to the different mine site catchment types based on experience and monitoring at other mine site locations. The catchments including pit areas, prestrip benches, unshaped and shaped spoils, rehabilitated areas, etc., parameters have been weighted to account for disturbed conditions. The model accumulates runoff in specific storages and calculates a system response after accounting for demand and supply.

6.2 Water Demand and Supply

Figure 25 provides a schematic of the mine water system showing operations for the north and south pits, the smaller pits, the washery, fine rejects emplacement area and proposed draw points for dust suppression. The clean water circuit comprises all runoff water derived from undisturbed or rehabilitated lands. The mine water circuit comprises all runoff derived from disturbed ground (pre strip, pit areas, unshaped spoils, haul roads, facilities and coal stock piles etc.) where there exists a potential for increased suspended solids or dissolved salts.

Overall mine site water demand at full production has been estimated on the basis of proposed Coal Preparation Plant (CPP) operations, and the likely extent of mining. The following Table 10 summarises expected water demands.

CPP usage is based upon conventional washing operations with a consumption rate identified from experience at a number of washeries including Hunter Valley Mine No. 1 - an average processing rate of 10.5 million tonnes per annum is assumed with a loss rate of 250 L/t ROM. Haul roads application assumes a water tanker carrying/spray capacity of 1.5 Litres/sq.metre/hr and average annual demand based upon experience at other locations (optimal road usage, wet weather provisions etc.).

Table 10: Projected Water Demand

Use	Demand (ML/day)	Water type	Comments
Coal Prep. Plant	7.2	clean/dirty	assumes 10.5 Mtpa @ 250 L/t loss rate
Haul roads dust	1.5	clean/dirty	based on experience
Stockpile dust	0.35	clean/dirty	nominal - based on experience
Truck washdown	0.1	clean/dirty	nominal - based on experience
Bath house	0.05	clean	assumes approx. 150 L/man
Other	0.2	clean/dirty	nominal provision
Total demand:	9.4		depending on rejects disposal

Table 11 provides a brief summary of water supply sources. Minimum contributions of 0 to 0.1ML/day can be expected from pit groundwater influx during the first year of mining thus leaving a deficit of as much as 9.3 ML/day to be met by catchment runoff harvesting or supply from alternative sources like the Hunter River. In following years, the water deficit will be steadily reduced due to increasing contributions from pit seepage. As the deficit is reduced, less water will be drawn from the Hunter River.

Table 11: Water Supply Sources

Use	Supply (ML/day)	Water type	Comments
Mine pit inflows	0 to 1.9	dirty	rising groundwater influx (year 0 to +20)
Catchment runoff	variable	clean	depends on rainfall
Hunter River water	7.5 to 9.4	clean	depends on overall deficit (year 0 to +20)

6.3 Water Management Simulation

Within the mine operational area, disturbed catchments have been identified, and any runoff generated within these catchments will need to be contained and directed to the main water storage dam. Outside the mine area, undisturbed catchments have been identified which contribute rainfall runoff to drainages where diversion works will be necessary.

Figure 26 indicates the mine operations at year 10 for the purpose of identifying catchment types. Reference to this figure indicates the pit areas where runoff is expected to be high (low infiltration capacity), the pre strip benched and shaped spoils areas where infiltration and storage capacities are expected to be high and runoff will be low, and the rehabilitated areas where characteristics will approach those of undisturbed catchments following rehabilitation. Hardstand areas account for expected high rates of runoff from the facilities and similar areas.

For modelling purposes catchment areas for each 5 year development scenario have been measured and interpolated at lesser time intervals (Table 12). In addition, 0.1 to 0.3 sq.km. of catchment will source water to the mine water system from the fine rejects emplacement area immediately to the west of the Authorisation.

Table 12: Summary Catchment Areas Within Mine Operational Area (sq. Km.)

Catchment	at 2 year	at 5 years	at 10 years	at 15 years	at 20 years
PA (pit areas)	0.152	0.340	0.253	0.450	0.242
PS (pre strip)	0.573	2.315	3.578	4.040	5.060
US (unshaped spoils)	0.317	1.650	2.258	3.055	2.853
RH (rehabilitated)	1.386	2.254	6.822	8.532	10.490
DA (hardstand)	0.485	0.485	0.485	0.485	0.485
SP (coal stockpile)	0.114	0.114	0.114	0.114	0.114
Fine rejects area	0.110	0.200	0.225	0.275	0.100
Piercefield Pit	0.829	0.829	0.829	0.829	0.829 *

Note: * Piercefield Pit area incorporated in PS area after being mined through.

Fundamentally, the water management model calculates the amount of rainfall available for runoff after accounting for the soil moisture components governed by storage and infiltration parameters within each catchment type. The runoff is then directed to storages where evaporation losses are calculated and various pumping strategies analysed. Subsequently, the model computes a water balance based on net receipts and consumption. The water balance module calculates accumulated net storages daily and storage summaries on a weekly basis after water usage requirements and open water evaporative losses are subtracted from contributions from rainfall, runoff and groundwater seepages. The module also provides, dam overflows resulting from accumulated net storages exceeding the maximum dam storage. Appendix G provides a summary of model parameters.

In order to understand the behaviour of the overall water management strategy an initial total mine storage capacity of 1000 ML was used as a starting condition. Catchments within the mine lease were then progressively modified in area to account for changing mining conditions as given in Table 12 and the changes in storage due to accumulated runoff then calculated. In this manner the capacity of the mine water system was analysed and the capacity of the system to store runoff arising from the various extreme conditions, assessed. An appropriate storage was identified by increasing capacity on subsequent model simulations until system overflows (discharges) were sufficiently low to meet HSTS compliance criteria for flood flows in the Hunter River at Muswellbrook.

Eight rainfall periods each of 21 years duration were selected from the historical daily rainfall record. These periods included the wettest and driest 3 years and the wettest and driest year on record. Each 21 year period was then simulated on a daily basis and the output processed to generate typical storage and overflow plots the mine life. In addition, the results of each simulation were incorporated in a number of plots describing the probability of storage exceedance, overflows and make up water requirements. This procedure assumes site water management will be undertaken using real time control systems for transferring water between the various storages in an efficient manner (eg. CiTect or equivalent systems).

A typical model output is presented as Figure 27 for the period 1945 to 1965. This period includes the 1955 flood year to illustrate extreme conditions. Results indicate storage below 500 ML for much of the period with elevated storage during 1950-1951, 1953 and 1955 to 1957. Overtopping of 3000 ML storage would have occurred during 1955 as indicated by the system overflow plot. Appendix G provides a more detailed discussion of the water management simulation model together with catchment distributions at 5 yearly intervals and output from each simulation period. Figure 28 provides a plot of the calculated probability of storage exceedance while Figure 29 shows make up water requirements.

6.4 Storage Requirements

The risk of storage surplus or depletion is directly related to the occurrence of rainfall. Figure 28 indicates that zero storage would be exceeded between 50 and 70% of time (depending upon climatic conditions) and hence, make up water will be required for large periods of time. Make up water will be drawn from the Hunter River and/or harvested from natural runoff (diversion dams) in some catchments.

The minimum storage requirement for mine water is between 1000 to 2000ML which would result in over topping less than 5% of time and allow discharge in compliance with flood flows as defined by the Hunter Salinity Trading Scheme. This storage will be developed from all dams, the greatest storage being available in the Piercefield Pit after the second year of mining. Appendix G provides a summary of catchment runoff and dam sizes based upon preliminary design criteria of a 1 in 20 year, t_c storm event (Rational method).

6.5 Surface Water Channels and Storage Structures

Runoff from undisturbed catchments will be directed via contour banks, drains and diversion channels to staging dams for limited harvesting or for discharge to the natural drainages. Nominal diversion channel and dam locations are shown on Figure 26 for the mine development scenario at 10 years. Appendix G provides proposed drainage details for 2, 5, 10, 15 and 20 year development scenarios together with summary calculations relating to catchment runoff and dam concept design.

Reference to Figure 26 shows numerous sediment dams, diversion dams, contour banks and channels in the western part of the Authorisation designed to convey runoff around the mine pit. All dams will be designed in accordance with established engineering design principles and the Dam Safety Committee requirements.

Certain dams will be designed to overflow or pump to contour drains while other dams will have an outlet structure for release to existing drainages.

Diversion drains and channels will contain peak runoff discharge rates for a 1 in 5 year Average Recurrence Interval (ARI) storm event. Drains and channels will be excavated to a conventional trapezoidal section with sectional area and hydraulic grades giving acceptable flow velocities of less than 2 m/sec.

Peak runoff discharge rates used in the design of dam structures have been determined using the critical storm duration (t_C) and corresponding storm intensity for respective catchments (Rational Method). Sedimentation dams have been sized to collect the total runoff from a 1 in 20 year ARI storm event. All dam structures will have the capacity to retain the design storm with sufficient freeboard and discharge capacity to convey a 1 in 10 year (time of concentration) storm event. Runoff from remaining areas including hardstand, pre strip areas, pit floors, shaped spoils, and haul roads has been classified as mine water.

Subject to detailed survey and design, the following management strategy will apply:

- Runoff from the facilities and stockpiles will be directed to a localised hardstand sump via catch drains, and directed to dam MW1 located east of the facilities area or directly to the coal preparation plant dam (CPP) dam. Runoff from the truck washdown area will be collected in a small localised concrete sump. Accumulated water will be directed through a conventional oil-water separator plant and then to either dam MW1 or directly to the CPP dam for use in coal washing.

- Fresh water will be drawn from the Hunter River to supply the bathhouse and office areas from a localised freshwater tank. Waste water will be pumped to a treatment plant and then disposed of via spray irrigation within an assigned area.

- A small catch dam will be constructed downgradient of the rail loop load out area to contain any runoff from that area. Water will be pumped northward to dam MW1. Storage in dam MW1 will be pumped either to the main water storage dam RW1 or to the CPP Dam. All haul roads will be constructed with catch drains on the down gradient verge. Runoff waters will be directed via these catch drains to the nearest mine water dam ensuring containment within the mine water system.

- During early years of mine development, runoff from the south pit will be pumped from the north end wall and the southern ramp to dam MW3 located near the south pit haul road. Dam MW3 will provide storage for dust suppression usage. Sedimentation dams located immediately east of the main bund will contain runoff from initial emplacements and from rehabilitated areas in subsequent years. Runoff from rehabilitated areas will be managed via deep ripping and contour furrows prior to entering contour banks and dams. Runoff will be released to the local drainages from the sedimentation dams when water quality is deemed to be acceptable.

- With development of the North Pit seepage and runoff will be directed either via the north end wall to Dam MW5 or via the southern ramp to SD5 which, after the first few years operation as a sedimentation dam, will be used as a mine water dam. These dams will be connected by pipeline with SD5 connected to a main located alongside the haulroad to facilitate supply of water to RW1 and the preparation plant. While unlikely during early development years, surplus water may also be directed to the Piercefield Pit. Temporary transfer dams and sumps may also be constructed in spoils or prestrip areas on a needs basis.

- By Year 10 of development, dams MW3 and SD5 will be mined through - M3 being replaced by M3a. South Pit mine water will be pumped either to M3a or the Piercefield Pit from where dust suppression water will be drawn for the truck fill points. North Pit water will be pumped to MW5 or via the southern ramp to MW3. Dam MW6 will be constructed when out of pit spoils located to the west of the North Pit are commenced. MW6 will retain runoff from these spoils and runoff from the haul road. Water will be used for dust suppression purposes. RW1 will continue to be supplied from surplus.

- By Year 15 dams MW5 and MW6 will be mined through - MW5 may be relocated within the same catchment at a higher elevation. Pit water from the North Pit will be pumped via the north end wall to MW5 or directly to the southern end haul road and thence to the Piercefield Pit. Temporary transfer dams and sumps may be constructed in spoils or prestrip areas on a needs basis.

- The Piercefield Pit will be mined through by year 20. All surplus mine water which hitherto had been directed to this pit, will be directed to the main storage dam RW1.

- During the mine life, makeup water will be drawn from the Hunter River. Water will be pumped directly to the coal preparation plant (CPP dam) and the main water storage dam RW1. This will facilitate maintenance of supply to the haul road truck fill points during dry and drought periods.

- Surplus water will be discharged from RW1 southward to the existing drainage and into the Hunter River via Bengalla.

Table 13 indicates dam usage schedules.

Table 13: Summary of Dam Usage During Mine Development

Dam	Year 1	Year 2	Year 5	Year 10	Year 15	Year 20
RW1	■	■	■	■	■	■
CPP	■	■	■	■	■	■
RL1	■	■	■	■	■	■
MW1	■	■	■	■	■	■
MW2	■	■	■	■		
MW3	■	■	■	■	■	
MW4	■	■	■	■	■	■
MW5			■	■	■	
MW6-SD5				■		
SD1	■	■	■	■	■	■
SD2	■	■	■	■	■	■
SD3	■	■	■	■	■	■
SD4	■	■	■	■	■	■
SD5	■	■	■			
SD6	■	■	■	■	■	■
SD7		■	■	■	■	■
SD8		■	■	■	■	■
ED1 rejects	■	■	■			
ED2 rejects				■	■	■
ED3 rejects						■

6.6 Surplus Water Discharges

Water management studies have indicated that the mine site will operate with a deficit in water supply. The greatest deficit will occur during early years of mining when zero or very low rates of groundwater influx to the pit operations occur. As the pit develops, increasing groundwater influx will reduce the deficit. Harvesting of some catchment runoff will assist in meeting water requirements, however make up water will be required on a regular basis throughout the mine life.

Surplus water discharges are only predicted to occur at times when extreme storm events lead to unacceptably high levels of water in the Piercefield Pit or in dam RW1. Since the mine water system will at all times be operated on a 'first draw off' to the CPP, mine water dams are not expected to overtop unless extreme climatic conditions occur. As noted, these times which are calculated to be less than 5% of the time, are most likely to equate to flood release opportunity regimes in accordance with the Hunter Salinity Trading Scheme for the Hunter River.

Clean water (sedimentation) dam overtopping may lead to releases to local drainages when design storm events are exceeded. These overflows are not expected to impair water quality in receiving drainages since such storms will be extreme and natural drainage runoff is likely to be high with elevated sediment load.

7. Potential Environmental Impacts

Proposed operations within the Mt. Pleasant Authorisation require the construction of mine pits to significant depths. Development of these pits will result in interception of runoff from drainage catchments on the eastern side of Mt. Pleasant and depressurisation of aquifer systems contained within the coal measures. Depressurisation of coal measures to elevations of less than 90 mAHD (20 year development) will induce regional seepage from the coal seams and localised leakage from alluvial materials. Pit seepage is expected to rise to a maximum rate of between 1.5 ML/day (cumulative impact estimate) and 1.9 ML/day (non cumulative impact estimate) after 21 years mining.

The potential impacts on the overall water regime arising from the development can be grouped as follows:

- Loss of runoff from surface drainages;
- potential for loss of groundwater yields at existing bore locations;
- potential for changes to groundwater quality in the coal measures or alluvial lands;
- potential for release of mine water to existing drainages and subsequent degradation of water quality within the Hunter River.

A summary of the expected impacts arising from the mine development is given below.

7.1 Loss of Catchment Runoff

Catchment runoff provides a mechanism for regular flushing of drainages and recharge to the alluvial lands. The development of mine pits and facilities areas, together with large areas of spoils emplacement, will result in loss of catchment area which would normally contribute to localised runoff on the eastern side of Mt. Pleasant. During the mine life, approximately 30 to 70% of catchment runoff within the eastern part of the Authorisation will be directed to the mine water system as rainfall received in pit, and rainfall received in other operational areas. The remaining 30 to 70% of runoff will be diverted around the mine site to natural drainages. The loss of runoff to low lying alluvial areas immediately east of the mine site is not expected to affect groundwater quantity or quality in a significant way. Rainfall and localised runoff will continue to permeate the shallow alluvium in eastern areas, and groundwater will continue to flow (in a regional context) in a downstream direction within the alluvium - groundwater levels will remain generally unaffected although changes could occur in areas disconnected from the mainstream alluvium but directly connected to structural conduits within the coal measures. During mining, runoff from fully rehabilitated areas to natural drainages will be rapidly re-established to sustain flows in drainages. Dams located on the eastern drainages will suffer from loss of runoff and alternative water sources will need to be located.

The development of a fine rejects emplacement area will result in loss of runoff to Sandy Creek during the mine life and for a short period thereafter. Emplacements in the north western catchment will result in loss of 43% of runoff declining to 34%, measured as discharge at the confluence with Sandy Creek while the south western catchment will lose 30% of runoff as discharge at the confluence with Sandy Creek. Existing dams will be affected, those highest in the catchment being most severely affected. Alternative supplies for dam water will need to be sought.

Loss of runoff is not expected to significantly affect subsurface groundwaters which will continue to seep from springs for a period of 2 to 5 years from commencement of mining. Thereafter, loss of pressure (induced by mine pit development) may result in premature drying. Since the identified springs only seep for short periods following rainfall and since a number of springs issue poorer quality water, the loss of seepage may improve quality of runoff albeit at lower flow rates at some locations.

7.2 Regional Groundwater Tables

During the course of mining, groundwater levels in the hardrock aquifers will steadily decline as water is drained from storage. The area of affectation will increase to a distance of more than 5 kilometres from the mine pit(s) after 21 years. At this time, more than 10,000 ha may be impacted by at least 5m loss of groundwater pressure with maximum impacts in excess of 100m adjacent to the pit faces.

Certain boreholes in the coal seams are likely to be affected by the depressurisation to a greater or lesser extent. Bores registered with DLWC that will be impacted by 5m or more, have been identified and are presented in Table 14. Reference to this table shows that of the 28 bores, 17 are located outside the Authorisation. Three of the registered bores No.s 44822, 35959 and 12693 are located within the area affected by depressurisation but no data is available to determine the impacts on the bores.

Loss of groundwater levels will require lowering of pumps at those locations where water is currently drawn from deep aquifers. Shallow water supplies are likely to be depleted but may replenish during periods of high rainfall. Augmentation or replacement of supply is expected at most affected locations.

On cessation of mining, groundwater levels will rise in the final void and ultimately reverse pressure gradients in the coal measures beneath the alluvium as the system equilibrates. Long term regional groundwater pressures and water tables in hardrock aquifers and spoils will then be determined largely by the hydraulics of the void and the active recharge processes occurring within rehabilitation areas. However the coal seam aquifer pressures/groundwater levels are not expected to return to current pressures/levels and will remain depleted. A long term equilibrated water level in the voids is predicted to be between 150 and 170 mAHD depending upon the bulk permeability of emplaced spoils with a recovery time calculated to be more than 100 years.

Table 14: Summary of 5m Impacts to DLWC Registered Bores at 20 Years

Registered Bore Number	Modelled Impact at 20 Years (m drawdown)
38582*	dewatered
29518	dewatered
16280*	dewatered
23652	dewatered
53159*	dewatered
32889	dewatered
11316*	dewatered
56514*	dewatered
44912	dewatered
38412	dewatered
49501*	dewatered
26295	31
33725	20
38752	17
61302*	15
11225*	13
13009	10
23103	9
64092*	7
13113	5
12693*	insufficient data
35959	insufficient data
44822	insufficient data
11315	bore abandoned
19455	bore abandoned
19456	bore abandoned
33267	bore abandoned
58147*	bore abandoned

Note: * Indicates bore located within Mt. Pleasant Coal Authorisation 459

As noted above, depressurisation of the coal measures is expected to initiate a reversal of pressures in coal measures immediately underlying river alluvium to the east of the Authorisation. Natural upward leakage from the coal measures is estimated from computer simulations at about 0.04 L/sq.metre of alluvial material per day and reversal would result in a downward leakage rising from zero to 0.1 L/sq. metre per day at maximum pit development (20 years). Following mining, the recovery of water levels in the mine pits would again lead to a change in flow directions in coal measures beneath the alluvium with upward leakage restored, although at a lower rate since hardrock aquifer pressures will not recover to the currently measured pressures.

The impacts within the alluvium due to depressurisation of underlying coal measures will be countered by recharge processes acting within the alluvium - rainfall and river recharge will act to replace the very small volumes of groundwater lost to vertically downwards seepage through rapid transmission along gravel and sand braids. Since it is unlikely that the frequency of rainfall and the frequency of high river flows will change significantly over the course of time (independent processes), the water table within the alluvial sediments will continue to be regularly recharged and will remain largely unaffected by depressurisation within the coal measures - impact on river water users and irrigators will be negligible.

7.3 Regional Water Quality

Water quality within the coal measures is generally regarded as poor with salinity/EC ranging from less than 2000 mg/L (3330 EC) to more than 4000 mg/L (6660 EC).

Depressurisation of coal seams is expected to have little impact on the water quality within the seams although in some areas, rainfall recharge may be induced to migrate to increased depth thus potentially leading to quality improvements. Beneath the alluvium, the current estimated rate of upward leakage of saline waters (to the alluvium) will be slowed and eventually reversed. The reversal of leakage will potentially result in improvement in water quality in underlying coal seams and improvement in quality in some areas of the alluvium although the change may be difficult recognise or measure.

On cessation of mining, groundwater seepage to the final void is expected to lead to a recovery of water levels within the coal measures and hence a reduction of downward leakage from the alluvium. Ultimately, when void levels recover to levels above the elevation of groundwater levels in the alluvium, a flow reversal will again occur leading to re-establishment of upward leakage from the coal measures to the alluvium but at a much lower rate than is postulated at present. The quality of water leaking upwards will initially reflect alluvial water quality but will ultimately tend towards a mixed water quality based on contributions from remaining in-situ coal seams and contributions from void and spoils water quality.

Void spoils water quality is estimated to potentially rise from about 2400 mg/L to a maximum of about 4800 mg/L based on an available and mobilisable salt load of 697000 tonnes. However, the leaching process is expected to be very slow; the process will only commence when water levels in the void recover and since this will be gradual and of the order of 80 years or more, the maximum predicted salinity of void water may not be reached. The solute will accumulate in the final void and can be expected to slowly migrate through the coal measures and potentially leak back to alluvial areas adjacent to the Authorisation as groundwater pressures steadily recover.

Groundwater recovery levels in spoils have been estimated using model simulations to be about 150 mAHD. This level results in a reduced flow rate to the alluvium about half the initial rate. The salinity of the spoils water is predicted to be 4800 mg/L maximum or double the salinity of coal measures waters. The combination of reduced flow rates but higher salt load will result in approximately the same transfer rate (of salt) through upward leakage beneath the alluvium.

7.4 Hunter River Water Quality

Impact of salinity within the mining operations can be attributed to changing salinity in groundwater (coal measures natural salinity and diffuse salinity in spoils), and increased salinity in surface water runoff.

Changes in groundwater salinity arising from mining operations are predicted to have negligible impact on the water resources of the alluvial lands and as a consequence, negligible impact on the Hunter River. Possible localised improvements in alluvial lands groundwater will be masked by the wider changes relating to natural recharge and discharge processes. Mine water runoff from the pit areas, haul roads, facilities hardstand and other areas will have elevated salt levels. Such waters will be entirely contained within the mine water management system and used in the coal washing process. In this manner, a component of the overall salt load will be removed from site through export of product coal.

7.5 Hunter River Water Supply

Detailed water management studies using a daily rainfall-runoff model have indicated a mine water deficit for most of the operational period, and a need to draw water from the Hunter. A minimum 1000 to 2000 ML of mine water storage is required to contain seepage and runoff water. When depleted, water will be drawn from the river at a maximum rate of 9.4 ML/day.

During exceptional rainfall periods, surplus storage of mine water will be released to the Hunter River in compliance with the Hunter Salinity Trading scheme. Such releases are calculated to equate to 'flood flows' of greater than 2000 ML/day. Releases in accordance with salinity credit allocations may also be made for lower flows which fall in the category of 'high flows' rather than flood flows. However these releases are most likely to occur during the later years of mining.

8. Environmental Monitoring

Surface waters and groundwaters together with numerous other environmental parameters, are currently monitored on a regular basis over a wide area. Locations include a number of boreholes within the alluvial lands, boreholes within the coal measures and surface drainages in the western fine rejects area.

A comprehensive surface and groundwater monitoring programme will be instigated as part of the mine environmental monitoring plan. The monitoring programme will include all current monitoring activities together with an expanded programme incorporating all dams and drainages, additional groundwater monitoring bores and real time mine water management through computer based systems. All data will be regularly reviewed with baseline and alert conditions being continually updated. Compliance monitoring will be maintained throughout the mine life and during the aftercare period.

In respect of mine pit and spoils seepage, regular monitoring of pit water and spoils leachate will be undertaken and the data used to develop an optimal strategy for salt minimisation within spoils. This may include accelerated or retarded leaching through enhanced percolation of rainfall.

Water management monitoring will include:

- weather monitoring - rainfall, evaporation, wind etc.
- measurement of water levels and water quality (EC, pH and ionic speciation) within a regional network of monitoring bores;
- measurement of water levels and water quality (EC and pH) within the mine water dam system through integrated real time management systems;
- monitoring of sedimentation dams for suitability of runoff releases to natural drainages;
- monitoring of the fine rejects emplacement area environment dam and downstream monitoring bores for water quality (EC, pH, ionic speciation and trace elements);
- monitoring of pumpage and water usage for washery, dust suppression, truck washdown;
- compliance monitoring and measurement of water discharges (including quality monitoring to Schedule 2, Clean Waters Act) to the Hunter River in accordance with the Hunter Salinity Trading Scheme;
- regular checks on all dams, contour banks, channels and diversions to ensure stable grassed surfaces;
- Installation of a transfer system to convey data from the mine to DLWC in compliance with the trading scheme;
- annual reporting as part of licensing conditions.

In addition to the above and as part of overall quality procedures, the monitoring programme will be subject to review annually by C&A Environmental Division and/or their appointed consultants.

9. Summary

Groundwater and surface water management studies have been conducted for the Mt. Pleasant Authorisation. The studies have included extensive drilling, sampling, testing and monitoring of the groundwater environment and detailed assessment and computer simulation modelling of proposed groundwater and surface water management scenarios.

Groundwater studies have included insitu testing of coal seams and interburden at more than 20 bore locations using injection, pump out and packer test methodologies. Results of drilling and testing confirm the presence of 2 basic aquifer regimes - the hardrock coal measures (including the shallow weathered zone) and the alluvium overlying the coal measures and hosting the Hunter River.

Within the hardrock aquifer system the coal seams act as the main water transmission zones albeit at very low rates of flow. Interburden materials comprising mostly sandstones and siltstones, indicate extremely low permeabilities with certain test zones indicating the potential to hydraulically isolate formations. The shallow weathered zone acts as a thin aquifer system providing a conduit for rainfall recharge to the deeper coal measures. The alluvium, in contrast to the coal measures, is a highly transmissive aquifer system comprised of gravels, sands and silts, hydraulically coupled to the Hunter River and other drainages. The alluvium acts as a major groundwater storage system being recharged by the river during periods of high river flow, and discharging to the river (via bank seepage) during periods of low flow.

Water qualities within the coal measures are generally poor with salinities ranging from 2000 mg/L to more than 4000 mg/L. Water qualities within the alluvium are variable. Near the river, salinity is reduced and the water quality is consistent with river water quality. In areas closer to the hills and areas where the alluvium permeability is reduced through the presence of silts, salinity is generally observed to increase. Where upward leakage from the coal measures is prevalent, it is likely that localised water quality will be impaired. Water qualities measured in 3 observation bores constructed within the alluvium vary from 485 mg/L to 587 mg/L while DLWC records indicate salinities as high as 1300 mg/L.

Monitoring of groundwater levels over a period of more than 2 years in test bores within the coal measures and in 3 observation bores constructed in the alluvial lands, indicates groundwater movements broadly correlating to rainfall or lack thereof. The extended drought period during 1992-1995 resulted in a steady decline in aquifer pressures measured at coal measures bores but generally stable or weakly declining levels in the alluvium.

The water table geometry supports a regional aquifer flow regime consistent with topography. Pressure gradients developed in the coal measures support an easterly flow direction towards the alluvium while groundwater levels within the alluvium support a downstream flow regime consistent with the direction of flow in the Hunter River. The elevated pressures within the coal measures suggest the potential for upward leakage beneath alluvium.

In order to understand the many complex groundwater flow processes which evolve during mining and to develop estimates of mine pit inflows, two computer based simulation models have been developed - a two layered regional model and a vertical section model. These models necessarily simplify the geological system based upon the available data base. In order to ensure findings are broadly acceptable for planning purposes, a conservative approach has been in-built in both models.

Computer simulation of regional effects arising from mine pit developments indicate pit seepage rates rising from zero at the commencement of mining to approximately 1.9 ML/day at year 21 (maximum extent of pit development). When the cumulative effects of mining operations at Bengalla and Dartbrook mines are introduced, the pit seepage rate at year 21 is observed to reduce to approximately 1.6 ML/day. The predicted rates of influx are in a range consistent with seepage rates at other mine locations and generally reflect the very low permeabilities prevailing within the coal measures. Vertical (sectional) model simulations suggest a lower pit influx of 1.2 ML/day.

Pit development will ultimately depressurise coal measures aquifers to a depth of more than 100 metres and potentially lead to a reversal of aquifer pressures beneath alluvial areas immediately east of the Mt. Pleasant Authorisation and west of the Hunter River. The change in aquifer pressures will initiate a reversal of flow beneath the alluvium and groundwater may leak from the alluvium to the coal measures. The rate of leakage is calculated to be of the order of 0.1 litres per square metre of alluvium per day and will be virtually imperceptible since rates of flow within the alluvium are orders of magnitude higher - replacement of the low loss rates will be rapid.

On cessation of mining, flow reversals are predicted to occur when final void water levels achieve an elevation higher than the elevation of the groundwater table in the alluvium. At this time groundwater will again leak upwards from the coal measures to the alluvium. However the rate of upward leakage is predicted to be substantially lower than the pre mining situation since aquifer pressures in the coal measures will never be restored to their original levels.

Mine development will affect 30 to 70% of the drainage catchments on the eastern side of the Authorisation. Rainfall runoff within the affected areas will be directed to the mine water management system while runoff outside the affected areas will be diverted around the mining operations via engineered diversion dams and channels, ultimately discharging into the natural drainages. Surface water runoff estimations within the affected areas have been calculated using a catchment simulation model based on daily rainfall receipts and daily soil moisture accounting. Parameters applied to the model have been derived from calibration of other catchments in the region, and from runoff monitoring and measurement at other mine site operations. While such parameters may not concisely reflect the future runoff regime at Mt. Pleasant, the estimations are considered to be sufficiently accurate for planning purposes.

Development of the fine rejects area to the west of Mt. Pleasant will result in loss of catchment runoff over the mine life. Within the north western sub catchment, approximately 43% loss of runoff (measured at the confluence with Sandy Creek) will occur during years 1 to 9 reducing to 34% during the years 10 through 20. In the southern sub catchment, 30 % loss of runoff will occur during the final years of mining. In the greater Sandy Creek catchment above the confluence with the southern sub catchment, approximately 3.6% loss of runoff will occur during the mine life. Seepage from beneath the rejects impoundments will be at a very low rate due to the low permeability of tailings. Seepage will migrate westward within coal measures for the first few years of mine development. Seepage pathways will be altered to an easterly direction as the mine pit is developed. Within 5 years most subsurface flow will be directly towards the pits and will remain that way for more than 80 years. Observation bores will be installed downstream of the emplacement area and regular monitoring will be conducted. Any suspected leakage will be contained by construction of interception trenches, equipping bores as pumping-capture wells or selective grouting of any conduit structures. Groundwater quality within the catchment will not be impaired.

Comprehensive mine water management simulations have been conducted on a daily accounting basis and have included provisions for the coal preparation plant, dust suppression and truck washdown together with minor provisions. A number of storage volumes have been tested against variable rainfall histories extracted from the 100 year rainfall record, to determine a target storage range and design storage volume based on containment of runoff from all catchments. The rainfall histories have included both an extreme drought period and an extreme wet period to explore storage responses. Findings clearly indicate a water deficit and hence a need to draw make up water from the Hunter River.

Storage requirements for mine water are estimated to be 1000ML to 2000ML. This storage volume may result in a need for mine water to be released from time to time depending upon climatic conditions during the 20 year mine life and the storage immediately prior to the onset of rainfall. The probability of mine water releases falls within the 6% opportunity window for releases during periods of flood flow in the Hunter River in accordance with the Hunter Salinity Trading Scheme.

9.1 Sustainable Development

The groundwater and surface water studies conducted at Mt. Pleasant have been designed to address the principles of ecologically sustainable development as defined within the EP&A Act. Two principles are relevant to the groundwater and surface management strategies and potential impacts arising therefrom. These are *the precautionary principle* and *the principle of intergenerational equity.*

The Precautionary Principle

In relation to the precautionary principle, detailed studies have been conducted to identify and predict the impacts arising from the proposed mine operations on the water regimes.

Groundwater impacts relate almost entirely to depressurisation of the hardrock coal measures aquifers. Such depressurisation will affect borehole water supplies constructed in coal measures in proximity to the mine. Water levels in these boreholes will decline steadily over the mine life and will not recover. Where economic loss of yield is demonstrated, water supplies will be replaced either by deepening or replacement of bores, or by provision of alternative sources of water in accordance with Coal & Allied Water Policy for Mt. Pleasant. Bores and groundwater resources within the alluvial lands immediately east of the Authorisation, will be generally unaffected.

Potential groundwater impacts have been identified within the western fine rejects catchment. Calculations indicate any deep seepage of rejects leachate is likely to adopt an easterly flow direction and emanate as highwall seepage within the developing mine pit. The leachate is expected to be benign in respect of trace elements but potentially elevated in salts although the salinity will fall over a period of time as leaching and flushing occurs within the emplacement structures. As a precautionary measure, observation bores will be constructed in the western catchment and equipped when necessary to act as pumping bores to attract seepage and return pumped waters to the mine water system.

In relation to surface water impacts, all rainfall and runoff waters falling in disturbed areas will be directed to, and contained within the mine water management system. Water within this system will exhibit increased salt content and will be used for dust suppression, coal washery, fire hazard control and other usages. Development of the mine will reduce runoff in local drainages until such time as lands are rehabilitated and the runoff redirected back to these drainages. Existing dams located on affected drainages will lose recharge capacity; where economic loss of yield is demonstrated, an alternative supply will be developed in accordance with the Water Policy.

A detailed water management simulation of the future mine developments using sophisticated computer based techniques has demonstrated that the mine will operate with a deficit in supply. Make up water will need to be drawn from the Hunter River at a declining rate from 9.4 ML/day at the commencement of mining, to approximately 7.5 ML/day during years 20 and 21. Water may be drawn from the Hunter River under DLWC licence conditions. Such draw off will not affect regulated flows in the river.

Intergenerational Equity

The principle of intergenerational equity requires that the health, diversity and productivity of the environment is maintained or enhanced for future generations. Since all areas of mining will be rehabilitated, there are no identifiable surface drainage impacts which would substantially affect intergenerational equity.

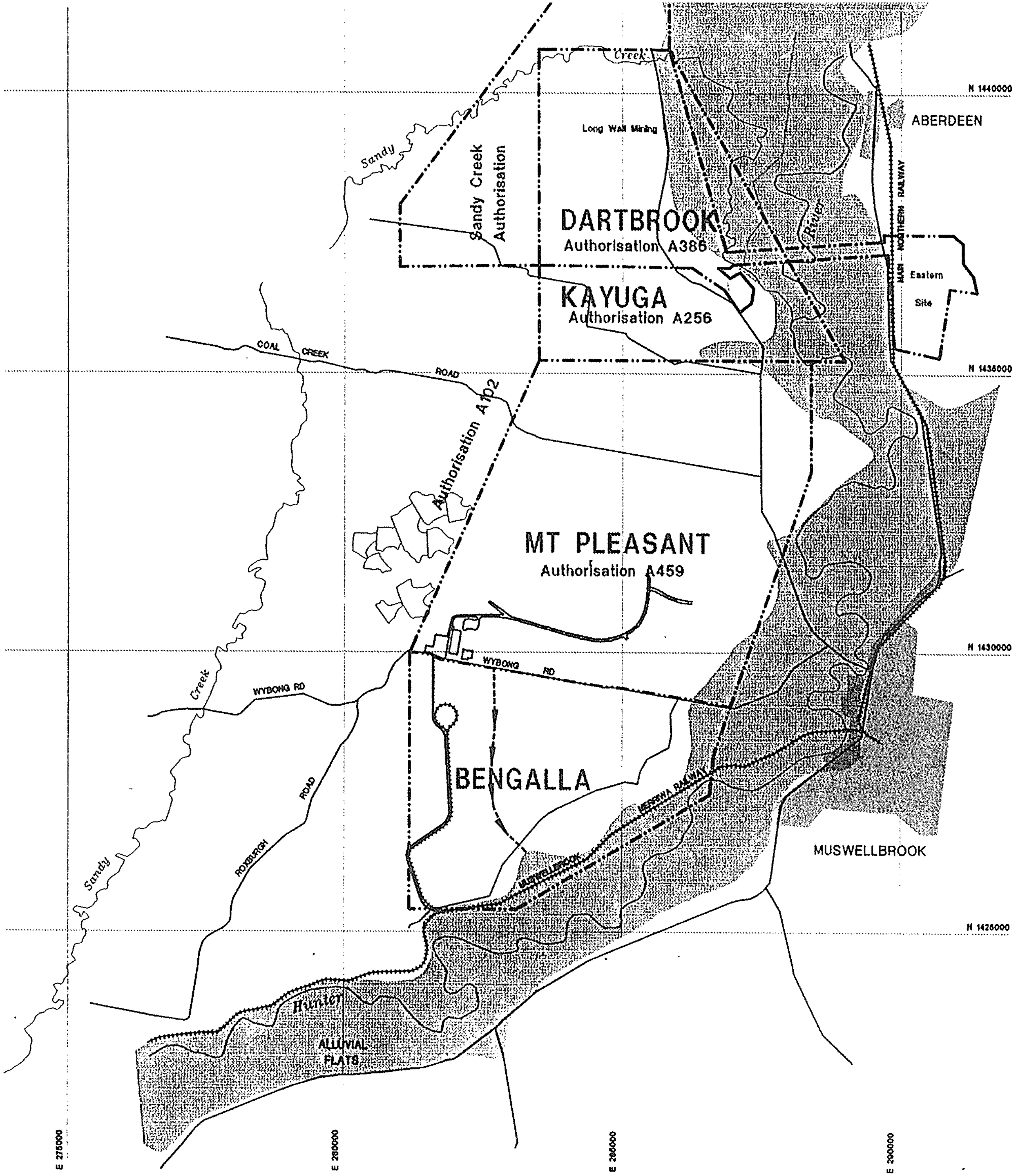
Groundwater seepage into the mine pit(s) will depressurise coal measures over the life of the mine site. During this period, it is possible that certain areas of the alluvium adjacent to the Hunter River which might presently be subject to upward migration of saline groundwater from the coal measures, could undergo a reversal of hydraulic gradients and improved quality groundwaters will result. Subsequent to mining and after a period of recovery of groundwater pressures, hydraulic gradients may again reverse and saline pockets may recur. While it is unlikely that groundwater levels in mined hardrock areas will ever return to pre mining levels due to replacement of hardrock with spoils, there is opportunity for marginally increased salt levels in spoils materials though the processes of leaching.

Seepage from spoils to areas beyond the proposed pits (via migration within coal seams) has the potential to affect water quality in localised areas within the alluvium. However calculations indicate that any seepage and impact on alluvial floodplain water quality would be an exceptionally slow process that would be largely mitigated by reduced salt loads and dilution effects within the floodplain. In addition seepage from the western fine rejects emplacements has the potential to migrate regionally within the deeper coal seams. However, calculations indicate seepage will be directed towards the mine pit and subsequent void. Carefully designed capping will ensure minimal percolation and leaching of salts contained within the emplacements.

In order to ensure correctness in these estimations, a long term programme of spoils and fines rejects leachate monitoring will be initiated. The findings from this programme will be compared with long term research efforts at other mine site locations and if any abnormal impacts can be identified, mitigative measures will be introduced.

10. References

1. Envirosciences Pty Ltd (1993): Environmental Impact Statement for Bengalla Coal Mines.
2. Mackie Martin & Associates (1993): Bengalla Joint Venture, Bengalla Coal Development Area, Hydrogeological Studies.
3. Mackie Martin-PPK (1994): New South Wales Coal Association, Hunter River Salinity Study.
4. Pitman, W.V., 1976. A mathematical model for generating daily river flows from meteorological data in South Africa. HRU Report 2/76
5. Townley, L.R. (1990): Description of and users manual for a multi layered finite element aquifer flow model AQUIFEMN.
6. McDonald M.G. and A.W. Harbaugh, 1988. A modular three-dimensional finite-difference groundwater flow model. USGS Report 83-875.
7. Lau, J., 1997. Report on field mapping on "Broomfield" - Mt. Pleasant lease. April 1997
8. CMPS&F, 1997. Report for coal fine reject storage facility to Coal & Allied Operations Pty Limited for Mt. Pleasant.



RUST PPK
Environment & Infrastructure

Coal & Allied Operations Pty. Limited
Mount Pleasant Project
Water Management Study

Legend

—··—··—	Authorisation boundary
——	Mine Infrastructure
++++++++	Rail (Existing and Proposed)
——	Proposed Pipeline
- - -◄- - -	Discharge Drainage Route
▨	Extent of alluvium
▢	Proposed Rejects Storage Dams

Notes

Co-ordinates are Integrated Survey Grid (ISG)

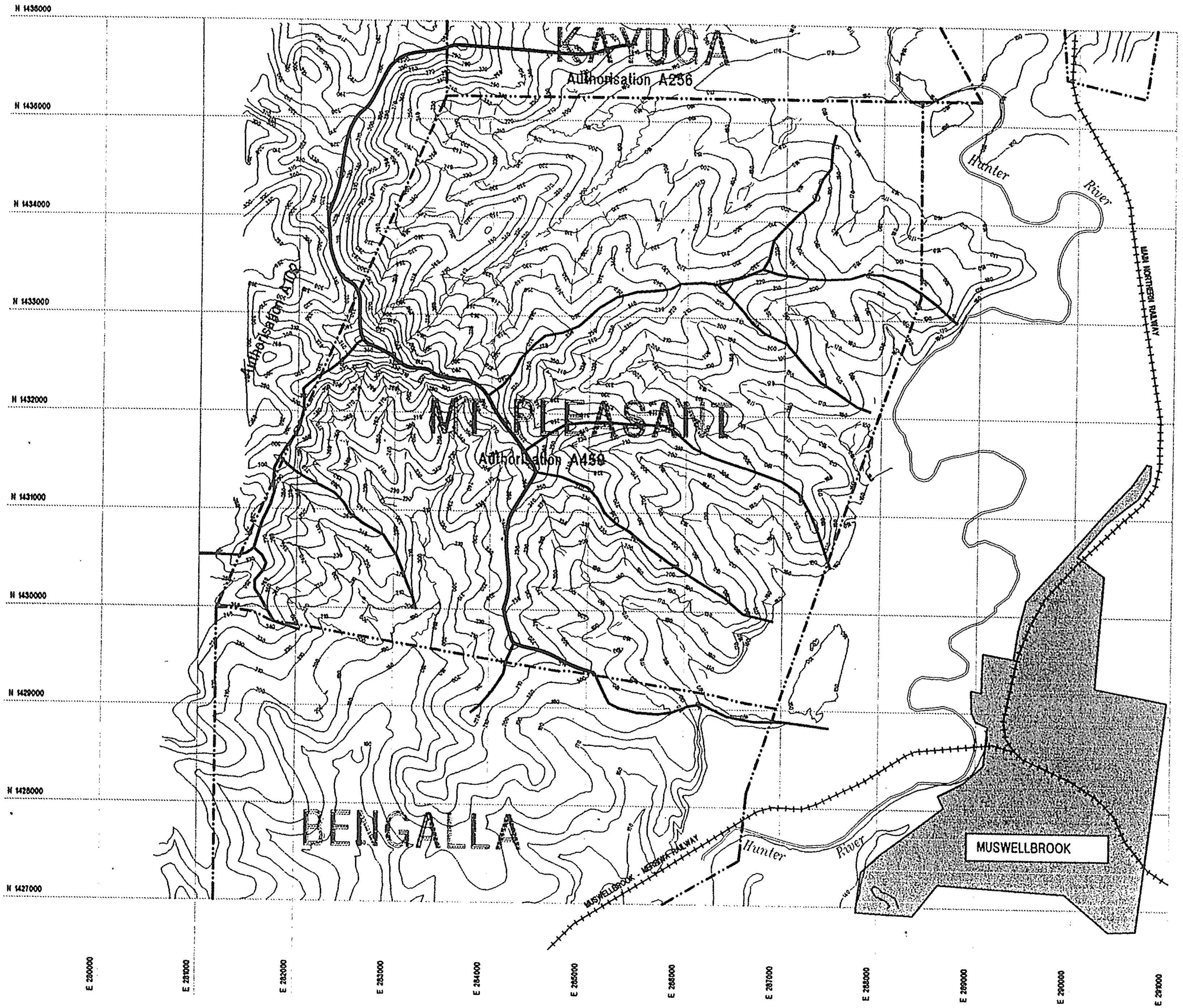
N

0 1000 2000 3000 4000 5000 Metres

Site Location

Figure 1

Coal & Allied Operations Pty. Limited
Mount Pleasant Project
Water Management Study



Legend

- ‒··‒··‒ Authorisation boundary
- ——250—— Topographic contours (mAHD)
- ——— Catchment divide

Notes

Contour Elevations in mAHD
Co-ordinates are Integrated Survey Grid (ISG)
Source of Data - Coal & Allied Operations Pty Limited

N

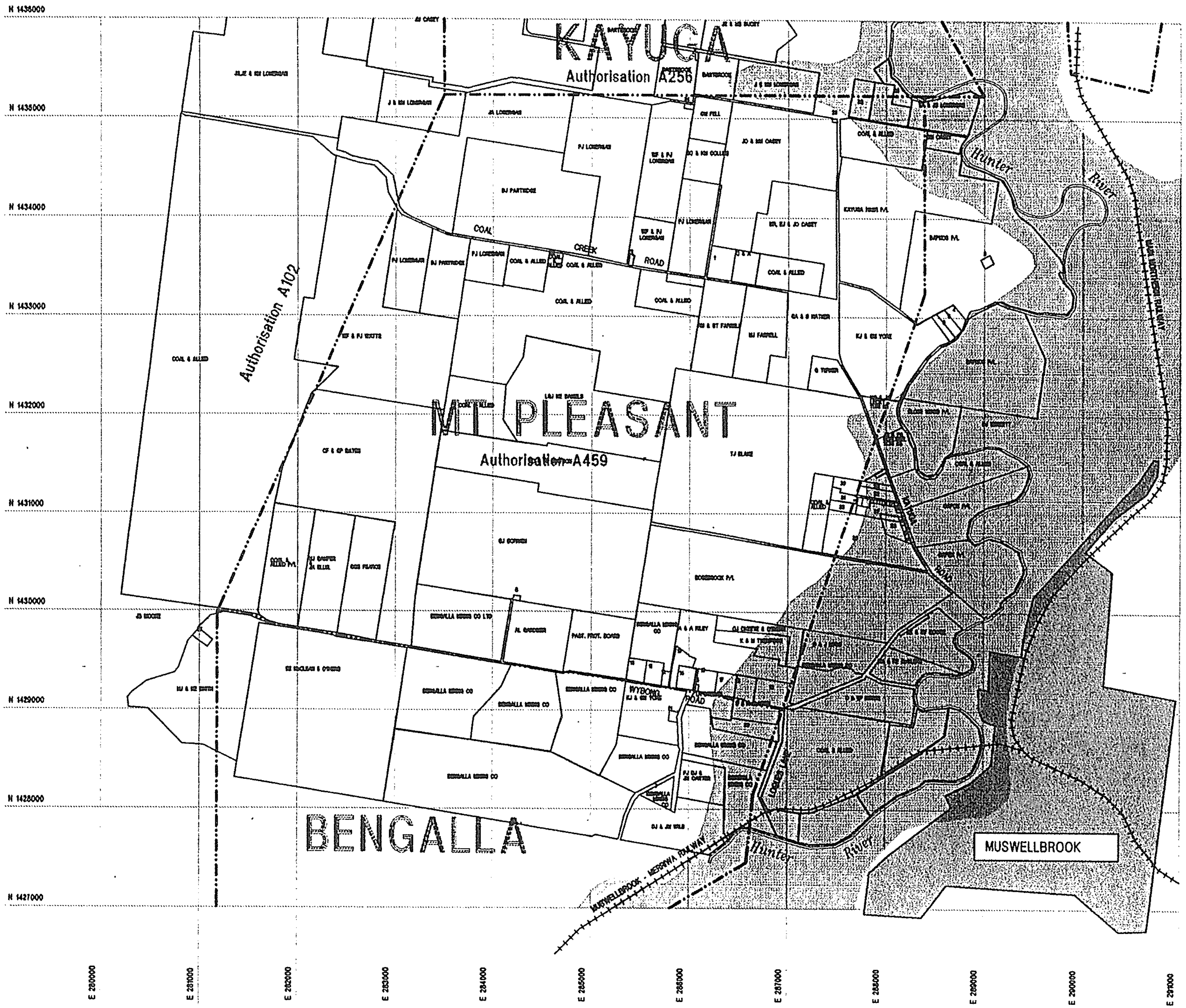
0 500 1000 1500 2000 2500 Metres
ORIGINAL SCALE 1: 40000

Topography

Figure 2

RUST PPK
Environment & Infrastructure

Coal & Allied Operations Pty. Limited
Mount Pleasant Project
Water Management Study



REFER	LAND OWNER
1	COAL & ALLIED
2	TW & ME COLLINS
3	RW & LP UPTON
4	DL YORE
5	S YORE
6	KJ & GM YORE
7	R & K COLLINS
8	AR SKIPPEN
9	OJ O'KEEFE & OTHERS
10	J REVNOLDS
11	BENGALLA MINING CO LTD
12	BENGALLA MINING CO LTD
13	R & M LAWRENCE
14	BENGALLA MINING CO LTD
15	BENGALLA MINING CO LTD
16	L & C HAMSON
17	N & R ELLIS
18	P & B McKINNON
19	G SCRIVEN
20	BENGALLA MINING CO LTD
21	BENGALLA MINING CO LTD
22	TEMPORY COMMON
23	BA & PE LAWERENCE
24	VACANT CROWN
25	COAL & ALLIED
26	J LONERGAN
27	MJ & RA SMITH
28	J & NM LONERGAN
29	COAL & ALLIED
30	JIM HAYES
31	COAL & ALLIED
32	DJ & TL MARSHALL
33	GB & DM BUDDEN
34	GG & PE BUDDEN
35	COAL & ALLIED
36	R BROTHERTON
37	ML GRAY

Legend

—··—··—	Authorisation boundary
▨	Extent of alluvium

Notes

Co-ordinates are Integrated Survey Grid (ISG).

Source of Data ; Coal & Allied Operations Pty Limited.

Coal & Allied is abbreviated to "C & A" for labelling purposes, in some instances.

Ownership details for small lots not shown.

0 500 1000 1500 2000 2500 Metres

ORIGINAL SCALE 1: 40000

Land Ownership

Figure 3

Rainfall Mass - Muswellbrook High School compared to monthly averages

Data supplied by Bureau of Meterology, missing records calculated with reference to Aberdeen Post Office

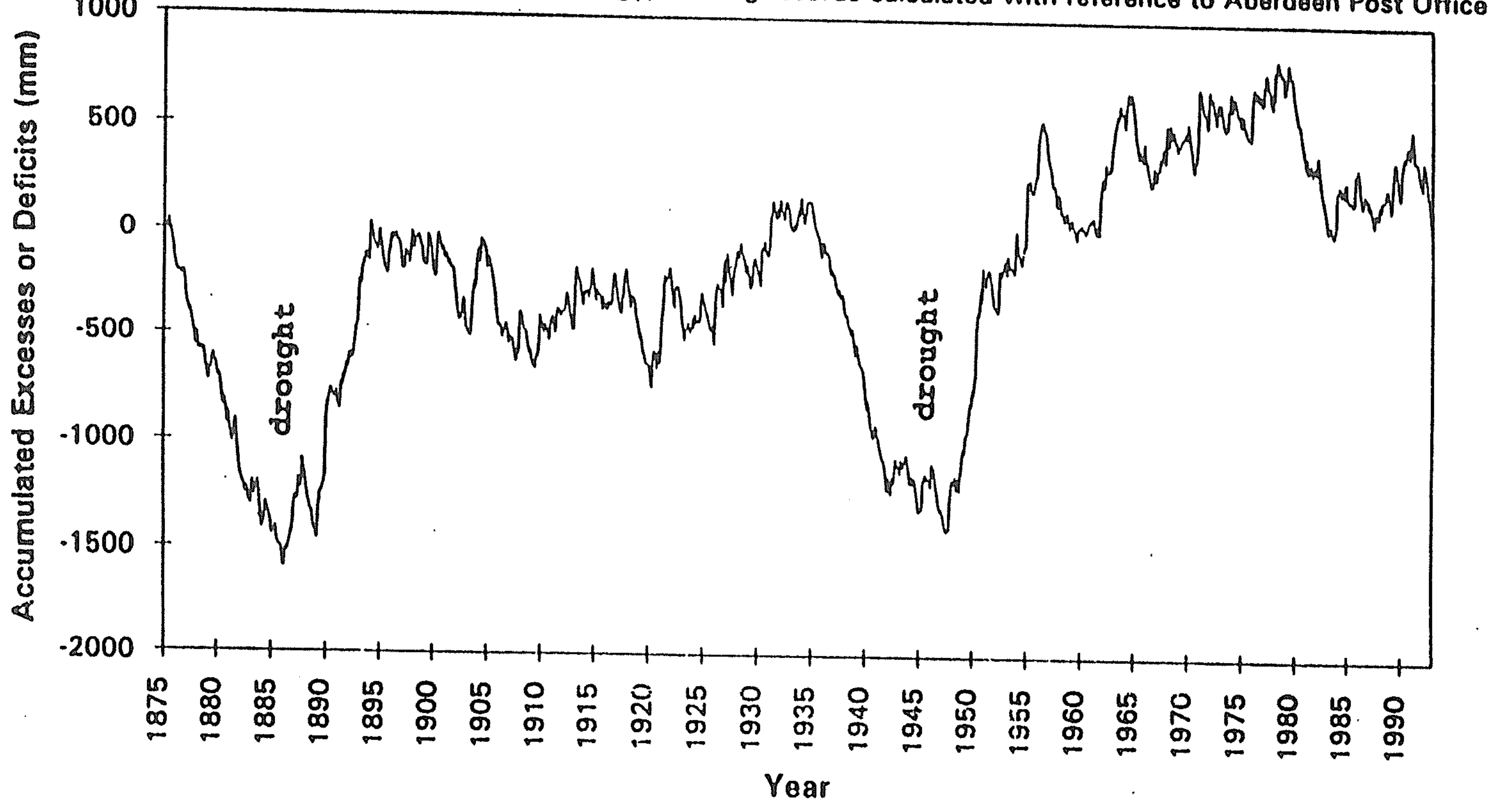
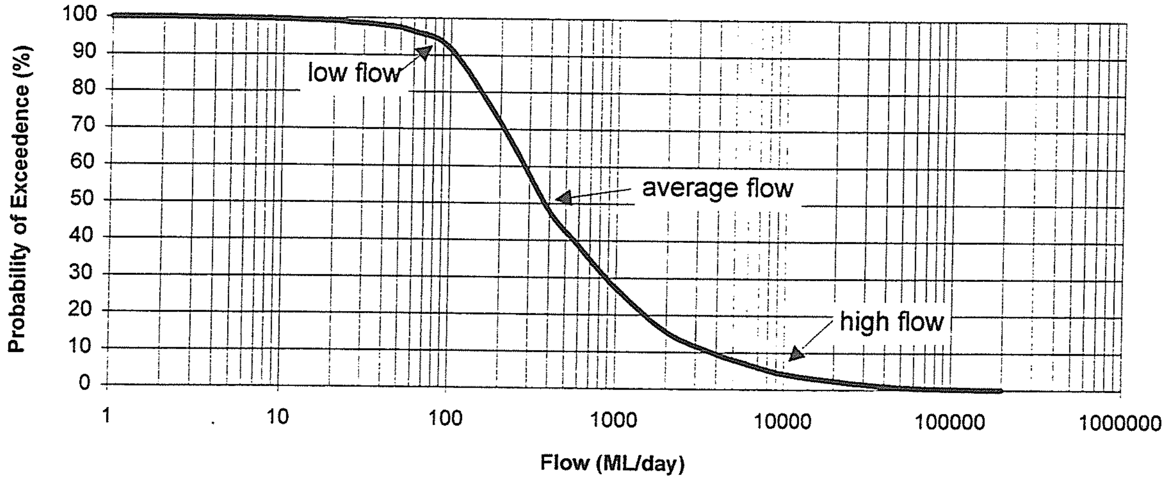


Figure 4

RUST PPK
Environment & Infrastructure

FLOW DURATION CURVE

Gauging Station No. 210001 - Hunter River at Singleton



FLOW DURATION CURVE

Gauging Station No. 210002 - Hunter River at Muswellbrook

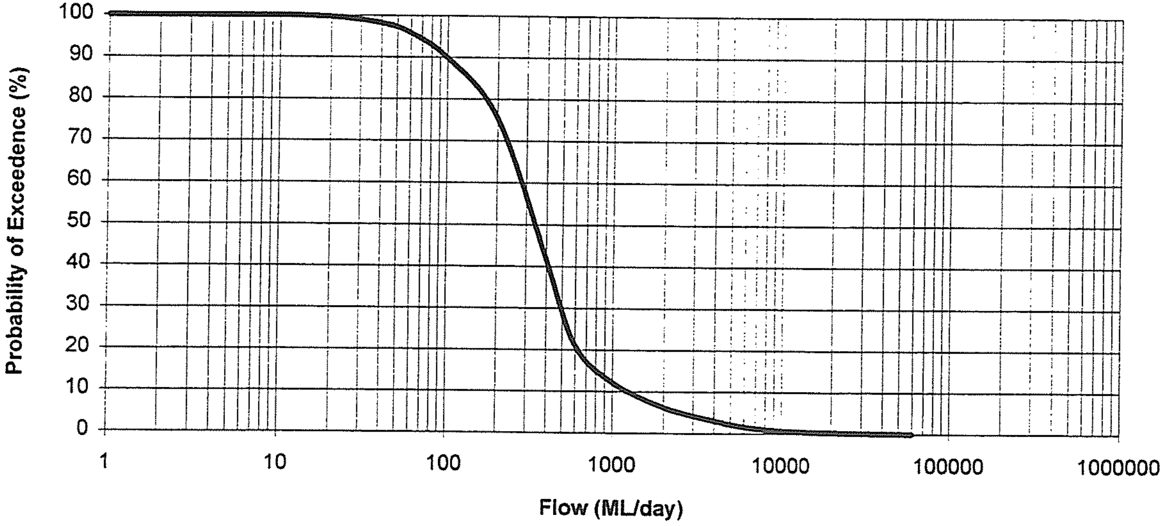
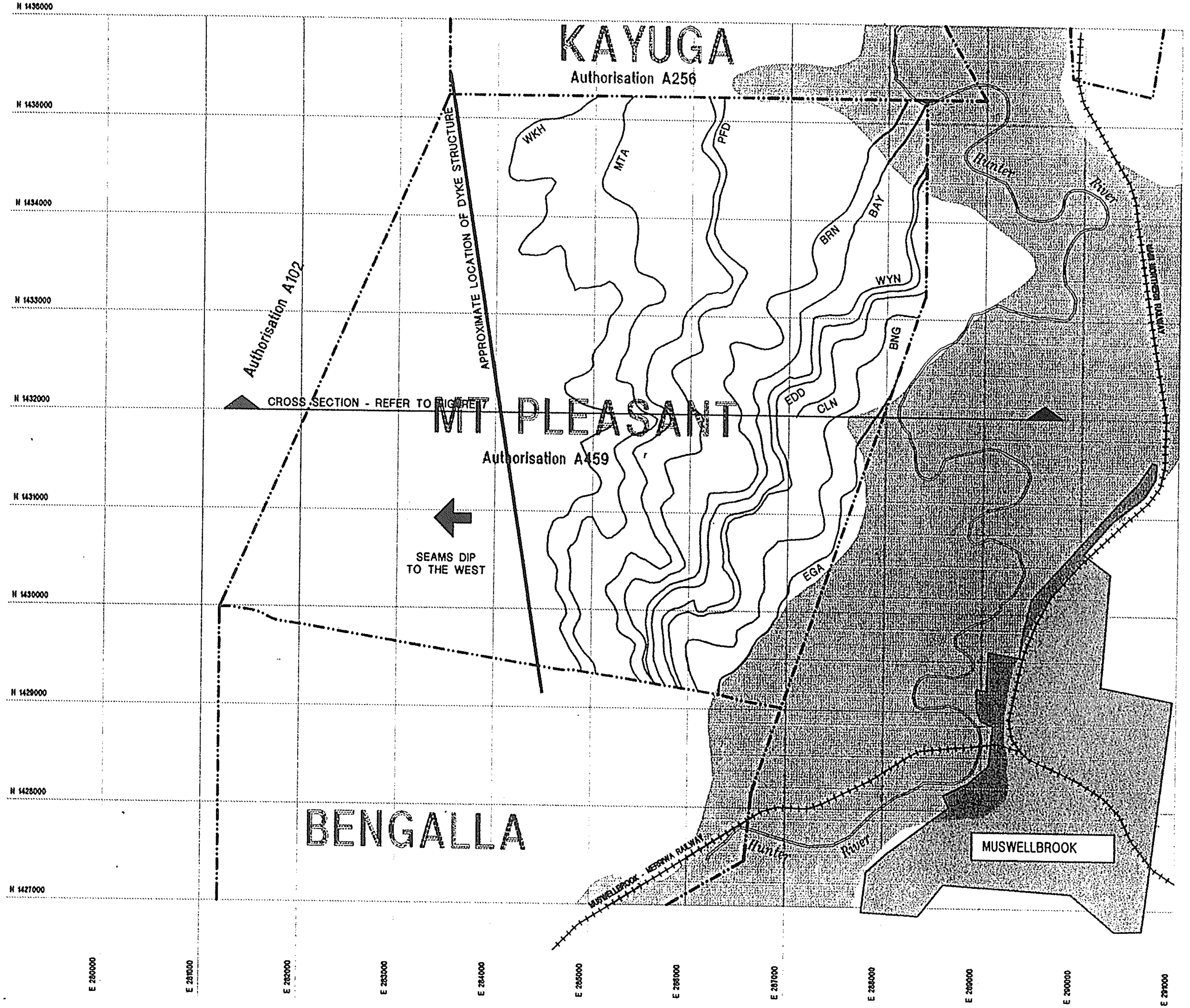


Figure 5

RUST PPK
Environment & Infrastructure

RUST PPK
Environment & Infrastructure

Coal & Allied Operations Pty. Limited
Mount Pleasant Project
Water Management Study



Legend

- —·—·— Authorisation boundary
- ▨ Extent of alluvium
- —— Coal Seam subcrop at base of weathering
- **——** Inferred dyke

Coal Seam Nomenclature

WKH	Warkworth Seam
MTA	Mt Arthur Seam
PFD	Piercefield Seam
VAU	Vaux Seam
BRN	Broonie Seam
BAY	Bayswater Seam
WYN	Wynn Seam
EDD	Edderton Seam
CLN	Clanricard Seam
BNG	Bengalla Seam
EGA	Edenglassie Seam

Notes

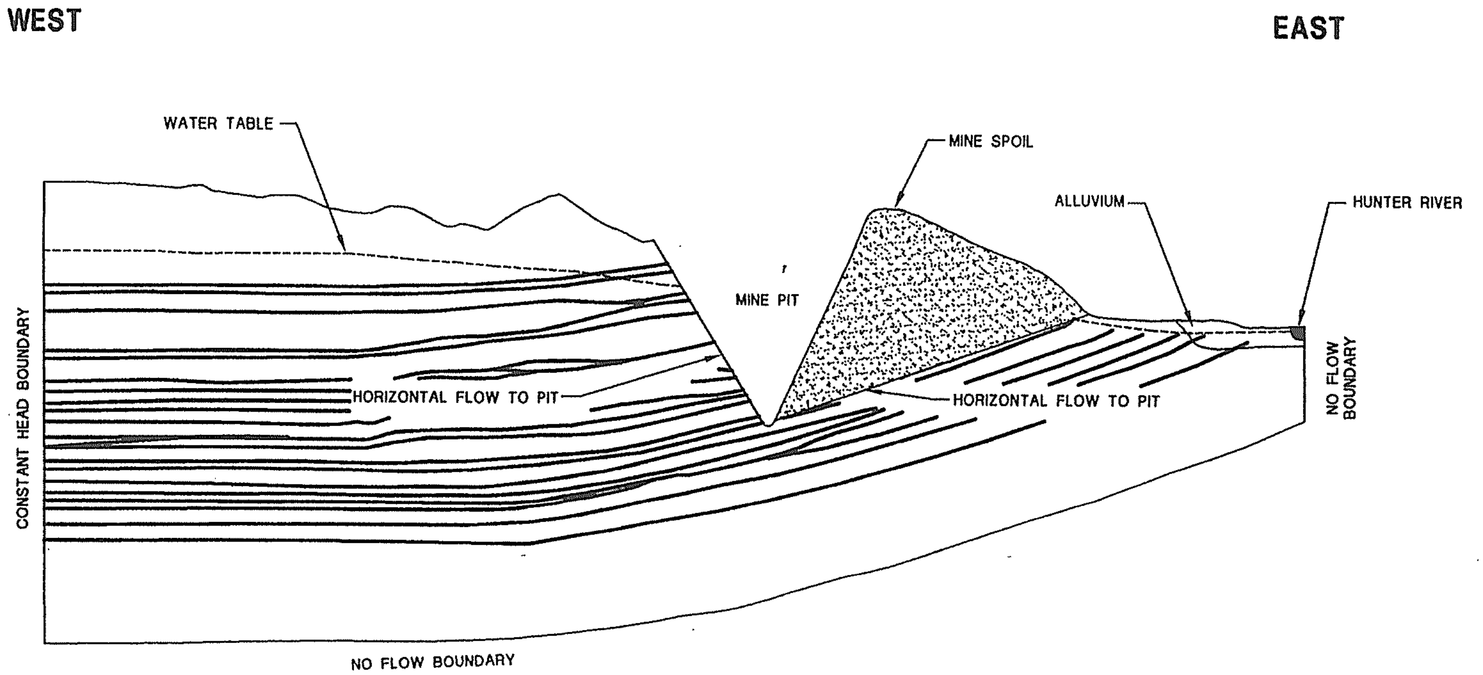
Co-ordinates are Integrated Survey Grid (ISG)

N

0 500 1000 1500 2000 2500 Metres
ORIGINAL SCALE 1: 40000

Local Geology

Figure 6



NOTES:

Not to Scale

Vertical Exaggeration Approximately 5:1

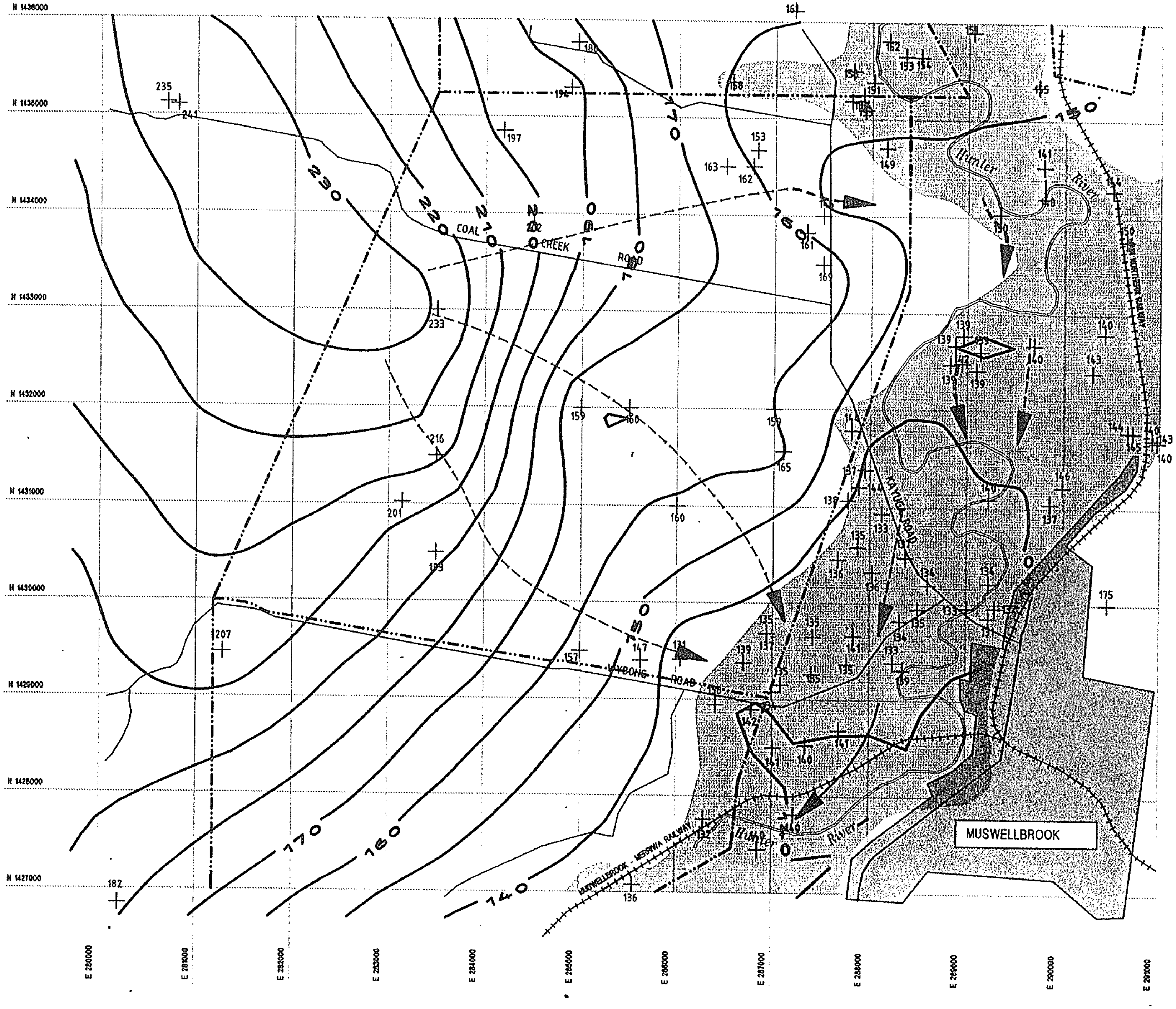
See Figure 6 For Approximate Location

Generalised East - West Cross Section
& Vertical Model Conceptualisation

Figure 7

RUST PPK
Environment & Infrastructure

Coal & Allied Operations Pty. Limited
Mount Pleasant Project
Water Management Study



Legend

—··—··	Authorisation boundary
— 150 —	Regional groundwater pressure distribution (mAHD)
125 +	Control points for groundwater pressures (mAHD)
— — ▶	Inferred groundwater flow line
▨	Extent of alluvium

Notes

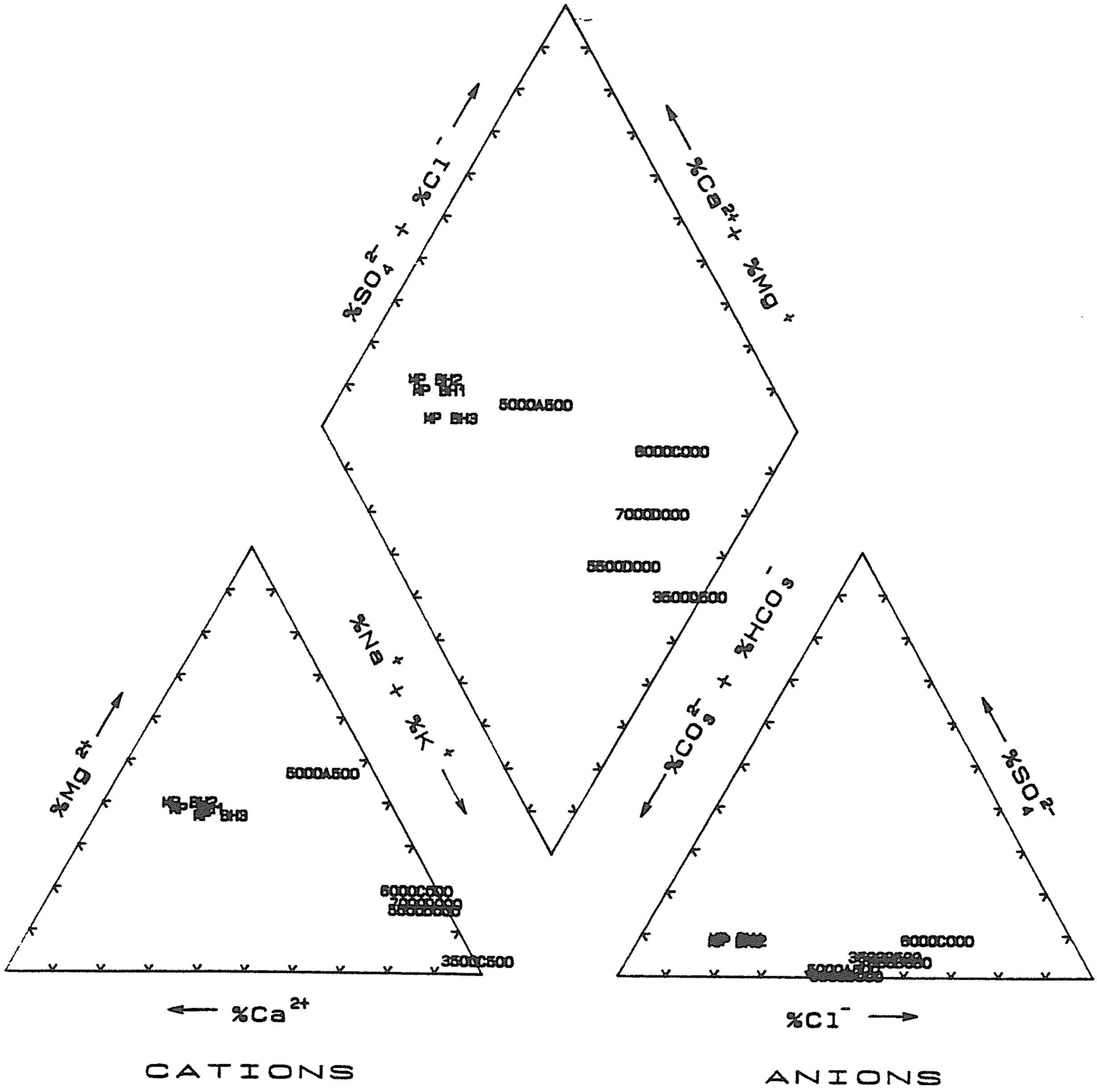
Co-ordinates are Integrated Survey Grid (ISG)
Contour Interval 10m Heights in mAHD
Static Water Level date from 'Department of Land and Water Conservation' records and current study

N

0 500 1000 1500 2000 2500 Metres
ORIGINAL SCALE 1: 40000

Regional Aquifer Pressures

Figure 8

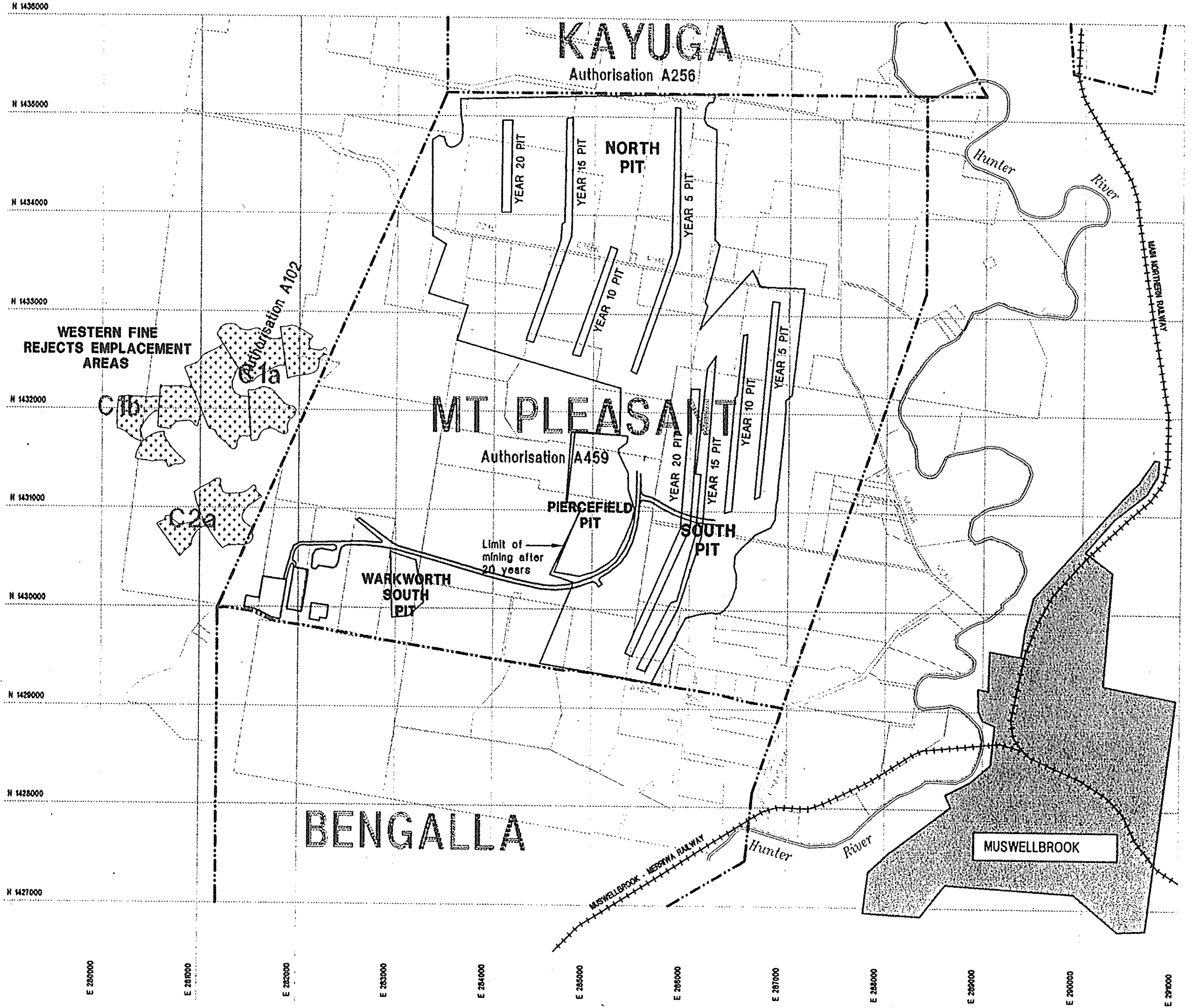


HYDROCHEMICAL FACIES DIAGRAM

Figure 9

RUST PPK
Environment & Infrastructure

Coal & Allied Operations Pty. Limited
Mount Pleasant Project
Water Management Study



Legend

—··—··—	Authorisation boundary
——	Pit floor outlines
☐	Disturbed ground
▨	Western Rejects Emplacement Areas

Notes

Co-ordinates are Integrated Survey Grid (ISG)

Mine infrastructure shown for 20 Year pit development stage

0 500 1000 1500 2000 2500 Metres

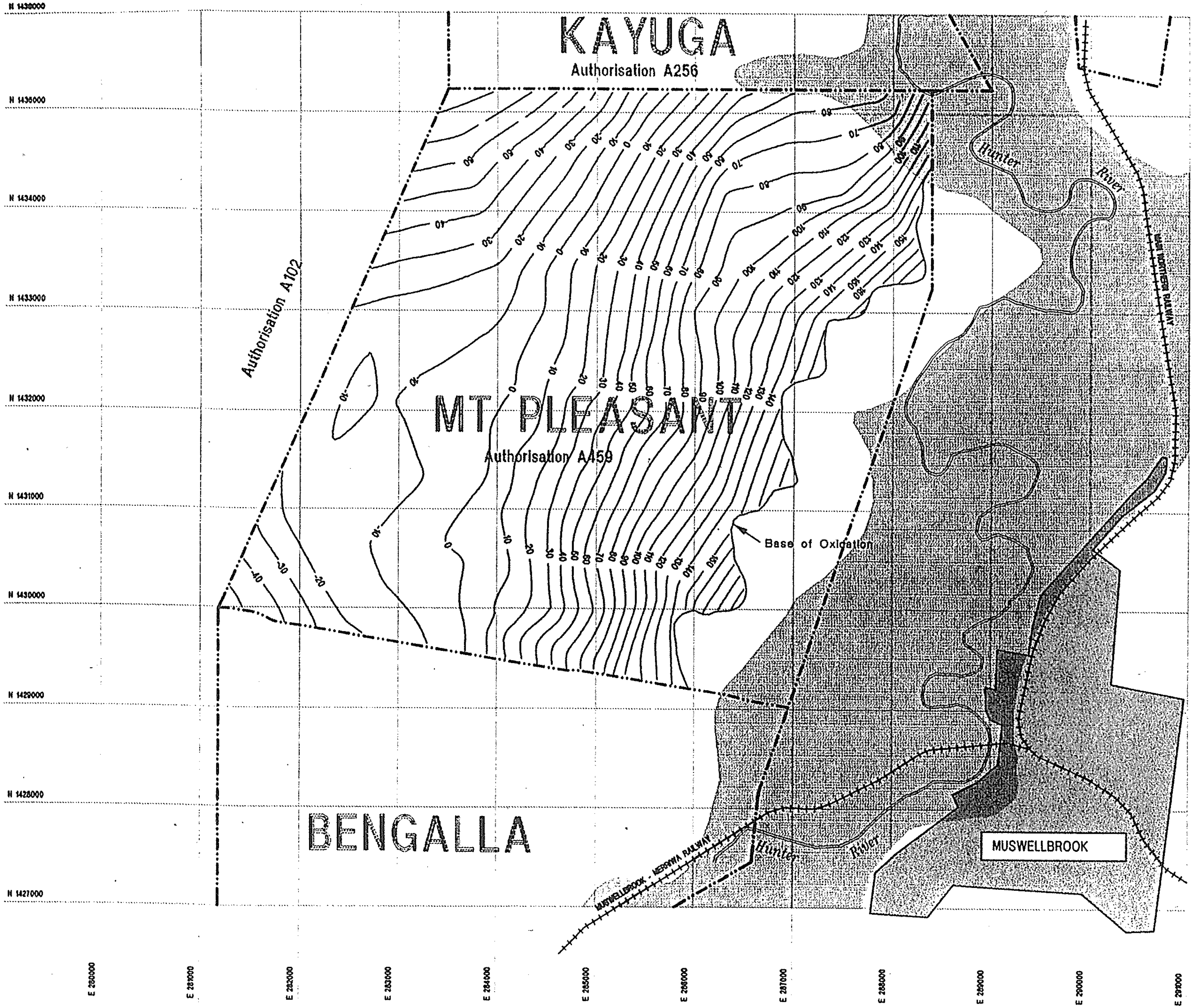
ORIGINAL SCALE 1: 40000

Proposed Pit Development

Figure 10

RUST PPK
Environment & Infrastructure

Coal & Allied Operations Pty. Limited
Mount Pleasant Project
Water Management Study



Legend

—··—··—	Authorisation boundary
——	Structure contours

Notes

Co-ordinates are Integrated Survey Grid (ISG)

Source of Data - Coal & Allied Operations Pty Limited

0 500 1000 1500 2000 2500 Metres

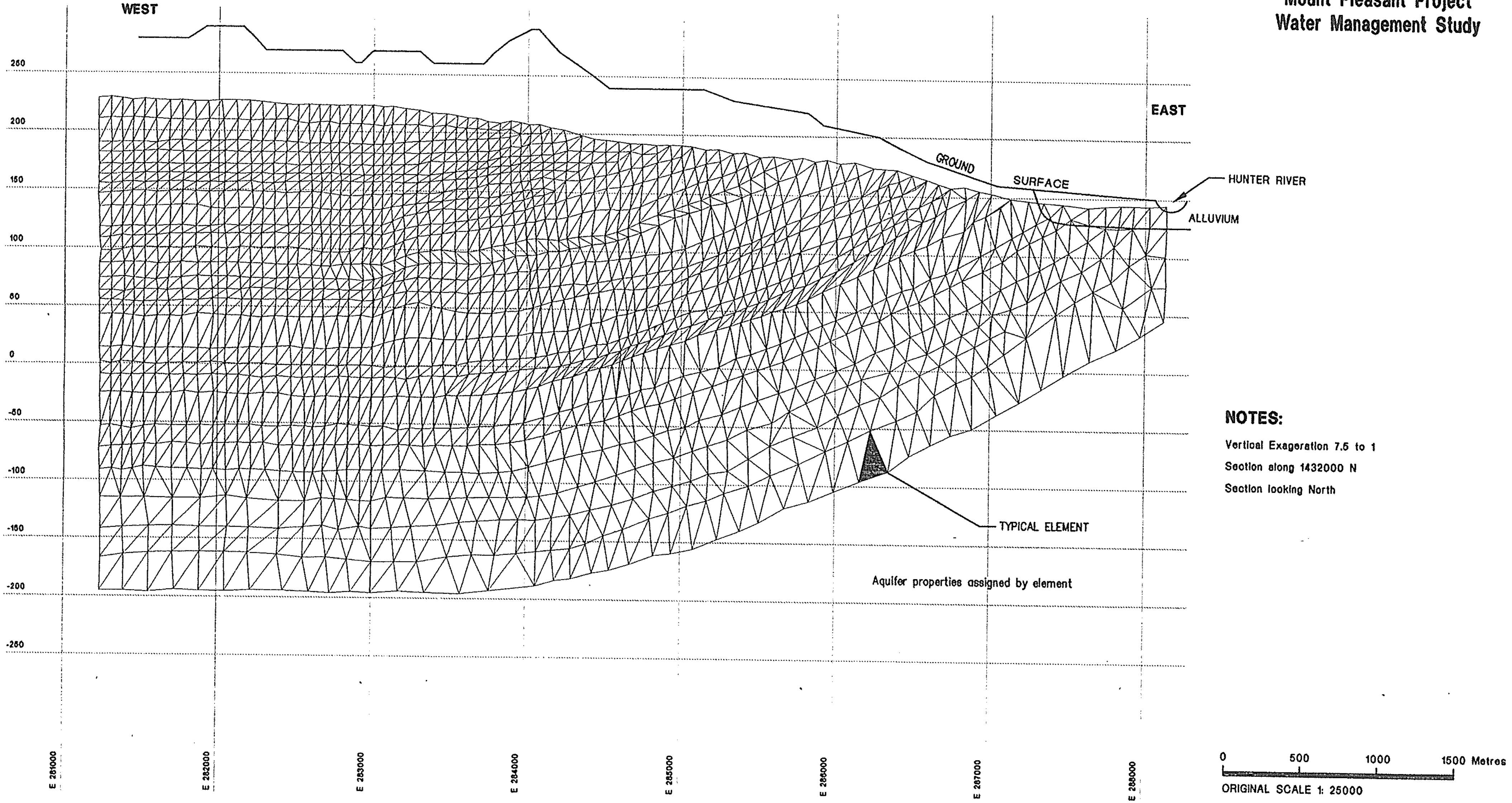
ORIGINAL SCALE 1: 40000

Structure Contours
Base of Edderton Seam

Figure 11

RUST PPK
Environment & Infrastructure

Coal & Allied Operations Pty. Limited
Mount Pleasant Project
Water Management Study



NOTES:

Vertical Exageration 7.5 to 1

Section along 1432000 N

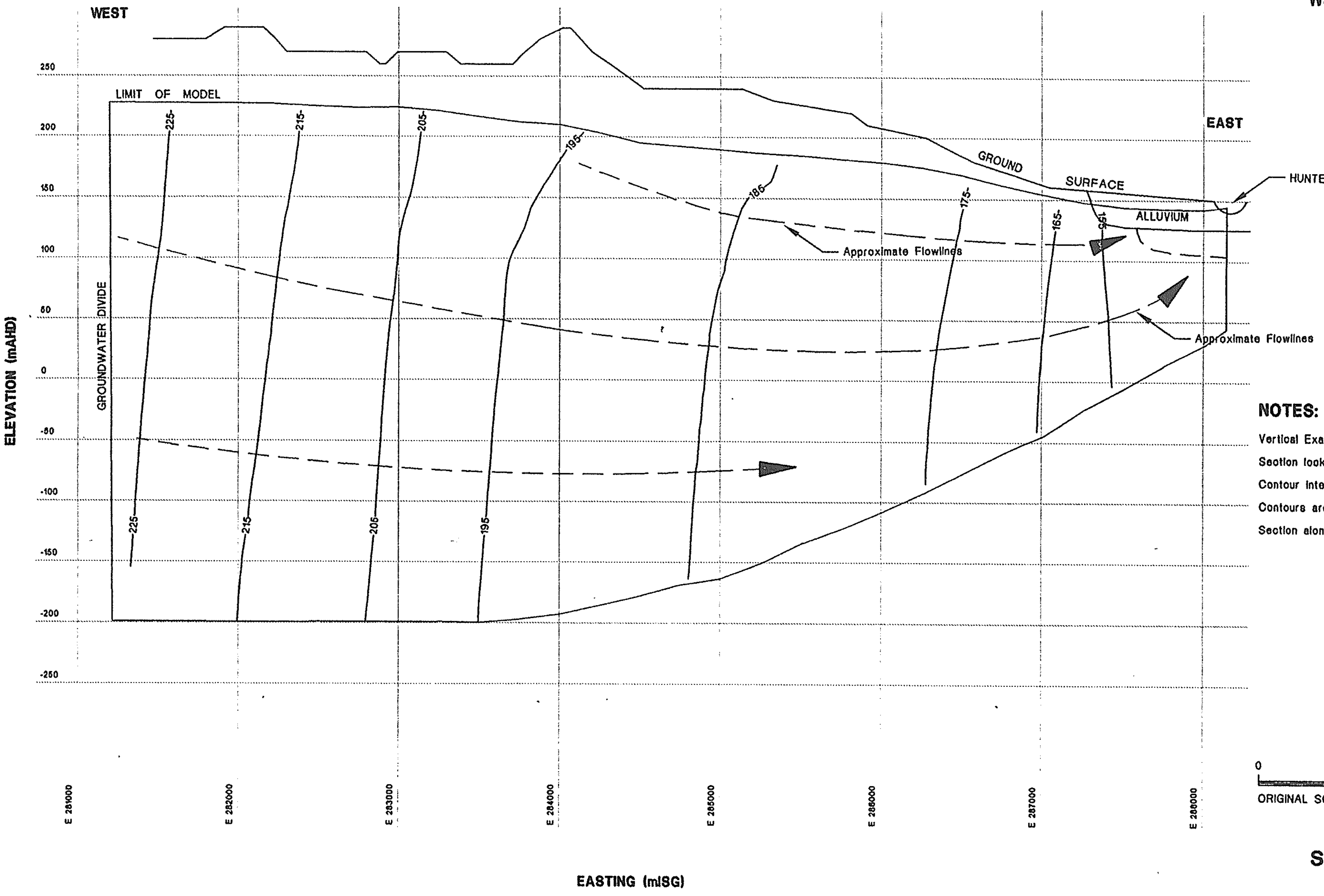
Section looking North

Vertical Aquifer Model Grid
(Finite Element)

Figure 12

RUST PPK
Environment & Infrastructure

Coal & Allied Operations Pty. Limited
Mount Pleasant Project
Water Management Study



NOTES:

Vertical Exageration 7.5 to 1

Section looking North

Contour Interval is 5 Metres

Contours are lines of equal head aquifer pressure

Section along 1432000 N

0 500 1000 1500 Metres

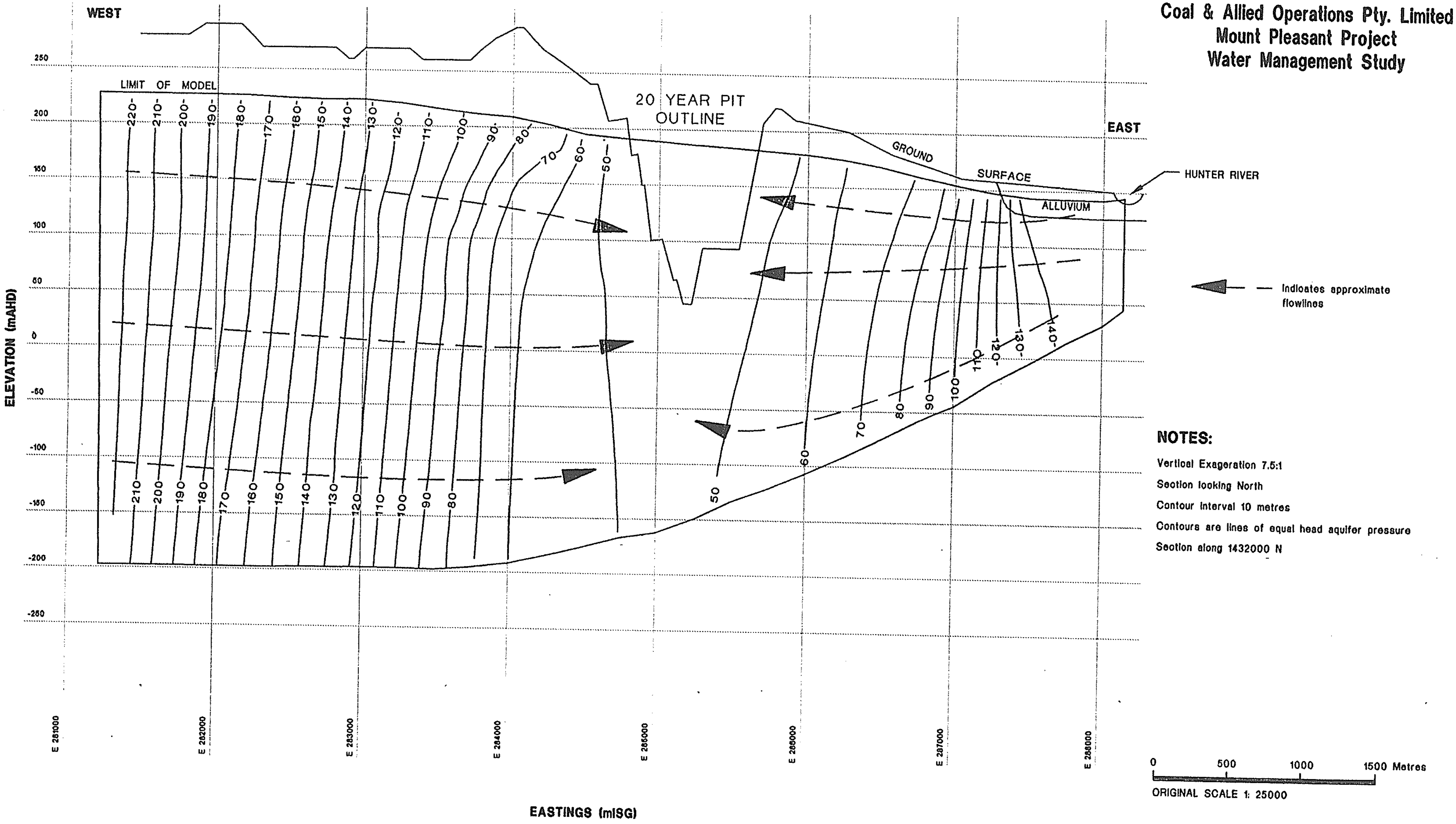
ORIGINAL SCALE 1: 25000

Steady State Calibration Vertical Model

Figure 13

RUST PPK
Environment & Infrastructure

Coal & Allied Operations Pty. Limited
Mount Pleasant Project
Water Management Study



NOTES:

Vertical Exageration 7.5:1

Section looking North

Contour interval 10 metres

Contours are lines of equal head aquifer pressure

Section along 1432000 N

Vertical Pressure Distribution at 20 Years

Figure 14

PIT SEEPAGE THROUGH WESTERN PIT FACE

MOUNT PLEASANT PROJECT

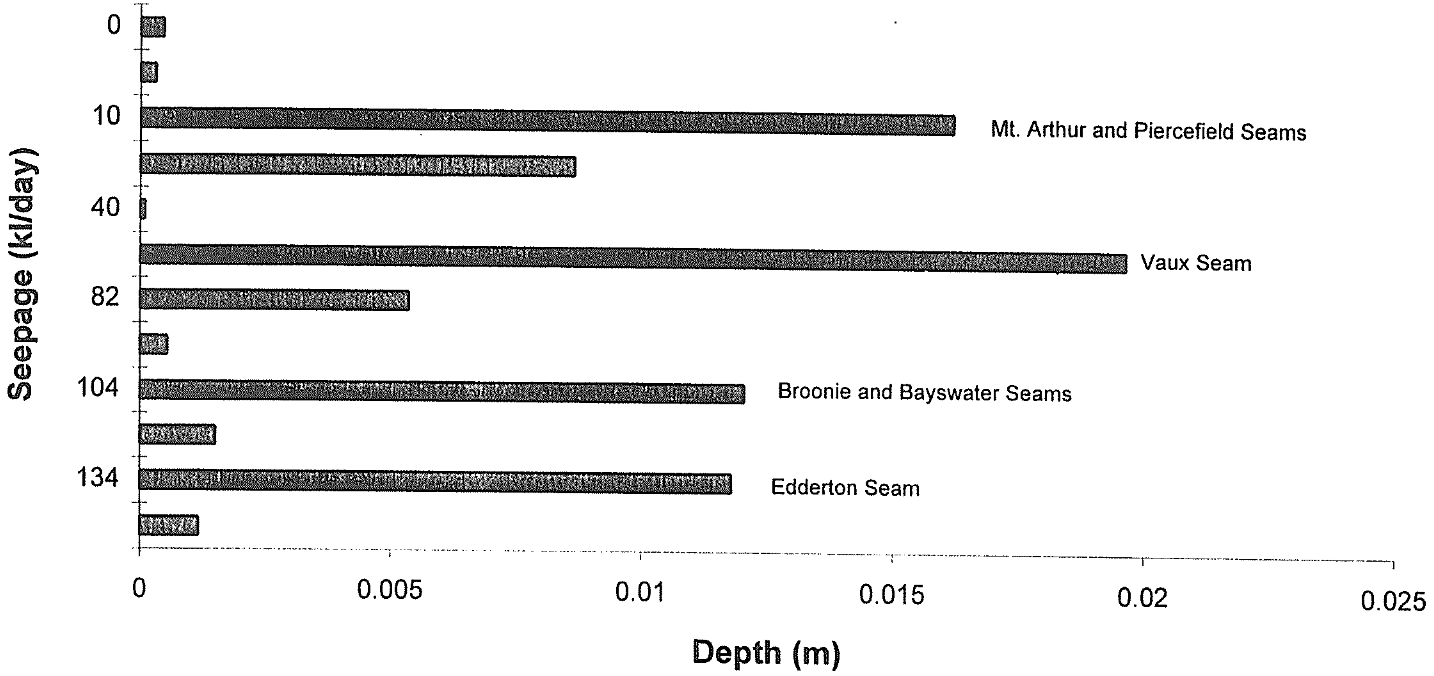
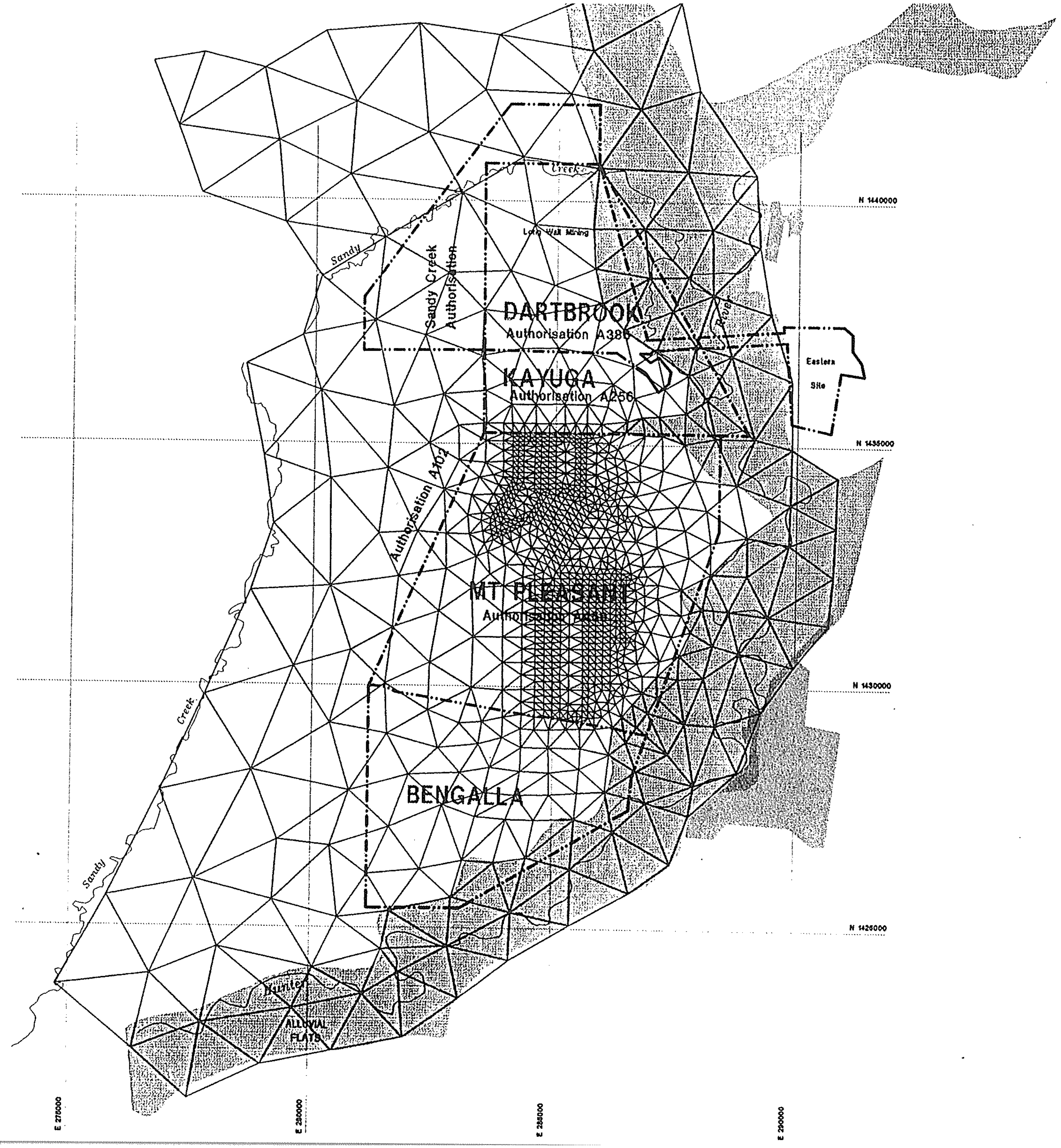


Figure 15

RUST PPK
Environment & Infrastructure

RUST PPK
Environment & Infrastructure

Coal & Allied Operations Pty. Limited
Mount Pleasant Project
Water Management Study



Legend

-··-··-	Authorisation boundary
───	Creeks and rivers
▨	Extent of alluvium

Notes

Co-ordinates are Integrated Survey Grid (ISG)

N

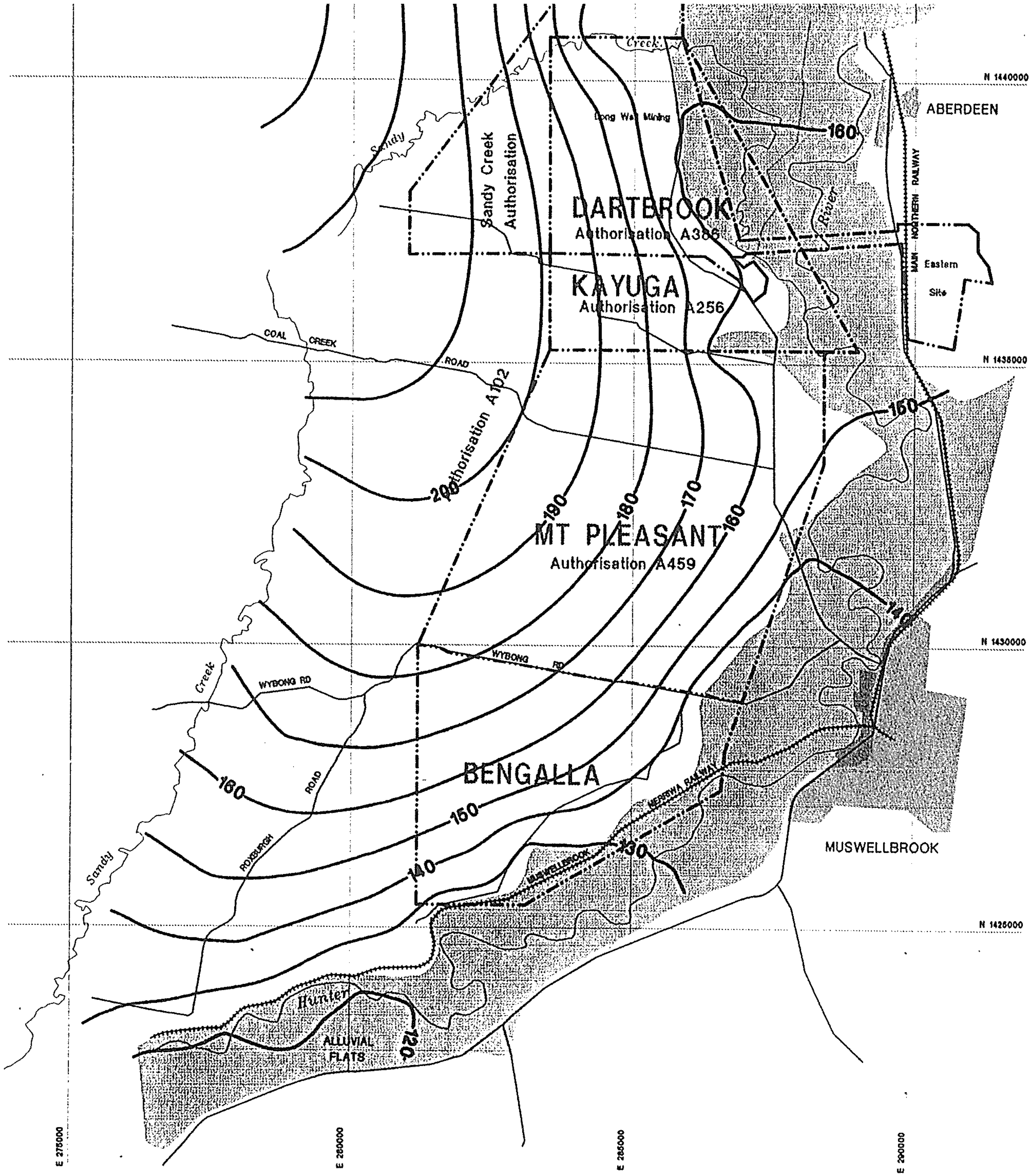
0 1000 2000 3000 4000 5000 Metres

Horizontal Aquifer Model Grid (Finite Element)

Figure 16

RUST PPK
Environment & Infrastructure

Coal & Allied Operations Pty. Limited
Mount Pleasant Project
Water Management Study



Legend

—·—··—	Authorisation boundary
▨	Extent of alluvium
— 140 —	Aquifer piezometric surface mAHD

Notes

Co-ordinates are Integrated Survey Grid (ISG)

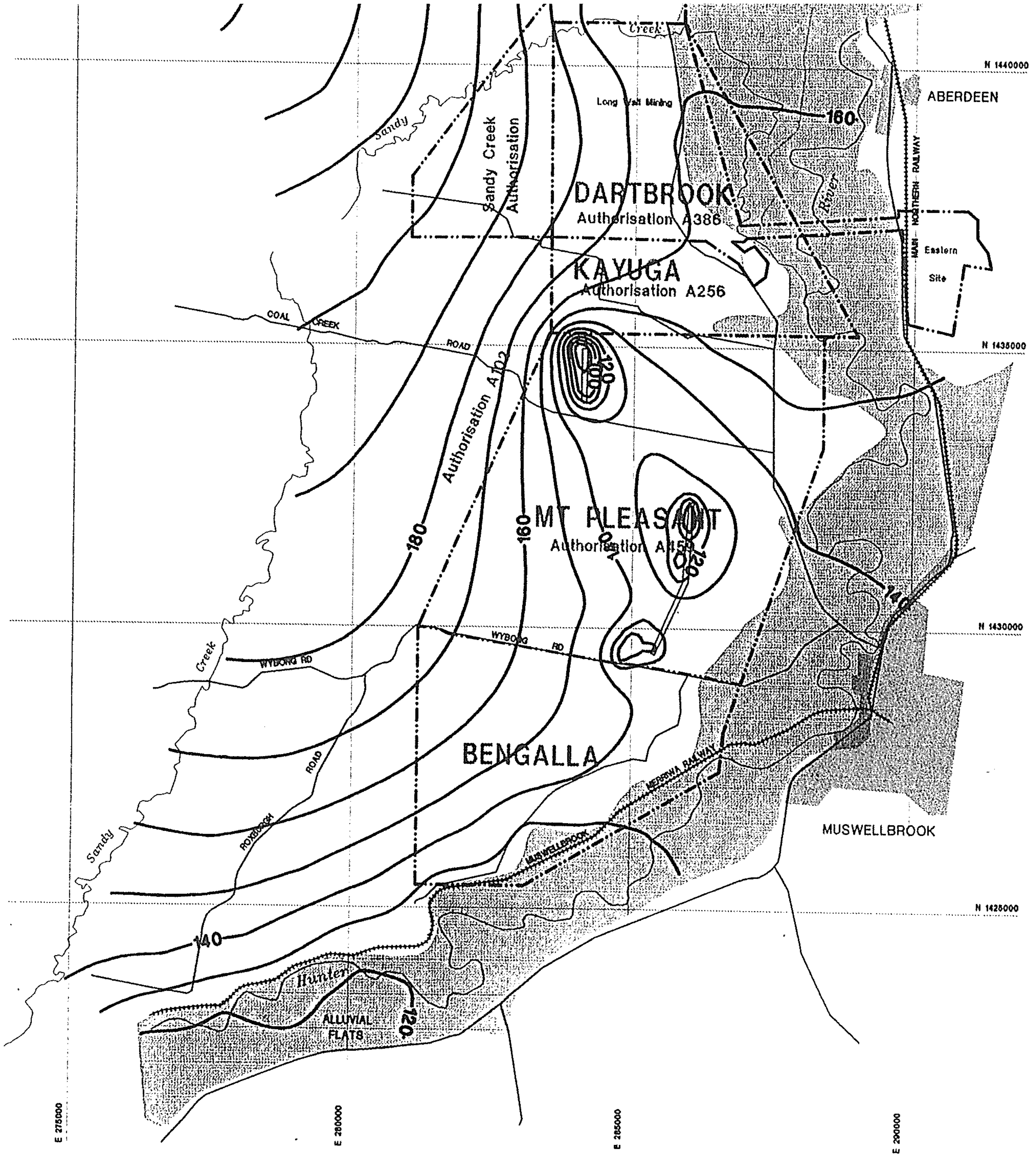
Model aquifer pressure for layer 1 - above Edderton seam floor

N

0 1000 2000 3000 4000 5000 Metres

Modelled Regional Water Table

Figure 17



Environment & Infrastructure

Coal & Allied Operations Pty. Limited
Mount Pleasant Project
Water Management Study

Legend

—··—··—	Authorisation boundary
▨	Extent of alluvium
— 140 —	Aquifer piezometric surface mAHD

Notes

Co-ordinates are Integrated Survey Grid (ISG)

Model aquifer pressure for layer 1 - above Edderton seam floor

Regional Water Table
20 Year Mine Development Scenario

Figure 18

SENSITIVITY OF PIT INFLUX TO PERMEABILITY

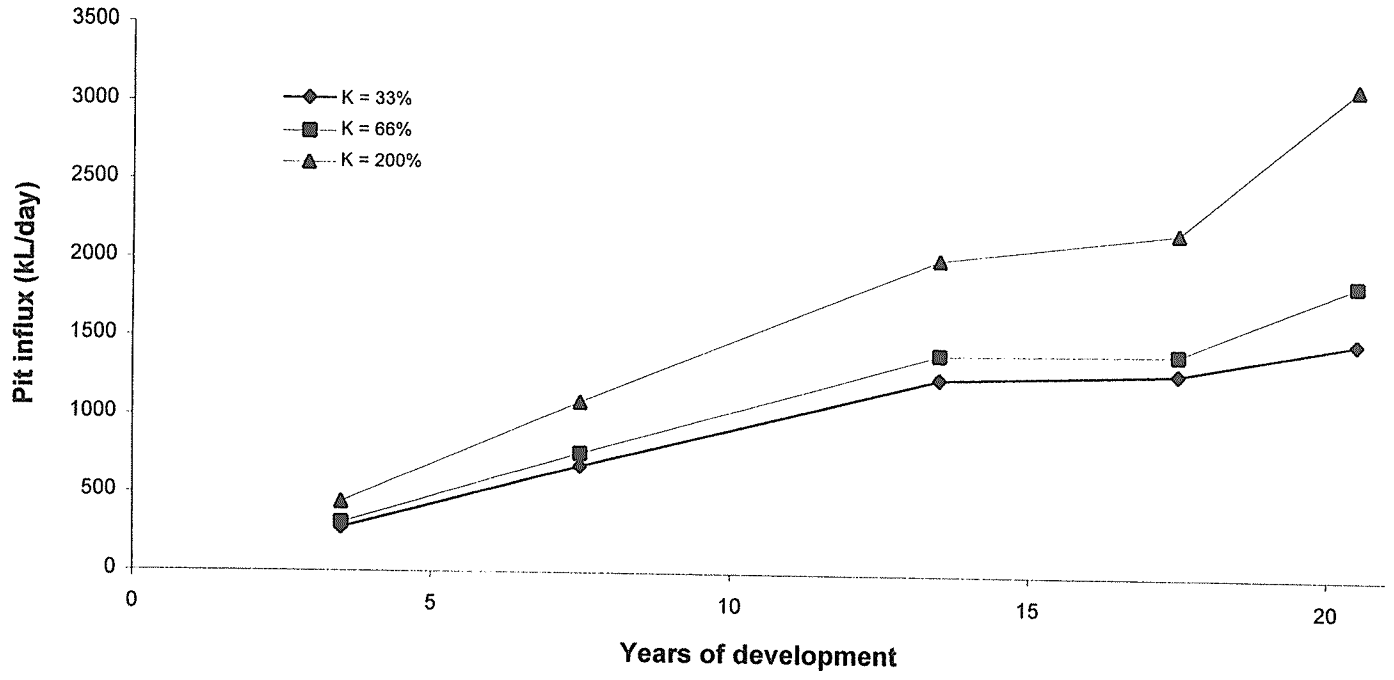


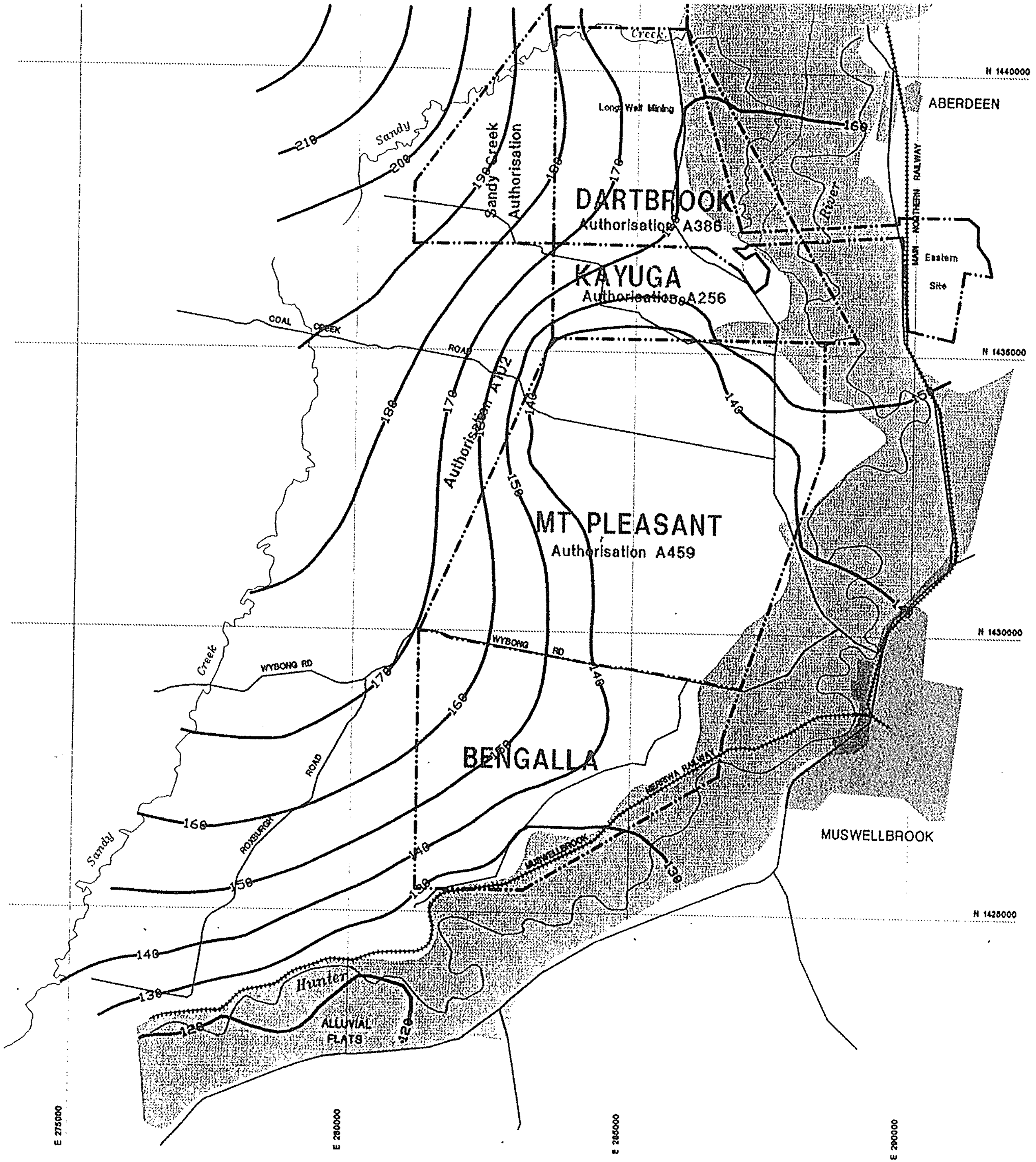
Figure 19

RUST PPK

Environment & Infrastructure

RUST PPK
Environment & Infrastructure

Coal & Allied Operations Pty. Limited
Mount Pleasant Project
Water Management Study



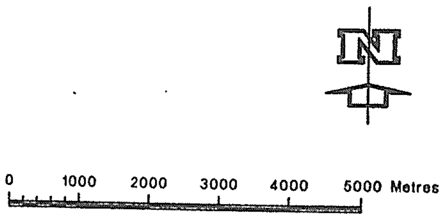
Legend

- Authorisation boundary
- ▨ Extent of alluvium
- 140 Aquifer piezometric surface mAHD

Notes

Co-ordinates are Integrated Survey Grid (ISG)

Model aquifer pressure for layer 1 - above Edderton seam floor



Final Void Water Table Recovery at 20 Years After Closure

Figure 20

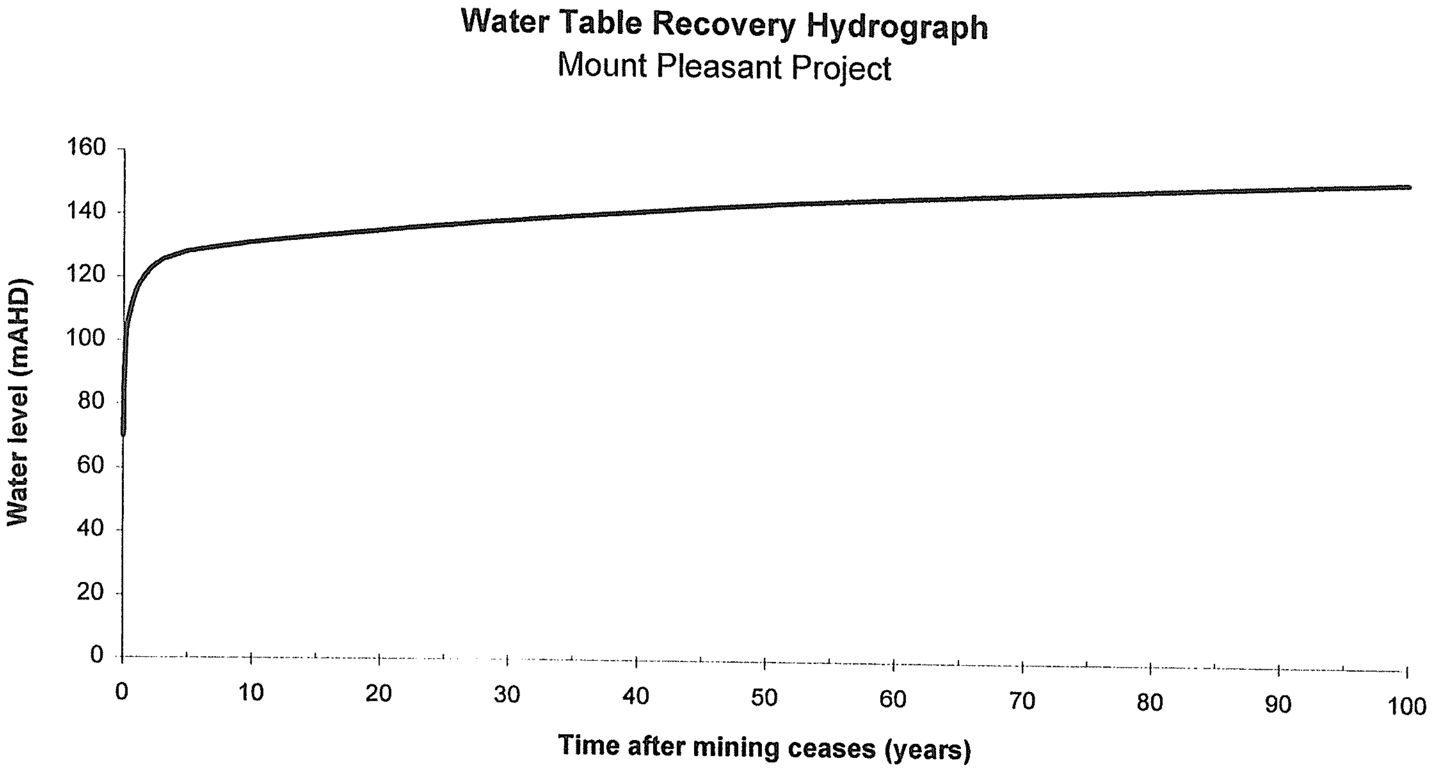
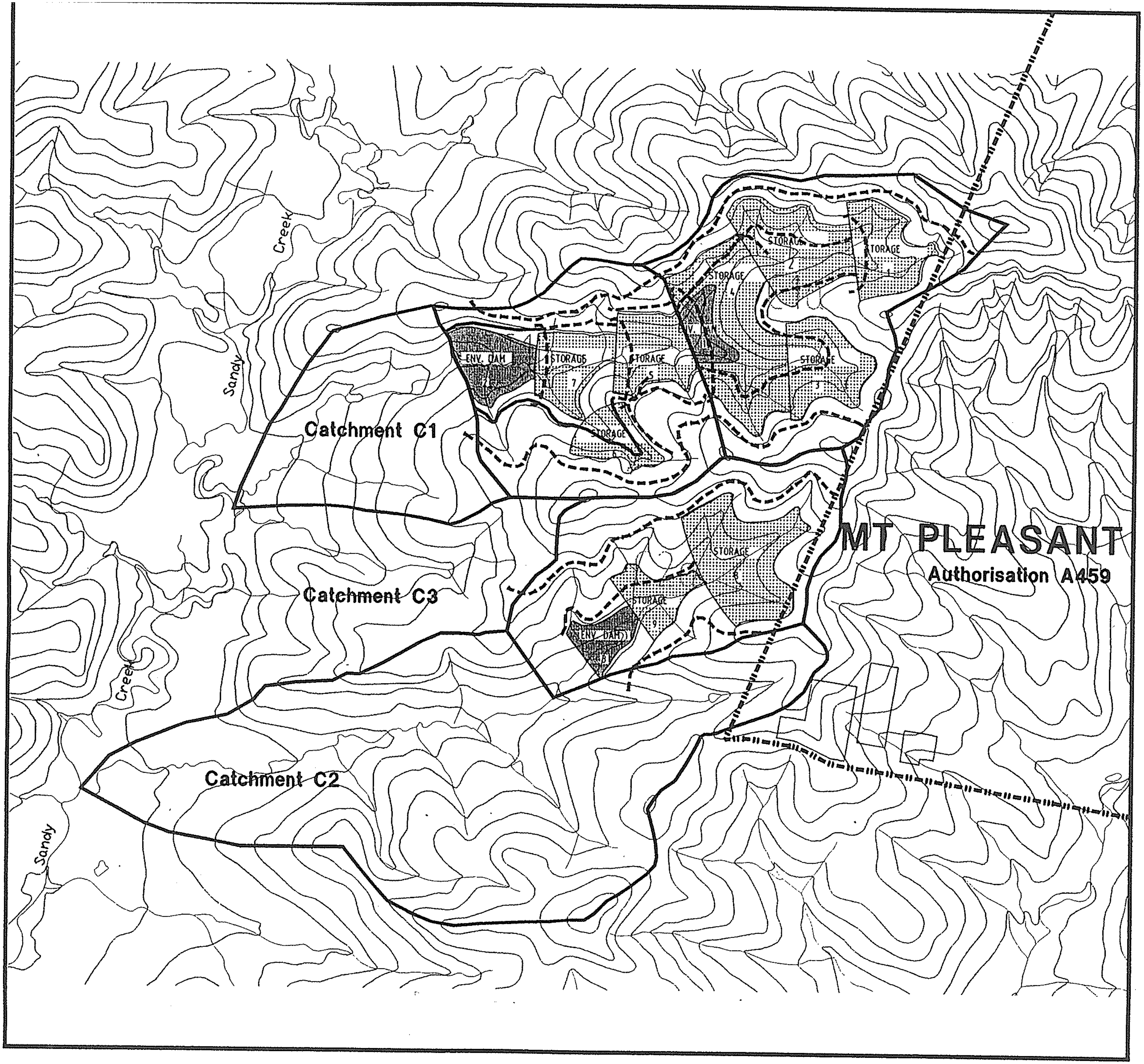


Figure 21

RUST PPK
Environment & Infrastructure

RUST PPK
Environment & Infrastructure

**Coal & Allied Operations Pty. Limited
Mount Pleasant Project
Water Management Study**



Western Rejects Emplacement Layout

Figure 22

TAILINGS SALINITY REDUCTION v. PORE SPACE VOLUME

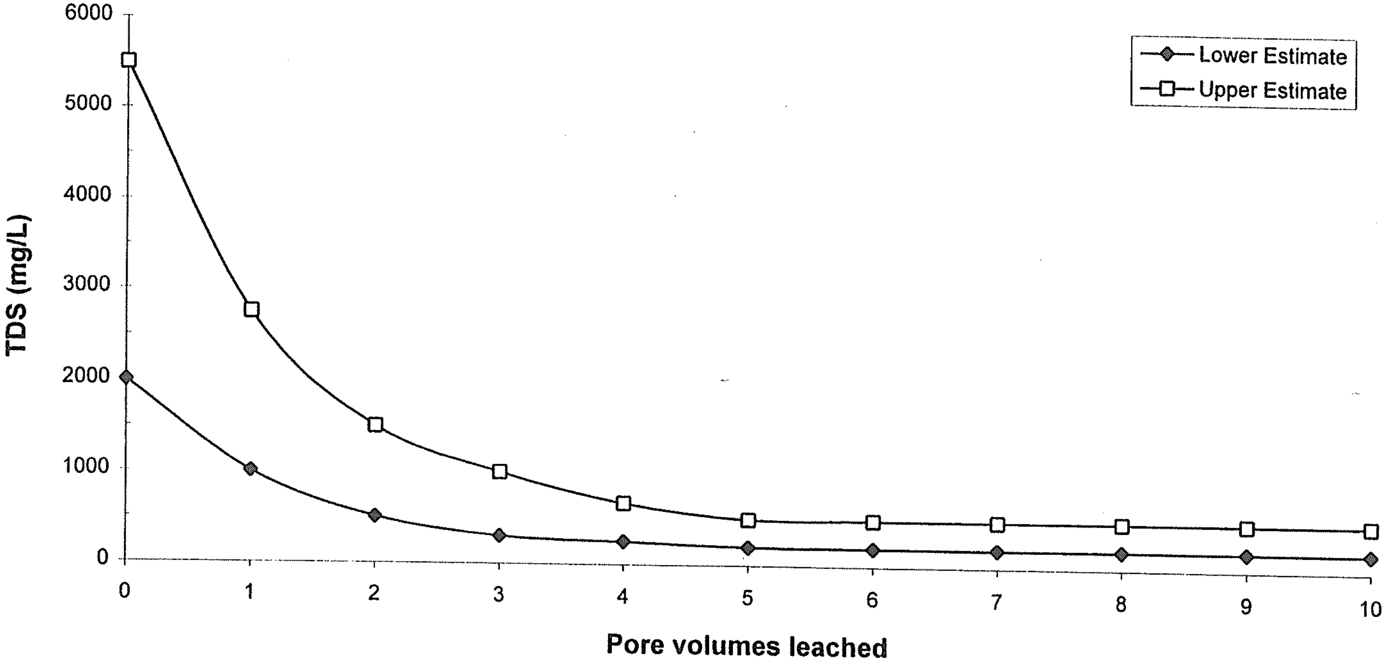
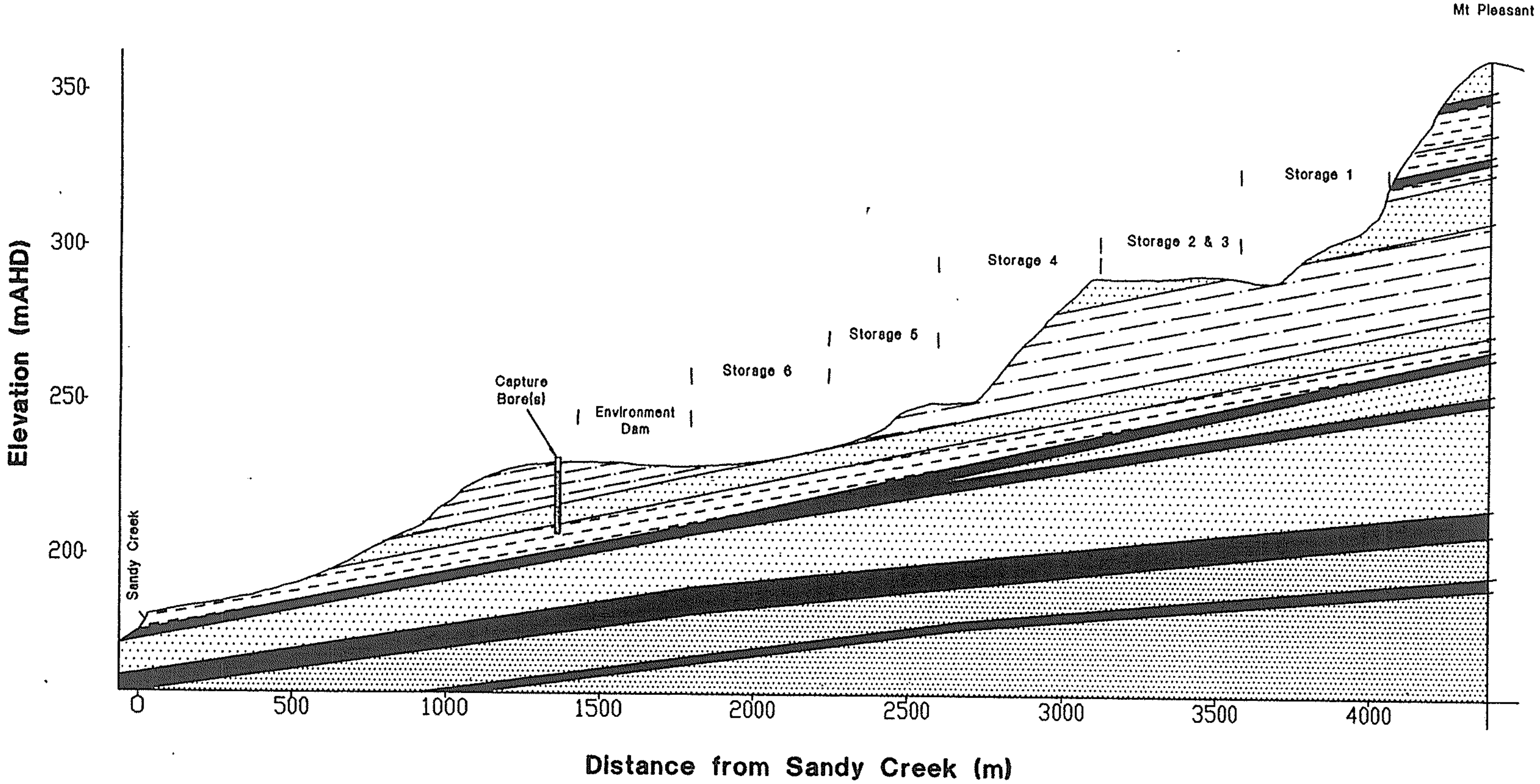
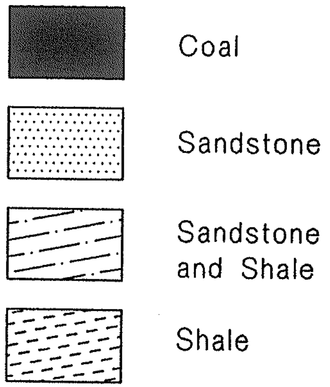


Figure 23

RUST PPK
Environment & Infrastructure





NOTES
Scale is approximate.
Vertical exaggeration 20 : 1.
Section looking North
Lithological information projected to section.

Long Section Through Rejects Emplacement Area

Figure 24