

# ELLENSFIELD COAL MINE PROJECT

## GEOCHEMICAL CHARACTERISATION AND ASSESSMENT OF OVERBURDEN AND POTENTIAL COAL REJECT MATERIAL

Report 08-003-13/R001

23 October 2008

*Prepared by:*

**Terrenus Earth Sciences**

Terrenus Pty Ltd ABN: 34 051 270 995  
12 Granville Street, Wilston QLD 4051  
Telephone / Fax: +61 7 3352 3692

*For:*

**URS Australia Pty Ltd**

Level 14, 240 Queen Street, Brisbane QLD 4000

*On behalf of:*

**Ellensfield Coal Management Pty Ltd**

GPO Box 731, Brisbane QLD 4001

## EXECUTIVE SUMMARY

Terrenus Earth Sciences has been commissioned by URS, on behalf of Ellensfield Coal Management Pty Ltd, to provide consulting services associated with the proposed development of the Ellensfield Coal Mine Project located west-southwest of Mackay, Queensland. These consulting services were required as an integral component of the Environmental Assessment documentation for the proposed development of the coal mine.

Terrenus Earth Sciences has geochemically characterised overburden, interburden and potential coal reject material from the proposed mine project.

The sampling program was weighted towards potential reject materials (coal seam roof and floor, and poor coal), since most of the mineral waste likely to report to surface will be coarse rejects and fine tailings (dewatered). A relatively small proportion of the mineral waste will be overburden from the box-cut. Overburden materials will be used mainly in construction of the waste emplacement facility. No overburden materials will be mined from the underground mining operation.

### ***Geochemical Characterisation and Assessment of Overburden and Potential Rejects***

Overburden and potential rejects generated by the proposed Ellensfield Coal Mine Project are likely to be relatively benign and are expected to generate slightly alkaline and low-to-moderately saline runoff and seepage following surface exposure. Most of the samples tested have very low total sulphur content and can be classified as barren. Acid generation from overburden and potential reject materials is extremely unlikely given the lack of oxidisable sulphur content, excess acid neutralising capacity and alkaline pH of these materials.

The concentration of metals in overburden and potential reject materials are, in most cases, well below the applied guideline criteria for soils and are unlikely to present any environmental issues associated with revegetation and rehabilitation of the WEF.

Water extract tests indicate that the concentration of soluble metals and salts in runoff and seepage from overburden and potential reject materials is likely to remain well within applied water quality guideline criteria and is unlikely to present any environmental risks for on-site or downstream water quality.

All overburden material tested is sodic and alkaline and its use as a cover material and/or as topsoil/growth layer will likely be subject to measures to improve the cation imbalance. All potential reject material is also sodic and alkaline.

The discussion of potential coal reject materials within this report should be placed in context to the type of drill-hole potential reject samples tested, since coal reject material from the coal preparation plant may have different geochemical characteristics having undergone bulk crushing and washing.

### ***Management Measures***

The ongoing management of mineral waste should consider the geochemistry of materials with respect to their potential risk to cause harm to the environment and their suitability for use in revegetation. The design of a mineral waste management strategy for the ECMP should consider:

- Placement of mineral waste materials, particularly potential rejects, to minimise run-off and erosion;
- ROM coal handling and management practices to minimise generation and distribution of saline leachate;

- Evaluating the geochemical characteristics of materials from 'new' areas or lithologies that have not been evaluated, in particular, the box-cut area has not been investigated in this study; and
- Characterisation of rejects from the CHPP (once operational) to verify the expected geochemical nature of these materials and then re-evaluate the mineral waste management strategies.

Leachate and site water derived from, or in contact with, spoil piles, reject materials or other mineral waste should be monitored to ensure that soluble metals and salt concentrations are below regulatory guidelines or licence conditions. The parameters monitored and the frequency of monitoring should be considered in the design of the site water monitoring program.

## TABLE OF CONTENTS

<b>EXECUTIVE SUMMARY .....</b>	<b>i</b>
<b>LIST of TABLES, FIGURES and APPENDICES .....</b>	<b>v</b>
<b>1 INTRODUCTION .....</b>	<b>1</b>
1.1 Objective .....	1
1.2 Background to the Ellensfield Coal Mine Project .....	1
<b>2 METHODOLOGY .....</b>	<b>5</b>
2.1 Desktop Review of Existing Information .....	5
2.2 Sampling Strategy for ECMP Geologic Materials .....	5
2.3 Geochemical Tests .....	6
2.4 Explanation of Geochemical Terminology .....	7
<b>3 GEOCHEMICAL TEST RESULTS .....</b>	<b>9</b>
3.1 Introduction .....	9
3.2 Acid-Base Tests .....	10
3.3 Multi-Elements in Solids .....	15
3.4 Cation Exchange Capacity and Sodicity .....	15
3.5 Multi-Elements in Water Extracts .....	16
3.6 pH and Salinity .....	16
<b>4 GEOCHEMICAL NATURE OF MINERAL WASTE MATERIALS .....</b>	<b>19</b>
4.1 Overburden .....	19
4.2 Potential Rejects .....	19
4.3 Coal .....	20
4.4 Material Classification .....	20
<b>5 MULTI-ELEMENTS COMPOSITION AND WATER QUALITY .....</b>	<b>22</b>
5.1 Overburden .....	22
5.2 Potential Rejects .....	22
<b>6 SUITABILITY OF MINERAL WASTE MATERIALS FOR USE IN REVEGETATION AND REHABILITATION .....</b>	<b>23</b>

<b>7</b>	<b>CONCLUSIONS</b> .....	<b>24</b>
7.1	Overburden.....	24
7.2	Potential Coal Reject (including coal).....	25
<b>8</b>	<b>MANAGEMENT MEASURES</b> .....	<b>26</b>
<b>9</b>	<b>REFERENCES</b> .....	<b>27</b>
<b>10</b>	<b>LIMITATIONS</b> .....	<b>28</b>

## **TABLES, FIGURES and APPENDICES**

### **TABLES**

Table 2-1	Summary of the geochemical test program .....	7
Table 2-2	Criteria used to classify the acid forming nature of mineral waste samples from the ECMP .....	8
Table 3-1	Acid-base test results for overburden and potential coal rejects .....	13
Table 3-2	Multi-element concentration and sodicity in overburden and potential coal rejects.....	17
Table 3-3	Multi-element concentration of water extracts from overburden and potential coal rejects .....	18
Table 6-1	Proportions of eCEC of major exchangeable cations .....	23

### **FIGURES**

Figure 1-1	Regional location map.....	3
Figure 1-2	Geochemical sample locations .....	4

### **APPENDICES**

APPENDIX A.	Composite Sample Details .....	29
APPENDIX B.	Evaluation and Interpretation of Static Geochemical Test Data .....	31

## 1 INTRODUCTION

Terrenus Earth Sciences (Terrenus) has been commissioned by URS Australia Pty Ltd (URS) on behalf of Ellensfield Coal Management Pty Ltd (ECM), a wholly owned subsidiary of Vale Limited (formerly CVRD), to provide consulting services associated with the proposed development of the Ellensfield Coal Mine Project (ECMP), located west-southwest of Mackay in Queensland (**Figure 1-1**). These consulting services were required as an integral component of the Environmental Assessment documentation for the proposed development of the ECMP.

Terrenus has geochemically characterised overburden (including interburden) and potential reject material (comprising coal, coal-seam roof and coal-seam floor) from the proposed ECMP. Due to the proposed project primarily being an underground coal mine within MLa70393, the volume of overburden expected to be mined from the box-cut, and report to out-of-pit disposal facilities, is expected to be relatively small compared to a typical open-pit coal mining operation. Therefore, the geochemical assessment was weighted towards potential reject materials, since the bulk of the mineral waste materials likely to report to surface will be coarse rejects and fine tailings. No overburden materials will be mined from the underground mining operation.

### 1.1 Objective

The overall objective of this project was to:

*Evaluate the geochemical nature of overburden, potential coal reject materials and potential coal combustion ash likely to be produced at the ECMP and identify potential environmental issues that may be associated with mining, handling and storing of these materials.*

### 1.2 Background to the Ellensfield Coal Mine Project

The Project will involve the following key components (**Figure 1-2**):

- An underground coal mining operation (longwall) mining the Leichhardt seam under MLa70393. The underground mine will be accessed from a box-cut located at the northern end of the site.
- The box cut will produce approximately 23 million bulk cubic metres (bcm) of overburden, which will be used to construct the out-of-pit waste emplacement facilities (WEF) and used in ongoing rehabilitation.
- Two WEF's are proposed:
  - a small 'starter' WEF with a footprint of approximately 14 ha and a capacity of about 740,000 bcm; and
  - a main WEF with a footprint of approximately 136 ha and a capacity of approximately 29 million bcm.
- The mine will process approximately five million tonnes per annum (Mtpa) of coking and thermal coal from a coal handling and preparation plant (CHPP) located on site.
- The CHPP will produce coarse and fine rejects, which will be disposed into the WEF. Fine rejects will be dewatered and dumped with the coarse rejects. A standby tailings storage facility (slurry facility) will be constructed within the starter WEF to handle tailings slurry in the event that the belt-presses in the CHPP fail.

- Coal mined from the box-cut will be processed at the nearby Carborough Downs Mine whilst the Ellensfield CHPP is being constructed.
- Based on the current estimate of reserves, the life of the mine is approximately 25 years.

### **Project Geology**

Coal resources in the northern part of the Bowen Basin, at ECMP, occur within the Rangal Coal Measures, which overlie the Fort Cooper Coal Measures.

The overburden geology of the area typically comprises fining upward sequences (5-10 metres thick) of Permian-age medium-coarse quartz sandstone to sandy siltstone. Finer (muddy siltstone and claystone) units are present in the immediate vicinity of the coal seams, but are generally not as fined-grained as found at other nearby coal deposits in the Bowen Basin. The Permian sediments are unconformably overlain by a thin and patchy blanket of Tertiary-age soils. The Permian sediments dip towards the southeast at approximately five to ten degrees (on average over the site). The thickness of overburden cover material above fresh coal at the open-cut area ranges from approximately 10 to 14 metres<sup>1</sup>.

The depth to base of weathering across the site is generally around 12 to 15 metres (as shallow as nine metres and infrequently as deep as 20 metres). Sub-cropping coal in the western area of the proposed open-cut area is oxidised, with coal quality improving towards the east with depth. From about 20 metres depth (below the base of weathering), coal is regarded as 'fresh'.

The major coal seam expected to be mined is the Leichhardt seam. Some minor coal can be found above the Leichhardt seam throughout the underground project area, however these coal seams are very thin, discontinuous and of poor quality. As such, they are uneconomic and will not be mined.

### **Overburden and Reject Volumes Likely to be Generated by the Project**

Approximately three Mbcm of overburden is expected to be mined from the box-cut. Overburden will be used to construct the WEF and in ongoing site rehabilitation. The WEF will contain the rejects.

Approximately nine million tonnes of coarse rejects and fine tailings (dewatered) are expected to be produced from the coal handling and preparation plant (CHPP) over a 20-year life (from an initial ROM coal quantity of approximately 94 million tonnes).

### **Mineral Waste Disposal**

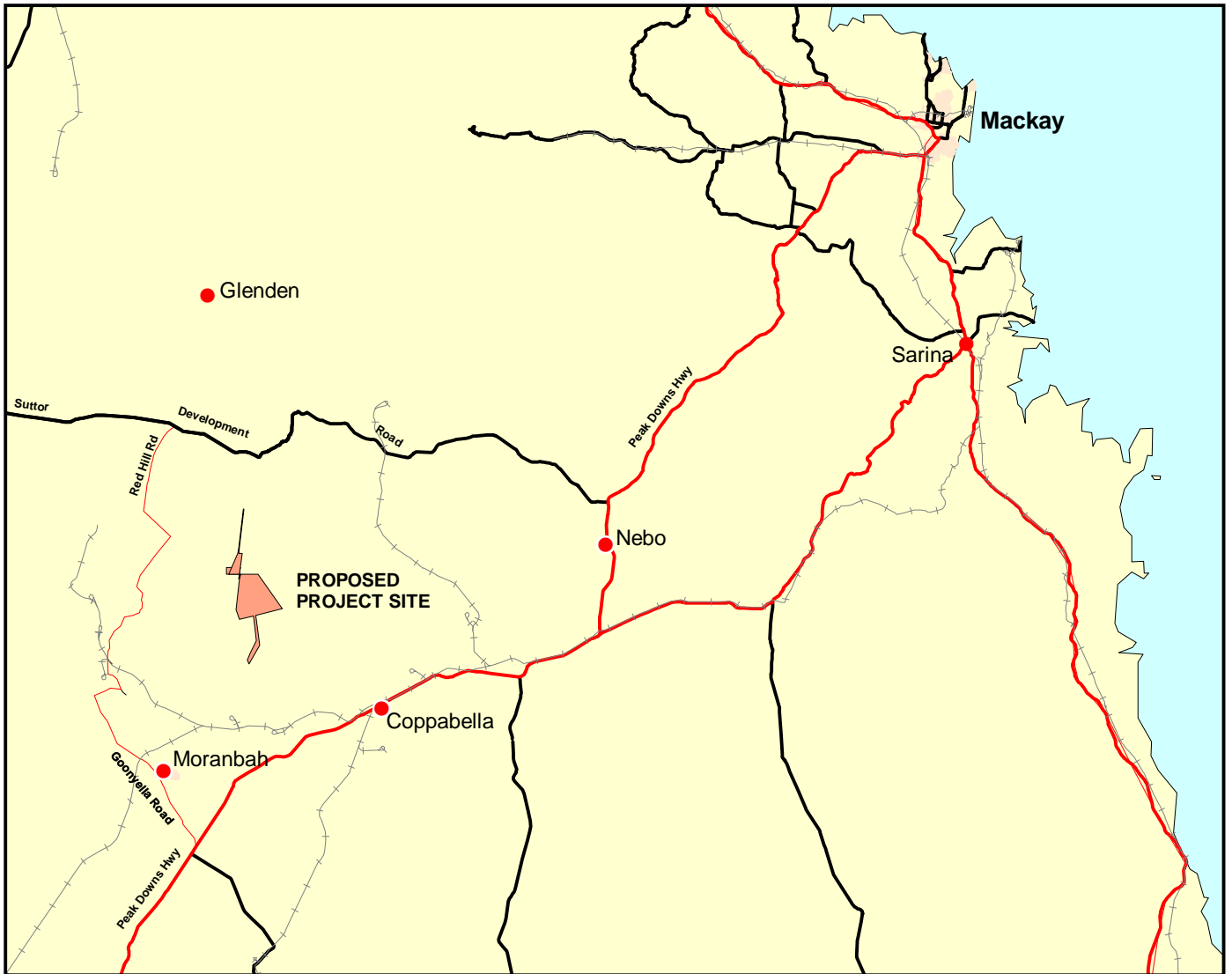
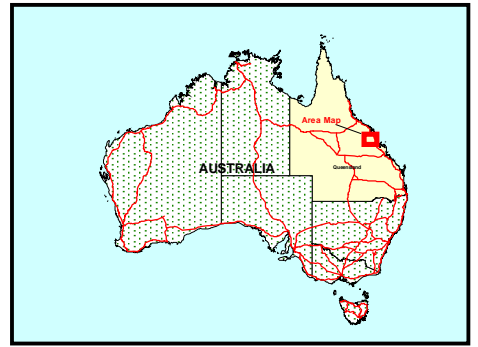
Overburden from the box-cut will be used to construct the WEF and used in ongoing rehabilitation. The proposed location of the WEF is shown on **Figure 1-2**. Remaining spoil will be disposed into a small out-of-pit spoil pile.

The coal rejects (coarse and fine) from the proposed CHPP will be disposed into the WEF, as will standby wet tailings in the event of belt-press failure in the CHPP. The WEF will be appropriately re-contoured and capped to counteract potential for capillary action (rise) of soluble materials harmful to flora or fauna, to ensure that no permanent water pondage occurs on the surface, and so that stormwater runoff is removed from the landform as quickly as possible.

Rehabilitation of reject placements will focus on the establishment of an adequate cap of at least 1.5 metres thick and a self-sustaining vegetative cover to prevent erosion, assist in the overall stability, and prevent the potential generation of acid rock drainage (ARD).

---


<sup>1</sup>. Geology information derived from drilling logs provided by ECM Senior Contract Geologist (G.Conquest).

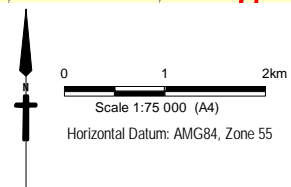
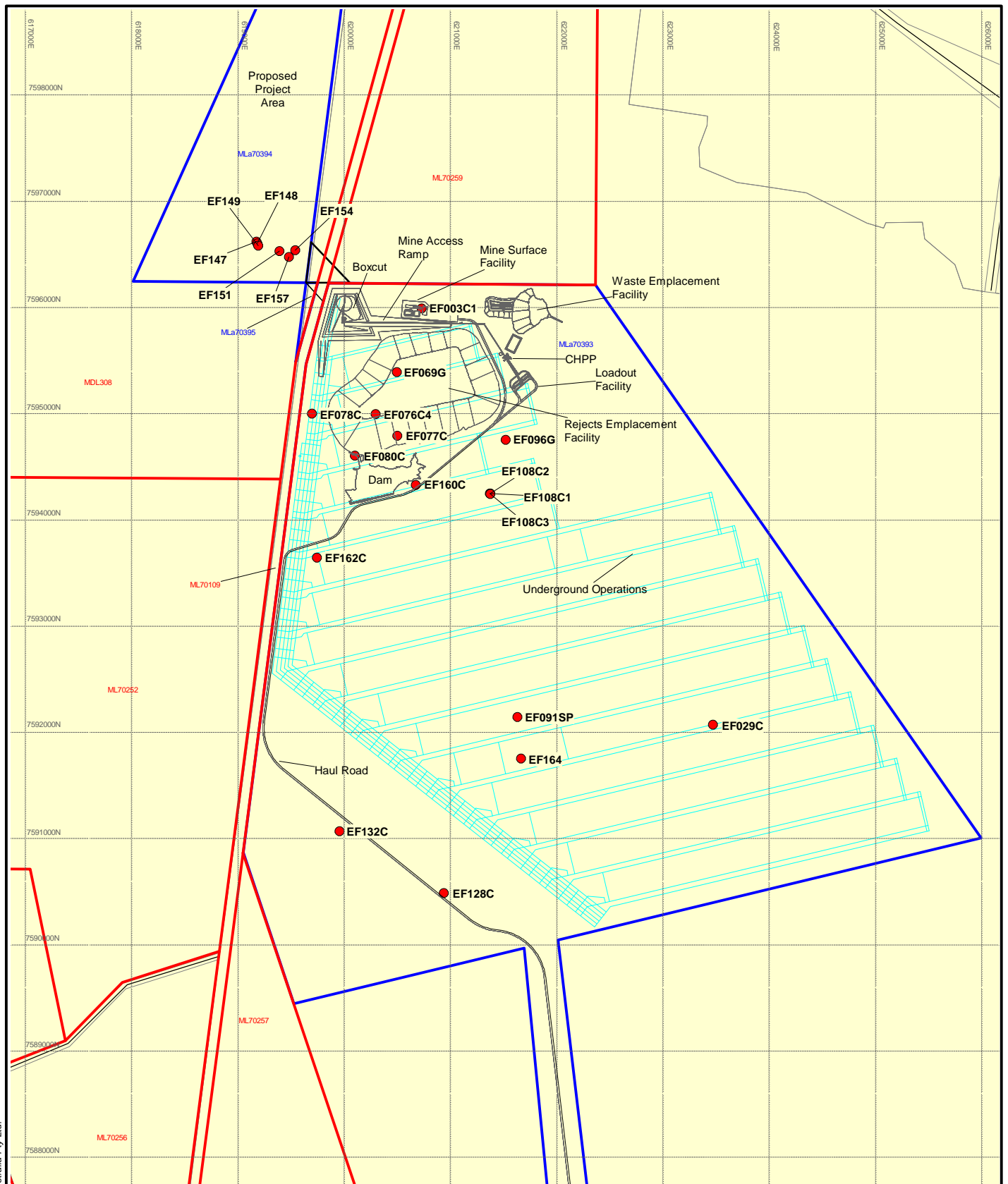


0 125 250km  
Scale 1:10 000 000 (A4)

This product incorporates data which is:  
Source: ©Commonwealth of Australia (Geoscience Australia) 2004.

This drawing is subject to COPYRIGHT. It remains the property of URS Australia Pty Ltd.

Client <b>ELLENSFIELD COAL MANAGEMENT PTY LTD</b>	Project <b>ELLENSFIELD COAL MINE GEOCHEMISTRY REPORT</b>	Title <b>PROJECT REGIONAL LOCATION</b>			
	Drawn: RG	Approved: RS	Date: 23-10-2008	Figure: 1-1	Rev: A
	Job No: <b>42626093</b>	File No: 42626093-g-321.wor			



- Project Area
- Mining Lease (ML)
- Drill Hole Location
- Cadastral Boundary

Source: Client supplied data set

This drawing is subject to COPYRIGHT. It remains the property of URS Australia Pty Ltd.

<p>Client</p> <p style="text-align: center;"><b>ELLENSFIELD COAL MANAGEMENT PTY LTD</b></p>	<p>Project</p> <p style="text-align: center;"><b>ELLENSFIELD COAL MINE GEOCHEMISTRY REPORT</b></p>	<p>Title</p> <p style="text-align: center;"><b>DRILL HOLE LOCATIONS FOR GEOCHEMICAL SAMPLES</b></p>
<p>Drawn: VH    Approved: IPS    Date: 23-10-2008</p> <p>Job No: <b>42626093</b>    File No: 42626093-g-322.wor</p>		<p>Figure: <b>1-2</b></p>
		<p>Rev: A</p> <p style="border: 1px solid black; padding: 2px;"><b>A4</b></p>

## 2 METHODOLOGY

This section provides the methodology used for the geochemical characterisation and assessment of overburden and potential reject materials likely to be produced at the ECMP.

### 2.1 Desktop Review of Existing Information

A desktop review of available project data including geological data, current and proposed coal exploration drilling programs, proposed mining methods and mine plan from ECM was completed. Discussions were held with ECM personnel (predominantly geologists and environmental personnel) to identify relevant information.

Geological information was primarily assessed from exploration and coal-quality drill hole logs from the proposed project area and discussions with ECM geologists<sup>2</sup>. Based on this information, an understanding of the geological environment (lithology and structure) at Ellensfield was gained.

### 2.2 Sampling Strategy for ECMP Geologic Materials

Terrenus and URS developed a geochemical sampling and testing program based on existing data that integrated with the exploration (resource definition) drilling program. The sampling program focussed on acquiring representative samples of the main overburden and potential reject material types (sandstone, siltstone, mudstone, coaly siltstone, coaly clay and coal), although unconsolidated soil, sands, gravels, sandy silts and clay materials are prevalent in the near surface materials.

There are currently no specific regulatory requirements regarding the number of samples required to be obtained and tested for overburden or potential reject materials at mines in Queensland. The recommended number of samples depends on a number of factors including the geological variability and complexity in rock types; the size of the operation; the potential for significant environmental or health impacts; statistical sample representation requirements; the volume of materials; the availability and representativeness of existing geochemical data; the level of confidence in predictive ability; and cost.

The overburden and potential reject sampling strategy developed by Terrenus and URS is based on the above requirements and also takes into account geological and exploration drilling information provided by ECM personnel, as well as the proposed mine plan. A key requirement of the sampling strategy was to ensure that drill samples were selected to represent the various overburden and potential reject rock types likely to be associated with the mine development.

The overburden samples were collected from the drill holes EF147 to EF157 located in MLa70394, northwest of the Mine Infrastructure Area. As evident from **Figure 1-2**, these drill holes are located outside of the proposed box-cut area. At the time of drilling and sample collection in December 2007, the box-cut was originally proposed to be located in the south-eastern corner of MLa70394, where drill holes EF147 to EF157 are located. The fact that the overburden samples were collected less than one kilometre from the proposed box-cut, and in similar geology/lithology, is not expected to have a significant effect on the validity of these overburden samples in this assessment.

On the basis of drilling, geological and mine planning information supplied to URS in December 2007, a total of 93 chip samples were collected from 33 drill holes. Of these, 51 samples from 23 drill holes in the proposed development area (**Figure 1-2**) were selected for laboratory analysis.

---

<sup>2</sup> Personal communications with Glenn Conquest (Senior Contract Geologist, ECM).

The 51 samples selected for analysis comprise:

- 15 overburden samples from above the Leichhardt seam;
- 34 potential reject samples:
  - 16 samples from immediately *above* the Leichhardt seam (roof material);
  - 18 samples from immediately *below* the Leichhardt seam (floor material);
- 2 coal samples from the Leichhardt seam:

In this report, overburden material refers to all non-coal rock types above the Leichhardt seam mined from the proposed open pit, *i.e.* all material reporting directly to either in-pit spoil or the WEF. Potential reject material comprises minor coal, coal-roof, coal-floor, and mixed coal / siltstone / mudstone and carbonaceous siltstone / mudstone immediately above or below a coal seam.

Coal samples are included in the geochemical test program since some uneconomic coal material may report to the WEF as mined waste or may report to the WEF as reject from the CHPP.

## 2.3 Geochemical Tests

Overburden and other potential reject samples were initially screened using a series of standard static acid-base characterisation tests including pH, Electrical Conductivity (EC), Acidity, Alkalinity, Total Sulphur, Total Organic Carbon (TOC), Acid Neutralising Capacity (ANC) and Net Acid Generation (NAG) capacity. The potential for a sample to generate acid was derived from the Total Sulphur content, the calculated Net Acid Production Potential (NAPP) value, the NAG capacity and NAG pH. Where samples had high TOC concentrations associated with low NAG pH values (typically NAGpH less than 4.5), a modified “extended boil” NAG test was used (Stewart *et al*, 2003) to better discriminate between organic acidity and pyritic acidity, since organic acidity does not contribute to acid rock drainage issues.

Analytical test-work was conducted by Australian Laboratory Services (ALS). The raw laboratory results are not included, but can be provided on request.

Upon receipt of the initial screening results, all 51 samples were combined into 13 composite samples according to lithology, sample depth, sample type (overburden, roof, floor or coal). All samples had similar static geochemical characteristics. Therefore it was unnecessary to composite samples based on the results of the static geochemical tests. The composites are described in **Appendix A**.

The multi-element composition of the composite samples was determined to identify the presence of any elements at concentrations of environmental significance. Solid samples were analysed for Ca, Mg, Na, K, Ag, Al, As, B, Ba, Be, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, P, Pb, S, Sb, Se, Sn, Sr, Ti, Tl, V and Zn. Water extracts from the composite samples were also subjected to the same multi-element analyses (soluble metals and major cations and anions) to determine the initial solubility and potential mobility of any elements of concern from the overburden and potential reject materials.

Additional tests and calculations were performed on composite samples to determine the suitability of overburden and potential reject materials for use in rehabilitation and establishment of vegetation. These tests included: pH, EC, Total Dissolved Solids (TDS) and alkalinity on 1:5 (sample:water w/v) extracts and exchangeable cation concentrations (Ca, Mg, Na and K) on solids. Exchangeable cation concentrations were used to calculate the effective Cation Exchange Capacity (eCEC) and Exchangeable Sodium Percentage (ESP). The above tests are used to determine the potential sodicity and dispersion characteristics of the materials. This information is useful for determining

leachate and run-off water quality, and also for the physical properties of the materials with regard to the design and construction of the WEF. **Table 2-1** summarises the geochemical test program.

**Table 2-1 Summary of the geochemical test program**

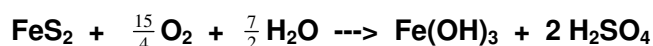
Analytical Tests	Overburden Materials	Potential Coal Reject Materials		
		Roof	Floor	Coal
Static acid-base (pH, EC, acidity, alkalinity, Total-S, TOC, ANC, NAG)	15 samples	16 samples	18 samples	2 samples
Multi-elements and eCEC on solids	3 composites	4 composites	5 composites	1 composite
Multi-element, pH, EC, TDS, alkalinity and acidity on water extracts	3 composites	4 composites	5 composites	1 composite

## 2.4 Explanation of Geochemical Terminology

Geochemical test results for all materials tested for the ECMP are presented in **Section 3**. A brief explanation of the terminology used as part of the geochemical assessment of mineral waste materials (including ash) is provided in the following sections (**Sections 2.4.1 to 2.4.3**). A more detailed description of the methodology used by Terrenus for evaluating and interpreting geochemical data is provided in **Appendix B**.

### **Acid Generation and Prediction**

Acid generation from mineral waste materials is caused by the exposure of sulphide minerals, most commonly pyrite (FeS<sub>2</sub>), to atmospheric oxygen and water. Sulphur assay results are used to calculate the maximum potential acid (MPA) that could be generated by a waste, either directly from pyritic sulphur content, or by assuming that all sulphur not present as sulphate occurs as pyrite. Pyrite oxidises to generate acid according to the following overall reaction:



The chemical components of the acid generation process consist of the above sulphide oxidation reaction and acid neutralisation, which is mainly provided by inherent carbonates and to a lesser extent silicate materials. The amount and rate of acid generation is determined by the interaction and overall balance of the acid generation and neutralisation components.

The NAPP is used as an indicator of materials that may be of concern with respect to acid generation and represents the balance between the MPA and the acid neutralising capacity (ANC) of the material, which is determined experimentally. By convention, the NAPP result is expressed in units of kg H<sub>2</sub>SO<sub>4</sub>/t sample. If the ANC exceeds the MPA, then the NAPP of the material is negative. Conversely, if the MPA exceeds the ANC, the NAPP of the material is positive. A strongly positive NAPP result generally indicates that a sample is potentially acid forming (PAF) whereas a strongly negative NAPP generally indicates that a sample is non-acid forming (NAF).

The NAG test is a confirmatory test used to validate (or otherwise) the results of the NAPP test. NAG capacity is expressed in units of kg H<sub>2</sub>SO<sub>4</sub>/t sample. The overall acid generating potential of a sample depends on the NAG capacity (kg H<sub>2</sub>SO<sub>4</sub>/t sample) and the NAG pH after oxidation. Where applicable, a modified NAG test involving an extended boiling period was undertaken on selected

samples to assess the effects of organic acids, the presence of which can lead to an overestimation of the acid forming potential. The modified NAG test was undertaken on two samples.

Terrenus has used total sulphur, NAPP and NAG data to classify the acid forming nature of all mineral waste materials at the ECMP. The criteria for material classification are presented in **Table 2-2**.

### Sample acid-generation classification

Sample classification of mineral waste materials from mining projects follows some general rules; however the classification of a sample with respect to its ability to generate acid typically has to take into account the site geology and other site-specific geochemical characteristics that may influence the classification criteria. For the ECMP mineral wastes an algorithm was used to classify samples as “barren non-acid forming” (NAF-barren), “non-acid forming” (NAF), “uncertain non-acid forming” (UC-NAF), “potentially acid forming – low capacity” (PAF-LC) and “potentially acid forming” (PAF), on the following basis (**Table 2-2**):

**Table 2-2 Criteria used to classify the acid forming nature of mineral waste samples from the ECMP**

Total Sulphur (%)	NAPP (kg H <sub>2</sub> SO <sub>4</sub> /t)	NAGpH	Sample Classification
< 0.1 %	---	---	Barren Non-Acid Forming (NAF-Barren)
$0.1 \leq S \leq 0.2$	$\leq 0$	$\geq 4.5$	Non-Acid Forming (NAF)
$0.1 \leq S \leq 0.2$	$\leq 0$	<4.5	Uncertain Non-Acid Forming (UC-NAF)
$0.2 < S \leq 0.5$	$0 > NAPP \leq 20$	$\leq 4.5$	Potentially Acid Forming Low Capacity (PAF-LC)
> 0.5	> 20	<4.5	Potentially Acid Forming (PAF)

### Assessment of Element Enrichment and Solubility

Multi-element scans are carried out to identify any elements (particularly metals) present in a material at concentrations that may be of environmental concern with respect to surface water quality and revegetation. The assay result for each element is compared to potentially relevant guideline criteria to determine any concerns related to mine operation and final rehabilitation. Elements identified as enriched may not necessarily be a concern for revegetation, drainage water quality, or public health, but their significance should be evaluated. Similarly, because an element is not enriched does not mean it will never be a concern, because under some conditions (e.g. low pH) the geochemical behaviour of common environmentally important elements such as Al, Cu, Cd, Fe and Zn increases significantly.

There are no guidelines and/or regulatory criteria specifically related to total metal concentrations in overburden, coal reject and coal combustion ash materials. In the absence of these and to provide relevant context, Terrenus has compared the total concentration of each element reported in all mineral waste samples (solids) to QLD-EPA (1998) environmental investigation levels (contaminated soils) and NEPC (1999a) health-based investigation levels (HIL)(E) for parks and recreation (open spaces). The QLD-EPA (1998) guidelines are primarily aimed at contaminated land investigations and, in this context, provide a suitable guideline for an industrial facility, such as a mine. The applicability of the NEPC (1999a) guidelines for ‘open spaces’ stems from the potential final land use of the mine following closure (i.e. livestock grazing).

The total metals concentration for individual elements in mineral waste materials can be relevant for revegetation activities and/or where the potential exists for human contact (*e.g.* if the material was to be used off-site). Of more importance to the mine is the potential for mineral waste materials to leach soluble metals at concentrations that may impact the environment or human health. Water extract tests are used to determine the immediate solubility and potential mobility of elements under existing pH conditions. Soluble element concentrations are generally compared with those recommended in relevant surface water and groundwater guideline criteria in order to determine their environmental significance.

Again, there are no guidelines and regulatory criteria specifically related to seepage from overburden and coal reject materials since guidelines (and regulatory criteria) will depend upon the end-use and receiving environment of the seepage. Therefore, to provide relevant context, Terrenus has compared the soluble concentration of each element extracted from all mineral waste materials to NEPC (1999b) investigation levels for groundwater and ANZECC (2000a) livestock drinking water guidelines. These guidelines allow for higher concentrations of individual parameters (appropriate for an industrial facility in a rural area) and are less prescriptive and more appropriate (in the context of the project) than guidelines designed for water to be used for human consumption or being directly discharged into an aquatic environment (*e.g.* stream, river, lake, *etc.*).

### **Sodicity and Dispersion**

The relative proportion of the various cations (*e.g.* calcium, magnesium, potassium and sodium) in overburden material can have a significant effect on the physical properties of that material. Potential effects can be indicated by assessment of material sodicity, as measured by the ESP. ESP is calculated from the eCEC of the material. When the ESP is high or the calcium/magnesium ratio is low, the material is more likely to disperse upon wetting. As the percentage of sodium in the material increases, the tendency for dispersion increases, resulting in crusting, reduced infiltration and consequent reduced plant growth, high runoff and erosion.

In general terms, ESP values of less than six per cent indicate that a material has a low risk of dispersion and ESP values greater than 12 per cent indicate that a material has a higher risk of dispersion. The effect of ESP on dispersion is also influenced by other soil properties such as organic matter content, clay mineralogy, cation composition, and particularly the electrolyte concentration of the soil and of any applied irrigation water (Isbell, 2002). Materials with a high risk of dispersion generally require management strategies to be put in place to ensure that slopes are stabilised against erosion.

## **3 GEOCHEMICAL TEST RESULTS**

### **3.1 Introduction**

The data and interpretations in this report are presented in context of material likely to report as waste versus material that will not be mined and, therefore, will have no bearing on the environmental impact or management of the waste. Coal, although mined, will generally not report as waste; however some coal from the CHPP (referred to as coal reject) is likely to be waste and will be co-disposed with spoil from the box-cut into the WEF. The data is summarised using the following groups:

- Overburden: Also called spoil. Comprises overburden, interburden and uneconomic minor coal interbeds above the Leichhardt seam. Most spoil will report as

waste, although some spoil will be used for construction and rehabilitation purposes. Only mined from the box-cut area.

- Roof and Floor: Comprises Leichhardt seam roof and floor. All material will report as waste.
- Coal: Will be mined, however minor coal will report as reject from the coal preparation plant.

## 3.2 Acid-Base Tests

### Overburden

Acid-Base test results for the 15 overburden samples representing specific lithological rock types are presented in **Table 3-1** and summarised as follows:

- The current pH<sub>1:5</sub> of the overburden samples is strongly alkaline (average pH 9.2; median pH 9.0) and ranges from pH 7.9 to 10.1. The current alkalinity is low (average value of 0.0003 kg H<sub>2</sub>SO<sub>4</sub>/t) and ranges from less than 0.0001 to 0.0009 kg H<sub>2</sub>SO<sub>4</sub>/t.
- The current electrical conductivity (EC<sub>1:5</sub>) is moderate to high and ranges from 396 to 1,210 µS/cm, with an average value of 714 µS/cm (median 605 µS/cm).
- The total sulphur content of the overburden samples is very low, ranging from less than 0.01 per cent to 0.11 per cent (average and median 0.04%). Only one sample contained total sulphur content greater than 0.1 per cent.
- The maximum potential acidity (MPA) that could be generated by these samples ranges from less than 0.3 to 3.4 kg H<sub>2</sub>SO<sub>4</sub>/t and is very low (median value is 0.9 kg H<sub>2</sub>SO<sub>4</sub>/t).
- The ANC values range from low to moderate, ranging from 5.4 to 105 kg H<sub>2</sub>SO<sub>4</sub>/t, and are generally moderate (median ANC value is 42 kg H<sub>2</sub>SO<sub>4</sub>/t).
- Based on the MPA and ANC values, the calculated NAPP values for the overburden samples are all negative and range from -102 to -5 kg H<sub>2</sub>SO<sub>4</sub>/t, with a median NAPP value of -40 kg H<sub>2</sub>SO<sub>4</sub>/t.
- The standard NAGpH values for the overburden samples ranged from NAGpH 6.8 to 8.9, with a median standard NAGpH of 8.2.

On the basis of these results, and applying the classification criteria outlined in **Table 2-2**, all of the overburden samples are classified as non-acid forming (NAF) and all except one sample have total sulphur values less than 0.1 per cent and hence are also classified as NAF-Barren.

The above results are generally not distinguishable by rock type (*e.g.* siltstone versus sandstone) or sample depth (**Table 3-1**). Therefore, from an acid-base perspective, the overburden material can be regarded as a relatively homogenous, non-acid forming unit, despite being comprised of different rock types.

### Roof

Acid-Base test results for the 16 roof samples from the Leichhardt seam that could potentially report as waste or reject are presented in **Table 3-1** and summarised below.

- The current pH<sub>1:5</sub> of the roof samples is strongly alkaline (median pH 9.9) and ranges from pH 6.3 to 10.2. The current alkalinity is very low, ranging from less than 0.0001 to 0.0005 kg H<sub>2</sub>SO<sub>4</sub>/t.

- The current EC<sub>1:5</sub> is variable, ranging from 102 to 1,770 µS/cm. The median value is 209 µS/cm, which is low to moderate.
- The total sulphur content is very low, ranging from 0.02 to 0.08 per cent, with a median value of 0.04 per cent. Accordingly, the MPA that could be generated by these roof samples is also very low, ranging from 0.6 to 2.5 kg H<sub>2</sub>SO<sub>4</sub>/t, with a median value of 1.1 kg H<sub>2</sub>SO<sub>4</sub>/t.
- The ANC values ranging from 5.1 to 191 kg H<sub>2</sub>SO<sub>4</sub>/t, with the median ANC value being 10 kg H<sub>2</sub>SO<sub>4</sub>/t, which is low.
- Based on the MPA and ANC values, the calculated NAPP values are all negative and range from -189 to -4 kg H<sub>2</sub>SO<sub>4</sub>/t, with a median NAPP value of -9 kg H<sub>2</sub>SO<sub>4</sub>/t.
- The standard NAGpH values for the roof samples ranged from NAGpH 6.0 to 8.8, with a median standard NAGpH of 7.6.

On the basis of these results, and applying the classification criteria outlined in **Table 2-2**, all of the roof samples are classified as NAF and all have total sulphur values less than 0.1 per cent, therefore are also classified as NAF-Barren.

### **Floor**

Acid-Base test results for the 18 floor samples from the Leichhardt seam that could potentially report as waste or reject are presented in **Table 3-1** and summarised below.

- The current pH<sub>1:5</sub> of the floor samples is strongly alkaline, ranging from pH 7.7 to 10.0 (median pH 9.4). The current alkalinity is very low, ranging from less than 0.0001 to 0.0002 kg H<sub>2</sub>SO<sub>4</sub>/t.
- The current EC<sub>1:5</sub> ranges from 51 to 925 µS/cm with a median EC of 106 µS/cm, which is relatively low.
- The total sulphur content is very low, ranging from 0.02 to 0.12 per cent, with a low median value of 0.03 per cent. Accordingly, the MPA that could be generated by these floor samples was very low, ranging from 0.6 to 3.7 kg H<sub>2</sub>SO<sub>4</sub>/t, with a median MPA value of 0.8 kg H<sub>2</sub>SO<sub>4</sub>/t.
- The ANC values are low, ranging from 1.2 to 69 kg H<sub>2</sub>SO<sub>4</sub>/t, with the median ANC value being 5.1 kg H<sub>2</sub>SO<sub>4</sub>/t.
- Based on the MPA and ANC values, the calculated NAPP values are all negative and range from -68 to -0.3 kg H<sub>2</sub>SO<sub>4</sub>/t, with a median NAPP value of -4.4 kg H<sub>2</sub>SO<sub>4</sub>/t.
- The standard NAGpH values for all except one floor sample were above NAGpH 4.5, and ranged from NAGpH 3.3 to 8.4, with a median standard NAGpH of 6.3.

On the basis of these results, and applying the classification criteria outlined in **Table 2-2**, all 18 floor samples are classified as NAF and all (except for one) samples have total sulphur values less than 0.1 per cent and are also classified as NAF-Barren.

### **Coal**

Acid-Base test results for the 2 coal samples from the Leichhardt seam that could potentially report as waste or reject are presented in **Table 3-1** and summarised below. One sample is from the Leichhardt seam in the open-cut area (drill hole EF149) and the other coal sample is from the Leichhardt seam in the underground area (drill hole EF164).

- The current pH<sub>1:5</sub> of the open-cut coal sample is neutral (pH 7.1), whereas the pH<sub>1:5</sub> of the underground coal sample is alkaline (pH 9.6). The current alkalinity is very low for both

samples (<0.0001 and 0.0001 kg H<sub>2</sub>SO<sub>4</sub>/t, respectively, for the open-cut and underground locations).

- The current EC<sub>1:5</sub> of the open-cut sample (584 µS/cm) is moderate, whereas the current EC<sub>1:5</sub> of the sample from the underground location (265 µS/cm) is low.
- The total sulphur content of the open-cut sample (0.50%) is marginally higher than the total sulphur content of the sample from the underground location (0.16%). The MPA that could be generated by these two coal samples is low (4.9 to 15 kg H<sub>2</sub>SO<sub>4</sub>/t) and has an average value of 10 kg H<sub>2</sub>SO<sub>4</sub>/t.
- The coal sample from the open-cut area has a very low ANC value (2.2 H<sub>2</sub>SO<sub>4</sub>/t), compared to the coal sample from the underground area (76 kg H<sub>2</sub>SO<sub>4</sub>/t).
- Based on the MPA and ANC values, the calculated NAPP value for the coal sample from the open-cut area is positive (+13 kg H<sub>2</sub>SO<sub>4</sub>/t), whereas the calculated NAPP value for the coal sample from the underground area is strongly negative (-71 kg H<sub>2</sub>SO<sub>4</sub>/t).
- The NAGpH value for the coal sample from the underground area is above NAGpH 4.5 (NAGpH 9.0), whereas the coal sample from the open-cut area had a NAGpH value of 2.3. The open-cut coal sample has a TOC content of 69 per cent and a total sulphur content of 0.5 per cent, indicating that the low NAGpH value is likely being influenced by organic acid interference. A modified NAG test (extended boiling method) was undertaken on the open-cut coal sample, which showed a significantly lower NAG (capacity) value and significantly higher NAGpH value, compared to the standard NAG test value, confirming that organic acid was present and disrupting the standard NAG test.

On the basis of these results, the coal sample from the underground area was classified as NAF, however the coal sample from the open-cut area was classified as potentially acid forming - low capacity (PAF-LC). The classification system used is presented in **Table 2-2**.

The significance of acid-base test results for mineral waste management at the ECMP is discussed in **Section 4** and **Section 8**.

**Table 3-1 Acid-Base Test Results for Overburden and Potential Coal Rejects - ECMP**

Sample ID	Sample Interval		Oxidation (weathered, fresh)	Sample Description	pH <sup>1</sup>	Alkalinity (to pH 5.5)	EC <sup>1</sup>	Total Sulfur	TOC <sup>2</sup>	MPA <sup>2</sup>	ANC <sup>2</sup>	NAPP <sup>2</sup>	NAG <sup>2,4</sup> (pH 4.5)	NAG <sup>2,4</sup> (pH 7.0)	NAG <sup>2,4</sup>	Sample Classification <sup>3</sup>
	from (m)	to (m)				(kg H <sub>2</sub> SO <sub>4</sub> /t)	(μS/cm)	(%)	(%)	(kg H <sub>2</sub> SO <sub>4</sub> /t)				pH		
<b>Overburden</b>																
EF147 - 01	4.00	5.50	hi. weathered	CLAYSTONE: medium brownish orange	9.9	0.0001	558	0.02	0.22	0.6	7.2	-6.6	<0.1	<0.1	7.8	NAF-barren
EF147 - 02	5.50	7.00	hi. weathered	CLAYSTONE: medium brownish orange	7.9	0.0001	453	0.02	0.10	0.6	5.4	-4.8	<0.1	<0.1	7.7	NAF-barren
EF157 - 02	5.80	9.20	mod. weathered	MUDSTONE: medium brownish yellow	9.6	0.0007	1030	0.02	0.83	0.6	59.6	-59.0	<0.1	<0.1	8.9	NAF-barren
EF148 - 01	6.21	8.21	mod. weathered	CLAYSTONE: medium orange yellow	7.9	0.0002	1210	0.02	0.15	0.6	10.5	-9.9	<0.1	<0.1	8.2	NAF-barren
EF154-02	7.00	9.00	slt. weathered	SILTSTONE: greyish-white	8.8	0.0001	981	0.03	0.72	0.9	7.6	-6.7	<0.1	1.5	6.8	NAF-barren
EF154-03	15.60	20.40	fresh	SILTSTONE: medium grey, some sandstone	9.8	0.0003	663	0.04	0.47	1.2	102	-101	<0.1	<0.1	8.4	NAF-barren
EF154-05	15.60	20.40	fresh	SILTSTONE: medium grey, some sandstone	10.1	0.0003	491	0.07	0.17	2.1	104	-102	<0.1	<0.1	8.5	NAF-barren
EF147 - 10	17.00	18.00	fresh	SILTSTONE: medium grey	8.6	0.0002	1090	0.04	0.96	1.2	41.5	-40.3	<0.1	<0.1	7.5	NAF-barren
EF148 - 05	19.40	23.11	fresh	SILTSTONE: med. grey, with sandstone bands	9.0	0.0001	819	0.07	2.14	2.1	14.3	-12.2	<0.1	<0.1	7.8	NAF-barren
EF147 - 12	22.60	24.10	fresh	SILTSTONE: medium grey, fining downwards	8.8	0.0009	974	0.04	1.06	1.2	79.9	-78.7	<0.1	<0.1	8.2	NAF-barren
EF147 - 13	24.10	25.70	fresh	SILTSTONE: vfg, lightish grey-white	9.9	0.0003	586	<0.01	0.15	0.3	39.1	-38.8	<0.1	<0.1	8.3	NAF-barren
EF157 - 04	21.60	22.60	fresh	SANDSTONE: vfg, light grey-white	9.0	0.0001	605	0.05	1.41	1.5	11.1	-9.6	<0.1	<0.1	8.0	NAF-barren
EF157 - 05	25.00	26.00	fresh	SANDSTONE: vfg, grey-white, some siltstone	10.0	0.0004	450	0.11	0.44	3.4	105	-102	<0.1	<0.1	8.5	Non Acid Forming
EF154-07	42.80	57.60	fresh	SANDSTONE: f-m, light grey, siltstone bands	10.0	0.0003	396	0.01	0.15	0.3	73.0	-72.7	<0.1	<0.1	8.6	NAF-barren
EF148 - 07	48.81	51.09	fresh	SANDSTONE: vfg, grey-white, some siltstone	9.0	0.0004	404	0.01	0.33	0.3	53.5	-53.2	<0.1	<0.1	8.1	NAF-barren
<b>Roof</b>																
EF148 - 02	8.21	10.18	weathered	CLAYSTONE: medium orange yellow	7.4	0.0002	1280	0.02	0.18	0.6	5.4	-4.8	<0.1	<0.1	7.1	NAF-barren
EF147 - 06	8.50	9.00	mod. weathered	CLAYSTONE: light orangy brown	8.3	0.0002	1770	0.03	0.05	0.9	9.8	-8.9	<0.1	<0.1	8.0	NAF-barren
EF151 - 02	10.18	10.98	fresh	SILTSTONE: medium grey	6.3	0.0000	702	0.02	11.80	0.6	6.9	-6.3	<0.1	3.7	6.0	NAF-barren
EF091SP Geochem 1 LR	310.16	310.41	fresh	MUDSTONE	9.9	0.0001	208	0.06	11.2	1.8	40.4	-38.6	<0.1	<0.1	7.7	NAF-barren
EF069G Geochem 2 LR	110.92	111.50	fresh	MUDSTONE: dark grey, carb. laminae	10.0	0.0002	210	0.04	2.52	1.2	10.3	-9.1	<0.1	<0.1	7.3	NAF-barren
EF108C3 Geochem 1 LR	243.10	243.30	fresh	SHALE: carbonaceous	9.8	0.0001	187	0.03	2.62	0.9	10.3	-9.4	<0.1	<0.1	7.1	NAF-barren
EF162C Geochem 1 LR	266.18	266.39	fresh	SHALE: carbonaceous	10.0	0.0002	239	0.04	4.66	1.2	5.2	-4.0	<0.1	<0.1	8.3	NAF-barren
EF003C1 Geochem 1 LR	89.45	89.62	fresh	SILTSTONE: carbonaceous	9.7	0.0001	107	0.03	2.06	0.9	5.1	-4.2	<0.1	1.6	6.4	NAF-barren
EF078C Geochem 2 LR	153.40	153.65	fresh	SILTSTONE: carbonaceous	10.0	0.0005	277	0.06	11.2	1.8	191	-189	<0.1	<0.1	8.8	NAF-barren
EF076C4 Geochem 1 LR	154.89	155.31	fresh	SILTSTONE: carbonaceous	9.7	0.0001	140	0.02	1.11	0.6	7.6	-7.0	<0.1	<0.1	7.5	NAF-barren
EF077C Geochem 1 LR	178.77	178.88	fresh	SILTSTONE: carbonaceous	9.9	0.0001	167	0.05	6.34	1.5	40.3	-38.8	<0.1	<0.1	7.8	NAF-barren
EF080C Geochem 1 LR	197.04	197.18	fresh	SILTSTONE: carbonaceous	9.6	0.0001	118	0.03	4.75	0.9	6.4	-5.5	<0.1	0.8	6.7	NAF-barren
EF160C Geochem 1 LR	219.97	220.29	fresh	SILTSTONE: carbonaceous with calc. laminae	10.0	0.0002	246	0.03	5.18	0.9	68.0	-67.1	<0.1	<0.1	8.4	NAF-barren
EF029C Geochem 1 LR	341.49	341.63	fresh	SILTSTONE: dark grey, carbonaceous	9.9	0.0001	107	0.04	3.38	1.2	6.4	-5.2	<0.1	<0.1	7.0	NAF-barren
EF132C Geochem 1 LR	379.64	379.82	fresh	SILTSTONE: carbonaceous	9.6	0.0001	102	0.05	4.10	1.5	48.5	-47.0	<0.1	<0.1	8.4	NAF-barren
EF128C Geochem 1 LR	410.78	410.92	fresh	SILTSTONE: dark grey	10.2	0.0003	330	0.08	9.56	2.5	109	-107	<0.1	<0.1	8.6	NAF-barren

**Table 3-1 Acid-Base Test Results for Overburden and Potential Coal Rejects - ECMP**

Sample ID	Sample Interval		Oxidation (weathered, fresh)	Sample Description	pH <sup>1</sup>	Alkalinity (to pH 5.5)	EC <sup>1</sup>	Total Sulfur	TOC <sup>2</sup>	MPA <sup>2</sup>	ANC <sup>2</sup>	NAPP <sup>2</sup>	NAG <sup>2,4</sup> (pH 4.5)	NAG <sup>2,4</sup> (pH 7.0)	NAG <sup>2,4</sup>	Sample Classification <sup>3</sup>
	from (m)	to (m)				(kg H <sub>2</sub> SO <sub>4</sub> /t)	(µS/cm)	(%)	(%)	(kg H <sub>2</sub> SO <sub>4</sub> /t)			pH			
<b>Floor</b>																
EF147 - 07	14.16	15.00	fresh	SILTSTONE: medium grey	7.7	0.0001	925	0.05	1.65	1.5	5.8	-4.3	<0.1	<0.1	7.2	NAF-barren
EF148 - 03	15.34	17.60	fresh	SILTSTONE: carb., dark black-brown	9.0	0.0001	389	0.12	9.03	3.7	11.3	-7.6	<0.1	<0.1	7.2	Non Acid Forming
EF069G Geochem 3 LF	116.82	117.17	fresh	MUDSTONE: dark grey	9.5	0.0000	71	0.02	2.00	0.6	7.1	-6.5	<0.1	6.6	5.8	NAF-barren
EF091SP Geochem 2 LF	316.17	316.57	fresh	MUDSTONE: dark grey	9.7	0.0001	167	0.03	1.23	0.9	4.5	-3.6	<0.1	0.6	6.7	NAF-barren
EF096G Geochem LF	321.69	321.92	fresh	MUDSTONE: dark grey, some siderite band	9.4	0.0000	66	0.02	2.72	0.6	2.7	-2.1	<0.1	3.6	5.8	NAF-barren
EF160C Geochem 2 LF	225.67	225.99	fresh	SHALE: carb., calcareous fragments	9.4	0.0000	51	0.03	2.64	0.9	38.1	-37.2	<0.1	1.0	6.3	NAF-barren
EF108C1 Geochem 2 LF	248.79	248.99	fresh	SHALE: carbonaceous	9.6	0.0001	129	0.02	1.68	0.6	7.6	-7.0	<0.1	0.9	6.7	NAF-barren
EF108C2 Geochem 2 LF	248.96	249.16	fresh	SHALE: carbonaceous	9.4	0.0001	89	0.02	1.99	0.6	5.6	-5.0	<0.1	4.8	6.1	NAF-barren
EF003C1 Geochem 2 LF	94.12	94.32	fresh	SILTSTONE: carbonaceous	9.4	0.0000	57	0.03	2.31	0.9	1.2	-0.3	<0.1	7.2	5.6	NAF-barren
EF078C Geochem 3 LF	158.48	158.66	fresh	SILTSTONE: carbonaceous, sandy	9.1	0.0000	98	0.02	2.11	0.6	5.1	-4.5	<0.1	6.6	5.6	NAF-barren
EF076C4 Geochem 2 LF	161.47	161.69	fresh	SILTSTONE: dark grey	9.4	0.0001	92	0.02	1.01	0.6	2.4	-1.8	<0.1	1.5	6.6	NAF-barren
EF077C Geochem 2 LF	183.92	184.09	fresh	SILTSTONE: medium blackish grey	9.7	0.0001	114	0.02	1.82	0.6	2.7	-2.1	<0.1	7.0	5.9	NAF-barren
EF080C Geochem 2 LF	202.36	202.49	fresh	SILTSTONE: med. Black-grey, claystone bands	9.5	0.0001	142	0.03	4.59	0.9	3.9	-3.0	<0.1	5.2	5.1	NAF-barren
EF108C3 Geochem 2 LF	249.41	249.59	fresh	SILTSTONE: sandy, medium black	9.2	0.0000	65	0.02	1.47	0.6	5.1	-4.5	<0.1	2.5	6.2	NAF-barren
EF162C Geochem 2 LF	272.22	272.44	fresh	SILTSTONE: medium brownish black	9.4	0.0001	188	0.02	2.49	0.6	4.7	-4.1	<0.1	<0.1	7.0	NAF-barren
EF164 Geochem LF	351.04	352.80	fresh	SILTSTONE: medium grey	10.0	0.0002	334	0.04	6.30	1.2	69.4	-68.2	<0.1	<0.1	8.4	NAF-barren
EF132C Geochem 2 LF	385.20	385.41	fresh	SILTSTONE: dark grey	9.4	0.0001	120	0.03	4.05	0.9	13.1	-12.2	<0.1	<0.1	7.9	NAF-barren
EF128C Geochem 2 LF	415.91	416.08	fresh	SILTSTONE: dark grey, coaly bands	9.5	0.0000	96	0.07	11.90	2.1	4.9	-2.8	8.3	23.8	3.3	NAF-barren
<b>Coal</b>																
EF164 Geochem LHD	345.62	351.04	fresh	COAL: some siltstone	9.6	0.0001	265	0.16	36.4	4.9	76.2	-71.3	<0.1	<0.1	9.0	Non Acid Forming
EF149	20.30	25.97	fresh	COAL	7.1	<0.0001	584	0.50	68.6	15.3	2.2	13.1	115	180	2.3	UC-PAF

Notes:

1. Natural pH and EC provided for 1:5 sample:water extracts
2. TOC = Total Organic Carbon; MPA = Maximum potential acidity; ANC = Acid neutralising capacity; NAPP = Net acid producing potential; NAGstd = Net Acid Generation Capacity (titrated to pH 4.5 and pH 7.0)
3. Sample classification provided in Table 2.2 and report text.
4. Extended boiling NAG method produced significantly different results to the NAGstd tests, indicating the presence of organic (non-pyritic) acidity.

### 3.3 Multi-Elements in Solids

**Table 3-2** presents the multi-element test results for the 13 composite samples, which represent:

- 3 overburden samples (all from drill holes EF147 to EF157 in MLa70394), comprising:
  - 5 weathered predominantly claystone and mudstone samples;
  - 6 fresh (unweathered) siltstone samples; and
  - 4 fresh (unweathered) sandstone samples.
- 4 roof samples, comprising:
  - 3 shallow claystone and siltstone samples from MLa70394;
  - 4 moderate-depth mudstone and shale samples from MLa70393 (the underground area);
  - 4 moderate-depth siltstone samples from the northern end of the underground area; and
  - 5 deep siltstone samples from the central and southern end of the underground area.
- 5 floor samples, comprising:
  - 2 shallow siltstone samples from MLa70394;
  - 3 moderate-depth mudstone samples from the underground area;
  - 3 deep shale samples from the underground area;
  - 5 moderate-depth siltstone samples from the northern end of the underground area; and
  - 5 deep siltstone samples from the central and southern end of the underground area.
- 1 coal sample comprising 1 sample each from the Leichhardt seam in MLa70394 and in the underground area (MLa70393).

The results in **Table 3-2** indicate that the overburden materials tested have manganese (Mn) concentrations in solids greater than QLD-EPA (1998) environmental investigation levels (EIL), but well below NEPC (1999a) health-based investigation levels (HIL) for soils. Three of the five floor composite samples have Cu concentrations in solids greater than QLD-EPA (1998) EIL but well below NEPC (1999a) HIL.

The environmental significance of identified metal concentrations in overburden and potential reject materials and their water solubility in terms of risk is discussed in **Section 4**.

### 3.4 Cation Exchange Capacity and Sodidity

The effective cation exchange capacity (eCEC) results presented in **Table 3-2** indicate that all materials tested (excluding one “floor” sample) have low eCEC values, as follows:

- eCEC of overburden samples ranges from 6.0 to 6.6 meq/100g;
- eCEC of roof material ranges from 4.7 to 6.4 meq/100g;
- eCEC of floor material ranges from 2.6 to 14.4 meq/100g (median = 3.2 meq/100g); and
- eCEC of coal material is 4.5 meq/100g.

The exchangeable sodium percentage (ESP) results presented in **Table 3-2** indicate that the sodicity is high in all tested materials:

- Sodicity of overburden materials ranges from 13 to 24% (median 18%);
- Sodicity of roof materials ranges from 14 to 43% (median 20%);
- Sodicity of floor materials ranges from 32 to 51% (median 39%); and
- Sodicity of the coal sample was 11%.

The environmental significance of sodicity levels in waste materials in terms of risk and revegetation management is discussed in **Section 4**.

### 3.5 Multi-Elements in Water Extracts

To evaluate the immediate solubility of multi-elements in solids, water extract (1:5 sample:water) tests were completed for the 13 composite samples. The results from these tests are provided in **Table 3-3** and indicate that, with the exception of soluble mercury in one overburden sample, leachate from all tested materials contains metal concentrations below the applied ANZECC (2000) livestock drinking water guidelines and NEPC (1999b) groundwater investigation levels. Two method blanks were completed and both returned soluble metal concentrations below the laboratory limit of reporting (LOR).

The environmental significance of identified metal concentrations in overburden and potential reject materials and their water solubility in terms of risk is discussed in **Section 4**.

### 3.6 pH and Salinity

Results for pH, alkalinity and salinity tests on the composite overburden, roof, floor and coal samples from the ECMP are presented in **Table 3-3**. The results are summarised below:

#### **pH**

The current pH of the three composite overburden samples is strongly alkaline (median pH 9.1) and ranges from 8.4 to 9.3. The current pH of the nine roof and floor composite samples is also strongly alkaline (median pH 9.2) and ranges from 6.4 to 9.6. The current pH of the coal composite sample is also alkaline (pH 8.7).

Therefore, the pH of leachate from any likely spoil material at the ECMP is likely to be alkaline.

#### **Salinity**

The current electrical conductivity (EC) of composite overburden samples is relatively high, ranging from 549 to 1,050  $\mu\text{S}/\text{cm}$ , with a median value of 845  $\mu\text{S}/\text{cm}$ . Similarly, the current EC of roof and floor samples is moderate, ranging from 128 to 1,350  $\mu\text{S}/\text{cm}$ , with a median value of 402  $\mu\text{S}/\text{cm}$ . The current EC of the coal sample is similarly moderate to high (516  $\mu\text{S}/\text{cm}$ ).

**Table 3-2 Multi-Element Concentration and Sodcity of Solids from Overburden and Potential Rejects - ECMP**

					Overburden			Roof				Floor					Coal
			Composite Number ---->		EF C1	EF C2	EF C3	EF C4	EF C5	EF C6	EF C7	EF C8	EF C9	EF C10	EF C11	EF C12	EF C13
			Material Type ---->		Weathered Claystone, Weathered Mudstone, Weathered Siltstone	Fresh Siltstone	Fresh Sandstone	Weathered Claystone, Fresh Siltstone	Fresh Mudstone, Fresh Shale	Fresh Siltstone	Fresh Siltstone	Fresh Siltstone	Fresh Mudstone	Fresh Shale	Fresh Siltstone	Fresh Siltstone	Coal
Parameters	Units	Detection Limit	QLD-EPA <sup>1</sup> Environmental Investigation Level	NEPC <sup>2</sup> Health-Based Investigation Level													
<b>Major Elements</b>																	
Ca	mg/kg	10	-	-	2,000	1,620	1,060	2,630	1,350	1,110	1,470	1,410	1,600	1,870	1,570	1,520	670
Mg	mg/kg	10	-	-	1,240	1,440	1,460	1,130	1,330	1,260	1,680	1,240	1,350	1,480	1,420	1,440	420
Na	mg/kg	10	-	-	4,890	13,500	19,100	2,210	4,870	25,900	23,600	910	990	790	1,100	3,500	8,270
K	mg/kg	10	-	-	3,180	6,800	7,070	2,120	2,780	3,500	3,570	2,790	960	370	490	1,460	1,520
Al	mg/kg	50	-	-	9,250	9,900	9,110	10,600	9,810	9,620	11,100	4,560	5,440	4,670	4,600	5,320	2,710
Fe	mg/kg	50	-	-	60,500	29,800	26,300	28,700	10,200	14,000	13,400	18,500	2,540	1,050	530	12,800	10,400
<b>Minor Elements</b>																	
Ag	mg/kg	2	-	-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
As	mg/kg	200	20	-	8	14	10	<5	<5	<5	7	9	<5	<5	<5	<5	<5
B	mg/kg	50	1 to 75*	6,000	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Ba	mg/kg	10	-	-	350	180	750	200	370	190	240	20	300	300	310	210	50
Be	mg/kg	1	-	40	1	<1	<1	<1	<1	<1	<1	<1	1	<1	<1	<1	<1
Cd	mg/kg	1	3	40	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Co	mg/kg	2	2 to 170*	200	17	17	12	70	4	7	10	7	7	4	<2	3	3
Cr	mg/kg	2	50 <sup>3</sup>	200	47	12	12	30	9	10	9	4	3	<2	<2	3	3
Cu	mg/kg	5	60	2,000	39	39	30	31	54	43	49	57	68	76	74	60	19
Hg	mg/kg	0.1	1	30	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1
Mn	mg/kg	5	500	3,000	916	857	705	261	135	196	112	351	31	10	<5	249	180
Mo	mg/kg	2	<1 to 20*	-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ni	mg/kg	2	60	600	32	27	20	46	11	16	17	16	11	7	4	7	4
P	mg/kg	50	-	-	700	520	510	1020	290	130	2750	60	50	<50	<50	140	870
Pb	mg/kg	5	300	600	16	14	13	13	25	19	19	20	22	23	20	17	6
S	mg/kg	50	-	-	160	370	430	180	180	150	230	490	130	140	110	120	1930
Sb	mg/kg	5	20	-	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Se	mg/kg	5	-	-	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Sn	mg/kg	5	50	-	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Sr	mg/kg	2	-	-	50	74	113	76	142	206	224	29	165	182	188	154	99
Ti	mg/kg	10	-	-	20	<10	10	20	10	10	10	<10	<10	<10	<10	<10	<10
Tl	mg/kg	5	-	-	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
V	mg/kg	5	-	-	79	29	29	42	22	24	23	15	9	<5	7	10	8
Zn	mg/kg	5	200	14,000	177	99	99	91	78	61	77	81	59	31	32	42	41
<b>Sodcity</b>																	
Exchangeable Ca	meq/100g	0.1	-	-	2.9	3.8	3.9	0.7	3.1	4.7	4.8	0.4	0.8	3.8	1.0	2.2	3.6
Exchangeable Mg	meq/100g	0.1	-	-	1.6	1.2	1.0	2.2	0.3	0.4	0.3	1.3	0.3	1.4	0.4	0.3	0.2
Exchangeable Na	meq/100g	0.1	-	-	1.5	1.2	0.8	2.3	1.1	0.9	1.1	1.2	1.2	7.4	1.1	1.3	0.5
Exchangeable K	meq/100g	0.1	-	-	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	1.9	0.2	0.3	<0.1
eCEC	meq/100g	0.1	-	-	6.2	6.6	6.0	5.4	4.7	6.2	6.4	3.2	2.6	14.4	2.8	4.1	4.5
Exchangeable Na %	%	0.1	-	-	24.2	18.2	13.3	42.6	23.4	14.5	17.2	37.5	46.2	51.4	39.3	31.7	11.1

Notes:

< indicates less than the analytical detection limit.

Shaded cells indicate values which exceed relevant QLD-EPA EIL (light shading) or NEPC HIL(E) (dark shading) guideline values.

\* Background levels

1. Queensland Government. Department of Environment. Draft Guidelines for the Assessment & Management of Contaminated Land in Queensland. May 1998.

2. National Environment Protection Council (NEPC). National Environmental Protection (Assessment of Site Contamination) Measure. Guideline on Investigation Levels for Soil and Groundwater (1999). HIL(E): parks, recreational open space and playing fields.

3. Cr (III). No background or QLD-EPA EIL's are available for Cr (VI).

**Table 3-3 Multi-Element Concentration of Water Extracts from Overburden and Potential Reject Samples - ECMP**

Parameters	Material Group -->		Overburden			Roof				Floor				Coal	
	Composite No. & Material Type --->		EF C1	EF C2	EF C3	EF C4	EF C5	EF C6	EF C7	EF C8	EF C9	EF C10	EF C11	EF C12	EF C13
	Detection Limit	ANZECC <sup>2</sup> / NEPC <sup>3</sup> Guidelines	Claystone, Mudstone and Siltstone (all weathered)	Siltstone (fresh)	Sandstone (fresh)	Claystone (weathered) and Siltstone (fresh)	Mudstone and Shale (fresh)	Siltstone (fresh)	Siltstone (fresh)	Siltstone (fresh)	Mudstone (fresh)	Shale (fresh)	Siltstone (fresh)	Siltstone (fresh)	Coa (fresh)
pH <sup>1</sup>	0.1	-	8.4	9.1	9.3	6.4	9.4	9.4	9.6	8.1	9.0	9.2	8.9	9.5	8.7
EC <sup>1</sup> (µS/cm)	1	3000 <sup>4</sup>	1050	845	549	1350	402	389	407	664	158	137	128	448	516
Total Dissolved Solids	5	-	151	152	484	140	316	1148	1352	160	640	1312	600	224	16
Alkalinity (kg H <sub>2</sub> SO <sub>4</sub> /t)	1	-	0.0011	0.0066	0.0054	0.0006	0.0012	0.0051	0.0029	0.0006	0.0007	0.0008	0.0006	0.0011	0.0002
Alkalinity (meq CaCO <sub>3</sub> /kg)	1	-	57	335	278	32	59	261	146	30	37	40	30	58	10
<b>Major Elements</b>	<b>mg/L</b>		<b>mg/L</b>												
Ca	2	1000	6	2	2	2	<2	<2	<2	<2	<2	<2	<2	<2	6
Mg	2	-	6	2	<2	6	<2	<2	<2	<2	<2	<2	<2	<2	2
Na	2	-	228	188	118	310	102	94	94	150	28	24	24	110	112
K	2	-	8	12	10	6	2	4	2	4	<2	<2	<2	2	4
Cl	2	-	248	166	68	364	16	12	10	148	10	<2	12	14	56
SO <sub>4</sub>	2	1000	46	56	42	70	16	12	16	46	16	14	8	14	82
<b>Minor Elements</b>	<b>mg/L</b>		<b>mg/L</b>												
Ag	0.02	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Al	0.2	5	<0.2	<0.2	<0.2	<0.2	0.2	<0.2	<0.2	<0.2	1.8	2.0	1.4	0.2	<0.2
As	0.02	0.5	<0.02	0.08	0.08	<0.02	<0.02	0.08	0.12	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
B	0.2	5	0.2	<0.2	<0.2	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Ba	0.2	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Be	0.02	0.1	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cd	0.02	0.01	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Co	0.02	1	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cr	0.02	1	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cu	0.02	0.5	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Fe	0.2	1 (irrigation)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Hg	0.0001	0.002	<0.001	0.0028	0.0004	0.0002	0.0001	0.0001	0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mn	0.02	2 (irrigation)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Mo	0.02	0.15	<0.02	0.04	0.02	<0.02	<0.02	0.10	0.08	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ni	0.02	1	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
P	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Pb	0.02	0.1	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Sb	0.02	-	0.04	<0.02	<0.02	<0.02	0.14	<0.02	<0.02	<0.02	<0.02	<0.02	0.16	<0.02	<0.02
Se	0.02	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Sn	0.02	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Sr	0.2	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.4
Ti	0.2	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Tl	0.2	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
V	0.02	0.1	<0.02	<0.02	<0.02	<0.02	<0.02	0.08	0.10	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Zn	0.02	20	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02

Notes:

- < Indicates concentration less than the detection limit.
- Shaded cells indicate values which exceed recommended maximum ANZECC/NEPM guideline values.
- 1. Natural pH and EC provided for 1:5 sample:water extracts
- 2. ANZECC and ARMCANZ, Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Environment Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, ACT (2000). Livestock drinking water.
- 3. National Environment Protection Council (NEPC). National Environment Protection (Assessment of Site Contamination) Measure. Guideline on Investigation Levels for Soil and Groundwater (1999). Groundwater Investigation Levels.
- 4. Approximate maximum EC (based on TDS of ~2000 mg/L) which sensitive animals (poultry) can tolerate without adverse effects (ANZECC 2000 Livestock drinking water quality). This value increases significantly for most other livestock.

## 4 GEOCHEMICAL NATURE OF MINERAL WASTE MATERIALS

### 4.1 Overburden

The results of the acid-base tests (**Table 3-1**) indicate that overburden from the ECMP will initially generate mildly alkaline, low to moderately saline (brackish) runoff/seepage following surface exposure (**Graph 1**).

All of the overburden samples have very low sulphur concentrations and are essentially barren. (**Graph 2**).

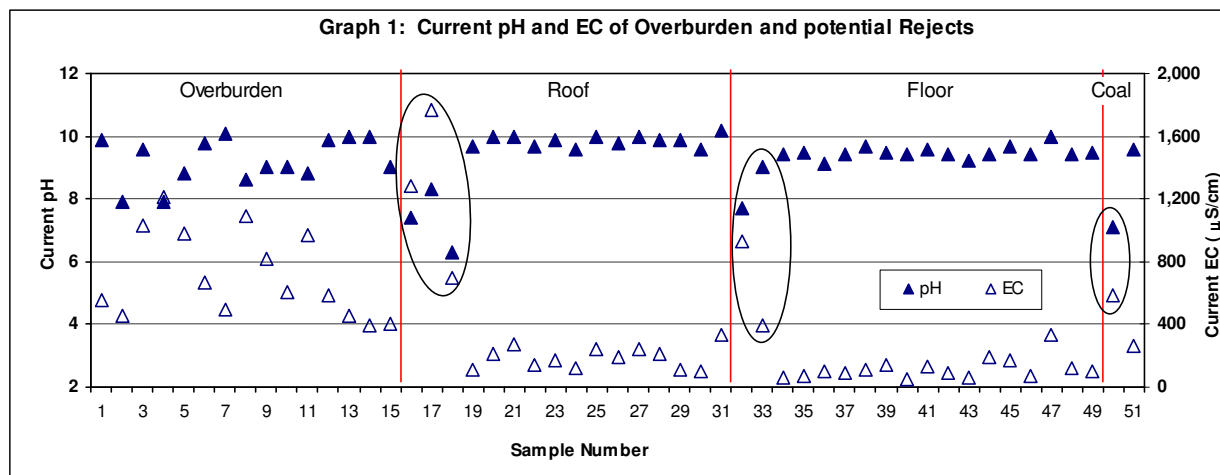
The ANC of overburden is generally moderate and, in all samples, greatly exceeds the MPA, indicating that the material has sufficient buffering capacity to neutralise the insignificant amount of acidity that could be generated from sulphide oxidation. All of the overburden samples have a negative NAPP value and NAGpH value greater than pH 4.5 (as illustrated in **Graph 3**), and are therefore classified as NAF.

### 4.2 Potential Rejects

The results of the acid-base tests (**Table 3-1**) indicate that all roof and floor samples (*i.e.* potential rejects) will also initially generate slightly alkaline, low-salinity runoff/seepage following surface exposure (**Graph 1**).

Of the 34 roof and floor samples collected from 18 drill holes distributed throughout the proposed open-cut and underground areas, only one sample had a total sulphur content greater than 0.1 per cent, and the total sulphur concentration in this single sample was 0.12 per cent, indicating that potential reject materials are overwhelmingly NAF, almost totally barren, and therefore have very limited potential to generate any acid (**Graphs 2 and 3**).

\*\*\*\*\*



As evident from **Graph 1**, the pH of all samples is generally alkaline. The EC of most roof and floor samples is generally low, whereas the EC of the overburden samples is typically higher. The circled samples in **Graph 1** represent roof, floor and coal samples obtained from drill holes EF147 to EF157 in MLa70394. These samples are all shallow, collected from depths less than 26 metres below natural surface, and have similar geochemical characteristics to the shallow overburden samples.

### 4.3 Coal

The results of the acid-base tests (**Table 3-1**) of the two coal samples indicate that coal material from the shallow box-cut area may initially generate neutral, moderate-salinity runoff/seepage following surface exposure, whereas coal from the deeper underground area may generate slightly alkaline, low-salinity runoff/seepage following surface exposure (**Graph 1**).

The total sulphur content of the coal samples was higher than for other materials tested, but was still relatively low, with the 'underground' coal sample having a total sulphur concentration of less than 0.2 per cent and the shallower coal sample having a total sulphur concentration of 0.5 per cent. The coal sample from the underground was clearly NAF, whereas the acid generating predictions for the shallow coal sample suggest that this material may be potentially acid forming, albeit at a low capacity.

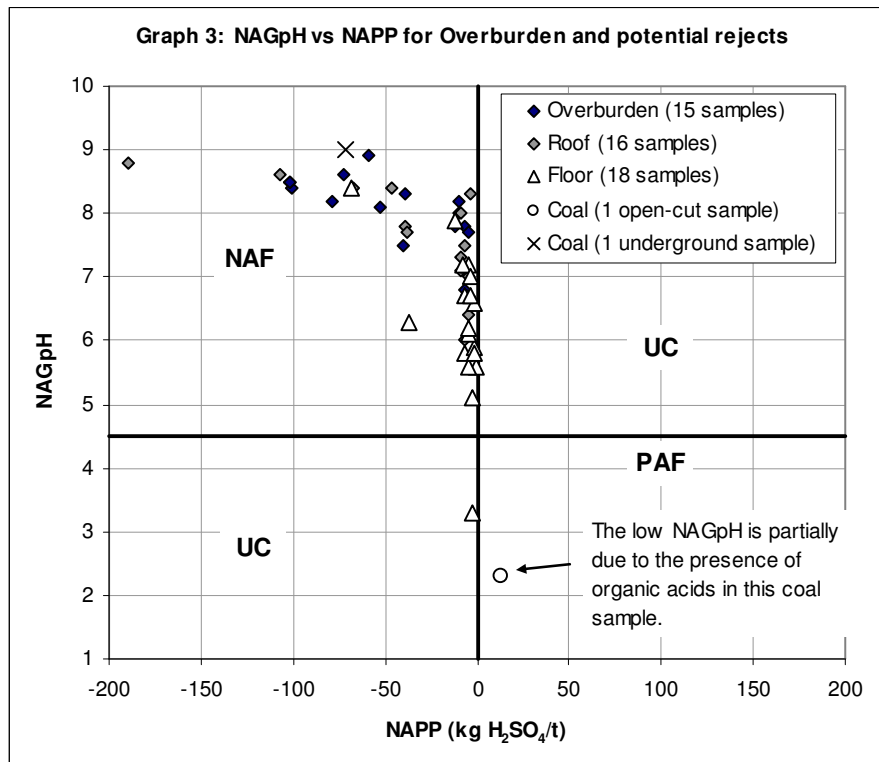
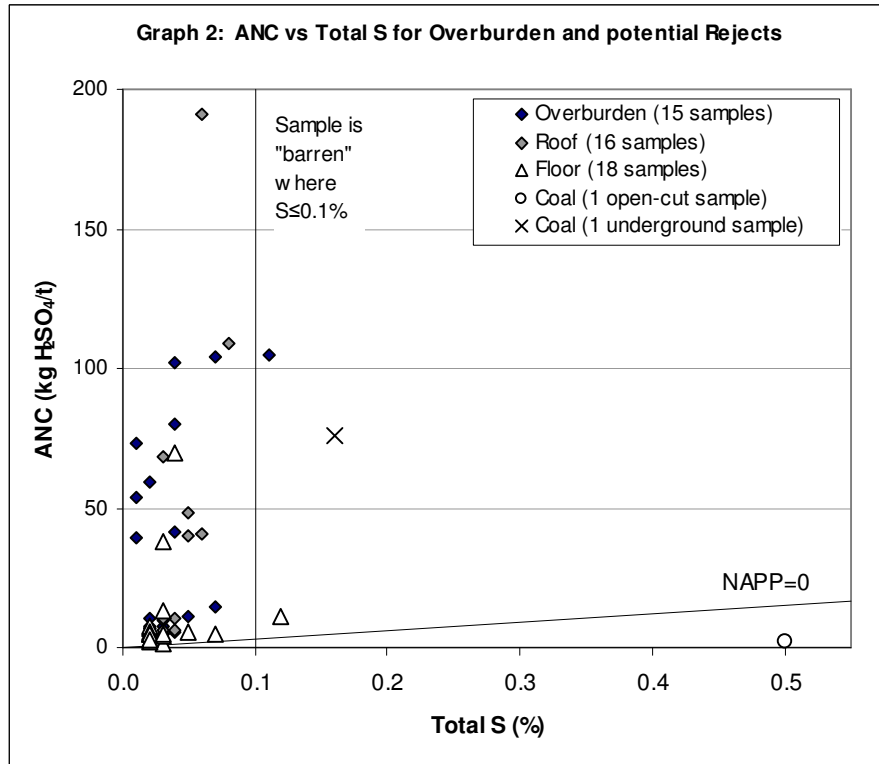
Since the large majority of the coal mined from the ECMP will be mined from the underground, it would appear that most ROM coal is likely to be NAF and would likely pose little or no risk of acid generation. Also, given that only very minor quantities of coal are expected to report as waste and this waste material will be deposited (co-disposed with overburden and other potential rejects) into the WEF, then the real risks of acid generation are small.

With regard to the coal from the box-cut, this coal is expected to be processed at Carborough Downs during the construction of the Ellensfield CHPP. Therefore, the potential low acid generating risk this shallow coal material may pose needs to be considered in the management of this coal at Carborough Downs.

### 4.4 Material Classification

The total sulphur content of material represented by the overburden and potential reject samples is very low compared to other coal mines in Australia. Various total sulphur concentrations are reported in the literature for indicating 'safe' maximum values for prevention of acid generation at coal mines. As a general rule, coal mine mineral wastes with a total sulphur content of less than 0.2 per cent can generally be classified as NAF. Furthermore, coal mine mineral waste materials with a total sulphur content of less than 0.5 per cent can generally be classified as having a low potential for both acid formation and generation of soluble salts, particularly if materials have a significant inherent ANC. Excluding the coal sample from the proposed open-cut area, all overburden and potential reject samples have total sulphur contents below 0.2 per cent (all samples less than 0.16%, with most below 0.1%). The shallow coal sample has a total sulphur content of 0.5 per cent.

The results displayed in **Graphs 2 and 3** indicate that the total sulphur test can be used as a simple, quick and cost-effective method at the ECMP to determine the likely acid forming nature of overburden and potential reject materials.



## 5 MULTI-ELEMENTS COMPOSITION AND WATER QUALITY

The multi-element composition of composite samples for overburden and potential reject materials is provided in **Table 3-2** and allows comparison of any enriched metal concentrations with those described in QLD-EPA (1998) environmental investigation levels (EIL), NEPC (1999a) health-based guidelines “E” for soils in open spaces (e.g. parks and recreational areas).

Additionally, the soluble multi-element composition of overburden and potential reject materials is provided in **Table 3-3** and also allows comparison of enriched metal concentrations in solution with applied ANZECC (2000a) and NEPC (1999b) livestock drinking water guidelines.

It is important to note that there are no specific regulatory criteria for multi-element concentrations in overburden and coal reject materials nor in leachate derived from such materials on mine sites. Terrenus has compared the multi-element concentrations in all of these mineral waste materials and in leachate from these materials with the above guidelines to provide some context for the discussion of test results.

### 5.1 Overburden

The multi-element results in **Table 3-2** indicate that in all three overburden composite materials tested, Mn concentrations in solids are greater than QLD-EPA (1998) environmental investigation levels (EIL), but well below the NEPC (1999a) health-based investigation levels (HIL) for soils (parks and recreational open spaces).

Water extract results (**Table 3-3**) indicate that the dissolved salt concentration in initial leachate from overburden is likely to be sodium-chloride (Na-Cl) dominated, with lesser concentrations of other major ions. Initial leachate from overburden is also likely to contain dissolved metal and salt concentrations well below those recommended in ANZECC (2000) and NEPC (1999b) guidelines, possibly with the exception of mercury (Hg), which was slightly elevated in one sample (measured value 0.0028 mg/L in fresh siltstone) with respect to the applied water quality guideline value of 0.002 mg/L.

### 5.2 Potential Rejects

The multi-element results (**Table 3-2**) indicate that all metal concentrations in potential seam roof and coal materials are well below the QLD-EPA (1998) EIL and the NEPC (1999a) HIL(E) for “parks and recreational open spaces”. Total copper concentrations were marginally elevated in 3 of the 5 floor samples with respect to the applied QLD-EPA (1998) EIL, but were all well below the applied NEPC (1999a) HIL(E).

Water extract results (**Table 3-3**) indicate that leachate from potential reject material, including coal, is likely to be Na-Cl and Na-SO<sub>4</sub> dominated, with lesser concentrations of other major ions.

Initial leachate from potential reject material, including coal, is likely to contain dissolved metal and salt concentrations well below those recommended for livestock drinking water (ANZECC, 2000; NEPC, 1999b). In most samples, elemental concentrations were below the laboratory limit of reporting.

In all cases, it should be noted that the water extract data represents overburden and reject pore water chemistry (1:5 w/v) and further dilution effects from rainfall and natural attenuation are likely occur in the field.

## 6 SUITABILITY OF MINERAL WASTE MATERIALS FOR USE IN REVEGETATION AND REHABILITATION

The following discussion applies primarily to overburden materials from the ECMP only. Potential coal rejects would never be expected to be used, on their own, as a growth medium during rehabilitation or reporting to final surfaces on in-pit or out-of-pit overburden spoil piles.

From a soil chemistry viewpoint the overburden materials have different characteristics compared to the potential reject materials, although the main geochemical difference between materials is primarily due to the state of oxidation (*i.e.* weathered versus fresh) more-so than overburden versus rejects. Even though most of the mineral wastes are expected to be rejects, and these will be co-disposed with overburden from the box-cut into the WEF, some quantity of overburden materials will need to be “set aside” for rehabilitation and revegetation of the spoil piles (*i.e.* it is not acceptable mining practice to allow rejects to report to final surfaces – typically they are buried well into the overburden material). Additionally, some overburden will report to an out-of-pit spoil pile (as well as the WEF). With this in mind, the suitability of mineral waste materials for use in revegetation and rehabilitation is focused on the overburden materials.

All of the tested overburden composite materials (and also the potential reject materials) had high Exchangeable Sodium Percentage (ESP) values, ranging from 13 to 51 per cent. Where the EC is relatively low, such as in the tested samples, an ESP value of 6 per cent or greater indicates that these materials are regarded as sodic and may be prone to dispersion (Isbell, 2002). Soil with an ESP value greater than 14 per cent is regarded as strongly sodic (Northcote and Skene, 1972). Strongly sodic materials are likely to have structural stability problems related to potential dispersion (Van de Graaff and Patterson, 2001). Treatment of all sodic overburden (and potential reject materials) would be required if these are to be used as vegetation growth medium.

Ideally, sodic and dispersive materials should be identified, selectively handled and placed within the core of spoil piles away from final surfaces, or returned to voids during mining. However, since *all* overburden and reject materials are expected to be strongly sodic, this method of managing sodic material is unlikely to be cost effective. Therefore, it is likely that treatment of the sodic waste materials would be required if these were to be used as an additional source of topsoil.

In addition to potential dispersion problems, sodic soils often have unbalanced nutrient ratios that can lead to macro-nutrient deficiencies (Hazelton and Murphy, 2007). The table below (**Table 6-1**) shows the proportions of each exchangeable cation relative to eCEC. The ‘desirable’ proportions of each major cation are also shown (Abbott, 1989, *in* Hazelton and Murphy, 2007).

**Table 6-1 Proportions of eCEC of major exchangeable cations**

Exchangeable Cation	Desirable ranges	Overburden	Roof	Floor
	% CEC			
Calcium (Ca)	65 - 80	47 – 65 (avg. 56)	13 – 76 (avg. 57)	13 – 54 (avg. 32)
Magnesium (Mg)	10 - 15	17 – 26 (avg. 20)	5 – 41 (avg. 15)	7 – 41 (avg. 17)
Potassium (K)	1 - 5	3 – 3 (avg. 3)	3 – 4 (avg. 4)	6 – 13 (avg. 8)
Sodium (Na)	0 - 1	13 – 24 (avg. 19)	15 – 43 (avg. 24)	32 – 51 (avg. 41)

When compared to the desirable ranges for exchangeable cations in soil (**Table 6-1**), average exchangeable Ca proportions in overburden are marginally low and average exchangeable Mg

proportions are marginally high. Of note, is that exchangeable Na proportions in overburden are extremely high. Soils that are high in exchangeable Na and Mg tend to show more dispersion than soils that are high in Na and Ca (Hazelton and Murphy, 2007). Exchangeable Ca:Mg ratios between four and six indicate that a soil is 'balanced' (Eckert, 1987, *in* Hazelton and Murphy, 2007). Exchangeable Ca:Mg ratios less than four indicate a calcium deficiency and ratios above 6 indicate a magnesium deficiency. Overburden samples from the ECMP have an exchangeable Ca:Mg ratio of between 1.8 and 3.9, suggesting a calcium deficiency.

The exchangeable cation proportions in potential rejects are similar to overburden materials, although the proportion of exchangeable Na in floor materials is higher than overburden materials. Also the exchangeable Ca:Mg ratios for floor materials much lower than roof materials.

It should be noted that in soil chemistry a pH<sub>1:5</sub> (solid:water) of between 7.9 and 8.4 is regarded as moderately alkaline and a soil pH<sub>1:5</sub> of between 8.5 and 9.0 is regarded as strongly alkaline. Two of the overburden samples are regarded as moderately alkaline and the remainder are regarded as strongly alkaline. Similarly, all except three potential reject samples are regarded as strongly alkaline. Therefore some degree of nutrient imbalance is likely to already exist in these materials.

In summary, *all* mineral waste materials tested are regarded as strongly alkaline. Weathered materials have generally moderate to high salinity, whereas fresh materials have a much lower salinity. All materials are strongly sodic and can be regarded as having an exchangeable cation imbalance. Amelioration of these materials will be likely before these materials can be successfully used as a vegetation growth layer.

## 7 CONCLUSIONS

The following conclusions are based only on the data and interpretations presented in this report. Further and more detailed testing of these materials, as recommended in the Management Measures section (**Section 8**), will undoubtedly improve the confidence in these conclusions.

### 7.1 Overburden

- Overburden generated by the proposed ECMP is likely to be benign and will generate slightly alkaline and potentially low- to moderate-salinity runoff and seepage following surface exposure.
- Almost all of the overburden is likely to have very low total sulphur content (<0.1%) and can be classified as barren. Only one sample had total sulphur above 0.1 per cent. No samples had total sulphur content above 0.2 per cent.
- Acid generation from overburden is extremely unlikely given the lack of oxidisable sulphur content, excess ANC and overall alkaline pH of these materials. All of the overburden samples are classified as NAF, with almost all also classified as NAF-barren.
- The concentration of metals in overburden materials are, in most cases, well below the applied guideline criteria for soils and are unlikely to present any environmental issues associated with revegetation and rehabilitation of the WEF.
- Water extract tests indicate that the concentration of soluble metals and salts in runoff and seepage from overburden is likely to remain well within applied water quality guideline criteria and is unlikely to present any significant environmental risks for on-site or downstream water quality.

- All overburden material tested is sodic and alkaline and its use as a cover material and/or as topsoil/growth layer will likely be subject to measures to improve the cation imbalance.

## 7.2 Potential Coal Reject (including coal)

- Roof, floor and potential coal reject material should be relatively benign and will likely generate slightly to moderately alkaline and relatively fresh (non-saline) runoff/seepage following surface exposure.
- Almost all roof and floor materials are likely to have very low total sulphur content (<0.1%) and can be classified as barren. No roof samples and only one floor sample had total sulphur contents above 0.1 per cent. No roof or floor samples had total sulphur contents above 0.2 per cent. No coal samples had total sulphur contents above 0.5 per cent.
- Acid generation from roof, floor and coal materials is extremely unlikely given the general lack of oxidisable sulphur content and slightly alkaline pH of these materials, despite the relatively low ANC in most potential reject samples.
- The concentration of metals in roof, floor and potential coal reject materials are, in most cases, well below the applied environmental and health-based investigation guideline levels for soils and are unlikely to present any significant environmental issues associated with revegetation and rehabilitation of the WEF.
- Water extract tests indicate that the concentration of soluble metals and salts in runoff and seepage from roof, floor and potential coal reject materials is generally likely to remain well within applied water quality guideline criteria and runoff/seepage is unlikely to present any significant environmental risks for on-site or downstream water quality.
- All roof, floor and potential coal reject material tested is strongly sodic and strongly alkaline.
- The discussion of potential coal reject materials (roof, floor and coal) within this report should be considered indicative only, since coal reject material from the CHPP may have slightly different geochemical characteristics having undergone crushing and washing in bulk quantities.

## 8 MANAGEMENT MEASURES

The ongoing management of mineral waste (overburden and potential reject materials) should consider the geochemistry of materials with respect to their potential risk to cause harm to the environment and their suitability for use in revegetation. The design of a mineral waste management strategy for ECMP should consider:

- placement of mineral waste materials to minimise run-off and erosion; and
- evaluating the geochemical characteristics of materials from 'new' areas or lithologies that have not been evaluated.

As would be evident from the distribution of drill holes used for geochemical sampling shown in **Figure 1-2**, ECM should undertake ongoing geochemical characterisation of mineral waste materials in the proposed box-cut area, and in new or expanded exploration areas associated with the ECMP, to confirm the geochemical findings discussed in this report.

Assuming the ECMP is approved and developed, characterisation of tailing and reject materials from the CHPP is required to verify the expected geochemical data of rejects. This data should be used to re-evaluate the management strategies of mineral waste materials.

This study has identified that overburden and potential reject materials are expected to be non-acid forming (NAF). As such, acid generation is considered to be very unlikely. Therefore, no special acid rock drainage management strategies will be required.

For future work, in addition to standard acid-base and metals testing (static tests), geochemical characterisation should include assessing the sodicity and erosion potential of mined waste materials to evaluate their suitability for use in revegetation activities.

Leachate and site water derived from, or in contact with, spoil piles, reject materials or other mineral waste should be monitored to ensure that soluble metals and salt concentrations are below regulatory guidelines or licence conditions. The parameters monitored and the frequency of monitoring should be considered in the design of the site water monitoring program, taking into account the results of the geochemical investigation tabled herein. Such parameters are likely to include a similar suite to those parameters referred to herein.

At a minimum, the range of analyses included in the water quality monitoring program for runoff/seepage from overburden and potential reject storage facilities should focus on pH, EC and TDS. Annual sampling and testing of the full suite of dissolved metals described in this report should be included in the water quality monitoring program developed for the project. If the pH of runoff and seepage from overburden or potential reject materials drops below pH 6.0 or the EC value increases by more than 50 per cent, then a more comprehensive range of water quality analysis may be warranted. Also, if the pH drops below 6.0 or the EC increases, the handling and storage (management) of all mineral waste materials should be re-evaluated.

## 9 REFERENCES

- ANZECC (2000a). Australian and New Zealand Guidelines for Fresh and Marine Water Quality: Livestock Drinking Water. Australian and New Zealand Environment Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ). Canberra, ACT.
- ANZECC (2000b). Australian and New Zealand Guidelines for Fresh and Marine Water Quality: Aquatic Ecosystems. Australian and New Zealand Environment Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ). Canberra, ACT.
- Hazelton, P.A. and Murphy, B.W (eds). (2007). Interpreting Soil Test Results: What do all the numbers mean? [2nd edn.] CSIRO Publishing, Collingwood, Victoria.
- Isbell, R.F. (2002). The Australian Soil Classification (revised edition). CSIRO Publishing. Victoria.
- NEPC (1999a). National Environment Protection Council. National Environmental Protection (Assessment of Site Contamination) Measure. Guideline on investigation levels for soil and groundwater. HIL(E); parks, recreation open space and playing fields.
- NEPC (1999b). National Environment Protection Council. National Environmental Protection (Assessment of Site Contamination) Measure. Guideline on investigation levels for soil and groundwater. Groundwater Investigations Levels.
- Northcote, K.H., and Skene, J.K.M. (1972). Australian soils with saline and sodic properties. CSIRO Australia, Soil Publication No. 27, Canberra.
- Standards Australia (1997a). AS4439.3-1997 Wastes, sediments and contaminated soils. Part 3: Preparation of leachates – Bottle leaching procedure. Homebush, NSW.
- Stewart W., Miller S., Thomas J. and Smart R., Evaluation of the Effects of Organic Matter on the Net Acid Generation (NAG) Test. Proceedings of the 6th International Conference on Acid Rock Drainage, 14-17 July, 2003, Cairns, Australia.
- Van de Graaff, R. and Patterson, R.A. (2001). Explaining the Mysteries of Salinity, Sodicity, SAR and ESP in On-site Practice. In: Proceedings of On-Site '01 Conference: Advancing On-Site Wastewater Systems. Patterson, R.A. & Jones, M.J. (Eds). Lanfax Laboratories, Armidale. pp 361-368.

## 10 LIMITATIONS

Terrenus Earth Sciences (Terrenus) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of URS Australia Pty Ltd (URS), Ellensfield Coal Management Pty Ltd (ECM) and only those additional parties who have been authorised in writing by Terrenus to rely on this report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the URS Proposal.

The methodology adopted and sources of information used by Terrenus are outlined in this report. Terrenus has made no independent verification of this information beyond the agreed scope of works and Terrenus assumes no responsibility for any inaccuracies or omissions outside of Terrenus' direct control. No indications were found during our investigations that information contained in this report as provided to Terrenus was false or misleading.

This report was prepared from August to October 2008, from data collected between November 2007 and October 2008, and is based on the conditions encountered and information reviewed during this period. Terrenus disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by parties other than URS and ECM. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

\* \* \* \* \*

### Terrenus Earth Sciences

Dr. Ian P Swane  
Director & Principal Consultant

**23 October 2008**

## **APPENDIX A. Composite Sample Details**

**Table A1. Composite sample details**

Individual Sample ID	Composite Sample ID	Sample Type	Sample Description
EF147 - 01	EF C1	Overburden (weathered)	Claystone, mudstone & siltstone (weathered)
EF147 - 02			
EF157 - 02			
EF148 - 01			
EF154-02			
EF154-03	EF C2	Overburden	Siltstone (fresh)
EF154-05			
EF147 - 10			
EF148 - 05			
EF147 - 12			
EF147 - 13	EF C3	Overburden	Sandstone (fresh)
EF157 - 04			
EF157 - 05			
EF154-07	EF C4	Leichhardt roof	Claystone (weathered) Siltstone (fresh)
EF148 - 07			
EF148 - 02			
EF147 - 06	EF C5	Leichhardt roof	Mudstone and shale, carbonaceous (fresh) 111m-310m
EF151 - 02			
EF091SP Geochem 1 LR	EF C6	Leichhardt roof	Siltstone, carbonaceous (fresh) 89m-179m
EF069G Geochem 2 LR			
EF108C3 Geochem 1 LR			
EF162C Geochem 1 LR			
EF003C1 Geochem 1 LR	EF C7	Leichhardt roof	Siltstone, carbonaceous (fresh) 198m-410m
EF078C Geochem 2 LR			
EF076C4 Geochem 1 LR			
EF077C Geochem 1 LR			
EF080C Geochem 1 LR			
EF160C Geochem 1 LR	EF C8	Leichhardt floor	Siltstone, carbonaceous (fresh) 14m-18m
EF029C Geochem 1 LR			
EF132C Geochem 1 LR			
EF128C Geochem 1 LR	EF C9	Leichhardt floor	Mudstone (fresh) 117m-322m
EF147 - 07			
EF148 - 03			
EF069G Geochem 3 LF	EF 10	Leichhardt floor	Shale, carbonaceous (fresh) 226m-249m
EF091SP Geochem 2 LF			
EF096G Geochem LF			
EF160C Geochem 2 LF	EF 11	Leichhardt floor	Siltstone, carbonaceous (fresh) 94m to 202m
EF108C1 Geochem 2 LF			
EF108C2 Geochem 2 LF			
EF003C1 Geochem 2 LF			
EF078C Geochem 3 LF			
EF076C4 Geochem 2 LF	EF 12	Leichhardt floor	Siltstone (fresh) 250m-416m
EF077C Geochem 2 LF			
EF080C Geochem 2 LF			
EF108C3 Geochem 2 LF			
EF162C Geochem 2 LF			
EF164 Geochem LF	EF 13	Leichhardt seam	Coal (fresh)
EF132C Geochem 2 LF			
EF128C Geochem 2 LF			
EF164 Geochem LHD			
EF149			

## **APPENDIX B. Evaluation and Interpretation of Static Geochemical Test Data**

## B1. Acid Generation and Prediction

Acid generation is caused by the exposure of sulphide minerals, most commonly pyrite (FeS<sub>2</sub>), to atmospheric oxygen and water. Sulphur assay results are used to calculate the maximum acid that could be generated by the sample by either directly determining the pyritic sulphur content or assuming that all sulphur not present as sulphate occurs as pyrite. Pyrite reacts under oxidising conditions to generate acid according to the following overall reaction:



According to this reaction, the maximum potential acidity (MPA) of a sample containing one per cent sulphur as pyrite would be 30.6 kg H<sub>2</sub>SO<sub>4</sub>/t.

The chemical components of the acid generation process consist of the above sulphide oxidation reaction and acid neutralisation, which is mainly provided by inherent carbonates and to a lesser extent silicate materials. The amount and rate of acid generation is determined by the interaction and overall balance of the acid generation and neutralisation components.

### Determination of pH and EC

pH and EC measured (and are reported) on 1:5 w/w water extract. This gives an indication of the inherent acidity and salinity of the mine material when initially exposed in an emplacement area.

### Total sulphur content, sulphate sulphur and Maximum Potential Acidity (MPA)

Total sulphur content is determined by the Leco high temperature combustion method. The total sulphur is used to calculate the Maximum Potential Acidity (MPA), which is based on the conservative assumption that all sulphur is present as reactive pyrite. If a more accurate estimate of the MPA is required, this can be achieved by determining pyritic sulphur and other sulphide forms directly.

### Acid neutralising capacity (ANC)

The ANC measures the capacity of a sample to react with and neutralise acid by addition of acid to a known weight of sample, then titration with NaOH to determine the amount of residual acid. The ANC can be further evaluated by slow acid titration to a set end-point and then calculation of the amount of acid consumed and evaluation of the resultant titration curve.

### Net acid producing potential (NAPP)

Calculated from the MPA and ANC results. The NAPP represents the balance between a samples inherent capacity to generate and neutralise acid. If the MPA is greater than the ANC then the NAPP is positive. If the MPA is less than the ANC then the sample then the NAPP is negative.

### Net acid generation (NAG) capacity and NAGpH

The net acid generation (NAG) test involves the addition of hydrogen peroxide to a sample of mine rock or process residue to oxidise reactive sulphide, then measurement of pH and titration of any net acidity produced by the acid generation and neutralisation reactions occurring in the sample. A significant NAG result (*i.e.* final NAGpH < 4.5) generally indicates that the sample is Potentially Acid Forming (PAF) and the test provides a direct measure of the net amount of acid remaining in the sample after all acid generating and acid neutralising reactions have taken place. A NAGpH ≥ 4.5 indicates that the sample is Non-Acid Forming (NAF).

The NAG test provides a direct assessment of the potential for a material to produce acid after a period of exposure and weathering and can be used to refine the results of the theoretical NAPP

predictions. The NAG test can be used as a stand-alone test but is recommended that this be considered only after site-specific calibration work is carried out.

In carbonaceous materials (where total organic carbon concentration is high) the standard NAG test can be augmented by a modified NAG test, containing an extended boiling step to identify the presence of organic acids. Unlike pyritic acidity, organic acidity does not contribute to acid mine drainage.

## **B2. Assessment of Element Enrichment and Solubility**

In mineralised areas it is common to find a suite of enriched elements that have resulted from natural geological processes. Multi-element scans are carried out to identify any elements that are present in a material at concentrations that may be of environmental concern with respect to surface water quality and revegetation. The samples are typically analysed for the following elements, although the actual suite of elements tested is project specific:

Major elements	Al, Ca, Fe, K, Mg, Na, Si, and S
Minor elements	As, B, Cd, Co, Cr, Cu, F, Hg, Mn, Mo, Ni, P, Pb, Sb, Se, Zn

The assay result for each element is compared to relevant environmental and health-based investigation levels (*e.g.* NEPC, 1999a,b) to determine any concerns related to rock emplacement or process residue facility operation and final rehabilitation.

Elements identified as enriched may not necessarily be a concern for revegetation, drainage water quality, or public health but their significance should be evaluated. Similarly, because an element is not enriched does not mean it will never be a concern, because under some conditions (*e.g.* low pH) the geochemical behaviour of common environmentally important elements such as Al, Cu, Cd, Fe and Zn increases significantly.

Water extracts are used to determine the immediate element solubilities under the existing sample pH conditions of the sample. Element concentrations are generally compared with those recommended in relevant surface water (ANZECC, 2000a and b) and groundwater (NEPC, 1999c) guidelines in order to determine their environmental significance. The following tests are normally carried out:

### **Multi-element composition of solids**

Multi-element composition of solid samples determined using a combination of ICP-mass spectroscopy (ICP-MS), ICP-atomic emission spectroscopy (AES), and atomic absorption spectrometry (AAS).

### **Multi-element composition of water extracts (1:5 sample:deionised water)**

Multi-element composition of water extracts from solid samples determined using a combination of inductively coupled plasma - mass spectroscopy (ICP-MS) and inductively coupled plasma - atomic emission spectroscopy (ICP-AES).

---

**Terrenus Earth Sciences**

ABN: 34 051 270 995

12 Granville Street  
Wilston QLD 4051 Australia  
Telephone / Fax: +61 7 3352 3692

---