CENTRAL WEST COAL PROJECT
AND
COOLIMBA POWER PROJECT

GEOCHEMICAL ASSESSMENT OF OVERBURDEN, POTENTIAL COAL REJECT AND COAL COMBUSTION ASH

Final Report 08-005-09/R002

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EXECUTIVE SUMMARY

Terrenus Earth Sciences (Terrenus) has been commissioned by URS Australia Pty Ltd (URS), on behalf of Aviva Corporation Ltd (Aviva), to provide consulting services associated with the proposed development of the Central West Coal (CWC) and Coolimba Power Projects located near Eneabba, approximately 270 km north of Perth, Western Australia. These consulting services were required as an integral component of the Public Environmental Review documentation for the proposed development of the coal mine and associated Coolimba coal-fired power station.

Terrenus has geochemically characterised overburden, interburden and potential coal reject material from the proposed mine project, as well as coal combustion material from the pilot-scale furnace.

Potential coal reject materials (coal seam roof, floor and coal) have been included in the scope to address potential environmental management issues should this material be generated as part of coal mining and processing activities. Coal combustion ash has been included in the scope to address potential environmental management issues associated with the proposed in-pit disposal of power station ash.

Geochemical Characterisation and Assessment of Overburden

Overburden generated by the proposed CWC Project is likely to be relatively benign and is expected to generate pH-neutral and low-to-moderately saline runoff and seepage following surface exposure. Over half of the overburden is expected to have very low total sulphur content and can be classified as barren. The risk of acid generation from overburden is expected to be low given the general lack of oxidisable sulphur content.

Over 80% of overburden samples tested are classified as non-acid forming (NAF), with a further 8% classified as uncertain-NAF. The remaining 10% (approximately) are classified as potentially acid forming (PAF).

The concentration of metals in overburden materials (solids) are within the applied guideline criteria for soils and are unlikely to present any environmental issues associated with revegetation and rehabilitation of any out-of-pit overburden storage facilities.

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

All overburden materials tested are strongly sodic, with significant exchangeable cation imbalances, and would likely require soil conditioning to be suitable to use as a cover material or as topsoil/growth layer.

Geochemical Characterisation and Assessment of Potential Rejects

Roof, floor and potential coal reject material is expected to generate weakly acidic (degree of acidity unknown) and moderately saline runoff/seepage following surface exposure.

With the exception of the floor of the EMS Lower seam, which has a mixed NAF-PAF acid-generation classification, *all* of the potential rejects are expected to be overwhelmingly PAF. As such, the potential rejects are classified as PAF.

The concentrations of metals in potential reject materials (solids) are generally within the applied guideline criteria for soils. Water extract tests indicate that the concentration of soluble metals and salts in runoff and seepage from potential rejects is generally likely to remain within the applied water quality guideline criteria, provided these materials do not undergo further oxidation, given their PAF classification.

The discussion of potential coal reject materials within this report should be considered indicative only, since coal reject material from the coal preparation plant may have different geochemical characteristics having undergone bulk crushing and washing.

Due to the PAF nature of potential rejects, the risk to the environment from these materials is considered to be high, until proven otherwise by more detailed test-work. As such, all potential coal reject materials (including coal) will need to be carefully managed to minimise oxidation, generation of acid and potential release of metals (and salts) into the environment.

Geochemical Characterisation and Assessment of Coal Combustion Ash

Coal combustion ash is expected to generate alkaline and relatively low-salinity runoff/seepage following surface exposure. All of the ash samples tested were non acid forming.

The multi-element results indicate that solid ash materials are expected to have total metals and nutrient concentrations (in solids) well below the applied guideline values. Results from bottle-leaching indicate that leachate from coal combustion ash is likely to contain some dissolved metals in concentrations that may exceed the applied water quality guidelines. The key metals and metalloids of concern are As, B, Cr, Cu, Mo, Se and Zn.

Very low concentrations of soluble uranium and thorium in leachate from coal combustion ash suggest that radioactivity associated with coal combustion ash (and coal) is expected to be within the background levels of soil.

The discussion of ash materials within this report should be considered indicative only, since ash wastes from the operational Coolimba Power Station may have different geochemical characteristics to these samples, which were generated from a batch process.

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 CWC should consider:

- Placement of mineral waste materials, particularly potential rejects, to minimise run-off and erosion. The current geochemical interpretation of potential reject materials suggests that encapsulation (burial) of these materials well within NAF overburden will be required to minimise oxidation and the onset of acid;
- Run of Mine (ROM) coal handling and management practices, since EMS coal is expected to generate acid leachate;
- Evaluating the geochemical characteristics of materials from ‘new’ areas or lithologies that have not been evaluated, in particular, the northern parts of the lease that have not been investigated in this study;
- Evaluating the long-term geochemical characteristics of materials identified as PAF or producing leachate containing elevated concentrations of metals or salts;
- Continued characterisation of rejects from the crushing circuit 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.

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1 INTRODUCTION

Terrenus Earth Sciences (Terrenus) has been commissioned by URS Australia Pty Ltd (URS) on behalf of Aviva Corporation Ltd (Aviva) to provide consulting services associated with the proposed development of the Central West Coal (CWC) and Coolimba Power Projects, located near Eneabba, approximately 270 km north of Perth, Western Australia (**Figure 1**). These consulting services were required as an integral component of the Public Environmental Review (PER) documentation for the proposed development of the coal mine and associated coal-fired power station.

Terrenus has geochemically characterised overburden, interburden and potential coal reject material from the proposed mine project, as well as coal combustion ash from the pilot-scale furnace for the Coolimba power project. Potential coal reject materials (coal seam roof & floor and poor coal) have been included in the scope to address potential environmental management issues should this (potential reject) material be generated as part of future coal processing activities. Coal combustion ash has been included in the scope to address potential environmental management issues associated with the proposed in-pit disposal of power station ash.

The Coolimba power station project comprises the construction and operation of a coal-fired power station located adjacent to the mine. This geochemical characterisation and assessment study incorporates the CWC and Coolimba Power projects.

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 Aviva CWC Project and Coolimba Power Project and identify potential environmental issues that may be associated with mining, handling and storing of these materials.*

Client	Project	Title
AVIVA CORPORATION LTD	AVIVA CENTRAL WEST COAL PROJECT	**REGIONAL LOCATION PLAN**
URS	Drawn: RG; Approved: JB; Date: 16-09-2008	Figure: **1**
	Job No: **4290 6631**; File No: 42906631-g-001.wor	Rev:A; **A4**

1.2 Background to the CWC Project

The Project will involve the mining of a sub-bituminous coal deposit (the Central West Coal Deposit) as an energy source for the proposed Coolimba Power Station.

The key components of the Project are as follows:

- An open-cut coal mining operation (strip mining) mining two plys from the EMS seam (the EMS Upper and EMS Lower).
- The mine will extract approximately 2 to 2.5 million tonnes per annum (Mtpa) of sub-bituminous coal.
- The mine will commence at the southern end of the deposit and progress northwards along the strike with a disturbed open area of approximately 75 ha at any point in time.
- The operation will enable a continual backfill and rehabilitation programme to be undertaken - returning the land to the original contours as the mine progresses.
- The pit will have an average width of 750 m with an average depth of 120 m.
- An initial out-of-pit spoil pile of approximately 22 Mm^3, which will cover an area of approximately 120 ha and have a height of approximately 25 m. Thereafter, overburden will be disposed of in-pit.
- The project is expected to leave a final void with an area of approximately 100 ha.
- Based on the current estimate of reserves, the anticipated life of the mine is approximately 30 years.

1.2.1 Project Geology

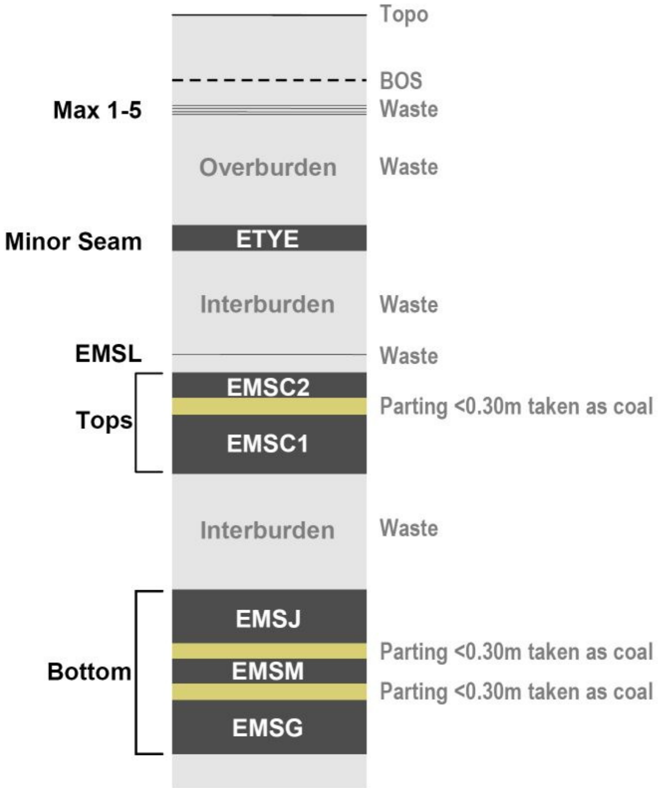
Coal resources in the region occur within the Jurassic Cattamarra Coal Measures - the upper member of the Cockleshell Gully Formation within the Dandaragan Trough. The Dandaragan Trough is a major fault-bounded subdivision in the deepest part of the Perth Basin (Minserve, 2006).

In the Project Area three main coal horizons have been identified in ascending (bottom to top) order: the Eneabba Main seam (EMS), the Eighty seam (ETYE) and the Maxwell seams (MAX). These coal horizons are characterised by upward fining sequences of sandstone, siltstone grading to mudstone and claystone / shale and ultimately coal. The sequences are cyclic with a cycle thickness of approximately 50 m between each successive coal horizon. The main economic seam in the area is the EMS (the deepest seam) which has undergone various seam splits along the strike of the project area from south to north (Minserve, 2006).

In the northern section of the Project Area, the EMS splits into two major plies, an upper ply which ranges in thickness from 4.5 m to 5.5 m, averaging 5.0 m thick and a lower ply comprising several seams ranging approximately from 3 m to 4.5 m thick. The EMS lower plies undergo considerable lateral variation, with the plies commonly splitting and re-coalescing regularly along the strike. The ETYE and MAX seams are considerably thinner and less prospective (Minserve, 2006). The generalised stratigraphy showing the Upper and Lower plys of the EMS seam is shown in **Figure 2** (reproduced from Minserve, 2006).

The deposit contains Measured and Indicated Resources for the EMS seams of 75.4 million tonnes (Mt) to a depth of 130 m of which 42.4 Mt is Measured Resources with the potential to be extracted by open cut methods. A further 11.3 Mt of Inferred Resources have also been estimated to be present in the EMS seams to a depth of 130 m. Inferred Resources of approximately 2.5 Mt to a depth of 130 m occurs in the ETYE seam (Minserve, 2006).

Figure 2 Generalised stratigraphy of the CWC project



* Figure 2 reproduced from Minserve, 2006.

1.2.2 Mineral Waste Quantities

Overburden and Reject Volumes Likely to be Generated by the Project

The quantities presented in this section are based on the "100m depth" block model (Minserve, 2006).

The total mined overburden and interburden volumes are expected to approximate over 375 million bulk cubic metres (bcm) over a 30-year mine life (estimated 525 million tonnes based on assumed sandstone/siltstone excavated density of 1.4).

There will also be additional poor-coal reject material generated by the project; primarily coal seam roof and coal seam floor material from the EMS coal seam. Approximately 19 million tonnes of coarse rejects are expected to be produced from the crushing circuit over a 30-year life (from an initial ROM coal quantity of approximately 58 to 69 million tonnes, processed at approximately 2.3 Mtpa).

On this basis, rejects are expected to comprise less than 4% of all geological waste (*i.e.* overburden, interburden and rejects) produced by the project. Most, if not all, of the rejects are expected to be co-disposed with spoil into the mined-out pit.

1.2.3 Mineral Waste Disposal

Out-Of-Pit Spoil Disposal

Overburden and interburden will be predominantly disposed of into the mined-out pit, however an out-of-pit (OOP) spoil pile will be constructed for the initial stages of mining. Approximately 22 Mm^3 (up to 6%) of all mined overburden and interburden is expected to report to the OOP spoil pile (Minserve, 2006; Aviva pers. comm., 22 August 2008).

Reject Disposal

The coal rejects from the proposed crushing circuit will be disposed into the mine void (co-disposed with spoil), once steady-state production is achieved.

Combustion ash produced from the Coolimba Power Project will be transported to the CWC Project and be disposed in the mine void during progressive mining and rehabilitation.

1.3 Background to the Coolimba Power Project

The proposed project will involve the construction and operation of a 450 MW (3 x 150 MW) coal-fired power station adjacent to the CWC mine (**Figure 3**).

From a mineral waste geochemistry viewpoint, the key waste component from the power station will be coal combustion ash from the boiler furnace, comprising fly-ash captured by electrostatic precipitators and bottom-ash collected from the base of the furnace. In addition to coal combustion ash, waste products from flue-gas desulphurisation (FGD) are also expected. At the time of reporting FGD options were still being assessed, however the likely option comprises a circulating fluidised bed (CFB) combustion process where limestone is added to the furnace, with the lime reacting to form sulphates, which become part of the ash. FGD waste product will exit along with fly- and bottom-ash. The expected mass ratio of fly-ash to bottom-ash is approximately 4:1 (ACIRL, 2007). This (approximately) 4:1 mass ratio is typical for coal-fired boilers throughout the world.

1.3.1 Ash and FDG Waste Quantities

The average production rate of combustion ash and FGD waste generated by the CFB process is expected to be in the order of 819,270 tonnes per annum (tpa), comprising approximately 331,920 tpa of FGD waste and 487,350 tpa of ash (*i.e.* the coal combustion ash will comprise approximately 59% of the solid waste leaving the furnace).

The assessment of FGD products was not included in this study (no FGD product was available), however FGD products, which are expected to comprise about 40% of the solid waste from the boiler, primarily comprise gypsum (calcium sulphate) and residual lime. Together, the gypsum and lime are expected to comprise approximately 94% of the FGD waste. Other impurities make up the 6% FGD remainder, *i.e.* “other impurities” account for about 2% (by weight) of the total solid waste from the boiler.

1.3.2 Ash and FDG Waste Disposal

It is anticipated that the bottom ash will be collected via a submerged scraper conveyor and transferred to a bottom ash storage silo via a crusher and bucket elevator. Fly ash will be collected from the bottom of the precipitator / bag house and transferred to onsite dry ash storage silo(s). The onsite ash/FGD storage silo(s) will be sized to accommodate a minimum of 24 hours production from each unit under conditions that will generate maximum plant ash production.

Storage silos will be configured to allow for gravity feed to wheeled transport vehicles (dump trucks), which will transport the ash and FGD products to the coal mine for proposed permanent disposal in the mine pit.

Combustion ash produced from the Coolimba Power Project will be transported to the CWC Project and be disposed in the mine void during progressive mining and rehabilitation. CWC ash and FGD waste is expected to comprise in the order of 3% (by weight) of the total mineral waste mass to be mined (overburden plus rejects).

2 METHODOLOGY

This section provides the methodology used for the geochemical characterisation and assessment of overburden, potential reject materials and coal combustion ash likely to be produced at the CWC and Coolimba Power Projects.

2.1 Desktop Review of Existing Information

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

Geological information was primarily assessed from the Minserve (2006) pre-feasibility report and enhanced by data from recent (2008) exploration drill hole logs from the proposed project area. Based on this information, an understanding of the geological environment (lithology and structure) at CWC was gained.

Some preliminary geochemical information (previously unreported work commenced by Graeme Campbell & Associates (GCA)) was available from two drill holes from the southern end of the project area. This information, where possible, has been incorporated into the new geochemical dataset collected by URS and reported herein.

In addition, Terrenus has reviewed data associated with the milling and combustion of coal for the power station component of the project (ACIRL, 2007).

2.2 Sampling Strategy for CWC 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 Western Australia. 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 Aviva 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.

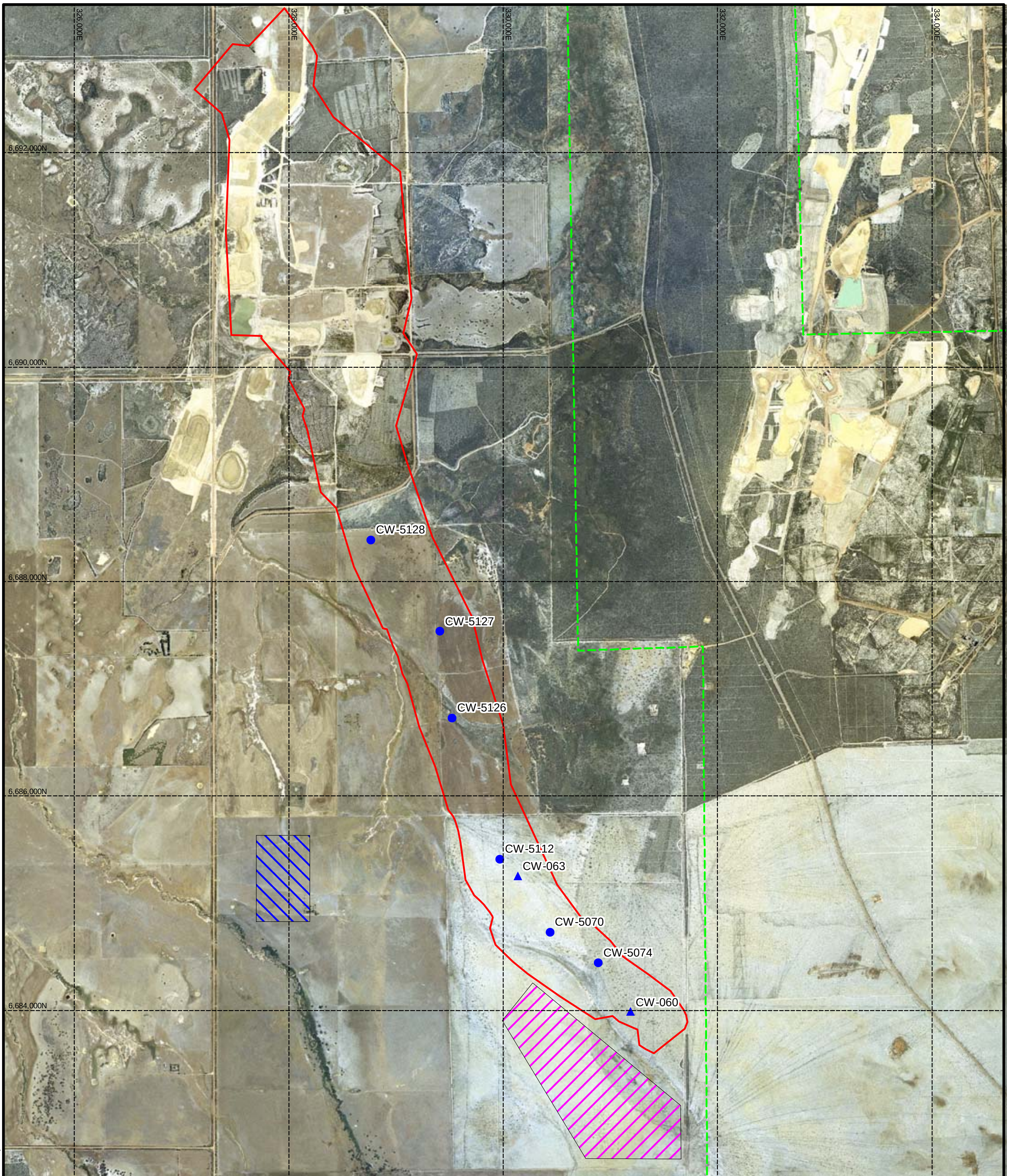
On the basis of initial information supplied to Terrenus and URS (primarily data from two earlier drill holes used to collect samples for geochemical testing), a total of 74 overburden, interburden and potential coarse reject samples were collected from 6 new drill holes (**Figure 3**). In addition, six new coal samples from the EMS seam were also included for testing. These 82 samples supplemented 87 existing overburden, potential coarse reject and coal samples collected in early 2007 by GCA.

In total, the 169 samples comprised:

- 127 overburden samples (2 of which are poor coal samples from the uneconomic ETYE seam);
- 24 potential coarse reject samples:
    - 6 roof samples from immediately above the EMS Upper seam;
    - 3 roof samples from immediately above the EMS Lower seam;
    - 2 roof samples from immediately above the EMS seam (undifferentiated);
    - 7 floor samples from immediately below the EMS Upper seam;
    - 5 floor samples from immediately below the EMS Lower seam; and
    - 1 floor sample from immediately below the EMS seam (undifferentiated);
- 18 coal samples from the EMS seam:
    - 3 coal samples from the EMS Upper seam;
    - 3 coal samples from the EMS Lower seam; and
    - 12 coal samples from the EMS seam (undifferentiated).

In this report, overburden material refers to all mined waste material above the EMS Upper seam and interburden between the EMS Upper and EMS Lower seams, *i.e.* all material reporting directly to either in-pit or ex-pit spoil. Potential reject material comprises minor coal, coal-roof, coal-floor, and mixed coal material immediately above or below the EMS seam.

Economic coal samples from the EMS seam are included in the geochemical test program since some coal material may report directly as mined spoil (depending on the resolution of the mining block model and accuracy of mining methods) or may report to waste as reject from the crushing circuit.



N

0 750 1500m

Scale 1:50,000 (A4)

Horizontal Datum: GDA94
Grid: MGA 94 Zone 50

▲	Drillhole Samples Collected by GCA 2007	red line	Open Pit Boundary
●	Drillhole Samples Collected by URS 2008	green dashed line	Nature Reserve
blue hatching	Proposed Coolimba Power Station	magenta hatching	Proposed out-of-pit Spoil Pile

Source: Client Supplied Data

Client	Project	Title
AVIVA CORPORATION LTD	AVIVA CENTRAL WEST COAL PROJECT	**DRILL HOLE LOCATIONS FOR GEOCHEMICAL SAMPLES**

URS

Drawn: RG	Approved: JB	Date: 16-09-2008	Figure: **3**
Job No: **4290 6631**	File No: 42906631-g-002.wor		Rev:A **A4**

The eight drill holes used for geochemical sampling for this assessment are all located in the southern half of the deposit (**Figure 3**), which represents the first 15 years (approximately) of mine life. Aviva has committed to undertaking geochemical testing of samples from drill holes in the northern section of the deposit once detailed drilling in the northern area commences.

2.3 Geochemical Tests

2.3.1 Mineral Waste Materials from the CWC Project

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 Sulphate, Total Organic Carbon (TOC), Acid Neutralising Capacity (ANC) and Net Acid Generation (NAG) capacity[1]. The potential for a sample to generate acid was derived from the Total Oxidisable Sulphur (TOS) content[2], the calculated 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 for the phase 1 testing (GCA) was conducted by Genalysis Laboratory Services (GLS). All subsequent 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 acid-base characterisation results of the "Phase 2" samples (*i.e.* those samples collected by Terrenus/URS in 2008), most of the 82 samples were combined into 22 composite samples according to lithology, sample depth, sample type (overburden, roof, floor or coal) and initial acid-base classification. The criteria used to determine the initial acid generating potential of each of the 169 overburden and potential reject samples is discussed in **Section 2**. 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

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[1]. The static geochemical testwork program for the initial samples collected by GCA was limited to total sulphur, total carbon and ANC (*i.e.* this first phase of testing did not include total sulphate and NAG tests).

[2] Total oxidisable sulphur (TOS) is calculated by subtracting the Sulphate–S concentration from the Total-S concentration and is assumed to represent total sulphide content. The maximum potential acidity (MPA) value is calculated from the TOS.

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 out-of-pit overburden dumps. **Table 1** summarises the geochemical test program.

2.3.2 Ash Samples from the Coolimba Power Project

Ash samples underwent similar geochemical testing to the drill-hole samples, but also included additional tests, such as bottle leaching tests and analysis for nutrients (ammonia, total nitrogen, nitrate, nitrite and cyanide).

Nutrient analysis was undertaken on these samples since coal combustion ash products are sometimes known to be elevated in nitrogen-compounds. The bottle leaching tests were undertaken as part of the initial ash test-work since, at the time of planning and undertaking the geochemical test work, the disposal strategies for ash materials from the Coolimba Power Project were still being developed and it was possible that the ash wastes may have needed to be disposed into above-ground monofill structures. (Such a strategy is unlike the disposal strategy for the mined materials, which will be disposed of back into the mined-out voids, thus significantly minimising their environmental risk)[3].

Aviva now plan to dispose of the coal combustion ash from the Coolimba Power Project into the mined-out-voids (*i.e.* co-disposed with the overburden and coal rejects).

The geochemical test program for all tested materials is summarised in **Table 1** below.

[3]. Terrenus recognises that in-pit disposal of mineral wastes significantly reduces, but does not eliminate, the potential risks to the environment. As such, based on the results of the initial acid-base characterisation test-work and multi-element test-work undertaken on overburden and potential reject samples, some of these materials will also likely undergo some form of leach testing to better evaluate their potential environmental risks and enable suitable management strategies to be developed. This is discussed in Sections 4, 5 and 8.

Table 1 Summary of the geochemical test program

Analytical Tests	Overburden Materials	Potential Coal Reject Materials			Ash samples
		Roof	Floor	Coal	
Static acid-base (Total-S, Total-C, ANC)	72 samples	2 samples	2 samples	11 samples	---
Static acid-base (pH, EC, acidity, alkalinity, Total-S, SO_4-S, ANC, NAG)	55 samples	9 samples	11 samples	7 samples	3 samples
Extended boil NAG (NAGorg)	3 samples	6 samples	7 samples	6 samples	---
Multi-elements on solids	13 composites	3 composites	4 composites	2 composites	3 samples
Cation exchange properties on solids	13 composites	3 composites	4 composites	2 composites	---
Nutrients on solids	---	---	---	---	3 samples
Multi-element, pH, EC, TDS and alkalinity on water extracts	13 composites	3 composites	4 composites	2 composites	---
Multi-elements and nutrients in leachate from bottle-tumbling tests	---	---	---	---	3 samples

2.4 Explanation of Geochemical Terminology

Geochemical test results for all materials tested for the CWC and Coolimba Power Projects 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 (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**.

2.4.1 Acid Generation and Prediction

Acid generation from mineral waste materials is caused by the exposure of sulphide minerals, most commonly pyrite (FeS_2), 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:

$$FeS_2 + \frac{15}{4}O_2 + \frac{7}{2}H_2O \text{ ---> } Fe(OH)_3 + 2\,H_2SO_4$$

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 net acid producing potential (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_2SO_4/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 net acid generation (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_2SO_4/t sample. The overall acid generating potential of a sample depends on the NAG capacity (kg H_2SO_4/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.

Terrenus has used Total Oxidisable Sulphur (TOS), NAPP and NAG data to classify the acid forming nature of all mineral waste materials at the CWC and Coolimba Power projects. The criteria for material classification are presented in **Table 2**.

Sample classification

Sample classification of mineral waste materials from mining projects follows some general rules, however the classification typically has to take into account the site geology and other site-specific geochemical characteristics that may influence the classification criteria. For the CWC and Coolimba Power Projects wastes, samples are classified into non acid forming (NAF), potentially acid forming (PAF), PAF low capacity (PAF-LC), and uncertain (UC) categories [UC-NAF and UC-PAF] (**Table 2**).

As shown in **Table 2**, the classification formula differs between the samples collected and analysed by GCA and those from the 2008 sample and testing program (Terrenus/URS), due to more detailed analytical test-work being undertaken for the recent samples (*i.e.* NAG and sulphur species testing was undertaken), allowing better use of the analytical data to establish the likelihood of a sample being NAF, PAF, *etc*. All ash samples were high in sulphate, therefore the total oxidisable sulphur was very low, and hence all ash samples were classified as NAF-barren, with no further classification criteria required.

Table 2 Criteria used by Terrenus to classify the acid forming nature of mineral waste samples from the CWC and Coolimba Power Projects

Total S	Total Oxidisable S	NAPP (kg H_2SO_4 /t)	NAGpH	Classification
Samples from phase 1 (GCA)				
≤ 0.1 %	---		---	NAF (barren)
< 0.2 %	---	< 5	---	NAF
≥ 0.2 and < 0.5 %	---	< 5	---	UC-NAF
≥ 0.2 and < 0.5 %	---	≥ 5 and < 10	---	UC-PAF
≥ 0.5 %	---	≥ 5 and < 10	---	PAF-LC
	---	≥ 10	---	PAF
				Else, uncertain
Samples from phase 2 (Terrenus/URS, 2008)				
≤ 0.1 %				NAF-barren
		< 0	≥ 4.5	NAF
	< 0.2 %	< 2	≥ 4.5	NAF
	< 0.2 %	≥ 2 and < 10	≥ 4.5	UC-NAF
	< 0.5 %	≥ 2 and < 10	≥ 4 and < 4.5	UC-PAF
	< 0.5 %	≥ 2 and < 10	< 4	PAF-LC
		≥ 10	<4	PAF
				Else, uncertain
Ash samples				
	≤ 0.1 %			NAF-barren

2.4.2 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 NEPC (1999a) health-based investigation levels (HIL)(E) for parks and recreation (open spaces) and also to the less-stringent NEPC (1999a) HIL(F) for commercial/industrial facilities. 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. Coal combustion ash has undergone shake flask tests (bottle-tumbling leach tests) to determine the potential multi-element and nutrient concentrations that may be readily leached from these ash materials.

Again, there are no guidelines and regulatory criteria specifically related to seepage from overburden, coal reject and coal combustion ash 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.).

2.4.3 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 Exchangeable Sodium Percentage (ESP). ESP is calculated from the effective cation exchange capacity (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 indicate that a material has a low risk of dispersion and ESP values greater than 12 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 Overburden and Coal Rejects

3.1.1 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 crushing circuit (referred to as coal reject) is likely to be waste and will be co-disposed with spoil. Also, some non-economic coal from minor seams higher up in the sequence is likely to be mined with the overburden. Potential reject material (roof, floor and coal material) has been estimated to comprise approximately 4% of the total mined material for the project. Approximately 92% (by volume) of all overburden (and interburden) are estimated to report as in-pit spoil and, therefore, will have a limited potential to contribute to any environmental impacts. The data is summarised using the following groups:

- Overburden: Comprises overburden, interburden and uneconomic minor coal seams above the EMS Upper seam (*e.g.* ETYE seam). All material will report as waste.
- Roof and Floor: Comprises EMS seam roof and floor. All material will report as waste;
- Coal: The EMS seam will be mined, however minor coal will report as reject from the coal preparation plant.

3.1.2 Acid-Base Tests

Overburden

Acid-Base test results for the overburden samples are presented in **Table 3** and summarised as follows:

- The current $pH_{1:5}$ of the overburden samples is neutral (average pH 7.3; median pH 7.3) and ranges from 4.2 to 9.1. The current alkalinity is low (average value of 0.0005 kg H_2SO_4/t) and ranges from less than 0.0001 to 0.0037 kg H_2SO_4/t.
- The current electrical conductivity ($EC_{1:5}$) is low to moderate and ranges from 45 to 1,310 µS/cm, with an average value of 461 µS/cm (median 466 µS/cm).
- The total sulphur content of all overburden samples is generally very low, ranging from less than 0.01% to 5.9% (average 0.18%; median 0.09%). Only four samples contained a total sulphur content greater than 0.5%, and only one sample contained a total sulphur content greater than 1%. The sample with the high total sulphur content (5.9%) contained visible pyrite. Most samples contained some sulphate which, when subtracted from the total sulphur content, produced an average and median total oxidisable sulphur (TOS) content of 0.23% and 0.07%, respectively.
- The maximum potential acidity (MPA) that could be generated by these samples ranges from less than 0.1 to 177 kg H_2SO_4/t and, with the exception of one sample (the pyritic sample mentioned above) is, overall, very low (median value is 2.5 kg H_2SO_4/t).

- The ANC values are generally low in all samples, ranging from less than 0.5 to 24 kg H_2SO_4/t (median ANC value is 3.4 kg H_2SO_4/t).
- Based on the MPA and ANC values, the calculated NAPP values range from -19 to +177 kg H_2SO_4/t, with a median NAPP value of -0.2 kg H_2SO_4/t.
- The standard NAGpH values for the overburden samples ranged from NAGpH 2.0 to 7.8, with a median standard NAGpH of 6.4.

On the basis of these results, and applying the classification criteria outlined in **Table 2**:

  - 81% of the overburden samples are classified as non-acid forming (NAF). Additionally, 58% of all overburden samples have total sulphur values less than 0.1% and hence are also classified as barren;
  - 8% of all overburden samples are classified as Uncertain-NAF (UC-NAF);
  - 2% are classified as Uncertain-Potentially Acid Forming (UC-PAF);
  - 5% are expected to be PAF with a low capacity to generate significant quantities of acid (PAF-LC); and
  - 4% are classified as PAF.

The above results are generally not distinguishable by rock type (*e.g.* siltstone versus sandstone) or sample depth (**Table 3**), however some of the UC-PAF, PAF-LC and PAF samples are noted as being carbonaceous, which may suggest that carbonaceous overburden materials at CWC appear, on the basis of the static testing alone, to have a greater potential to generate acid. (This point is supported by the coal reject results below).

Therefore, from an acid-base perspective, the overburden material can be regarded as a relatively homogenous, generally non-acid forming unit, despite being comprised of different rock types.

Roof

Acid-Base test results for the 11 roof samples from the EMS seam that could potentially report as waste or reject are presented in **Table 3** and summarised below.

- The current $pH_{1:5}$ of the roof samples is generally neutral (median pH 6.6) and ranges from 5.8 to 7.1. The current alkalinity is very low, ranging from less than 0.0001 to 0.0004 kg H_2SO_4/t.
- The current $EC_{1:5}$ is variable, ranging from 295 to 1,580 µS/cm. The median value is 636 µS/cm, which is moderate.
- The total sulphur content is relatively low, ranging from 0.1 to 0.86%, with a median value of 0.5%. Most samples contained low sulphate concentrations which, when subtracted from the total sulphur content, produced an average and median total oxidisable sulphur (TOS) content of 0.48% and 0.42%, respectively.
- The MPA that could be generated by these roof samples is also relatively low, ranging from 3.5 to 26 kg H_2SO_4/t, with a median value of 13 kg H_2SO_4/t.
- The ANC values are generally very low, ranging from 1.2 to 34 kg H_2SO_4/t, with the median ANC value being 6.0 kg H_2SO_4/t.

- Based on the MPA and ANC values, the calculated NAPP values range from -13 to +23 kg H_2SO_4/t, with a median NAPP value of +6.7 kg H_2SO_4/t.
- The standard NAGpH values for the roof samples ranged from NAGpH 2.6 to 5.2, with a median standard NAGpH of 3.4. Six roof samples underwent modified (extended boil) NAG testing (Stewart *et.al*, 2003) to try and determine if the standard NAGpH results were being effected (*i.e.* reporting too low) by the influence of organic acids. In all six samples the influence of organic acids was considered to be low or negligible and the standard NAG result was taken as being representative of pyritic acidity.

On the basis of these results, and applying the classification criteria outlined in **Table 2**:

- 2 of the 11 roof samples (18%) are classified as non-acid forming (NAF);
- 2 of the 11 samples (18%) are classified as Uncertain-NAF (UC-NAF);
- 2 of the 11 samples (18%) are classified as Uncertain-Potentially Acid Forming (UC-PAF);
- 27% (3 samples) are expected to be PAF with a low capacity to generate significant quantities of acid (PAF-LC); and
- 18% (2 samples) are classified as PAF.

The above results are generally not distinguishable by ply (*i.e.* there appears to be little distinction between the acid-base geochemistry of the EMS Upper roof from the EMS Lower roof).

Therefore, almost 63% of the roof materials appear to be classified as UC-PAF, PAF-LC or PAF. Only 18% of roof samples were clearly non-acid-forming.

Floor

Acid-Base test results for the 13 floor samples from the EMS seam that could potentially report as waste or reject are presented in **Table 3** and summarised below.

- The current $pH_{1:5}$ of the floor samples is mildly acidic, ranging from pH 4.9 to 7.6 (median pH 5.7). The current acidity is generally low, ranging from less than 0.0001 to 0.003 kg H_2SO_4/t.
- The current $EC_{1:5}$ is moderate, ranging from 255 to 2,870 µS/cm with a median EC of 752 µS/cm.
- The total sulphur content is low to moderate, ranging from 0.11 to 3.8%, with a generally low median value of 0.7% (average 1.0%). Most samples contained low sulphate concentrations which, when subtracted from the total sulphur content, produced an average and median total oxidisable sulphur (TOS) content of 1.1% and 0.6%, respectively.
- The MPA that could be generated by these floor samples ranged from 2.3 to 113 kg H_2SO_4/t, with an average value of 29 kg H_2SO_4/t and a median value of 11 kg H_2SO_4/t.
- The ANC values are very low, ranging from 1 to 13 kg H_2SO_4/t, with the median ANC value being 4.4 kg H_2SO_4/t.
- Based on the MPA and ANC values, the calculated NAPP values range from -9 to +100 kg H_2SO_4/t, with a median NAPP value of +14 kg H_2SO_4/t.

- The standard NAGpH values for the floor samples ranged from NAGpH 2.1 to 6.9, with a median standard NAGpH of 2.8. Seven floor samples underwent modified (extended boil) NAG testing (Stewart *et.al*, 2003) to try and determine if the standard NAGpH results were being effected (*i.e.* reporting too low) by the influence of organic acids. In some of the samples the influence of organic acids was evident, however the influence was considered to be not significant enough to "improve" the initial acid-base classification (*i.e.* Terrenus has adopted a conservative approach with respect to classifying these samples and the standard NAG result was taken as being representative of pyritic acidity).

On the basis of these results, and applying the classification criteria outlined in **Table 2**:

- 4 of the 13 floor samples (31%) are classified as non-acid forming (NAF). Only 1 sample had a total sulphur value less than 0.1% and hence was also classified as barren;
- 1 of the 13 samples was classified as Uncertain-Potentially Acid Forming (UC-PAF);
- 1 sample is expected to be PAF with a low capacity to generate significant quantities of acid (PAF-LC); and
- 7 samples (54%) are classified as PAF.

The above results <u>do</u> show some distinction between plys or layers (refer to **Table 3**), with the floor of the EMS Upper seam being almost exclusively PAF, whereas the floor of the EMS Lower seam appears to have a more mixed acid-base classification, slightly skewed towards NAF.

From a conservative viewpoint, the samples from the combined EMS floors are, overall, potentially acid forming, however this PAF classification is influenced strongly by the floor samples from the EMS Upper seam.

Coal

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

- The current $pH_{1:5}$ of the coal samples is mildly acidic, ranging from pH 5.1 to 6.6 (median pH 5.8). The current acidity is generally low, ranging from 0.0002 to 0.0025 kg H_2SO_4/t.
- The current $EC_{1:5}$ is moderate, ranging from 274 to 2,890 µS/cm with a median EC of 897 µS/cm.
- The total sulphur content is low to moderate, ranging from 0.26 to 4.2%, with a median value of 1.3%. Most samples contained low sulphate concentrations which, when subtracted from the total sulphur content, produced a median total oxidisable sulphur (TOS) content of 1.4%.
- The MPA that could be generated by these coal samples was moderate and ranged from 8 to 120 kg H_2SO_4/t, with an average value of 44 kg H_2SO_4/t and a median value of 40 kg H_2SO_4/t.
- The ANC values range from less than 0.5 to 55 kg H_2SO_4/t, with the median ANC value of 5.4 kg H_2SO_4/t being low.
- Based on the MPA and ANC values, the calculated NAPP values range from -32 to +120 kg H_2SO_4/t, with a median NAPP value of +31 kg H_2SO_4/t.
- The standard NAGpH values for the coal samples ranged from NAGpH 1.8 to 5.0, with a low median standard NAGpH of 2.2. Six coal samples underwent modified (extended boil) NAG

testing (Stewart *et.al*, 2003) to try and determine if the standard NAGpH results were being effected (*i.e.* reporting too low) by the influence of organic acids. As expected, in all of the samples the influence of organic acids was evident, however the organic acid influence (over the pyritic acidity) was considered to be relatively low. As such, Terrenus has adopted a conservative approach with respect to classifying these samples and the standard NAG result was taken as being representative of pyritic acidity.

On the basis of these results, and applying the classification criteria outlined in **Table 2**:

- 1 coal sample is classified as non-acid forming (NAF);
- 1 coal sample is classified as Uncertain-Non Acid Forming (UC-NAF);
- 1 sample is expected to be PAF with a low capacity to generate significant quantities of acid (PAF-LC); and
- The remaining 15 samples (83%) are classified as PAF.

The above results are generally not distinguishable by coal seam (*i.e.* there appears to be little distinction between the acid-base geochemistry of the EMS Upper seam from the EMS Lower seam).

From a conservative viewpoint, the coal samples from the EMS seam(s) are, overall, potentially acid forming.

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

Table 3: Acid-Base Test Results for Overburden and Potential Coal Rejects - Central West Coal Project

Sample ID	Sample Type	Sample Interval		Oxidation (weath., fresh)	Sample Description	pH	Alkalinity	Acidity	EC	Total Sulfur	Total Sulfate	TOS	TOC	MPA	ANC	NAPP	NAG (pH 4.5)	NAG (pH 7.0)	NAG	Sample Classification
		from (m)	to (m)				(kg H_2SO_4/t)		(µS/cm)	(%)				(kg H_2SO_4/t)					pH	
					Overburden															
CW060 - 2295	Overburden	0	2	Weathered	SAND f-mg					0.02			0.11	0.61	<1	-0.29				NAF-barren
CW060 - 2296	Overburden	2	4	Weathered	SAND f-cg					0.04			0.04	1.19	1	0.19				NAF-barren
CW060 - 2297	Overburden	4	6	Weathered	SAND f-cg					0.04			0.07	1.16	1	0.16				NAF-barren
CW060 - 2298	Overburden	6	8	Weathered	SAND f-mg					0.03			0.04	1.04	1	0.04				NAF-barren
CW060 - 2299	Overburden	8	10	Weathered	SAND fg					0.02			0.03	0.70	<1	-0.20				NAF-barren
CW060 - 2300	Overburden	10	12	Weathered	SAND f-mg					0.02			0.04	0.58	<1	-0.32				NAF-barren
CW060 - 2301	Overburden	12	14	Weathered	SAND fg					0.05			0.05	1.38	<1	0.48				NAF-barren
CW060 - 2302	Overburden	14	16	Weathered	SAND fg, with SILTY CLAY					0.06			0.03	1.75	<1	0.85				NAF-barren
CW060 - 2303	Overburden	16	18	Weathered	SAND fg and SILTY CLAY					0.05			0.03	1.50	<1	0.60				NAF-barren
CW060 - 2304	Overburden	18	20	Weathered	SAND fg, with SILTY CLAY					0.05			0.05	1.38	<1	0.48				NAF-barren
CW060 - 2305	Overburden	20	22	Weathered	SILTY CLAY, with SAND fg					0.07			0.13	2.02	2	0.02				NAF-barren
CW060 - 2306	Overburden	22	24	Weathered	SILTY CLAY					0.05			0.63	1.65	3	-1.3				NAF-barren
CW060 - 2307	Overburden	24	26	Weathered	SILTY CLAY, with SAND fg					0.07			0.30	2.24	2	0.24				NAF-barren
CW060 - 2308	Overburden	26	28	Weathered	SILTY CLAY and SAND fg					0.04			0.12	1.26	2	-0.74				NAF-barren
CW060 - 2309	Overburden	28	30	Weathered	SILTY CLAY, with SAND fg					0.06			0.62	1.84	2	-0.16				NAF-barren
CW060 - 2318	Overburden	46	48	Fresh	CLAY					0.14			0.94	4.26	14	-9.7				Non-Acid Forming
CW060 - 2319	Overburden	48	50	Fresh	SAND fg, with COAL					0.05			0.52	1.50	5	-3.5				NAF-barren
CW060 - 2320	Overburden	50	52	Fresh	CLAY, some SAND fg					0.21			0.82	6.40	13	-6.6				UC-NAF
CW060 - 2321	Overburden	52	54	Fresh	CLAY, with SAND fg					0.29			2.8	8.79	11	-2.2				UC-NAF
CW063 - 2367	Overburden	0	2	Weathered	SAND f-cg					0.07			0.24	2.27	2	0.27				NAF-barren
CW063 - 2368	Overburden	2	4	Weathered	SAND f-cg					0.10			0.22	3.12	2	1.1				Non-Acid Forming
CW063 - 2369	Overburden	4	6	Weathered	SAND f-cg					0.05			0.11	1.59	<1	0.69				NAF-barren
CW063 - 2370	Overburden	6	8	Weathered	SAND f-mg					0.04			0.07	1.10	1	0.10				NAF-barren
CW063 - 2371	Overburden	8	10	Weathered	SAND f-mg					0.05			0.05	1.41	<1	0.51				NAF-barren
CW063 - 2372	Overburden	10	12	Weathered	SAND f-mg					0.04			0.06	1.35	1	0.35				NAF-barren
CW063 - 2373	Overburden	12	14	Weathered	SAND fg, some SILTY CLAY					0.04			0.05	1.16	1	0.16				NAF-barren
CW063 - 2374	Overburden	14	16	Weathered	SAND fg					0.05			0.06	1.50	1	0.50				NAF-barren
CW063 - 2375	Overburden	16	18	Weathered	SAND vfg					0.11			0.05	3.25	1	2.2				Non-Acid Forming
CW063 - 2376	Overburden	18	20	Weathered	SAND vfg and SILTY CLAY					0.09			0.13	2.76	2	0.76				NAF-barren
CW063 - 2377	Overburden	20	22	Weathered	SAND vfg, with SILTY CLAY					0.08			0.15	2.48	1	1.5				NAF-barren
CW063 - 2378	Overburden	22	24	Weathered	SAND vfg and SILTY CLAY					0.10			0.09	3.15	1	2.2				Non-Acid Forming
CW063 - 2379	Overburden	24	26	Weathered	SAND fg, with SILTY CLAY					0.07			0.05	2.02	1	1.0				NAF-barren
CW063 - 2380	Overburden	26	28	Weathered	SAND fg, some SILTY CLAY					0.02			0.02	0.58	1	-0.42				NAF-barren
CW063 - 2381	Overburden	28	30	Weathered	SILTY CLAY, with SAND vfg					0.09			0.13	2.63	1	1.6				NAF-barren
CW063 - 2382	Overburden	30	32	Weathered	SILTY CLAY, with SAND vfg					0.06			0.15	1.68	2	-0.32				NAF-barren
CW063 - 2383	Overburden	32	34	Weathered	SILTY CLAY and SAND vfg					0.05			0.15	1.47	1	0.47				NAF-barren
CW063 - 2384	Overburden	34	36	Weathered	SILTY CLAY and SAND vfg					0.08			0.19	2.48	2	0.48				NAF-barren
CW063 - 2385	Overburden	36	38	Sl. Weathered	SILTY CLAY					0.06			0.36	1.96	2	-0.04				NAF-barren
CW063 - 2386	Overburden	38	40	Sl. Weathered	SILTY CLAY, some SAND vfg					0.13			1.2	3.86	7	-3.1				Non-Acid Forming
CW063 - 2387	Overburden	40	42	Fresh	SILTY CLAY and SAND vfg					0.15			1.6	4.59	6	-1.4				Non-Acid Forming
CW063 - 2388	Overburden	42	44	Fresh	SILTY CLAY					0.12			1.3	3.80	4	-0.20				Non-Acid Forming
CW063 - 2389	Overburden	44	46	Fresh	SILTY CLAY, some SAND vfg					0.16			1.9	4.90	4	0.90				Non-Acid Forming
CW063 - 2390	Overburden	46	48	Fresh	SILTY CLAY					0.26			2.4	7.99	13	-5.0				UC-NAF
CW063 - 2391	Overburden	48	50	Fresh	SILTY CLAY					0.17			2.3	5.05	13	-7.9				Non-Acid Forming
CW063 - 2392	Overburden	50	52	Fresh	SAND vfg, with SILTY CLAY					0.14			0.71	4.35	4	0.35				Non-Acid Forming
CW063 - 2393	Overburden	52	54	Fresh	SAND vfg, with SILTY CLAY					0.08			0.70	2.30	4	-1.7				NAF-barren
CW063 - 2394	Overburden	54	56	Fresh	Unknown (sample contamination)					0.11			0.40	3.34	1	2.3				Non-Acid Forming
CW063 - 2395	Overburden	56	58	Fresh	Unknown (sample contamination)					0.06			0.38	1.75	1	0.75				NAF-barren
CW063 - 2396	Overburden	58	60	Fresh	SAND fg, with SILTY CLAY					0.05			0.34	1.59	<1	0.69				NAF-barren
CW063 - 2397	Overburden	60	62	Fresh	SAND fg, some SILTY CLAY					0.05			0.23	1.65	1	0.65				NAF-barren
CW063 - 2398	Overburden	62	64	Fresh	SILTY CLAY, some SAND fg					0.23			1.0	6.92	4	2.9				UC-NAF
CW063 - 2399	Overburden	64	66	Fresh	SAND fg, with SILTY CLAY					0.10			0.47	2.91	1	1.9				NAF-barren
CW063 - 2400	Overburden	66	68	Fresh	SAND fg, some SILTY CLAY					0.10			0.19	3.15	<1	2.3				Non-Acid Forming
CW063 - 2401	Overburden	68	70	Fresh	SILTY CLAY, some SAND fg					0.40			0.97	12.31	3	9.3				UC-PAF
CW063 - 2402	Overburden	70	72	Fresh	SILTY CLAY and SAND fg					0.21			0.95	6.37	3	3.4				UC-NAF
CW063 - 2403	Overburden	72	74	Fresh	SAND fg, with SILTY CLAY					0.07			0.43	2.27	1	1.3				NAF-barren
CW063 - 2404	Overburden	74	76	Fresh	SAND fg, with SILTY CLAY					0.42			0.4	12.86	1	12				PAF

Table 3: Acid-Base Test Results for Overburden and Potential Coal Rejects - Central West Coal Project

Sample ID	Sample Type	Sample Interval from (m)	Sample Interval to (m)	Oxidation (weath., fresh)	Sample Description	pH	Alkalinity (kg H_2SO_4/t)	Acidity (kg H_2SO_4/t)	EC (µS/cm)	Total Sulfur (%)	Total Sulfate (%)	TOS (%)	TOC (%)	MPA (kg H_2SO_4/t)	ANC (kg H_2SO_4/t)	NAPP (kg H_2SO_4/t)	NAG (pH 4.5) (kg H_2SO_4/t)	NAG (pH 7.0) (kg H_2SO_4/t)	NAG pH	Sample Classification
CW063 - 2405	Overburden	76	78	Fresh	SILTY CLAY, with SAND vfg					0.21			0.86	6.46	4	2.5				UC-NAF
CW063 - 2406	Overburden	78	80	Fresh	SAND fg					0.15			2.0	4.50	1	3.5				Non-Acid Forming
CW063 - 2407	Overburden	80	82	Fresh	SAND fg					0.10			0.83	3.19	1	2.2				Non-Acid Forming
CW063 - 2408	Overburden	82	84	Fresh	SILTY CLAY, some SAND fg					0.15			1.1	4.69	3	1.7				Non-Acid Forming
CW063 - 2409	Overburden	84	86	Fresh	SILTY CLAY, some SAND fg					0.13			1.2	3.92	6	-2.1				Non-Acid Forming
CW063 - 2410	Overburden	86	88	Fresh	SILTY CLAY, some SAND vfg					0.15			2.0	4.44	9	-4.6				Non-Acid Forming
CW063 - 2411	Overburden	88	90	Fresh	SAND vfg, with SILTY CLAY					0.28			1.3	8.64	3	5.6				UC-PAF
CW063 - 2412	Overburden	90	92	Fresh	SILTY CLAY, with SAND vfg					0.72			0.89	22.05	4	18				PAF
CW063 - 2413	Overburden	92	94	Fresh	SILTY CLAY					0.12			1.7	3.74	7	-3.3				Non-Acid Forming
CW063 - 2421	Overburden	108	110	Fresh	CLAY					0.18			1.0	5.45	14	-8.5				Non-Acid Forming
CW063 - 2422	Overburden	110	112	Fresh	CLAY					0.17			1.1	5.30	6	-0.70				Non-Acid Forming
CW063 - 2423	Overburden	112	114	Fresh	CLAY					0.38			1.6	11.52	12	-0.48				UC-NAF
CW063 - 2424	Overburden	114	116	Fresh	CLAY, with COAL, with SAND fg					0.47			2.5	14.33	11	3.3				UC-NAF
CW063 - 2425	Overburden	116	118	Fresh	CLAY					0.21			1.8	6.34	13	-6.7				UC-NAF
CW063 - 2426	Overburden	118	120	Fresh	CLAY					0.22			1.6	6.58	10	-3.4				UC-NAF
CW5070 - 4820	Overburden	8	10	Weathered	SAND vfg with SILTY CLAY	7.3	0.0002	0.0001	317	0.01	<0.003	0.01	<0.5	0.3	<0.5	-0.1	<0.1	7.7	5.8	NAF-barren
CW5070 - 4830	Overburden	28	30	Weathered	SAND vfg with SILTY CLAY	6.9	0.0001	0.0001	675	0.01	0.012	0.00	<0.5	<0.3	0.6	-0.4	<0.1	2.2	6.3	NAF-barren
CW5070 - 4836	Overburden	40	42	Fresh	SILTY CLAY with SAND vfg	8.1	0.0006	0.0001	558	0.05	0.015	0.03	1.2	1.1	13.7	-12.6	<0.1	<0.1	7.3	NAF-barren
CW5070 - 4840	Overburden	48	50	Fresh	SILTY CLAY with SAND vfg	7.5	0.0003	0.0002	1310	0.06	0.017	0.04	1.4	1.3	8.9	-7.6	<0.1	<0.1	7.1	NAF-barren
CW5070 - 4845	Overburden	58	60	Fresh	SILTY CLAY with SAND vfg	7.4	0.0003	0.0003	829	0.10	0.029	0.07	1.7	2.2	3.0	-0.8	<0.1	0.8	6.0	NAF-barren
CW5070 - 4854	Overburden	68	69	Fresh	SILTY CLAY with SAND vfg	7.3	0.0002	0.0001	528	0.06	0.017	0.04	1.1	1.3	0.6	0.7	4.2	8.0	3.2	NAF-barren
CW5070 - 4857	Overburden	71	72	Fresh	SAND vfg and SILTY CLAY, some carb.	6.2	<0.0001	0.0003	740	0.13	0.047	0.08	1.4	2.5	2.9	-0.4	1.1	6.0	3.9	NAF-barren
CW5070 - 4861	Overburden	75	76	Fresh	SILTY CLAY, some SAND vfg	8.1	0.0005	0.0001	676	0.06	0.015	0.04	1.7	1.4	4.7	-3.3	<0.1	<0.1	7.2	NAF-barren
CW5070 - 4863	Overburden	77	78	Fresh	SILTY CLAY and SAND vfg	7.2	0.0003	0.0003	635	0.09	0.024	0.07	1.7	2.0	2.4	-0.4	<0.1	<0.1	7.3	NAF-barren
CW5070 - 4869	Overburden	83	84	Fresh	SAND vf-fg, some pyrite	4.2	<0.0001	0.0005	619	5.85	0.060	5.79	<0.5	177	<0.5	177	109	127	2.0	PAF
CW5070 - 4871	Overburden	85	86	Fresh	SILTY CLAY with SILT and SAND vfg	6.9	0.0002	0.0002	584	0.10	0.018	0.08	3.3	2.5	2.4	0.1	<0.1	2.0	5.5	NAF-barren
CW5074 - 5098	Overburden	24	26	Weathered	SAND fg	7.9	0.0001	0.0000	45	0.01	<0.003	0.01	<0.5	0.3	<0.5	-0.1	<0.1	7.8	6.0	NAF-barren
CW5074 - 5108	Overburden	44	46	Weathered	SILTY CLAY and SAND, vfg	8.0	0.0003	0.0000	224	0.08	0.011	0.07	<0.5	2.1	9.6	-7.5	<0.1	<0.1	7.1	NAF-barren
CW5074 - 5114	Overburden	56	58	Fresh	SAND vfg with SILTY CLAY	7.8	0.0004	0.0000	277	0.06	0.015	0.04	1.0	1.4	5.4	-4.0	<0.1	<0.1	7.1	NAF-barren
CW5074 - 5120	Overburden	68	70	Fresh	SAND vfg with SILTY CLAY	7.8	0.0003	0.0000	483	0.17	0.013	0.16	0.8	4.8	6.0	-1.2	<0.1	0.4	6.4	Non-Acid Forming
CW5074 - 5122	Overburden	72	74	Fresh	SAND f-mg with SILTY CLAY, some carb.	7.0	0.0001	0.0001	959	0.36	0.018	0.34	<0.5	10.5	3.6	6.9	13.1	18.4	2.7	PAF-LC
CW5074 - 5124	Overburden	76	78	Fresh	SAND vfg, carbonaceous	6.9	0.0000	0.0001	617	0.22	0.016	0.20	1.1	6.2	0.6	5.6	12.4	17.0	2.7	PAF-LC
CW5074 - 5127	Overburden	82	84	Fresh	SAND f-mg and SILTY CLAY	6.2	<0.0001	0.0001	395	0.23	0.024	0.21	<0.5	6.3	6.0	0.3	5.0	7.4	3.0	PAF-LC
CW5074 - 5130	Overburden	88	90	Fresh	SAND vfg with SILTY CLAY	7.5	0.0003	0.0001	411	0.08	0.013	0.07	<0.5	2.1	10.7	-8.6	5.8	30.3	3.3	NAF-barren
CW5074 - 5134	Overburden	93	94	Fresh	SAND vfg, some SILTY CLAY	7.5	0.0003	0.0001	441	0.09	0.007	0.08	1.5	2.5	8.9	-6.4	9.2	23.8	3.4	NAF-barren
CW5074 - 5137	Overburden	96	97	Fresh	SAND m-vcg	6.9	0.0001	0.0001	230	0.18	0.013	0.17	<0.5	5.1	23.9	-18.8	<0.1	<0.1	7.0	Non-Acid Forming
CW5074 - 5140	Overburden	99	100	Fresh	SILTY CLAY with SAND vfg	7.9	0.0004	0.0001	575	0.06	0.012	0.05	1.3	1.5	9.0	-7.5	<0.1	<0.1	7.3	NAF-barren
CW5112 - 6215	Overburden	14	16	Weathered	SAND vfg	8.1	0.0001	0.0000	358	0.03	0.007	0.02	0.04	0.7	2.4	-1.7	<0.1	7.3	6.1	NAF-barren
CW5112 - 6221	ETYE seam	26	28	Weathered	COAL, COALY CLAY and SILTY CLAY	6.8	0.0004	0.0009	268	0.48	0.050	0.43	5.8	13.2	2.4	10.8	7.1	22.6	3.4	PAF
CW5112 - 6226	Overburden	36	38	Weathered	SAND vfg with SILTY CLAY	7.0	0.0001	0.0001	325	0.09	0.008	0.08	0.1	2.5	2.4	0.1	<0.1	2.0	6.3	NAF-barren
CW5112 - 6235	Overburden	54	56	Fresh	SILTY CLAY	7.6	0.0001	0.0002	746	0.10	0.028	0.07	1.2	2.2	9.9	-7.7	<0.1	0.5	6.6	NAF-barren
CW5112 - 6237	Overburden	58	60	Fresh	SAND vfg, some SILTY CLAY	7.4	0.0005	0.0002	623	0.06	0.015	0.04	1.0	1.4	11.8	-10.4	<0.1	<0.1	7.0	NAF-barren
CW5112 - 6239	Overburden	62	64	Fresh	SILTY CLAY, some SAND vfg	7.3	0.0004	0.0002	530	0.08	0.019	0.06	1.6	1.9	3.5	-1.6	<0.1	0.8	6.5	NAF-barren
CW5112 - 6241	Overburden	66	68	Fresh	SILTY CLAY, some SAND vfg	7.7	0.0008	0.0002	474	0.06	0.018	0.04	1.8	1.3	4.7	-3.4	<0.1	0.4	6.6	NAF-barren
CW5112 - 6243	Overburden	70	72	Fresh	SAND vfg with SILTY CLAY	6.9	0.0001	0.0003	437	0.32	0.016	0.30	1.5	9.3	3.4	5.9	4.0	8.6	3.3	PAF-LC
CW5112 - 6244	Overburden	72	73	Fresh	SILTY CLAY with SAND vfg	7.1	0.0004	0.0002	597	0.53	0.021	0.51	1.4	15.6	7.1	8.5	5.8	11.2	3.2	PAF-LC
CW5112 - 6246	Overburden	74	75	Fresh	SILTY CLAY with SAND vfg	7.2	0.0004	0.0002	483	0.07	0.014	0.06	1.3	1.7	10.5	-8.8	<0.1	<0.1	7.0	NAF-barren
CW5112 - 6247	Overburden	75	76	Fresh	SAND vfg, trace SILTY CLAY	6.8	0.0002	0.0001	191	0.06	0.011	0.05	0.7	1.5	7.0	-5.5	<0.1	<0.1	7.0	NAF-barren
CW5126 - 6900	Overburden	12	14	Weathered	SAND vfg	6.6	<0.0001	0.0003	334	0.01	0.011	0.00	0.1	0.0	2.3	-2.3	<0.1	5.3	5.8	NAF-barren
CW5126 - 6907	Overburden	26	28	Weathered	VFG sand and silty clay	6.4	0.0002	0.0002	236	0.01	0.009	0.00	0.3	0.0	1.2	-1.2	<0.1	0.5	6.6	NAF-barren
CW5126 - 6913	Overburden	38	40	Fresh	SILTY CLAY with SAND vfg	7.1	0.0007	0.0002	197	0.14	0.015	0.12	1.4	3.8	7.5	-3.7	<0.1	0.9	6.1	Non-Acid Forming
CW5126 - 6915	Overburden	42	44	Fresh	SAND fg with SILTY CLAY	7.5	0.0003	0.0001	276	0.07	0.013	0.06	1.0	1.7	7.5	-5.8	<0.1	0.6	6.7	NAF-barren
CW5126 - 6917	Overburden	46	48	Fresh	SILTY CLAY, some SAND vfg	7.3	0.0006	0.0002	303	0.12	0.018	0.10	1.0	3.1	6.4	-3.3	<0.1	0.2	6.7	Non-Acid Forming
CW5126 - 6921	Overburden	51	52	Fresh	SILTY CLAY with SAND vfg	7.9	0.0006	0.0002	476	0.08	0.018	0.06	1.7	1.9	10.0	-8.1	<0.1	0.1	6.9	NAF-barren
CW5126 - 6927	Overburden	57	58	Fresh	SILTY CLAY with SAND vfg	7.3	0.0001	0.0000	252	0.08	0.018	0.06	1.3	1.9	3.4	-1.5	<0.1	0.3	6.5	NAF-barren
CW5127 - 6954	Overburden	12	14	Weathered	SAND fg	9.1	0.0009	<0.0001	262	0.03	0.005	0.02	0.04	0.8	4.2	-3.4	<0.1	4.8	6.6	NAF-barren
CW5127 - 6959	Overburden	22	24	Weathered	SILTY CLAY with SAND fg	8.2	0.0009	0.0000	466	0.01	0.005	0.00	0.2	0.2	3.0	-2.8	<0.1	<0.1	7.8	NAF-barren
CW5127 - 6968	ETYE seam	40	42	Fresh	COALY CLAY, some SAND fg	7.1	0.0037	0.0007	385	0.47	0.036	0.43	8.7	13.3	10.6	2.7	2.0	18.9	4.1	UC-PAF
CW5127 - 6973	Overburden	50	52	Fresh	SILTY CLAY, some SAND vfg	7.9	0.0024	0.0003	136	0.11	0.015	0.09	1.0	2.9	14.8	-11.9	<0.1	<0.1	7.0	NAF-barren
CW5127 - 6977	Overburden	58	60	Fresh	SAND vfg with SILTY CLAY	7.5	0.0009	0.0004	410	0.54	0.017	0.52	2.7	16.0	18.3	-2.3	<0.1	4.7	4.8	Non-Acid Forming
CW5127 - 6981	Overburden	66	68	Fresh	SAND vfg	7.6	0.0006	0.0002	449	0.04	0.010	0.03	0.8	0.9	10.1	-9.2	<0.1	<0.1	7.4	NAF-barren

Table 3: Acid-Base Test Results for Overburden and Potential Coal Rejects - Central West Coal Project

Sample ID	Sample Type	Sample Interval from (m)	Sample Interval to (m)	Oxidation (weath., fresh)	Sample Description	pH	Alkalinity	Acidity	EC	Total Sulfur	Total Sulfate	TOS	TOC	MPA	ANC	NAPP	NAG (pH 4.5)	NAG (pH 7.0)	NAG	Sample Classification
							(kg H_2SO_4/t)		(μS/cm)	(%)				(kg H_2SO_4/t)					pH	
CW5127 - 6985	Overburden	74	76	Fresh	SILTY CLAY	7.6	0.0003	0.0002	210	0.25	0.023	0.23	1.3	7.0	11.8	-4.8	<0.1	0.7	6.4	Non-Acid Forming
CW5127 - 6988	Overburden	79	80	Fresh	SILTY CLAY with SAND fg	7.6	0.0007	0.0004	194	0.22	0.019	0.20	1.5	6.2	6.5	-0.3	<0.1	2.2	4.9	Non-Acid Forming
CW5127 - 6993	Overburden	84	85	Fresh	SILTY CLAY with SAND vfg	7.6	0.0015	0.0005	260	0.12	0.035	0.08	2.0	2.6	10.6	-8.0	<0.1	<0.1	7.2	NAF-barren
CW5128 - 7021	Overburden	8	10	Weathered	SILTY CLAY, some SAND vfg	6.8	0.0001	0.0003	554	0.02	0.012	0.01	0.1	0.2	1.2	-1.0	<0.1	<0.1	7.1	NAF-barren
CW5128 - 7027	Overburden	20	22	Weathered	SILTY CLAY with SAND vfg	6.9	0.0002	0.0001	528	0.19	0.062	0.13	0.7	3.9	2.9	1.0	<0.1	<0.1	7.2	Non-Acid Forming
CW5128 - 7034	Overburden	34	36	Fresh	SILTY CLAY with SAND vfg	7.3	0.0005	0.0003	743	0.20	0.023	0.18	1.2	5.4	7.7	-2.3	<0.1	1.0	5.6	Non-Acid Forming
CW5128 - 7035	Overburden	36	37	Fresh	SILTY CLAY, some SAND fg	7.2	0.0002	0.0001	500	0.11	0.022	0.09	0.9	2.7	2.3	0.4	<0.1	0.6	6.4	NAF-barren
CW5128 - 7037	Overburden	38	39	Fresh	SAND vfg, some SILTY CLAY	6.5	0.0000	0.0019	487	0.30	0.048	0.25	1.4	7.7	1.2	6.5	2.5	6.8	3.5	PAF-LC
CW5128 - 7047	Interburden	48	49	Fresh	SILTY CLAY and SAND fg	5.8	<0.0001	0.0006	527	0.50	0.040	0.46	1.18	14.1	2.3	11.8	6.9	11.6	3.1	PAF
EMS Roof																				
CW5070 - 4872	EMS Upper	86	87	Fresh	SILTY CLAY and SILT, some SAND vfg, some COAL	6.4	0.0001	0.0000	561	0.29	0.031	0.26	4.5	7.9	3	4.9	31.6	56.2	2.6	PAF-LC
CW5074 - 5144	EMS Upper	103	104	Fresh	CLAY and SILTY CLAY, some COAL	6.6	0.0001	0.0002	636	0.46	0.038	0.42	5.6	12.9	6.0	6.9	3.9	19.4	3.9	PAF-LC
CW5074 - 5145	EMS Upper	104	105	Fresh	CLAY and SILTY CLAY, some COAL	6.9	0.0001	0.0001	484	0.13	0.016	0.11	4.8	3.5	9.1	-5.6	<0.1	5.7	5.2	Non-Acid Forming
CW5126 - 6931	EMS Upper	61	62	Fresh	SAND vfg with SILTY CLAY	6.6	0.0001	0.0005	1580	0.86	0.022	0.84	2.2	25.7	2.9	22.8	15.4	22.5	2.6	PAF
CW5127 - 6998	EMS Upper	89	90	Fresh	SILTY CLAY with SAND vfg	7.1	0.0004	0.0011	592	0.72	0.028	0.69	2.0	21.2	34.0	-12.8	<0.1	3.7	5.1	Non-Acid Forming
CW5128 - 7040	EMS Upper	41	42	Fresh	SILTY CLAY and SAND vfg	5.8	<0.0001	0.0009	729	0.62	0.044	0.58	2.1	17.6	1.2	16.4	11.7	14.7	2.9	PAF
CW060 - 2310	Undiff. EMS	30	32	Sl. Weathered	SILTY CLAY and SAND fg, with COAL					0.25			3.6	7.56	3	4.6				UC-NAF
CW063 - 2414	Undiff. EMS	94	96	Fresh	COAL and SILTY CLAY					0.31			8.7	9.59	6	3.6				UC-NAF
CW5070 - 4881	EMS Lower	95	96	Fresh	CLAY	6.6	0.0001	0.0002	771	0.46	0.045	0.41	4.4	12.7	6.0	6.7	0.4	5.5	4.3	UC-PAF
CW5074 - 5155	EMS Lower	114	115	Fresh	CLAY with COAL	6.9	0.0001	0.0004	694	0.71	0.041	0.67	5.1	20.5	11.5	9.0	7.3	36.4	3.4	UC-PAF
CW5128 - 7049	EMS Lower	50	51	Fresh	SAND fg with SILTY CLAY	6.0	<0.0001	0.0003	295	0.34	0.026	0.31	1.2	9.6	2.4	7.2	6.1	9.9	3.0	PAF-LC
EMS Coal																				
CW5070 - 4877	EMS Upper	91	92	Fresh	COAL	5.1	<0.0001	0.0017	2890	4.20	0.270	3.93	15.0	120.3	<0.5	120	145	210	1.8	PAF
CW5074 - 5150	EMS Upper	109	110	Fresh	COAL	6.5	0.0002	0.0003	897	1.28	0.044	1.24	13.0	37.9	20.5	17.4	68.4	176	2.4	PAF
CW5112 - 6252	EMS Upper	80	81	Fresh	COAL	5.8	0.0002	0.0025	1130	1.47	0.069	1.40	39.6	42.9	7.1	35.8	141	226	2.2	PAF
CW060 - 2311	Undiff. EMS	32	34	Sl. Weathered	COAL					0.89			5.1	27.20	4	23				PAF
CW060 - 2312	Undiff. EMS	34	36	Fresh	COAL					0.51			3.6	15.62	<1	15				PAF
CW060 - 2313	Undiff. EMS	36	38	Fresh	COAL					1.3			4.4	40.00	<1	39				PAF
CW060 - 2314	Undiff. EMS	38	40	Fresh	COAL					0.48			4.0	14.64	2	13				PAF
CW060 - 2315	Undiff. EMS	40	42	Fresh	COAL					0.57			17.8	17.43	11	6.4				PAF-LC
CW060 - 2316	Undiff. EMS	42	44	Fresh	COAL					0.26			3.5	7.99	8	-0.01				UC-NAF
CW063 - 2415	Undiff. EMS	96	98	Fresh	COAL					1.3			25.7	40.21	4	36				PAF
CW063 - 2416	Undiff. EMS	98	100	Fresh	COAL					1.8			45.7	54.24	13	41				PAF
CW063 - 2417	Undiff. EMS	100	102	Fresh	COAL					1.3			49.3	40.00	14	26				PAF
CW063 - 2418	Undiff. EMS	102	104	Fresh	COAL and CLAY					1.6			17.2	49.83	2	48				PAF
CW063 - 2419	Undiff. EMS	104	106	Fresh	COAL					2.3			39.7	68.97	14	55				PAF
CW5128 - 7051	Undiff. EMS	52	53	Fresh	COAL	5.6	0.0001	0.0008	274	1.88	0.067	1.81	32.8	55.5	4.1	51.4	100	165	2.2	PAF
CW5070 - 4882	EMS Lower	96	97	Fresh	COAL, some sand/silt contamination	5.5	0.0000	0.0008	2360	3.25	0.175	3.07	14.3	94.2	<0.5	93.8	151	214	1.9	PAF
CW5074 - 5156	EMS Lower	115	116	Fresh	COAL	6.6	0.0001	0.0002	870	1.11	0.046	1.06	13.1	32.6	6.6	26.0	165	250	2.1	PAF
CW5112 - 6258	EMS Lower	86	87	Fresh	COAL and CLAY	6.2	0.0002	0.0009	736	0.79	0.008	0.78	6.2	23.9	55.4	-31.5	<0.1	11.9	5.0	Non-Acid Forming
EMS Floor																				
CW5070 - 4880	EMS Upper	94	95	Fresh	COAL with CLAY	4.9	<0.0001	0.0015	2870	2.91	0.267	2.64	12.5	81.0	<0.5	80.6	108	161	2.1	PAF
CW5074 - 5154	EMS Upper	113	114	Fresh	COAL with CLAY	5.7	0.0000	0.0002	1,520	3.83	0.146	3.68	7.3	112.8	13.2	99.6	52.9	95.1	2.4	PAF
CW5112 - 6257	EMS Upper	85	86	Fresh	CLAY	5.3	0.0000	0.0016	401	0.67	0.093	0.58	6.1	17.7	2	15.4	8.9	21.2	3.0	PAF
CW5126 - 6939	EMS Upper	69	70	Fresh	COAL and COALY CLAY	5.1	<0.0001	0.0030	1860	2.03	0.165	1.87	20.8	57.1	1.2	55.9	57.6	97.7	2.2	PAF
CW5126 - 6940	EMS Upper	70	71	Fresh	COALY CLAY	5.0	<0.0001	0.0016	255	0.71	0.090	0.62	5.2	19.0	1.2	17.8	14.0	21.9	2.8	PAF
CW5127 - 7009	EMS Upper	100	101	Fresh	CLAY and COALY CLAY	7.0	0.0002	0.0000	752	0.26	0.031	0.23	4.6	7.0	3.5	3.5	<0.1	7.8	4.6	UC-PAF
CW5128 - 7045	EMS Upper	46	47	Fresh	COAL, SILTY CLAY and SAND fg	5.4	0.0000	0.0019	664	1.20	0.048	1.15	11.9	35.3	2.3	33.0	26.5	43.5	2.5	PAF
CW060 - 2317	Undiff. EMS	44	46	Fresh	CLAY					0.17			0.7	5.11	9	-3.9				Non-Acid Forming
CW063 - 2420	EMS Lower	106	108	Fresh	CLAY					0.12			3.5	3.77	13	-9.2				Non-Acid Forming
CW5070 - 4883	EMS Lower	97	98	Fresh	CLAY	7.0	0.0003	0.0002	866	0.35	0.049	0.30	5.7	9.2	4.7	4.5	3.3	12.8	3.6	PAF-LC
CW5074 - 5157	EMS Lower	116	117	Fresh	CLAY	7.6	0.0003	0.0001	507	0.46	0.029	0.43	5.6	13.2	12.6	0.6	<0.1	2.7	6.0	Non-Acid Forming
CW5112 - 6260	EMS Lower	88	89	Fresh	CLAY and COALY CLAY	6.8	0.0008	0.0005	298	0.11	0.033	0.08	3.6	2.3	5.9	-3.6	<0.1	0.2	6.9	NAF-barren
CW5128 - 7054	EMS Lower	55	56	Fresh	COAL and COALY CLAY	6.2	0.0004	0.0015	912	0.65	0.053	0.60	12.3	18.3	4.1	14.2	33.4	65.4	2.7	PAF

3.1.3 Multi-Elements in Solids

Table 4 presents the multi-element test results for the 22 composite samples, which represent:

- 13 composite overburden samples, comprising:
  - 3 weathered silty clay and sand (NAF);
  - 7 fresh (unweathered) silty clay and sand (NAF);
  - 2 fresh (unweathered) silty clay and sand (PAF-LC); and
  - 1 fresh (unweathered) sand with trace pyrite (PAF).
- 3 composite roof samples, comprising:
  - 1 silty clay with sand and some coal from the EMS Upper roof (NAF);
  - 1 silty clay with sand and some coal from the EMS Upper roof (PAF-LC and PAF); and
  - 1 sand, silty clay and coal from the EMS Lower roof (UC-PAF & PAF-LC).
- 4 floor samples, comprising:
  - 1 silty clay and coaly clay from the EMS Upper floor (PAF);
  - 1 coal and coaly clay from the EMS Upper floor (PAF);
  - 1 coal and coaly clay from the EMS Lower floor (PAF-LC and PAF); and
  - 1 clay and coaly clay from the EMS Lower floor (NAF).
- 2 coal samples comprising 1 sample each from the EMS Upper and EMS Lower seams (both PAF).

The results in **Table 4** indicate that the total metals concentrations in all solid samples tested are low. Only one composite sample from the EMS Upper roof has Mn concentrations in solids greater than the applied NEPC (1999a) health-based investigation levels (HIL's) for soils.

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**.

3.1.4 Cation Exchange Capacity and Sodicity

The effective cation exchange capacity (eCEC) results presented in **Table 4** indicate that the:

- eCEC of overburden samples ranges from 5.3 to 25.6 meq/100g (average = 17.1 meq/100g; median 17.3 meq/100g);
- eCEC of roof material ranges from 12.3 to 15.5 meq/100g (average = 14 meq/100g);
- eCEC of floor material ranges from 15.9 to 31.2 meq/100g (average = 24.1 meq/100g); and
- eCEC of coal material is almost the same in both the Upper and Lower EMS seams, ranging from 26.1 to 26.7 meq/100g.

The exchangeable sodium percentage (ESP) results presented in **Table 4** indicate that the sodicity is high in all tested materials:

- Sodicity of all overburden materials ranges from 21 to 37% (average 27%; median 26%);
- Sodicity of roof materials ranges from 25 to 30% (average and median 27%);
- Sodicity of floor materials ranges from 20 to 29% (average 25%; median 24%); and
- Sodicity of the two coal samples was approximately 27%.

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

3.1.5 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 22 composite samples. The results from these tests are provided in **Table 5** and indicate that leachate from overburden composite samples contains metal concentrations generally below those recommended in ANZECC (2000a) livestock drinking water guidelines and NEPC (1999b) groundwater investigation levels. Cobalt and nickel concentrations significantly exceeded the applied water quality guidelines in the PAF composite (individual) sample containing pyrite (sample AvC-20). Concentrations of other elements such as Al, Fe and Mn are elevated in this same sample compared to all other composite samples. The presence of metals in this sample is not unexpected, since the natural pH of this sample was pH 3.6, indicating that any metals likely to be in solution at low pH would be present.

Se was marginally above the applied ANZECC/NEPC guidelines in one roof sample and all of the floor samples. 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**.

3.1.6 pH and Alkalinity

Results for pH and alkalinity tests on the composite overburden, roof, floor and coal samples from the CWC Project are presented in **Table 5**. The results are summarised below:

- The current pH of the 13 composite overburden samples is generally neutral to mildly acidic. With the exception of one sample that had a pH of 3.9, the pH of all other composite overburden samples ranges from pH 5.5 to pH 7.0 (average pH 6.4).
- The current pH of the three roof composite samples is also neutral to mildly acidic, ranging from pH 5.9 to pH 6.5 (average pH 6.1). The current pH of the four floor samples is slightly lower than the roof samples, ranging from pH 4.6 to 6.5 (average pH 5.6). The current pH of the coal composite samples from the EMS Upper and EMS Lower seam is pH 5.6 and 5.7, respectively.
- The current alkalinity of all composite samples tested is low. The acidity is also low in all tested samples.

Therefore, the pH of leachate from any likely spoil material at the CWC project is likely to be neutral to mildly acidic.

3.1.7 Salinity

Results for salinity tests on the composite overburden, roof, floor and coal samples from the CWC Project are presented in **Table 5**. The results are summarised below:

- The current EC of the 13 composite overburden samples is generally low to moderate, ranging from 432 to 1,010 µS/cm (average 599 µS/cm; median 534 µS/cm);
- The current EC of the three roof composite samples is also moderate, ranging from 444 to 854 µS/cm (average 668 µS/cm; median 706 µS/cm);
- The current EC of the four floor samples is greater than the roof samples, ranging from 732 to 2,890 µS/cm (average 1,431 µS/cm; median 1,050 µS/cm); and
- The current EC of the coal composite samples from the EMS Upper and EMS Lower seam is 1,570 µS/cm and 1,420 µS/cm, respectively.

Therefore, leachate from any likely spoil material at the CWC project is likely to be moderately saline.

Table 4: Multi-Element Concentration and Sodicity of Solids from Overburden and Potential Rejects - Central West Coal Project

Parameters	Units	Detection Limit	NEPC[1] Health-based Investigation Level E	NEPC[2] Health-based Investigation Level F	Overburden													Potential Rejects									
					Weathered			Fresh										Roof			Floor				Coal	
				Composite No.--->	AvC-01	AvC-10	AvC-17	AvC-02	AvC-08	AvC-11	AvC-13	AvC-18	AvC-19	AvC-21	AvC-14	AvC-22	AvC-20	AvC-09	AvC-03	AvC-05	AvC-04	AvC-12	AvC-07	AvC-16	AvC-15	AvC-06
				Description --->	Drillhole CW5128; silty clay; weathered; NAF	Drillhole CW5126; sand and clay; weathered; NAF	Drillhole CW5070; sand with clay; weathered; NAF	Drillhole CW5128; silty clay; Predominantly NAF	Drillhole CW5127; silty clay with sand; NAF	Drillhole CW5126; silty clay with sand; NAF	Drillhole CW5112; silty clay with sand; NAF	Drillhole CW5070; silty clay with sand; 40-60m; NAF	Drillhole CW5070; silty clay with sand; 68-86m; NAF	Drillhole CW5074; sand with silty clay; NAF	Drillhole CW5112; sand and silty clay; PAF-LC	Drillhole CW5074; sand with silty clay, some carbonaceous material; PAF-LC	Drillhole CW5070; sand with some pyrite; PAF	EMS Upper: Silty clay with sand, some coal; NAF	EMS Upper: Silty clay with sand, some coal; PAF & PAF-LC	EMS Lower: Sand, silty clay & coal; UC-PAF & PAF-LC	EMS Upper: Silty clay and coaly clay; PAF	EMS Upper: Coal and coaly clay; PAF	EMS Lower: Coal and coaly clay; PAF & PAF-LC	EMS Lower: Clay and coaly clay; NAF	EMS Upper coal; PAF	EMS Lower coal (with some minor silt); PAF
Major Elements																										
Ca	mg/kg	10	-	-	340	200	260	390	1,650	660	890	1,020	260	2,020	670	520	100	4,180	570	1,650	1,140	4,410	1,280	2,650	5,370	2,760
Mg	mg/kg	10	-	-	2,240	1,410	1,230	1,690	3,590	2,660	2,630	3,040	1,420	2,830	1,990	1,020	450	2,730	1,480	1,820	1,540	2,100	2,710	3,280	2,100	1,860
Na	mg/kg	10	-	-	1,070	1,110	1,380	1,120	1,300	1,240	1,110	1,900	1,120	900	950	690	570	840	1,110	1,080	1,090	1,580	1,720	1,500	1,530	1,610
K	mg/kg	10	-	-	700	560	490	850	1,420	1,160	1,210	1,200	500	870	970	410	310	1,290	770	1,080	950	480	1,170	1,780	100	180
Al	mg/kg	50	-	-	4,310	3,980	2,870	3,490	6,360	4,820	4,630	4,270	2,210	3,510	3,970	2,760	1,260	4,630	3,230	4,380	4,420	2,690	5,280	7,860	1,700	1,430
Fe	mg/kg	50	-	-	15,400	7,500	7,940	7,400	35,000	19,400	24,100	23,600	1,870	54,400	20,500	8,540	51,800	63,100	4,880	13,100	8,770	26,800	6,200	14,200	21,300	14,400
Minor Elements																										
Ag	mg/kg	2	-	-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
As	mg/kg	5	200	500	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	22	<5	<5	<5	<5	10	<5	<5	<5	<5
B	mg/kg	50	6,000	15,000	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Ba	mg/kg	10	-	-	1,460	40	60	60	190	90	50	60	20	180	20	10	20	100	50	50	70	40	230	170	20	30
Be	mg/kg	1	40	100	1	<1	<1	2	2	2	2	2	1	3	1	<1	<1	1	3	<1	1	2	2	2	<1	2
Cd	mg/kg	1	40	100	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	2	2	<1	<1
Co	mg/kg	2	200	500	7	<2	<2	13	14	14	18	19	59	12	15	16	66	20	14	20	13	10	30	35	<2	4
Cr (total)	mg/kg	2	-	-	12	11	72	10	15	11	12	16	15	15	10	38	50	18	15	19	19	22	22	26	8	15
Cu	mg/kg	5	2,000	5,000	20	10	6	19	25	22	23	22	17	16	20	7	7	32	33	31	35	30	38	39	12	20
Hg	mg/kg	0.1	30	75	<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	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1
Mn	mg/kg	5	3,000	7,500	7	26	9	139	1,260	961	970	1,110	<5	2,620	838	68	23	4,900	6	537	16	55	46	442	851	52
Mo	mg/kg	2	-	-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ni	mg/kg	2	600	3,000	10	4	3	21	22	19	22	24	60	15	34	26	232	24	28	31	23	28	37	44	3	10
P	mg/kg	50	-	-	90	90	60	90	300	100	140	190	70	220	100	140	<50	620	100	210	180	320	130	250	870	<50
Pb	mg/kg	5	600	1,500	10	8	7	10	12	12	13	15	11	9	12	7	28	15	16	16	17	11	18	19	5	7
S	mg/kg	50	-	-	470	110	140	1,860	1,680	850	580	560	710	680	4,240	2,600	52,300	3,700	3,980	4,060	6,760	27,400	3,060	1,400	15,200	15,000
Sb	mg/kg	5	-	-	<5	<5	<5	<5	<5	<5	<5	<5	<5	<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	<5	<5	<5	<5	8	<5	<5	<5	<5
Sn	mg/kg	5	-	-	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Sr	mg/kg	2	-	-	13	<2	5	6	12	8	10	11	2	9	7	<2	<2	17	9	21	24	37	20	29	94	23
Ti	mg/kg	10	-	-	20	20	20	60	60	60	70	80	40	70	80	70	30	200	140	180	180	480	220	250	330	470
Tl	mg/kg	5	-	-	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
V	mg/kg	5	-	-	15	10	16	13	20	14	17	16	11	12	16	9	6	25	22	27	32	51	39	40	18	29
Zn	mg/kg	5	14,000	35,000	50	19	68	62	60	59	65	117	107	80	51	72	50	59	60	77	74	39	108	96	9	20
Sodicity																										
Exchangeable Ca	meq/100g	0.1	-	-	1.2	0.7	1	1.2	2.6	1.6	2	1.7	1.1	2.4	1.5	1.4	0.4	2.2	1.4	4	3.6	12.2	3.8	7.8	9.8	8.7
Exchangeable Mg	meq/100g	0.1	-	-	14.8	9	8.4	9.3	13.7	12.6	11.7	14.6	10.4	11.5	8.8	5.6	3.2	6.4	7.7	6.7	7.1	12.2	12.5	10.6	9.4	9.9
Exchangeable Na	meq/100g	0.1	-	-	4.81	4.33	5.82	4.5	5.43	5.01	4.24	8.22	5.04	3.87	3.63	2.65	1.65	3.04	4.28	4.12	4.35	6.34	7.21	5.39	7.25	7.2
Exchangeable K	meq/100g	0.1	-	-	0.92	0.76	0.55	0.98	1.35	1.19	1.12	1.05	0.72	0.72	0.9	0.44	<0.10	0.68	0.74	0.66	0.83	0.44	1	1.06	0.2	0.26
eCEC	meq/100g	0.1	-	-	21.7	14.8	15.8	16.0	23.1	20.4	19.1	25.6	17.3	18.5	14.8	10.1	5.3	12.3	14.1	15.5	15.9	31.2	24.5	24.9	26.7	26.1
Exchangeable Na %	%	0.1	-	-	22	29	37	28	24	25	22	32	29	21	24	26	31	25	30	27	27	20	29	22	27	28

Notes:

< indicates less than the analytical detection limit.

Shaded cells indicate values which exceed relevant NEPC HIL(E) (light shading) or NEPC HIL(F) (dark shading) guideline values.

1. 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.
2. National Environment Protection Council (NEPC). National Environmental Protection (Assessment of Site Contamination) Measure. Guideline on Investigation Levels for Soil and Groundwater (1999). HIL(F): Commercial/Industrial: includes premises such as shops and offices as well as factories and industrial sites.
3. No NEPC EIL's are available for Cr (total).

Table 5: Multi-Element Concentration of Water Extracts from Overburden and Potential Rejects - Central West Coal Project

	Material Group -->		Overburden													Roof			Floor				Coal	
	Composite No. & Material Type --->		AvC-01	AvC-10	AvC-17	AvC-02	AvC-08	AvC-11	AvC-13	AvC-18	AvC-19	AvC-21	AvC-14	AvC-22	AvC-20	AvC-09	AvC-03	AvC-05	AvC-04	AvC-12	AvC-07	AvC-16	AvC-15	AvC-06
Parameters	Detection Limit	ANZECC[2] / NEPC[3] Guidelines	Drillhole CW5128; silty clay; weathered; NAF	Drillhole CW5126; sand and clay; weathered; NAF	Drillhole CW5070; sand with clay; weathered; NAF	Drillhole CW5128; silty clay; Predominantly NAF	Drillhole CW5127; silty clay with sand; NAF	Drillhole CW5126; silty clay with sand; NAF	Drillhole CW5112; silty clay with sand; NAF	Drillhole CW5070; silty clay with sand; 40-60m; NAF	Drillhole CW5070; silty clay with sand; 68-86m; NAF	Drillhole CW5074; sand with silty clay; NAF	Drillhole CW5112; sand and silty clay; PAF-LC	Drillhole CW5074; sand with silty clay, some carbonaceous material; PAF-LC	Drillhole CW5070; sand with some pyrite; PAF	EMS Upper: Silty clay with sand, some coal; NAF	EMS Upper: Silty clay with sand, some coal; PAF & PAF-LC	EMS Lower: Sand, silty clay & coal; UC-PAF & PAF-LC	EMS Upper: Silty clay and coaly clay; PAF	EMS Upper: Coal and coaly clay; PAF	EMS Lower: Coal and coaly clay; PAF & PAF-LC	EMS Lower: Clay and coaly clay; NAF	EMS Upper coal; PAF	EMS Lower coal (with some minor silt); PAF
pH[1]	0.1	-	6.6	5.8	5.5	6.5	7.0	6.5	6.6	7.0	6.4	6.4	6.4	5.5	3.6	6.5	5.9	5.9	5.1	4.6	6.2	6.5	5.6	5.7
EC[1] (µS/cm)	1	3,000[4]	448	423	540	665	490	562	503	939	706	431	534	533	1,010	444	706	854	1,160	2,890	940	732	1,570	1,420
Total Dissolved Solids	1	2,000	184	52	436	264	568	156	340	524	172	604	5,080	92	200	256	88	120	188	696	160	172	348	232
Alkalinity (kg H_2SO_4 /t)	0.00002	-	0.00008	0.00004	0.00004	0.00010	0.00027	0.00020	0.00023	0.00020	0.00010	0.00012	0.00010	0.00002	<0.00002	0.00016	0.00004	0.00004	0.00002	<0.00002	0.00016	0.00016	0.00008	0.00008
Acidity (kg H_2SO_4 /t)	0.00002	-	0.00023	0.00010	0.00006	0.00016	0.00006	0.00006	0.00004	0.00004	0.00010	0.00002	0.00010	0.00006	0.00033	0.00008	0.00031	0.00022	0.00041	0.00012	0.00027	0.00012	0.00006	0.00008
Major Elements	mg/L	mg/L	mg/L													mg/L			mg/L				mg/L	
Ca	2	1,000	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	10	<2	<2	6	22	204	<2	2	32	24
Mg	2	-	<2	<2	<2	2	<2	<2	<2	4	4	<2	2	6	54	<2	4	10	32	182	4	2	58	42
Na	2	-	74	76	98	112	82	98	86	168	124	74	90	86	72	76	120	134	154	244	174	132	226	212
K	2	-	4	4	4	10	6	8	8	10	8	6	10	10	<2	8	10	12	16	16	10	10	4	6
Cl	2	-	56	86	138	66	54	72	68	220	112	60	76	68	68	40	90	114	80	84	134	112	64	80
SO_4	2	1,000 / -	52	24	24	148	60	58	70	80	110	50	90	114	366	80	140	184	372	1510	194	114	520	426
Minor Elements	mg/L	mg/L	mg/L													mg/L			mg/L				mg/L	
Al	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	5.2	<0.2	<0.2	<0.2	<0.2	1.0	<0.2	<0.2	0.2	0.2
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	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
As	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	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
B	0.20	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	<0.02	<0.02	<0.02	<0.02	1.20	<0.02	0.20	1.40	1.40
Ba	0.20	-	<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	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Be	0.02	ID / 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	<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	<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	3.2	<0.02	<0.02	<0.02	0.1	0.1	<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	0.3	<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	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Fe	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	17.0	<0.2	<0.2	<0.2	<0.2	0.4	<0.2	<0.2	<0.2	<0.2
Hg	0.0001	0.002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Mn	0.02	-	<0.02	<0.02	<0.02	0.02	<0.02	0.02	<0.02	0.04	0.02	0.04	0.06	0.06	2.68	0.06	<0.02	0.24	0.32	2.36	<0.02	0.04	0.48	0.14
Mo	0.02	0.15 / 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	<0.02	<0.02	<0.02	<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	0.04	4.7	<0.02	<0.02	<0.02	0.04	0.06	<0.02	<0.02	<0.02	<0.02
P	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<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	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Sb	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	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<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	0.02	0.04	0.02	0.04	0.08	0.08	0.10	<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	<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	<0.2	<0.2	<0.2	<0.2	<0.2	1.20	<0.2	<0.2	<0.2	<0.2
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	<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	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
V	0.02	ID / 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	<0.02	<0.02	<0.02	<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	3.24	<0.02	<0.02	<0.02	0.08	0.08	<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 and/or NEPC 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 ~2,000 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.

3.2 Coal Combustion Ash

3.2.1 Introduction

One fly-ash composite sample and one bottom-ash composite sample from the CWC project were provided to URS/Terrenus (by ACIRL) for geochemical testing.

From these two composite samples, URS/Terrenus created a 4:1 w/w mixed ash sample comprising 4 parts fly-ash to 1 part bottom-ash.

The mixed ash sample is deemed to represent the likely ash composition in mineral waste from the power station. Aviva propose to dispose of ash wastes from the Coolimba Power project in the mined-out void(s) of the CWC mine. The ash would likely be co-disposed with mined spoil (overburden) and rejects from the crushing circuit.

No FGD product has been produced for testing.

3.2.2 Acid-Base Tests

Fly Ash

Acid-Base test results for the 3 ash samples representing fly-ash, bottom-ash and a mixed fly-ash:bottom-ash sample (4:1 mass ratio) are presented in **Table 6** as follows:

Table 6 Acid-base test results for coal combustion ash

	Units	Fly-Ash	Bottom-Ash	Ash-mix 4:1
pH[1]	pH units	8.7	8.0	8.6
Electrical Conductivity (EC)[1]	µS/cm	1,140	1,430	1,160
Alkalinity (to pH 5.5)	kg H_2SO_4/t	0.0002	<0.0001	0.0003
Acidity (to pH 8.3)	kg H_2SO_4/t	---	---	---
Total Sulphur (as S)	%	0.25	0.24	0.28
Sulphate Sulphur (as S)	%	0.19	0.21	0.19
Total Oxidisable Sulphur (TOS)[2]	%	0.06	0.03	0.09
Maximum Potential Acidity (MPA)[3]	kg H_2SO_4/t	1.7	1.0	2.7
Acid Neutralising Capacity (ANC)	kg H_2SO_4/t	18	8.6	18
Net Acid Producing Potential (NAPP)	kg H_2SO_4/t	-17	-7.6	-15
Net Acid Generation (NAG) (to pH 4.5)	kg H_2SO_4/t	<0.1	<0.1	<0.1
Net Acid Generation (NAG) (to pH 7.0)	kg H_2SO_4/t	3.9	6.4	5.4
NAGpH	pH units	6.5	6.0	6.3
Sample Classification[4]		Non-Acid Forming	Non-Acid Forming	Non-Acid Forming

Notes:

1. Natural pH and EC provided for 1:5 sample:water extracts.
2. TOS concentration is calculated from the difference between total S and sulphate sulphur concentrations.
3. MPA calculated using TOS.
4. Samples are regarded as Non-Acid Forming due to the low TOS content, negative NAPP and NAGpH greater than pH 4.5.

On the basis of these results, all of the ash samples are classified as non-acid forming (NAF). All samples have total oxidisable sulphur values less than 0.1% and hence have a negligible capacity to generate acid.

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

3.2.3 Multi-Elements and Nutrients in Ash Solid

The multi-element results for the three coal combustion ash samples (**Table 7**) indicate that none of the ash samples tested have element concentrations in solids greater than the NEPC (1999a) health-based investigation levels (HIL) for soils. The nutrient concentrations in all samples were low, or in most cases, below the limit of laboratory detection. No applied NEPC guideline values are available for nutrients in solids.

3.2.4 Multi-Elements and Nutrients in Ash Leachate

To evaluate the immediate solubility of multi-elements in solids, bottle-tumbling leachate tests following Australian Standard AS4439.3-1997 (Standards Australia, 1997) were completed for the three ash samples. The results from these tests are provided in **Table 8** and indicate that soluble concentrations of Al, As, B, Cr, Cu, Mo, Se and Zn were present at levels generally above those recommended in one or more of ANZECC (2000b) 90% and 95% trigger levels in freshwater aquatic ecosystems, ANZECC (2000a) livestock drinking water guidelines and NEPC (1999b) groundwater investigation levels. Of the three ash samples tested, the bottom ash sample generally had the lowest soluble metal concentrations, followed by the mixed ash sample. Guideline values for nutrients are only available for ammonia, and all ash samples reported ammonia concentrations well below the applied guideline values. Guideline values are not available for other nutrients (P, NO_3, NO_2, ammonia, and Total N) however the concentrations of these parameters are low in all samples.

In 2007, ACIRL (2007) reported leachate testing on a fly ash sample following a similar leach testing method (ASTM D3987 shake flask extraction test) to that undertaken in this study. The metal concentrations in leachate from the ACIRL test are provided in **Table 8** and are shown to be generally comparable to those from this recent study. Notable differences are potassium and fluoride, which have higher concentrations in the ACIRL leachate compared to the recent leachate. Some differences would be expected in the concentrations of some elements due to the natural heterogeneity of coal and ash materials from one batch to the next, and that the leach methods, although similar, are not identical.

3.2.5 pH and Salinity in Ash Leachate

Salinity and pH results for the three ash samples indicate that the leachate from ash is expected to be neutral to slightly alkaline, with a relatively low EC.

- The pH of the two primary ash samples after leaching ranged from 7.1 in the bottom ash to 8.0 in the fly ash. The mixed ash sample reported a pH of 8.2.
- The EC of the leachate samples was similar for all three samples, ranging from 505 µS/cm in the fly ash sample to 560 µS/cm in the bottom ash sample. Correspondingly, the mixed ash sample, being primarily comprised of fly ash, had an EC similar to the fly ash sample.

The environmental significance of identified metal concentrations in coal combustion ash and their water solubility in terms of risk is discussed in **Section 4**.

Table 7 Multi-element and nutrient concentration in coal combustion ash

	Detection Limit	NEPC[1] HIL E	NEPC[2] HIL F	Fly Ash	Bottom Ash	Fly Ash:Bottom Ash mix (4:1 mass ratio)
Major Elements (total conc.)	**mg/kg unless otherwise indicated**					
Calcium (Ca)	50	-	-	16,400	5,250	13,400
Magnesium (Mg)	50	-	-	8,730	1,310	7,020
Sodium (Na)	50	-	-	4,020	550	3,240
Potassium (K)	50	-	-	860	100	690
Aluminium (Al)	50	-	-	33,700	4,790	27,300
Iron (Fe)	50	-	-	19,400	21,300	19,800
Minor Elements (total conc.)	**mg/kg unless otherwise indicated**					
Antimony (Sb)	5	-	-	<5	<5	<5
Arsenic (As)	5	200	500	22	<5	19
Barium (Ba)	10	-	-	730	580	900
Beryllium (Be)	1	40	100	6	<1	5
Boron (B)	50	6,000	15,000	190	<50	150
Cadmium (Cd)	1	40	100	1	<1	<1
Chromium (Cr)*	2	-	-	42	13	40
Cobalt (Co)	2	200	500	8	3	7
Copper (Cu)	5	2,000	5,000	69	20	57
Fluoride (F)	40	-	-	70	<40	60
Lead (Pb)	5	600	1,500	22	<5	18
Manganese (Mn)	5	3,000	7,500	318	253	290
Mercury (Hg)	0.1	30	75	<0.1	<0.1	<0.1
Molybdenum (Mo)	2	-	-	5	<2	4
Nickel (Ni)	2	600	3,000	27	26	24
Phosphorus (P)	50	-	-	1380	810	1250
Selenium (Se)	5	-	-	9	<5	6
Silver (Ag)	2	-	-	<2	<2	<2
Strontium (Sr)	2	-	-	420	143	349
Sulphur (S)	50	-	-	2170	2160	2100
Thallium (Tl)	5	-	-	<5	<5	<5
Tin (Sn)	5	-	-	6	<5	6
Titanium (Ti)	10	-	-	2200	370	1870
Vanadium (V)	5	-	-	159	30	129
Zinc (Zn)	5	14,000	35,000	49	<5	40
Nutrients (total conc.)	**mg/kg unless otherwise indicated**					
Ammonia (as N)	20	-	-	<20	<20	<20
Nitrate + Nitrite (NOx)	0.1	-	-	0.1	<0.1	0.1
Total Kjeldahl Nitrogen	20	-	-	50	30	<20
Total Organic Carbon (TOC)	0.02%	-	-	<1	<1	<1
Total Cyanide (CN^-)	1	-	-	<1	<1	<1

Notes:

< indicates less than the analytical detection limit.

NEPC: National Environmental Protection (Assessment of Site Contamination) Measure (NEPM). Guideline on Investigation Levels for Soil and Groundwater (1999).

1). HIL(E): parks, recreational open spaces and playing fields.

2). HIL(F): commercial / industrial.

* No NEPC HIL's are available for Total Cr.

Table 8: Bottle Tumbling Leach Test Results for Coolimba Power Project - Composite Ash Samples (coal from Aviva CWC Project)

Parameters	Detection Limit	Water Quality Guidelines			Fly Ash (ACIRL, 2007)	Fly Ash	Bottom Ash	Fly Ash:Bottom Ash mix (4:1 mass ratio)	Summary of Guideline Exceedances (ACIRL 2007 fly ash results not included)
		Freshwater[1] (95%)	Freshwater[1] (90%)	Livestock Drinking Water[2,3]					
mg/L unless otherwise stated									
Initial pH Value	0.01	-	-	-	-	7.71	7.05	8.13	
Final pH	0.1	-	-	-	9	8.00	7.10	8.20	
EC (µS/cm)	1	-	-	-	558	505	560	509	
Nutrients									
Ammonia as N	0.01	0.9	1.43	-	-	0.07	0.018	0.061	
Nitrite + Nitrate as N[7]	0.01	-	-	-	-	0.018	0.011	0.02	
Total Kjeldahl Nitrogen as N	0.1	-	-	-	-	0.5	0.2	<0.1	
Total Nitrogen as N	0.1	-	-	-	-	0.5	0.2	<0.1	
Major Elements (Leachable)									
Calcium	1	-	-	1,000	62	55	80	60	
Chloride	1	-	-	-	11.1	20	4	3	
Magnesium	1	-	-	-	15.5	16	17	16	
Sodium	1	-	-	-	29	21	8	18	
Potassium	1	-	-	-	5.3	<1	<1	<1	
Sulphate as SO_4^{2-}	1	-	-	1000 / -	240	227	267	234	
Minor Elements (Leachable)									
Aluminium	0.01	0.055	0.080	5	-	0.62	0.15	0.35	90% & 95% trigger level in all samples
Antimony	0.001	ID	ID	-	-	0.002	<0.001	0.002	
Arsenic	0.001	0.013[4]	0.042[4]	0.5	0.09	0.066	0.006	0.055	90% & 95% trigger level in fly and mixed ash
Barium	0.001	-	-	-	0.26	0.166	0.139	0.034	
Beryllium	0.001	ID	ID	ID / 0.1	-	<0.001	<0.001	<0.001	
Boron	0.1	0.37	0.68	5	<0.01	1.9	0.2	1.6	90% & 95% trigger level in fly and mixed ash
Cadmium	0.0001	0.0002	0.0004	0.01	<0.001	<0.0001	<0.0001	<0.0001	
Chromium	0.001	0.001[5]	0.006[5]	1[5]	0.025	0.029	<0.001	0.02	90% & 95% trigger level in fly and mixed ash
Cobalt	0.001	ID	ID	1	-	<0.001	<0.001	<0.001	
Copper	0.001	0.0014	0.0018	0.5	<0.01	0.003	<0.001	<0.001	90% & 95% trigger level in fly ash
Total Cyanide	0.004	0.007	0.011	-	-	<0.004	<0.004	<0.004	
Fluoride	0.1	-	-	2	5.51	1.8	<0.1	1.5	
Iron	0.05	ID	ID	-	<0.1	<0.05	<0.05	<0.05	
Lead	0.001	0.0034	0.0056	0.1	<0.1	<0.001	<0.001	<0.001	
Lithium	0.001	-	-	-	-	0.096	0.071	0.083	
Manganese	0.001	1.9	2.5	-	0.02	0.018	0.596	0.026	
Mercury	0.0001	0.0006[6]	0.0019[6]	0.002	<0.0005	<0.0001	<0.0001	<0.0001	
Molybdenum	0.001	ID	ID	0.15 / 0.01	-	0.11	0.005	0.082	NEPC livestock drinking water trigger in fly and mixed ash
Nickel	0.001	0.011	0.013	1	<0.01	0.006	0.004	0.004	
Phosphorus	0.01	-	-	-	-	0.08	0.18	0.1	
Selenium	0.01	0.011	0.018	0.02	0.119	0.065	<0.010	0.052	All guidelines in fly and mixed ash
Silver	0.001	0.00005	0.0001	-	<0.01	<0.001	<0.001	<0.001	
Strontium	0.001	-	-	-	-	0.178	1.52	0.219	
Thallium	0.001	ID	ID	-	-	<0.001	<0.001	<0.001	
Thorium	0.001	-	-	-	-	<0.001	<0.001	<0.001	
Tin	0.001	ID	ID	-	-	<0.001	<0.001	<0.001	
Titanium	0.01	-	-	-	-	<0.01	<0.01	<0.01	
Uranium	0.001	ID	ID	0.2 / -	-	<0.001	<0.001	<0.001	
Vanadium	0.01	ID	ID	ID / 0.1	-	0.09	0.05	0.08	
Zinc	0.005	0.008	0.015	20	<0.01	0.082	0.027	<0.005	90% & 95% trigger level in fly and bottom ash

Notes:

1. ANZECC (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality: Trigger values for Freshwater - 95% and 90% Level of Protection. Australian and New Zealand Environment Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ). Canberra, ACT. **ID** = insufficient data to derive a reliable trigger value (ANZECC, 2000).

2. ANZECC (2000). Same publication as note 1. Trigger values for Livestock Drinking Water.

3. NEPC (1999). National Environment Protection (Assessment of Site Contamination) Measure. Guideline on Investigation Levels for Soil and Groundwater (1999). Groundwater Investigation Level (livestock drinking water). National Environmental Protection Council (NEPC).

4. As(V) - assumption that As value measured is present predominantly as arsenate (AsV). **5.** Cr(VI) - criteria used for coal combustion ash because the industrial oxidation of chromium and/or the combustion of fossil fuels results in the oxidation of Cr(III) to Cr(VI).

6. Inorganic mercury. **7.** ANZECC guidelines report that nitrate should not exceed 400 mg/L and nitrite should not exceed 30 mg/L. Therefore, although not specified in the ANZECC guidelines, the combined NO3 + NO2 concentration should reasonably be less than 450 mg/L.

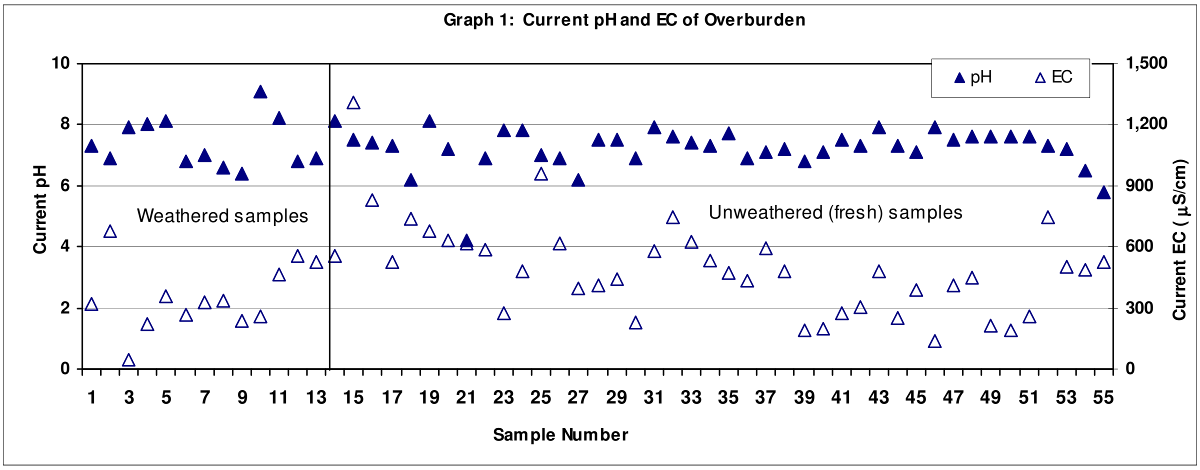
4 GEOCHEMICAL NATURE OF MINERAL WASTE MATERIALS

4.1 Introduction

Due to the different analytical test methods undertaken between the phase 1 (GCA) and later phase (this study) sampling and testing programs, the methodology used to classify samples (in terms of their likely acid generating capacity) had to differ slightly to make use of the extra geochemical information available for the phase 2 testing but still being able to use the large data set from the phase 1 test program. Terrenus applied the chosen classification criteria to the phase 2 samples and then adopted a simplified classification methodology for the phase 1 samples based on NAPP and total sulphur alone. This simplified phase 1 classification formula was then re-applied to the phase 2 samples and adjusted slightly until the same (or very similar) classifications were derived using both methods. This calibration step allowed the acid-base results from both phases of testing to be comparable. In the following sections the results are discussed in terms of the entire data set, *i.e.* all results available for the CWC project from both phases of testing. In most of the graphs, however, only on the recent data is shown, since the phase 1 test program did not include pH, EC, sulphate (to generate TOS values) and NAG tests.

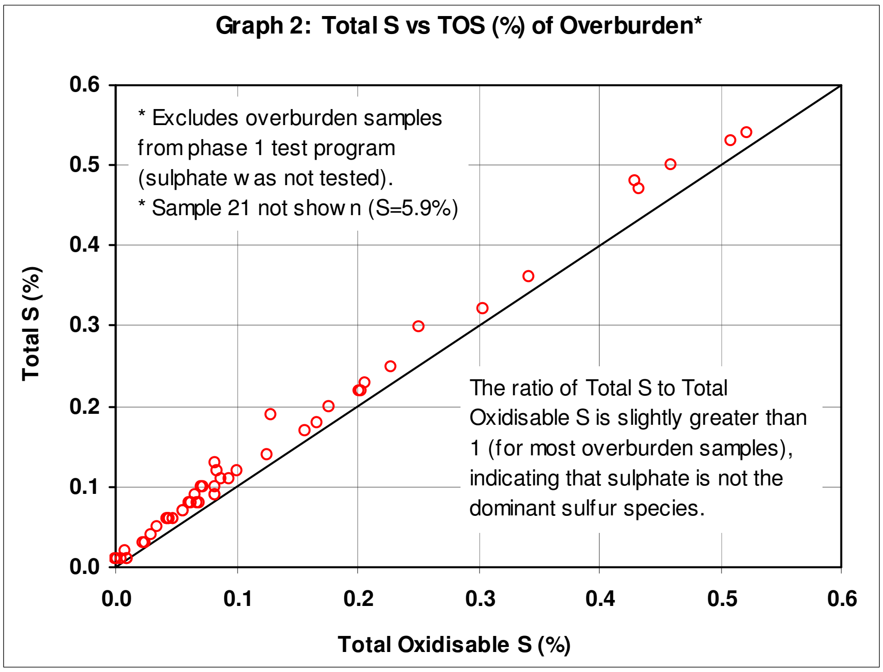
4.2 Overburden

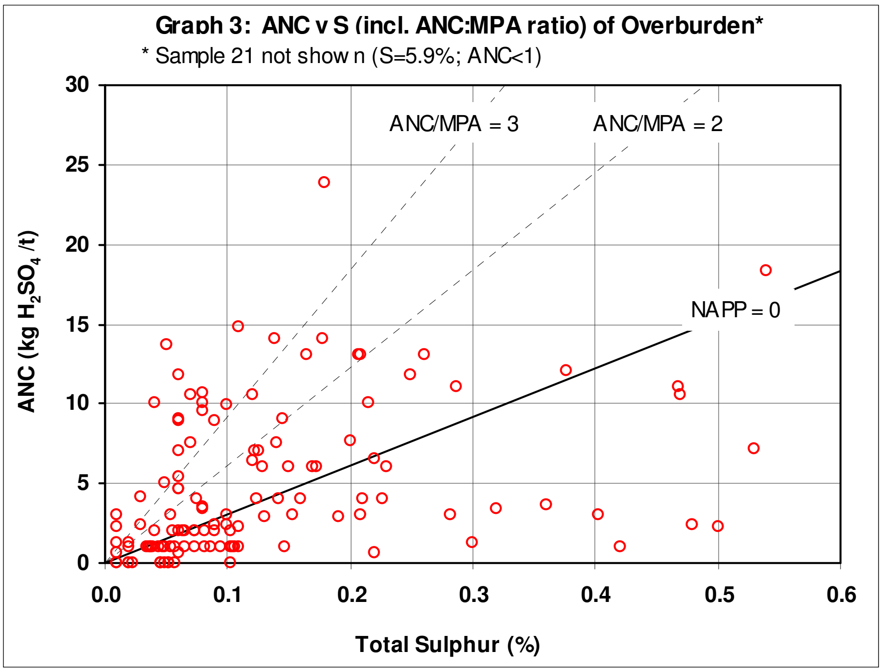
The results of the acid-base tests (**Table 3**) indicate that overburden from the CWC Project will initially generate pH-neutral, low-to-moderate salinity runoff/seepage following surface exposure (**Graph 1**).



The total sulphur concentration of overburden samples is, with the exception of one pyritic sample, very low. 97% of overburden samples (*i.e.* 123 out of 127 samples) have a total sulphur concentration below 0.5% and over half of the overburden samples have a total sulphur concentration below 0.1% and are essentially barren (**Graph 2** and **Graph 3**).

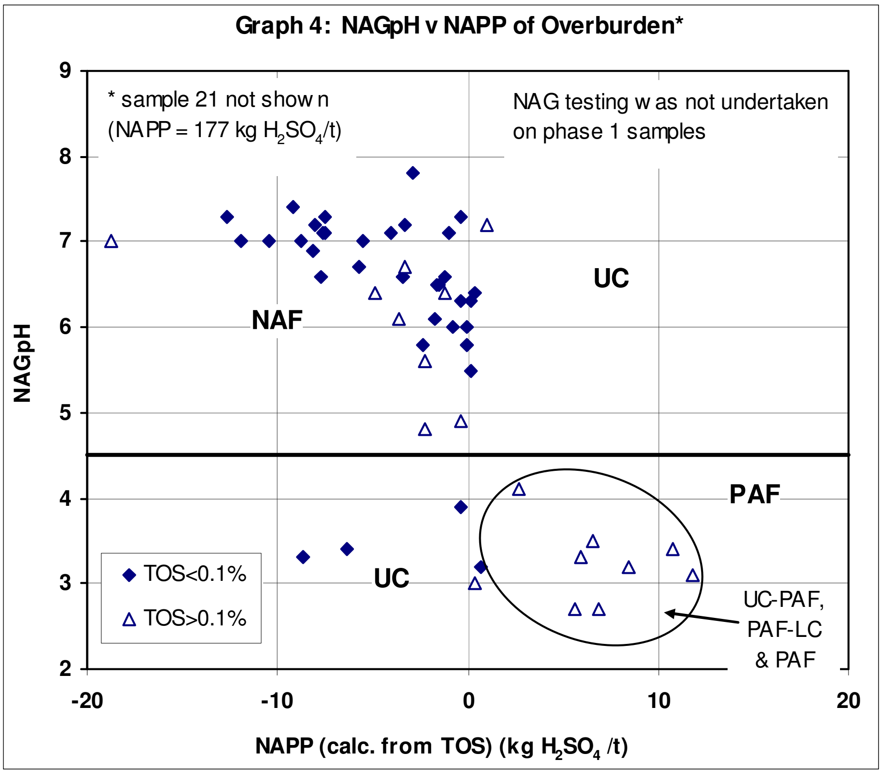
The ANC of overburden is generally low and, in many samples, is only marginally greater than the MPA. The ANC/MPA ratio for overburden samples is spread from less than one (NAPP = 0) to over 10 (**Graph 3**). ANC/MPA ratios below one are typically associated with potentially acid-forming materials, since theoretically there is less neutralising capacity to acid generating capacity. However, the (generally) very low sulphur concentration of overburden materials translates to very low quantities of acid that could be produced. Therefore, in general, overburden materials have a poor buffering capacity to neutralise the generally insignificant amount of acidity that could be generated from sulphide oxidation





There are exceptions to this generalisation. Some overburden samples tested are clearly potentially acid forming (PAF), such as one or two samples containing visible pyrite, however the PAF samples are expected to comprise less than 10% of the total overburden volume. Of these PAF materials, over half are expected to have only a limited capacity to generate acid (*i.e.* they are considered to be PAF-low capacity (PAF-LC)), since they have very low sulphur concentrations, despite having a positive NAPP and low NAGpH.

Over 80% of overburden samples are classified as non-acid forming (NAF) and a further 8% are classified as uncertain-NAF. Approximately 9% of all overburden samples were classified as either PAF-LC or PAF. A further 2% have an uncertain classification, but are expected to be PAF-LC (**Graph 4**). Therefore, from a mineral waste management perspective, the overburden materials can generally be regarded as NAF.

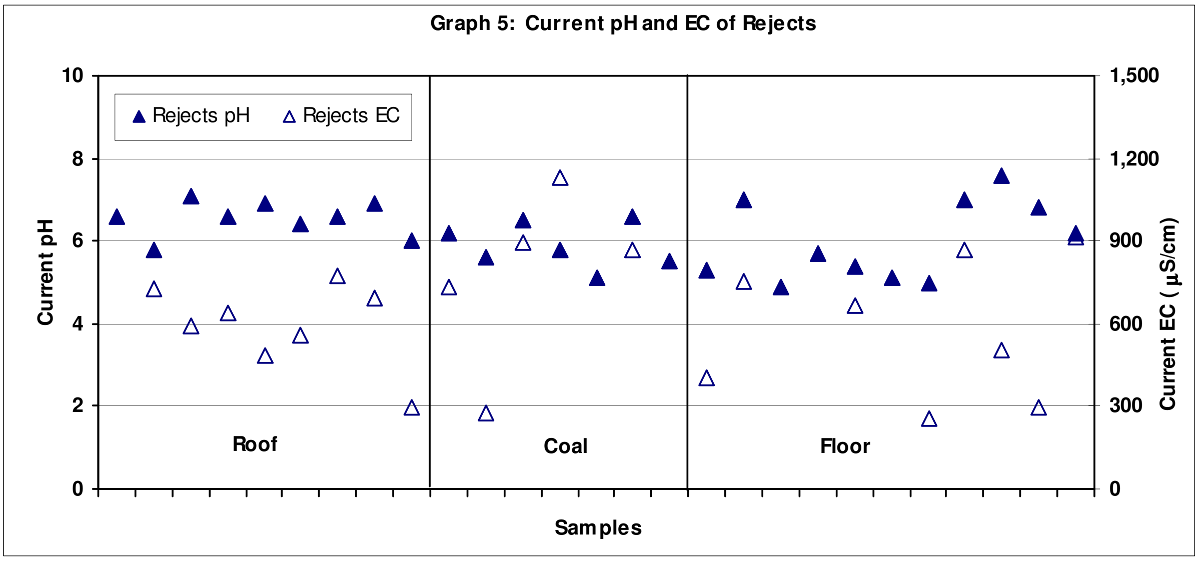


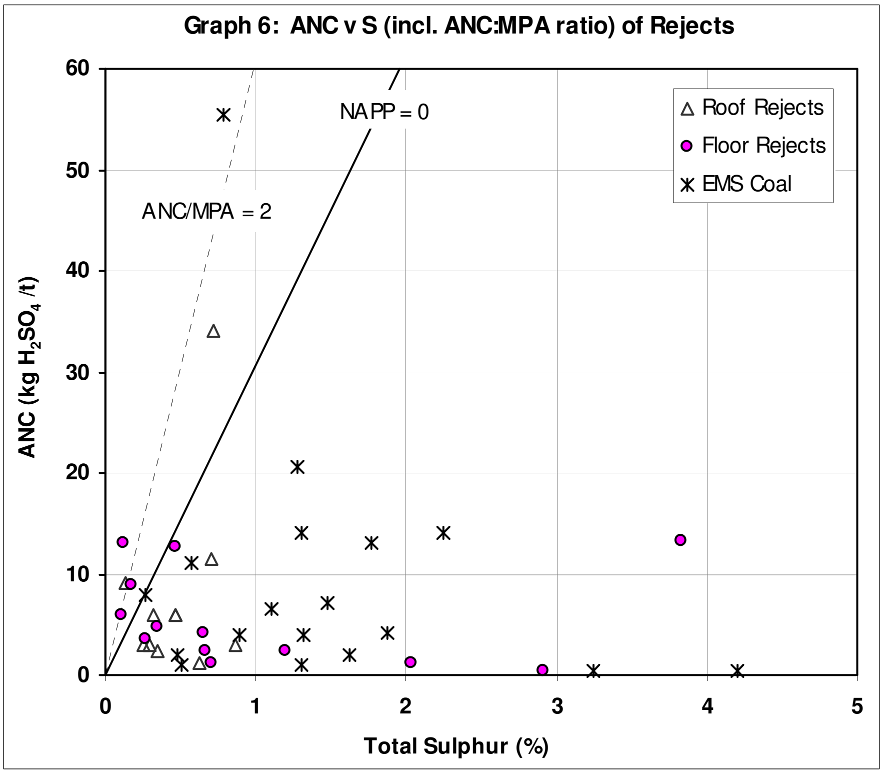
4.3 Potential Coal Rejects (Roof, Floor and Coal)

The results of the acid-base tests (**Table 3**) indicate that potential rejects (roof, floor and coal) from the CWC Project will initially generate pH-neutral to very mildly acidic, moderate salinity runoff/seepage following surface exposure (**Graph 5**).

The total sulphur concentration of roof and floor samples is slightly greater than for the overburden samples, with the floor samples having total sulphur concentrations marginally greater than the roof samples. The total sulphur concentration of coal samples from the EMS seam is double that of the roof and floor, but still has a median concentration of only 1.3%.

The ANC of potential rejects is very low and, in most samples, is less than the MPA, providing ANC/MPA ratios generally less than one (**Graph 6**).

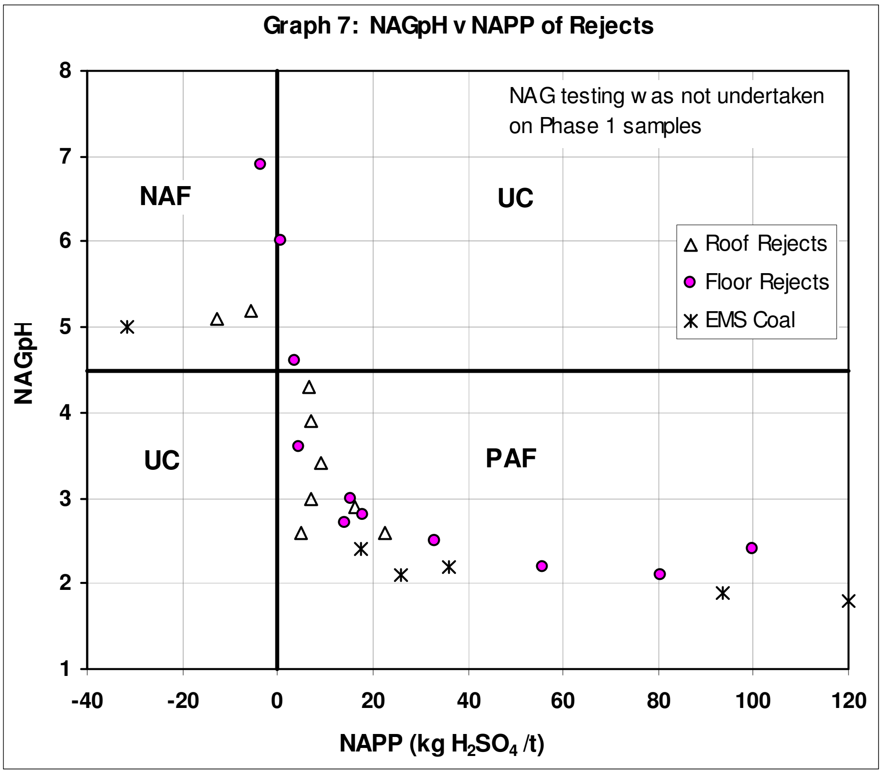




On the basis of sulphur, NAPP and, where available, NAGpH values:

- 63% of roof materials are classified as UC-PAF, PAF-LC or PAF. Only 18% of roof samples are clearly NAF.
- Over half of floor materials are classified as PAF and about one-third are classified as NAF. The remainder are UC-PAF and PAF-LC. The floor of the EMS Upper seam is almost entirely PAF, whereas the floor of the EMS Lower has a mixed acid-generating classification.
- Over 80% of the coal materials are classified as PAF, with the remainder having a mixed classification (NAF, UC-NAF and PAF-LC).

Usually with potential reject materials it is difficult to selectively wash rejects from particular parts of a coal seam unless the parts of the seam are selectively (individually) mined, and the CWC project is likely to be no exception. Aviva propose to mine the EMS seam as one unit, thereby taking the floor of the Upper seam and the roof of the Lower seam in the same block, along with the thin interburden unit between the plys. In addition, the floor of the EMS Lower seam is likely to contribute less volume of reject than the floor of the EMS Upper seam, due to the way the seam will be mined. Therefore, from a mineral waste management perspective, the potential coal reject materials (as a bulk waste material) can generally be regarded as PAF (**Graph 7**).



4.4 Coal Combustion Ash

Coal combustion ash has a slightly alkaline pH and is moderately saline. The total sulphur concentration is similar in all ash products tested (about 0.25%), however the high sulphate concentration accounts for approximately 80% of the total sulphur concentration, thereby providing a total oxidisable sulphur concentration in all three ash composite samples of less than 0.1%. On this basis, and due to all three samples having a negative NAPP and NAGpH greater than pH 4.5[4], all three ash samples have been classified as NAF.

5 MULTI-ELEMENTS COMPOSITION AND WATER QUALITY

The multi-element composition of composite samples for overburden and potential reject materials is provided in **Table 4**, and for ash samples in **Table 7**, and allows comparison of any enriched metal concentrations with those described in NEPC (1999a) health-based guidelines "E" for soils in open spaces (*e.g.* parks and recreational areas) and "F" for commercial/industrial facilities.

Additionally, the soluble multi-element composition of overburden and potential reject materials is provided in **Table 5**, and for ash samples in **Table 8**, and also allows comparison of enriched metal concentrations in solution with applied ANZECC (2000a) and NEPC (1999b) livestock drinking water guidelines, and for ash samples, ANZECC (2000b) aquatic ecosystem 90% and 95% trigger values.

It is important to note that there are no specific regulatory criteria for multi-element concentrations in overburden, coal reject (and ash) 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 Mine Materials (Overburden and Potential Rejects)

The multi-element results in **Table 4** indicate that, with the exception of elevated Mn concentration in one roof sample tested, the element concentrations in solids in all samples are well below the NEPC (1999a) health-based investigation levels (HIL) for soils (parks and recreational open spaces) and, by default, the less-stringent NEPC (1999a) HIL(F) for commercial/industrial facilities.

Water extract results (**Table 5**) indicate that the dissolved salt concentration in initial leachate from overburden is likely to be sodium-chloride (Na-Cl) and sodium-sulfate ($Na\text{-}SO_4$) dominated, with lesser concentrations of other major ions. The pH and EC in leachate from overburden and reject materials is likely to initially be neutral and moderately saline. Initial leachate from overburden is also likely to contain dissolved metal and salt concentrations typically below those recommended in ANZECC (2000a) and NEPC (1999b) guidelines. Some minor exceptions apply, such as overburden samples with pyrite, but this is expected to comprise an insignificant proportion of the overall overburden waste volume.

[4] Samples with a NAGpH less than pH 4.5 are typically regarded as potentially acid forming.

The expected PAF nature of rejects suggests that over time (period unknown) the pH and probably EC in leachate from reject materials is likely to deteriorate if these materials were to be exposed to oxidising conditions. Comparatively, the generally NAF classification of overburden suggests that, over time, the pH of leachate from overburden materials shouldn't deteriorate significantly.

With regard to potential rejects, only soluble Se concentrations in some roof and all floor samples exceeded the applied water quality guidelines. However, if rejects are exposed to oxidising conditions and the pH was to fall, the concentration of soluble metals would be expected to increase.

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.

5.2 Coal Combustion Ash

The multi-element results in **Table 7** indicate that ash materials are expected to have total metals and nutrient concentrations (in solids) well below the applied NEPC (1999a) HIL(E) and HIL(F) guideline values.

Results from bottle-leaching (**Table 8**) indicate that leachate from coal combustion ash is likely to be alkaline, relatively low salinity and Ca-SO_4 dominated. Despite the relatively low total metals concentrations in solid ash samples, leachate from coal combustion ash is likely to contain some dissolved metals in concentrations that may exceed the applied ANZECC (2000b) 90% and 95% trigger values for freshwater aquatic ecosystem protection and also ANZECC (2000a) livestock drinking water guidelines. The key metals of concern are As, B, Cr, Cu, Mo, Se and Zn.

5.2.1 Radioactive elements in coal and fly ash

Some trace elements commonly found in coal and coal combustion ash are naturally radioactive, such as uranium (U), thorium (Th) and their decay products, such as potassium (K), polonium (Po), lead (Pb), radium (Ra) and radon (Rn). In general, the radionuclide content of coal is usually below the content of local soil, but this depends on where the mine is located. In addition, the radionuclide content of coal combustion ash is generally greater than the source coal (Cooper, 2005).

Cooper (2005) report various background levels for coal and coal combustion ash throughout Australia, and also background levels for natural soils and rocks. The data indicate that most coals and combustions ash have radionuclide levels below or within the range typically found naturally in soils and rocks. Coal from Western Australia had the lowest average radionuclide content compared to other Australian States, however combustion ash from Western Australia was generally higher than combustion ash from other Australian states.

A detailed radionuclide study was not undertaken on coal from the CWC Project or coal combustion ash from the Coolimba Power Project, however concentrations of soluble U and Th in leachate from the ash samples found that in all sample types (fly ash, bottom ash and 4:1 mixed ash) the soluble U and Th concentrations were below the limit of laboratory reporting (<0.001 mg/L). This suggests that the very low concentrations of U and Th are likely to generate insignificant concentrations of radionuclide decay products. This is supported by the US Geological Survey (USGS, 1997), which states:

> "Limited measurements of dissolved uranium and radium in water leachates of fly ash and in natural water from some ash disposal sites indicate that dissolved concentrations

of these radioactive elements are below levels of human health concern, and would be expected to be in the range found naturally in soils."

In addition, the ash products from the Coolimba Power Project will be disposed in-pit, which significantly reduces their environmental risk.

5.3 Expected Pit Wall Geochemistry

The expected water quality of overburden and coal materials suggests that seepage water in the pit will probably require management prior to release off site. Overburden water quality is expected to be pH-neutral, moderately saline with low concentration of total and soluble metals. Coal water quality is expected to be acidic, moderately saline with low concentration of total and soluble metals. The acid-base classification of coal samples found that most coal samples were PAF, although the capacity to generate significant quantities of acid from coal seams in the pit walls is expected to be low due to the relatively low sulphur concentration of coal and the significantly greater proportion of pH-neutral overburden in pit walls compared to coal.

The baseline groundwater quality in the vicinity of the proposed pit area is understood by Terrenus to be variable, ranging from 500 to 1800 mg/L total dissolved solids (TDS) in the shallow aquifer, through to 1500 to 8300 mg/L TDS in the regional aquifer (Cattamarra Formation) (URS, 2005). This suggests that seepage water potentially emanating from the pit walls is, overall, likely to have a similar water quality to the local groundwater, although this would clearly need to be evaluated further during hydrogeological and pit void studies.

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

The following discussion applies to mined materials from the CWC project only. Ash materials from the Coolimba Power station 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. Even though the proposed mining strategy is to dump almost all rejects and overburden materials together back into the void behind the mining (stripping) face, 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). Also, a small proportion of overburden (less than 3% of the overall total) will be disposed in the early stages of mining into an out-of-pit dump. 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 Exchangeable Sodium Percentage (ESP) values well above 20% (the highest ESP value was 37% in a weathered composite sample). Where the EC is relatively low, such as in the tested samples, an ESP value of 6% 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% 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 coarse reject material is 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 9**) 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 9 Proportions of CEC of major exchangeable cations

Exchangeable Cation	Desirable ranges	Overburden	Coarse Rejects
	% CEC		
Calcium (Ca)	65 - 80	5 – 14 (average 9)	10 – 39 (average 26)
Magnesium (Mg)	10 - 15	53 – 68 (average 60)	35 – 55 (average 45)
Potassium (K)	1 - 5	2 – 6 (average 5)	20 – 30 (average 26)
Sodium (Na)	0 - 1	21 – 37 (average 27)	20 – 35 (average 27)

When compared to the desirable ranges for exchangeable cations in soil (**Table 9**), exchangeable Ca proportions in overburden are extremely low and exchangeable Mg and Na proportions in overburden are extremely high. The imbalanced Ca:Mg proportions become clearer when considering that exchangeable Ca:Mg ratios less than two typically require amelioration before these materials can be used as a growth layer. At the CWC project, the overburden materials all have exchangeable Ca:Mg ratios of less than 0.3. Amelioration with lime ($CaCO_3$) would add necessary calcium and the additional alkalinity would also help reduce the potential for materials to generate acidic leachate.

The exchangeable cation proportions in potential rejects are also imbalanced, however not as extreme as the overburden materials.

In summary, all of the overburden materials are generally pH-neutral. All have generally low to moderate salinity (median EC = 466 µS/cm) and display moderate to high eCEC values. All overburden materials are strongly-sodic and have a significant exchangeable cation imbalance, particularly with respect to exchangeable Ca:Mg ratios.

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 CWC Project is likely to be relatively benign and is expected to generate pH-neutral (~pH 6.5 to 7) and low-to-moderately saline runoff and seepage following surface exposure.
- Over half of the overburden is expected to have very low total sulphur content (<0.1%) and can be classified as barren. 97% of the overburden samples had total sulphur contents below 0.5%.
- The risk of acid generation from overburden is expected to be low given the general lack of oxidisable sulphur content. Over 80% of overburden samples are classified as NAF, with a further 8% classified as UC-NAF. The remaining 10% (approximately) are classified as PAF, PAF-LC or UC-PAF.
- Given the generally low sulphate–sulphur content of the samples, total sulphur can be used as a simple, quick and cost-effective method for screening the acid forming nature of overburden materials.
- The concentration of metals in overburden materials are within the applied guideline criteria for soils and are unlikely to present any environmental issues associated with revegetation and rehabilitation of any out-of-pit overburden storage facilities.
- The concentration of soluble metals and salts in runoff and seepage from overburden is likely to remain well within the applied water quality guideline criteria and is unlikely to present any environmental risks for on-site or downstream water quality.
- All overburden materials tested are strongly sodic, with significant exchangeable cation imbalances, and would likely require soil conditioning to be suitable to use as a cover material or as topsoil/growth layer.

7.2 Potential Coal Reject (including coal)

- Roof, floor and potential coal reject material is expected to generate weakly acidic (degree of acidity unknown) and moderately saline runoff/seepage following surface exposure.
- The roof and floor materials have a median total sulphur content of 0.7%, whereas coal has a median total sulphur content of 1.3%.
- With the exception of the floor of the EMS Lower seam, which has a mixed NAF-PAF acid-generation classification, all of the potential rejects are expected to be overwhelmingly PAF. Therefore, from a management perspective, the potential rejects are classified as PAF.
- Given the generally low sulphate–sulphur content of most potential reject samples, total sulphur can be used as a simple, quick and cost-effective method for identifying the acid forming nature of roof, floor and potential coal reject materials.

- The concentration of metals in potential reject materials are generally within the applied guideline criteria for soils.
- The concentration of soluble metals and salts in runoff and seepage from potential rejects is generally likely to remain within the applied water quality guideline criteria, provided these materials do not undergo further oxidation, given their PAF classification.
- All potential reject materials tested are strongly sodic, with significant exchangeable cation imbalances, and would likely require soil conditioning to be suitable to use in revegetation activities.
- The discussion of potential coal reject materials within this report should be considered indicative only, since coal reject material from the coal preparation plant may have different geochemical characteristics having undergone bulk crushing and washing. This is especially applicable since the washing process may initiate the onset of acid generation, given the PAF classification of these materials.
- Potential reject materials are expected to comprise less than 4% of all mined waste and initially appear to have a low propensity to leach metals and salts in significant quantities. Despite this apparent low risk, potential coal reject materials are classified as PAF and the risk to the environment from these materials is considered to be high, until proven otherwise by more detailed test-work. As such, all potential coal reject materials (including coal) will need to be carefully managed to minimise oxidation, generation of acid and potential release of metals (and salts) into the environment.
- The capacity to generate significant quantities of acid from coal seams in the pit walls is expected to be low due to the relatively low sulphur concentration of coal and the significantly greater proportion of pH-neutral overburden in pit walls compared to coal.

7.3 Coal Combustion Ash

- Coal combustion ash is expected to generate alkaline and relatively low-salinity runoff/seepage following surface exposure.
- The ash materials have a median total sulphur content of 0.25%, although are highly concentrated in sulphate, which results in a TOS of less than 0.1% for all tested materials.
- On the basis of the negligible TOS, negative NAPP and high NAGpH, all of the ash samples are NAF.
- The multi-element results indicate that ash materials are expected to have total metals and nutrient concentrations (in solids) well below the applied guideline values.
- Results from bottle-leaching indicate that leachate from coal combustion ash is likely to contain some dissolved metals in concentrations that may exceed the applied water quality guidelines. The key metals of concern are As, B, Cr, Cu, Mo, Se and Zn.
- Very low concentrations of soluble uranium and thorium in leachate from coal combustion ash suggest that radioactivity associated with coal combustion ash (and coal) is expected to be within the background levels of soil.
- The discussion of ash materials within this report should be considered indicative only, since ash wastes from the operational Coolimba Power Station may have different geochemical characteristics to these samples, which were generated from a pilot process which did not simulate the flue gas desulphurisation process.

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 CWC should consider:

- placement of mineral waste materials to minimise run-off and erosion;
- evaluating the geochemical characteristics of materials from 'new' areas or lithologies that have not been evaluated;
- evaluating the long-term geochemical characteristics of materials identified as potentially acid forming or producing leachate containing elevated concentrations of metals or salts; and
- evaluating the geochemical nature of the expected combined ash-FGD product from the Coolimba Power Project. This evaluation can only be undertaken once the CFB and boiler process has been finalised and a pilot-scale test process developed.

As would be evident from the skewed distribution of drill holes used for geochemical sampling shown in **Figure 3**, Aviva should undertake ongoing geochemical characterisation of mineral waste materials in the northern exploration areas associated with the CWC project. Terrenus acknowledges that at the time of writing drilling access to the northern areas was still being sought. Additionally, the northern areas represent the period of mining many years into the future.

Assuming the CWC project is approved and developed, continued characterisation of reject materials from the crushing circuit 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 materials are expected to predominantly be non-acid forming (NAF), however almost all potential reject materials are expected to be potentially-acid forming (PAF) and will need to be managed to minimise the onset of acid. The detailed strategy for managing rejects is beyond the scope of this study, however methods such as encapsulation of rejects within NAF overburden material would be appropriate. The timing of the onset of acid generation from potential rejects (and also from ROM coal) is unknown, as is the amount of acid likely to be generated. Further testing (for example, kinetic column tests) would be required to understand the long-term geochemistry of all mineral waste materials.

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. Periodic sampling and testing of the full suite of dissolved metals described in this report (*e.g.* every two years) 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%, 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.

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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), Aviva Corporation Limited (Aviva) 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 / Terrenus 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 finalised in October 2008, from data collected between January 2008 and September 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 Aviva. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

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Terrenus Earth Sciences

Dr. Ian P Swane
Director & Principal Consultant

21 October 2008

APPENDIX A. Composite Sample Details

Table A1. Composite sample details

Individual Sample ID	Composite Sample ID	Sample Type	Sample Description
CW5128 - 7021	AvC-01	Overburden (weathered)	Silty clay, weathered, NAF
CW5128 - 7027			
CW5128 - 7034	AvC-02	Overburden	Silty clay, fresh, predominantly NAF
CW5128 - 7035			
CW5128 - 7037			
CW5128 - 7040	AvC-03	EMS Upper roof	Silty clay with sand, some coal; PAF & PAF-LC
CW5126 - 6931			
CW5070 - 4872			
CW5128 - 7045	AvC-04	EMS Upper floor	Silty clay and coaly clay; PAF
CW5126 - 6940			
CW5112 - 6257			
CW5128 - 7049	AvC-05	EMS Lower roof	Sand, silty clay & coal; UC-PAF & PAF-LC
CW5070 - 4881			
CW5074 - 5155			
CW5128 - 7051	AvC-06	EMS Lower seam	Coal & minor silt; PAF
CW5070 - 4882			
CW5074 - 5156			
CW5128 - 7054	AvC-07	EMS Lower floor	Coal and coaly clay; PAF & PAF-LC
CW5070 - 4883			
CW5127 - 6973	AvC-08	Overburden	Silty clay with sand, fresh, NAF
CW5127 - 6977			
CW5127 - 6981			
CW5127 - 6985			
CW5127 - 6988			
CW5127 - 6993			
CW5127 - 6998	AvC-09	EMS Upper roof	Silty clay with sand, some coal; NAF
CW5074 - 5145			
CW5126 - 6900	AvC-10	Overburden (weathered)	Sand and silty clay, weathered, NAF
CW5126 - 6907			
CW5126 - 6913	AvC-11	Overburden	Silty clay with sand, fresh, NAF
CW5126 - 6915			
CW5126 - 6917			
CW5126 - 6921			
CW5126 - 6927			
CW5126 - 6939	AvC-12	EMS Upper floor	Coal and coaly clay; PAF
CW5070 - 4880			
CW5074 - 5154			
CW5112 - 6237	AvC-13	Overburden	Silty clay with sand, fresh, NAF
CW5112 - 6235			
CW5112 - 6246			
CW5112 - 6239			
CW5112 - 6241			
CW5112 - 6247			
CW5112 - 6243	AvC-14	Overburden	Sand and silty clay, fresh, PAF-LC
CW5112 - 6244			
CW5112 - 6252	AvC-15	EMS Upper seam	Coal; PAF
CW5070 - 4877			
CW5074 - 5150			
CW5112 - 6260	AvC-16	EMS Lower floor	Clay and coaly clay; NAF
CW5074 - 5157			

Individual Sample ID	Composite Sample ID	Sample Type	Sample Description
CW5070 - 4820	AvC-17	Overburden (weathered)	Sand with silty clay, weathered, NAF
CW5070 - 4830			
CW5070 - 4836	AvC-18	Overburden	Silty clay with sand; fresh, 40-60m; NAF
CW5070 - 4840			
CW5070 - 4845			
CW5070 - 4854	AvC-19	Overburden	Silty clay with sand; fresh, 68-86m; NAF
CW5070 - 4857			
CW5070 - 4861			
CW5070 - 4863			
CW5070 - 4871			
CW5070 - 4869	AvC-20	Overburden	Sand with some pyrite, fresh, PAF
CW5074 - 5114	AvC-21	Overburden	Sand with silty clay, fresh, NAF
CW5074 - 5130			
CW5074 - 5134			
CW5074 - 5140			
CW5074 - 5137			
CW5074 - 5120			
CW5074 - 5127	AvC-22	Overburden	Sand with silty clay, some carbonaceous, fresh, PAF-LC
CW5074 - 5122			
CW5074 - 5124			

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_2), 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:

$$FeS_2 + \frac{15}{4} O2 + \frac{7}{2} H_2O \text{ ---> } Fe(OH)_3 + 2\, H_2SO_4$$

According to this reaction, the maximum potential acidity (MPA) of a sample containing 1%S as pyrite would be 30.6 kg H_2SO_4/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 sulphate content is determined by ICP-AES. The total oxidisable sulphur (TOS) content is calculated as the total sulphur less the sulphate sulphur content. The TOS is then used to calculate the Maximum Potential Acidity (MPA), which is based on the assumption that only the TOS content 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 is 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.* ANZECC and NEPC) 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, 1999) 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).

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