MOOLARBEN COAL PROJECT

APPENDIX 10

Geochemical Assessment

Prepared by:

ENVIRONMENTAL GEOCHEMISTRY INTERNATIONAL PTY LTD

81A College Street, Balmain, NSW 2041 Australia
Telephone: (61-2) 9810 8100 Facsimile: (61-2) 9810 5542
Email: egi@geochemistry.com.au
ACN 003 793 486   ABN 12 003 793 486

For:

Wells Environmental Services

3/95 High St, East Maitland NSW
PO Box 205, East Maitland NSW 2323
Telephone: (02) 4934 6588 Facsimile: (02) 4934 6788

On Behalf of Moolarben Coal Pty Limited

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Geochemical Assessment of the Moolarben Coal Project

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Executive Summary

Environmental Geochemistry International Pty Ltd (EGi) were commissioned by Wells Environmental Services on behalf of Moolarben Coal Mines Pty Limited to carry out a geochemical assessment of the Moolarben Coal Project, located in the Hunter Valley, NSW, approximately 3km east of the village of Ulan. The objective of this work was to assess the acid rock drainage (ARD), salinity and sodicity hazards associated with development of the coal resource.

Testing was carried out on representative samples of overburden from the proposed underground and open cut developments, and samples of Ulan Seam coal and washability trial rejects.

Results of ARD investigations indicate that over 90% of overburden material for open cut and underground operations is likely to be non acid forming (NAF). The remainder is expected to be potentially acid forming low capacity (PAF-LC), with a low ARD potential. No potentially acid forming (PAF) materials were identified for floor samples from the open cut, which suggests that final pit floors will not be a source of ARD. Preliminary results indicate roof and floor materials for the underground project may be PAF-LC.

Most of the coal seam samples tested were PAF-LC, indicating potential acid release from coal stockpiles and underground workings. The coal reject samples were acid forming, with export coal rejects showing the highest ARD potential.

Testing also indicates that overburden, floor and coal reject materials are likely to be non-saline. Coal samples were moderately saline to saline.

Exchangeable sodium percentages and Emerson aggregate test (EAT) results indicate a possible sodicity hazard for topsoil, Quaternary/Tertiary alluvials and weathered Permian. Materials with sodic/dispersion potential may require treatment (with gypsum or lime) if exposed on dump surfaces or used in engineered structures.

No significant enrichment of metals/metaloids was detected in overburden, coal or reject solids.

The findings of these initial investigations have the following implications for materials management:

- Results suggest that normal run-of-mine operational blending of overburden should be sufficient to control ARD, pending confirmation with leach column testing.
- Containment of run off and leachate from coal stockpiles and underground operations may be required to monitor water quality and determine whether treatment is required. Results indicate that these waters may be saline and acidic. The sensitivity of groundwater and surface water to saline and acidic water should be investigated to determine the degree of management required. Provision for acid treatment may be

needed, which could include use of a mobile lime dosing plant to treat acid waters and broadcast application of agricultural lime.

- Rejects appear to have a higher ARD risk than other mine materials, and are likely to require specific management to control ARD. Possible approaches include underwater disposal, lime treatment, isolation from infiltration, or a combination of these.
- Materials with sodic/dispersion potential may require treatment (with gypsum or lime) if exposed on dump surfaces or used in engineered structures.
- A routine system of ARD testing should be established during operations to check the ARD potential of mine materials and allow for modification of materials management strategies if required.

1.0 Introduction

Environmental Geochemistry International Pty Ltd (EGi) were commissioned by Wells Environmental Services on behalf of Moolarben Coal Mines Pty Limited to carry out a geochemical assessment of the Moolarben Coal Project, located in the Hunter Valley, NSW, approximately 3km east of the village of Ulan. The objective of this work was to assess the acid rock drainage (ARD), salinity and sodicity hazards associated with development of the coal resource. It is understood that findings from this report will be used as part of an Environmental Assessment Report (EAR).

The work carried out included the following:

- A site visit by EGi to view the project area, examine drill hole samples, gather background data, discuss the project with relevant site personnel, and scope the investigations required;
- Selection of samples in conjunction with site personnel, and assistance in organising sample crushing and splitting prior to delivery to the EGi laboratory;
- Characterisation of materials in terms of ARD potential, sodicity, salinity, and enrichment/availability of elements of environmental concern;
- Evaluation of results and completion of a technical report, detailing results and implications for mine operations and overburden management.

2.0 Background Data

The Moolarben project stratigraphy comprises a sequence of Permian sandstone, siltstone, mudstone, tuff and coal, of which the Ulan Seam is the only seam of economic significance. The Permian sediments appear to have been deposited in a mainly fluvial dominated environment, although worm burrows are observed in some of the sandstone horizons, suggesting occasional marine influence. Pyrite is not generally observed in the drill core. Quaternary/Tertiary alluvial erosion channels cut through portions of the Permian sequence, and could make up around 10% of the total overburden. Siderite is the main carbonate observed, and application of 10% HCl to the core during the site visit showed only minor and occasional fizzing, suggesting a lack of acid neutralising minerals.

Mining will comprise both open cut and underground development operating concurrently, with all coal washed on site. The full Ulan seam will be recovered in the open cut operations, and a partial section will be recovered in the underground operations.

Open pit mining will utilise conventional truck and shovel methods. Open Cut 1 (northern pit) will be developed first, followed by Open Cut 2 (middle pit) and Open Cut 3 (Southern Pit). It is understood that the open cut operations will produce two coal products, a high ash domestic thermal product from the combined mining and washing of seams A to C, and an export thermal product from the combined mining and washing of seams D to E. The full Ulan seam will be mined in two passes and processed separately to produce these two products.

Out of pit placement of overburden will be required during initial pit development, but it is understood that most overburden will be backfilled into the pit.

Underground mining will be carried out north of the open pit development and use longwall mining methods. The underground coal will be restricted to the D and E top section of the Ulan seam, and will also be separated into a low ash export product and a high ash domestic product. Overburden extracted as part of access drives, ventilation shafts and other underground workings will be dumped with overburden.

3.0 Sample Collection and Preparation

One hole from each of the three proposed open pits, and one hole from the underground development were selected for sampling. In each case holes were selected that best represented the full mine stratigraphic section.

Diamond drillholes WMLB24, WMLB15 and WMLB5 were selected to represent stratigraphy in pits Open Cut 1 (OC1), Open Cut 2 (OC2) and Open Cut 3 (OC3) respectively. The weathered upper portion (6-15m) of these holes was pre-collared by open hole and chips were not available for sampling. WMLB75 was collared close to WMLB5, and chips from the upper 7m of this hole were used to provide a full section in pit OC3, that included weathered Permian. Open hole TB103 was used to represent overburden materials expected to be extracted during development of vent shaft and access for the proposed underground operations.

Open hole chips from WMLB54 in OC1 were used to represent Quaternary/Tertiary alluvials for the open cut, and additional Quaternary/Tertiary alluvials were sampled in the top 24m of drillhole TB103 testing underground development. The Quaternary/Tertiary alluvials are not expected to vary significantly across the site.

Sample intervals were selected based on geological descriptions provided by Moolarben project personnel and consultants. Continuous intervals of overburden were sampled in each hole to ensure the full stratigraphic section was represented. Moolarben personnel organised diamond core samples to be crushed and split, and 1-5 kg sub-samples were dispatched to EGi. Splits of open hole chip samples were sent to EGi without further crushing. At EGi a 300g split of all crushed core and open chip samples was collected, and dispatched to Sydney Environmental and Soil Laboratory (SESL) for pulverising to -75µm.

In addition to overburden samples, Ulan Seam samples from hole TB103, and two reject samples from washability trials of the Ulan Seam from hole WMLB24 were tested. The two reject samples were produced by Carbon Consulting and are expected to approximately represent the combined fine and coarse rejects from the proposed wash plant after processing the two coal products from open cut mining.

4.0 Methodology

The following tests were carried out on all samples:

- $pH_{1:2}$ and electrical conductivity $(EC)_{1:2}$ on deionised water extracts;
- Leco total S;
- acid neutralising capacity (ANC);
- the net acid producing potential (NAPP) calculated from total S and ANC results; and
- single addition net acid generation (NAG) test.

The following tests were carried out on selected samples:

- organic carbon single addition NAG (NAGorg) for samples with high organic carbon contents;
- kinetic NAG;
- acid buffering characteristic curve (ABCC) tests;
- multi-element scans of solids;
- multi-element scans of water extracts at a ratio of 1:2 (w/w) solid to deionised water; and
- soluble and exchangeable cations and Emerson dispersion test

A general description of the pH/EC, total S, ANC and NAG test methods is included in Appendix A.

High organic carbon contents (>7%C) can cause generation of organic acids in the NAG test, which can cause misleading low NAGpH values. The NAGorg test involves a combination of extended heating and NAG solution assay to identify and quantify any effects of organic acid generation on NAG test results.

Total sulphur assays, soluble and exchangeable cation testing, and Emerson dispersion tests were carried out by Sydney Environmental and Soil Laboratory (SESL). Multi-elements analyses were carried out by Genalysis Pty Ltd (Perth). All other analyses were carried out by EGi.

5.0 Overburden and Floor Results

5.1 pH and EC

The $pH_{1:2}$ and $EC_{1:2}$ tests were carried out by equilibrating crushed solid sample in deionised water for approximately 16 hours at a solid to water ratio of 1:2 (w/w). This gives an indication of the inherent acidity and salinity of the waste material when initially exposed in a waste emplacement area. Results are shown in Table 1 (open cut) and 2 (underground).

Circum-neutral $pH_{1:2}$ values were recorded for all overburden samples from open cut and underground drill holes, indicating no existing acidity in these samples. $EC_{1:2}$ values were all non saline at less than 0.4 dS/m, indicating a negligible salinity potential from these materials.

Ulan Seam floor samples from open pit and underground drillholes also have circum-neutral $pH_{1:2}$ values and non-saline to slightly saline $EC_{1:2}$ values of up to 0.41 dS/m.

5.2 Acid Base (NAPP) Results

Total S, ANC and net acid production potential (NAPP) results are presented in Table 1 and 2.

Total S is low for overburden and floor samples, ranging from below detection to 0.29%S, and with a median of 0.03%S. ANC ranges from 0 to 94 kg H_2SO_4/t, but is mainly (85%) less than 20 kg H_2SO_4/t, with a median of 5 kg H_2SO_4/t.

The NAPP value is an acid-base account calculation using measured total S and ANC values. It represents the balance between the maximum potential acidity (MPA) calculated from the total S and ANC. A negative NAPP value indicates that the sample may have sufficient ANC to prevent acid generation. Conversely, a positive NAPP value indicates that the material may be acid generating.

Figure 1 is an acid base accounting plot showing total S versus ANC, with NAPP positive and NAPP negative domains indicated. The plot highlights the low S (<0.1%) for most samples and high ANC/MPA ratios for many samples. There is a small population of NAPP positive samples, accounting for approximately 20% of all samples tested.

5.3 Single Addition NAG Results and Sample Classification

Single addition NAG test results are presented in Tables 1 and 2. A NAGpH < 4.5 indicates the sample is acid producing. NAG test results are used in conjunction with NAPP values to classify samples according to acid forming potential.

NAGpH values for overburden and floor range from 2.2 to 8.8, with most samples (>80%) having a NAGpH greater than 4.5.

Figure 2 is an ARD classification plot showing NAGpH versus the NAPP value. Potentially acid forming (PAF), non acid forming (NAF) and uncertain (UC) classification domains are indicated. A sample is classified PAF when it has a positive NAPP and NAGpH < 4.5, and NAF when it has a negative NAPP and NAGpH ≥ 4.5. Samples are classified uncertain when there is an apparent conflict between the NAPP and NAG results, i.e. when the NAPP is positive and NAGpH ≥ 4.5, or when the NAPP is negative and NAGpH < 4.5.

Figure 2 shows that most samples plot clearly within either the NAF or PAF domains, but there is a population of NAPP negative samples that plot in the bottom left hand uncertain domain. These samples have low total S of less than 0.3%S and are generally described as being carbonaceous or including carbonaceous materials. Carbonaceous materials can interfere with the standard NAG test by releasing organic acids causing anomalously low NAGpH values. These samples are therefore expected to be NAF as indicated by the NAPP results, and have been classified UC(NAF).

For a number of the PAF samples, the NAG to pH 4.5 values exceed the maximum potential acidity (MPA), again indicating overestimation of acid capacity in the NAG test due to carbonaceous materials. NAG test results which are influenced by organic acid effects are highlighted yellow in Tables 1 and 2.

The NAGorg method was carried out on 8 selected overburden samples in which organic acid effects were indicated. Results are shown in Table 3, which show that in all cases the NAGpH value after the extended boiling step is greater than 4.5 compared to acidic NAGpH values in the standard test, which confirms the effects of organic acids. The calculated NAG value is based on the concentration of dissolved S assumed to be derived from pyrite, and the concentration of cations (particularly Ca and Mg) indicative of acid neutralising reactions. The calculated NAG values of samples 30392 and 30412 are negative, indicating that all acid generated in the NAG test is organic, and that these samples are unlikely to generate acid. The remaining samples have low calculated NAG values of 3-6 kg H_2SO_4/t, indicating these samples are PAF-low capacity (PAF-LC), consistent with the NAPP values.

Based on results and discussions above, the geochemical classifications for samples are provided in Tables 1 and 2. Classification into NAF, UC(NAF), PAF-LC and PAF was carried out on the following basis:

- Samples with a NAPP ≤0 and NAGpH ≥4.5 were classified NAF.
- Samples with total S ≤0.05% were classified NAF regardless of NAPP or NAG results due to the very low risk of acid formation from these samples.
- Samples with a positive NAPP and NAGpH <4.5 were classified PAF-LC, since all NAPP positive values were less than 10 kg H_2SO_4/t.

- Uncertain samples with a NAPP >0 and NAGpH ≥4.5 were classified UC(NAF), since the NAGpH values indicate the samples are unlikely to generate significant acid.
- Uncertain samples with a NAPP ≤0 and NAGpH <4.5 were classified UC(NAF), since the NAGpH values were affected by organic acids and in this case the NAPP values are expected to be a better indication of acid potential.

Overall results suggest that the majority of overburden from the open cut and underground development will be NAF, with a small proportion of PAF-LC. Drillholes sampled for the open cut development were selected to maximise the mine stratigraphy tested, and results are not necessarily representative of the overall distribution of ARD types in the overburden. However, as a guide, the weighted distribution (results weighted according to sample interval length) of NAF in the overburden tested for the open cut is greater than 90%. Only one sample in the underground drillhole was PAF-LC, which again equates to over 90% NAF overburden.

Figure 3 is a box plot showing the distribution of MPA and ANC for overburden samples from open cut and underground operations. The plot shows that although the median ANC values are low (less than 10 kg H_2SO_4/t), they significantly exceed the median MPA values. Given the small proportion and low ARD potential of the PAF-LC materials and the higher background ANC, normal run-of-mine operational blending of overburden materials during mining should be sufficient to prevent ARD, without the need for any further materials management. Leach column testing of blended materials and ongoing testing and monitoring of overburden materials during operations would be required to confirm the validity of this approach.

None of the floor materials tested from the open cut were classified PAF-LC, which suggests that final pit floors will not be a source of ARD. Note that no specific testing of roof and floor materials for the underground development was carried out, but it is expected that these materials may be PAF-LC, consistent with Ulan Seam coal samples tested in hole TB103 (see Section 6).

5.4 Acid Buffering Characteristic Curve (ABCC) Testing

An acid buffering characteristic curve (ABCC) is produced by slow titration of a sample with acid, and provides an indication of the relative reactivity of the ANC measured. The acid buffering of a sample to pH 4 can be used as an estimate of the proportion of readily available ANC. ABCC tests were carried out on 8 selected samples from overburden and floor to evaluate the availability of the ANC measured. Results are presented in Figures 4 to 8, with calcite, dolomite, ferroan dolomite and siderite standard curves as reference. Calcite and dolomite readily dissolve in acid and exhibit strongly buffered pH curves in the ABCC test, rapidly dropping once the ANC value is reached. The siderite standard provides very poor acid buffering, exhibiting a very steep pH curve in the ABCC test. Ferroan dolomite is between siderite and dolomite in acid buffering availability.

Figure 4 shows the ABCC profile for sandstone sample 28523, which has a high ANC value of 94 kg H_2SO_4/t. The plot shows strong buffering similar to dolomite, and indicates most (>90%) of the total ANC measured is readily available for acid buffering.

Figure 5 shows the ABCC profile for sandstone sample 30418, which has a high ANC value of 82 kg H_2SO_4/t. The sample profile plots between the dolomite and ferroan dolomite standard curves, indicating the ANC is due to ferroan dolomite, and will be less reactive than dolomite. The curve indicates that approximately 75% of the total ANC will be readily available for acid buffering.

Figures 6 to 8 show ABCC profiles for a variety of lithologies with varying ANC. All curves plot between the ferroan dolomite and siderite trends, indicating poor reactivity. Results suggest that a large proportion of the total ANC will be ineffective, with readily available proportions ranging from 15% to 60% of the total ANC.

Results indicate that the measured ANC in the overburden at Moolarben may not be fully effective, except for the higher ANC (>80 kg H_2SO_4/t) sandstone. Reliance on acid buffering from these materials is likely to require long residence times and low flushing rates.

5.5 Elemental Enrichment and Solubilities

Results of multi-element scans for 17 selected overburden and floor sample solids were compared to the median soil abundance (from Bowen, 1979[1]) to highlight enriched elements.

The extent of enrichment is reported as the Geochemical Abundance Index (GAI), which relates the actual concentration with an average abundance on a log 2 scale. The GAI is expressed in integer increments where a GAI of 0 indicates the element is present at a concentration similar to, or less than, average abundance; and a GAI of 6 indicates approximately a 100-fold enrichment above average abundance. As a general rule, a GAI of 3 or greater signifies enrichment that warrants further examination.

Results of multi-element analysis are presented in Table 4, and the corresponding GAI values are presented in Table 5. Results show enrichment of Be in most samples but with a maximum of 6.2 mg/kg, which is within normal ranges for soils. No other elements were significantly enriched compared to normal soils.

The same 17 overburden sample solids were subjected to water extraction at a solids:liquor ratio of 1:2. The results are shown in Table 6, and provide a guide to those elements readily liberated when flushed. The pH of the extracts was greater than 6.5, and little mobilisation of metals and metaloids was expected. The extracts show elevated concentrations of Al (>1mg/L), but given the circum neutral pH, the elevated Al is likely to be due to the presence of colloidal or very fine silicate minerals in the solution after

[1] Bowen, H.J.M. (1979) Environmental Chemistry of the Elements. Academic Press, New York, p 36-37.

filtering the extracts. Slightly elevated Co (0.3 mg/L) and Ni (0.4mg/L) were measured in sample 28495. No other significant mobilisation of elements of environmental concern was evident.

5.6 Sodicity and Dispersion

Soluble and exchangeable cations and Emerson aggregate tests (EAT) were carried out on selected overburden samples to provide a preliminary indication of any sodicity and dispersion issues. Results are presented in Table 7.

Sodic materials tend to form low permeability soil horizons, accelerating erosion and inhibiting plant growth. Sodic soils are also dispersive and should not be used as construction materials since they are prone to tunnelling and collapse. The exchangeable sodium percentage (ESP) is a measure of exchangeable Na as a percentage of the total effective cation exchange capacity (ECEC). The ESP can be used to classify samples according to sodicity as follows:

ESP < 6% - Non-Sodic
ESP 6-15% - Sodic
ESP 15-30% - Strongly Sodic
ESP >30% - Very Strongly Sodic

The ESP for the single topsoil sample was sodic (ESP 6%-15%). ESP's for Quaternary/Tertiary Alluvial samples ranged from sodic (ESP 6%-15%) to strongly sodic (15-30%). ESP's for weathered Permian samples were all sodic (ESP 6%-15%). ESP's for unweathered Permian samples were all non-sodic (ESP <6%). Sodic materials may be subject to surface crusting and high erosion rates if placed in the surface of dumps and exposed directly to rainfall.

The dispersive properties of materials can also be measured more directly using the Emerson aggregate test (EAT). This test assigns classes to samples according to dispersive behaviour of sample aggregates in water. The samples are divided into 8 main classes, and up to 4 sub classes. In general, samples classified as Class 1 or 2 indicate dispersion and associated risk of tunnelling, surface crusting and water erosion.

Emerson aggregate test (EAT) classes generally indicated low dispersion risk (Class 5), apart from topsoil sample 30386, Quaternary/Tertiary Alluvial sample 30380 and weathered Permian sample 30377. A moderate dispersion risk (Class 2) was indicated for the weathered Permian sample 30377. Topsoil sample 30386 and Quaternary/Tertiary Alluvial sample 30380 had ESP's of class 3, and are not likely to be dispersive unless worked extensively when wet.

Results indicate a possible sodicity hazard for topsoil, Quaternary/Tertiary alluvials and weathered Permian. Materials with sodic/dispersion potential may require treatment (with gypsum or lime) if exposed on dump surfaces or used in engineered structures.

6.0 Coal and Reject Results

6.1 Geochemical Characterisation

Six Ulan Coal Seam samples were tested from underground drillhole TB103, representing the full seam interval from 114m to 128m depth. Two reject samples from coal washing trials of coal samples from WMLB24 were also tested, representing a high ash domestic thermal product (Ulan seams A to C) and an export thermal product (Ulan seams D to E). Results of geochemical characterisation for coal samples and reject samples are shown in Tables 8 and 9, respectively.

The coal samples generally had slightly acidic $pH_{1:2}$ values of down to pH 4.5, and moderately saline to saline $EC_{1:2}$ values of up to 2 dS/m. The samples also have elevated total sulphur of up to 0.66%S, and it is likely that the lower pH and elevated EC are due to accumulation of pyrite oxidation products between sampling and testing.

The high ash domestic coal reject sample (EGi sample No 30372) had a pH of 5.9 and a non saline EC of 0.31 dS/m, indicating a lack of existing acidity or salinity in this sample. The export coal reject sample has a lower pH of 4.2, indicating some minor existing acidity is this sample, but a non saline EC of 0.31 dS/m.

Total S ranged from 0.14% to 0.66%S in the coal, and 0.27% to 1.06%S in the rejects. The export thermal coal reject sample had the highest S. ANC was low for coal and rejects, ranging from 2 to 11 kg H_2SO_4/t for the coal, and 0 to 1 kg H_2SO_4/t for the rejects. Sulphur ranges for the coal were consistent with Moolarben total S test results of washed coal samples from the open cut deposit (reproduced in Table 10), and raw coal from underground deposit (reproduced in Table 11).

Figure 9 is an acid base account plot for coal and reject samples. The figure shows that all samples plot in the NAPP positive domain, apart from one coal sample (30425). Figure 10 is an ARD classification plot for coal and reject samples. The plot shows that most samples plot in the PAF domain, one sample in the NAF domain, and one in the upper right hand uncertain domain. The uncertain coal sample has a very low NAPP value of 2 kg H_2SO_4/t, and a low S value of 0.30%S, which if present as pyrite would be expected to completely react in a single addition NAG test. The NAG results suggest that this borderline NAPP positive sample is NAF.

NAG test results to pH 4.5 for 4 of the coal samples and the high ash coal reject sample 30372 are greater than the MPA, indicating organic acid effects. The NAGorg method was carried out on 2 coal samples and both reject samples to determine the proportion of acid measured in the standard NAG test that can be attributed to pyrite oxidation. Results are shown in Tables 8 and 9.

The calculated NAG values for the coal samples are significantly lower than the NAPP values, suggesting that most of the S measured in the coal samples is in non-acid generating forms (possibly organic S). The calculated NAG value for one of the coal samples (30428) was 0 kg H_2SO_4/t, and is classified UC(NAF). The calculated NAG value for the other coal sample (30429) was 4 kg H_2SO_4/t, indicating the sample is PAF, but with a low capacity (PAF-LC).

The high ash coal reject sample (30372) has a calculated NAG value of 6 kg H_2SO_4/t, consistent with the NAPP value and the sample is classified PAF-LC. The other reject sample has 1%S, and the NAPP, standard NAG to pH 4.5, and calculated NAG are all similar, confirming a PAF classification for this sample.

Kinetic NAG tests provide an indication of the kinetics of sulphide oxidation and acid generation for a sample. Kinetic NAG testing was carried out on the export thermal coal reject sample (30373) with a S value of 1%S. The kinetic NAG pH and temperature profiles are presented in Figure 11. The sample shows very rapid acid production within the first few minutes of the test, and indicates that pyritic reject materials are likely to produce acid within days to weeks after exposure. In addition, the temperature profile is typical of pyritic samples, and confirms that most of the 1% S in the sample is in pyritic form.

Figure 12 shows the ABCC profile for a coal sample with an ANC of 11 kg H_2SO_4/t. The sample profile plots between the ferroan dolomite and siderite trends, indicating poor reactivity as with many of the overburden samples (see Section 5.4). Results suggest that about 40% of the total ANC is readily available.

Results of testing indicate that coal may leach minor amounts of ARD. Run off and leachate from coal stockpiles and underground workings (in which coal seams will be exposed in pillars, roof and floor) may need to be contained, monitored and possibly treated.

Based on results from the two reject samples tested, rejects appear to be acid forming and fast reacting, with the export coal rejects showing the highest ARD potential. Pyritic rejects will require management to control ARD, which may involve underwater disposal, lime treatment, isolation from infiltration, or a combination of these.

6.2 Multi-Elements

Two coal and both reject sample solids were analysed for multi-elements. Results of multi-element analysis and the corresponding GAI values are presented in Table 12. Results show that in addition to S (which is discussed in relation to acid forming potential), there is enrichment of Be in the coal and export thermal coal reject sample, and enrichment of Ag in the high ash coal reject sample. However, overall the concentration of metals and metaloids in the solids is similar to background in soils.

The same sample solids were subjected to water extraction at a solids:liquor ratio of 1:2. The results are shown in Table 13. There was no significant mobilisation of metals/metaloids from the two coal samples, but some minor mobilisation of Co, Cu and

Zn was indicated for the high ash coal reject extract, and minor mobilisation of Al, Ni and Zn for the export coal reject extract. Mobilisation of these elements and other metals/metaloids will be largely controlled by pH, so that management of ARD will effectively manage metal/metaloid release.

7.0 Conclusions and Recommendations

Results of ARD investigations indicate that over 90% of overburden material for open cut and underground operations is likely to be non acid forming (NAF). PAF-LC materials appear to have low ARD potential and represent a small proportion of overburden to be mined. Although the ANC is poorly reactive, it significantly exceeds the background MPA, and normal run-of-mine operational blending of overburden materials during mining should be sufficient to control ARD without the need for any further materials management. Leach column testing of blended materials and ongoing testing and monitoring of overburden materials during operations would be required to confirm the validity of this approach.

No PAF materials were identified for floor samples from the open cut, which suggests that final pit floors will not be a source of ARD. Preliminary results indicate roof and floor materials for the underground project may be PAF-LC.

Most of the coal seam samples tested were PAF-LC, indicating potential acid release from coal stockpiles and underground workings. Coal reject samples were acid forming, with export coal rejects showing the highest ARD potential.

Testing indicates that overburden, floor and coal reject materials are likely to be non-saline. Coal samples were moderately saline to saline.

Exchangeable sodium percentages and Emerson aggregate test (EAT) results indicate a possible sodicity hazard for topsoil, Quaternary/Tertiary alluvials and weathered Permian. Materials with sodic/dispersion potential may require treatment (with gypsum or lime) if exposed on dump surfaces or used in engineered structures.

No significant enrichment of metals/metaloids was detected in overburden, coal or reject solids.

The findings of these initial investigations have the following implications for materials management:

- Results suggest that normal run-of-mine operational blending of overburden should be sufficient to control ARD.
- Containment of run off and leachate from coal stockpiles and underground operations may be required to monitor water quality and determine whether treatment is required. Results indicate that these waters may be saline and acidic. The sensitivity of groundwater and surface water to saline and acidic water should be investigated to

determine the degree of management required. Provision for acid treatment may be needed, which could include use of a mobile lime dosing plant to treat acid waters and broadcast application of agricultural lime.

- Rejects appear to have a higher ARD risk than other mine materials, and are likely to require specific management to control ARD. Possible approaches include underwater disposal, lime treatment, isolation from infiltration, or a combination of these.
- Materials with sodic/dispersion potential may require treatment (with gypsum or lime) if exposed on dump surfaces or used in engineered structures.
- A routine system of ARD testing should be established during operations to check the ARD potential of mine materials and allow for modification of materials management strategies if required.

The following work is recommended to finalise materials management requirements:

- More widespread sampling and testing of overburden materials should be carried out to ensure there are no significant PAF units within overburden and floor, and confirm the distribution and ARD potential of mine materials indicated by testing to date.
- Leach column testing of PAF-LC overburden blended with NAF overburden should be carried out to confirm the validity of the operational blending approach.
- Additional samples of representative reject and coal materials should be tested to determine the variability in ARD potential.
- Leach column testing of coal and reject materials should be carried out to determine lag times and acid release rates, which in turn can be used to determine appropriate treatment rates and other management requirements.

Table 1: Geochemical characterisation results for samples from the proposed open pit.

Hole No	Open Cut Pit No	EGi Code	Moolarben Sample No	Depth (m)			Unit	Material Type	Geological Description	$pH_{1:2}$	$EC_{1:2}$	ACID-BASE ANALYSIS					NAG TEST			ARD Classification
				From	To	Interval						Total %S	MPA	ANC	NAPP	ANC/MPA	NAGpH	$NAG_{(pH4.5)}$	$NAG_{(pH7.0)}$	
WMLB54	OC1	30380		0.00	1.00	1.00	Quaternary/Tertiary	Overburden	Alluvium	8.11	0.07	<0.01	0	1	-1.0	-	6.7	0	1	NAF
WMLB54	OC1	30381		1.00	2.00	1.00	Quaternary/Tertiary	Overburden	Alluvium	8.16	0.06	<0.01	0	1	-1.0	-	6.2	0	4	NAF
WMLB54	OC1	30382		2.00	3.00	1.00	Quaternary/Tertiary	Overburden	Alluvium	7.78	0.06	<0.01	0	1	-1.0	-	6.1	0	6	NAF
WMLB54	OC1	30383		3.00	4.00	1.00	Quaternary/Tertiary	Overburden	Alluvium	8.04	0.08	<0.01	0	1	-1.0	-	6.2	0	6	NAF
WMLB54	OC1	30384		4.00	5.00	1.00	Quaternary/Tertiary	Overburden	Alluvium	7.87	0.09	0.01	0	0	0.0	-	6.1	0	4	NAF
WMLB54	OC1	30385		5.00	6.00	1.00	Quaternary/Tertiary	Overburden	Alluvium	7.81	0.09	<0.01	0	0	0.0	-	6.0	0	6	NAF
WMLB24	OC1		Open Hole	0.00	6.00	6.00														
WMLB24	OC1		Open Hole	6.00	10.00	4.00	Permian	Overburden	Sandstone, as above, moderately fresh at 10m											
WMLB24	OC1		Open Hole	10.00	13.20	3.20	Permian	Overburden	Sandstone with siltstone, probably laminated											
WMLB24	OC1		Open Hole	13.20	14.00	0.80	Permian	Overburden	Coal, stoney											
WMLB24	OC1		Open Hole	14.00	14.95	0.95	Permian	Overburden	Claystone, off white tuffaceous, few coaly bands											
WMLB24	OC1	28490	WMLB24-E1	14.95	15.45	0.50	Permian	Overburden	Coal, shaley, banded with mudstone, dark brown	6.82	0.09	0.19	6	3	3	0.52	2.3	76	122	PAF-LC
WMLB24	OC1	28491	WMLB24-E2	15.45	16.60	1.15	Permian	Overburden	Mudstone, carbonaceous, coaly tuffaceous in part	6.88	0.09	0.11	3	3	0.4	0.89	2.5	37	66	PAF-LC
WMLB24	OC1	28492	WMLB24-E3	16.60	18.59	1.99	Permian	Overburden	Claystone, cream, tuffaceous in part, few carbonaceous traces	6.76	0.06	0.03	1	15	-14	16.34	7.3	0	0	NAF
WMLB24	OC1	28493	WMLB24-E4	18.59	19.04	0.45	Permian	Overburden	Mudstone, coaly and carbonaceous	6.66	0.06	0.14	4	2	2	0.47	2.2	45	79	PAF-LC
WMLB24	OC1	28494	WMLB24-E5	19.04	19.91	0.87	Permian	Overburden	Siltstone,few sandy laminae, grey	6.59	0.04	0.03	1	2	-1	2.18	2.5	12	33	NAF
WMLB24	OC1	28495	WMLB24-E6	19.91	24.00	4.09	Permian	Overburden	Sandstone, very coarse, tending to granular conglomerate rare fe st	7.12	0.04	<0.01	0	1	-1	-	5.6	0	17	NAF
WMLB24	OC1	28496	WMLB24-E7	24.00	27.40	3.40	Permian	Overburden	Sandstone, very coarse, tending to granular conglomerate rare fe st minor claystone, tuffaceous cherty	7.16	0.03	<0.01	0	0	0	-	5.7	0	16	NAF
WMLB24	OC1	28497	WMLB24-E8	27.40	28.26	0.86	Permian	Overburden	Sandstone, fine, irregular silty laminae throughout, worm burrows	6.65	0.09	0.02	1	3	-2	4.90	6.9	0	0	NAF
WMLB24	OC1	28498	WMLB24-E9	28.26	30.45	2.19	Permian	Overburden	Sandstone, fine rare silty laminae, off white	6.62	0.10	<0.01	0	6	-6	-	7.1	0	0	NAF
WMLB24	OC1	28499	WMLB24-E10	30.45	33.65	3.20	Permian	Overburden	Sandstone as above, minor aquiclude at 33.1	6.92	0.11	0.02	1	7	-6	11.44	7.4	0	0	NAF
WMLB24	OC1	28500	WMLB24-E11	33.65	36.45	2.80	Permian	Overburden	Sandstone, fine, common silty laminae, worm burrows	6.88	0.06	0.02	1	14	-13	22.88	7.6	0	0	NAF
WMLB24	OC1	28501	WMLB24-E12	36.45	39.45	3.00	Permian	Overburden	Sandstone, fine, common silty laminae, worm burrows, few lenses of coarse sandstone	6.91	0.06	0.02	1	8	-7	13.07	7.7	0	0	NAF
WMLB24	OC1	28502	WMLB24-E13	39.45	39.80	0.35	Permian	Overburden	Mudstone, carbonaceous in part, few coaly traces	7.32	0.09	0.09	3	3	0	1.09	2.6	20	40	UC(NAF)
WMLB24	OC1		Core Loss	39.80	40.21	0.41	Permian	Overburden												
WMLB24	OC1	28503	WMLB24-E14	40.21	40.86	0.65	Permian	Overburden	Mudstone, carbonaceous, few penny bands of b coal	7.35	0.11	0.20	6	2	4	0.33	2.4	43	73	PAF-LC
WMLB24	OC1	28504	WMLB24-E15	40.86	42.45	1.59	Permian	Overburden	Sandstone, medium fine, rare silty traces, tending to massive at base, minor fizzing (10%HCl)	7.46	0.08	0.01	0	1	-1	3.27	5.7	0	1	NAF
WMLB24	OC1		Coal	42.45	54.99	12.54	Permian	Coal	Coal - Ulan Seam A - E											
WMLB24	OC1	28505	WMLB24-E16	54.99	56.55	1.56	Permian	Floor	Sandstone fine, laminated with siltstone, carbonaceous at top	7.41	0.11	0.03	1	3	-2	3.27	3.0	6	22	NAF
WMLB15	OC2		Open Hole	0.00	5.00	5.00	Permian	Overburden	Loam, abundant floaters of claystone											
WMLB15	OC2		Open Hole	5.00	6.00	1.00	Permian	Overburden	Sandstone? Uphole caving Minor Gravel											
WMLB15	OC2	28506	WMLB15-E1	6.00	8.12	2.12	Permian	Overburden	Siltstone, sandstone very fine, laminated, brownish grey, weathered	7.55	0.08	0.02	1	7	-6	11.44	6.1	0	6	NAF
WMLB15	OC2	28507	WMLB15-E2	8.12	8.50	0.38	Permian	Overburden	Mudstone, grey subfissile, moderately fresh, lesser siderite	7.62	0.10	0.06	2	8	-6	4.36	7.2	0	0	NAF
WMLB15	OC2	28508	WMLB15-E3	8.50	9.64	1.14	Permian	Overburden	Coal (Moolarben), Dmb, stoney, minor tuff and sideritic in part	7.66	0.13	0.21	6	5	1	0.78	2.4	68	109	PAF-LC
WMLB15	OC2	28509	WMLB15-E4	9.64	10.28	0.64	Permian	Overburden	Claystone, tuffaceous, puggy in part	7.86	0.18	0.03	1	13	-12	14.16	7.1	0	0	NAF
WMLB15	OC2	28510	WMLB15-E5	10.28	11.10	0.82	Permian	Overburden	Coal (Moolarben), stoney and sideritic, minor tuff	7.81	0.17	0.18	6	11	-5	2.00	2.5	32	58	UC(NAF)
WMLB15	OC2	28511	WMLB15-E6	11.10	11.90	0.80	Permian	Overburden	Mudstone, carbonaceous traces, few penny bands of bright coal	7.89	0.14	0.13	4	9	-5	2.26	2.6	35	67	UC(NAF)
WMLB15	OC2	28512	WMLB15-E7	11.90	13.58	1.68	Permian	Overburden	Siltstone, sandstone very fine, few laminae, light	7.71	0.13	0.05	2	24	-22	15.69	7.4	0	0	NAF
WMLB15	OC2	28513	WMLB15-E8	13.58	13.91	0.33	Permian	Overburden	Claystone, tuffaceous, cream	7.79	0.11	0.04	1	5	-4	4.08	4.7	0	12	NAF
WMLB15	OC2	28514	WMLB15-E9	13.91	14.83	0.92	Permian	Overburden	Mudstone, carbonaceous	7.73	0.14	0.20	6	2	4	0.33	2.4	37	68	PAF-LC
WMLB15	OC2	28515	WMLB15-E10	14.83	15.35	0.52	Permian	Overburden	Sandstone, fine, few carbonaceous traces and laminae	7.62	0.12	<0.01	0	2	-2	-	5.2	0	4	NAF
WMLB15	OC2	28516	WMLB15-E11	15.35	17.98	2.63	Permian	Overburden	Sandstone, very coarse, tending to granular conglomerate, sucrosic, minor fine sandstone at base, some fizzing (10% HCl)	7.32	0.14	<0.01	0	1	-1	-	5.7	0	14	NAF
WMLB15	OC2	28517	WMLB15-E12	17.98	20.15	2.17	Permian	Overburden	Sandstone fine, siltstone, laminated, few sandy phase and silty blebs	7.46	0.13	0.02	1	12	-11	19.61	7.4	0	0	NAF
WMLB15	OC2	28518	WMLB15-E13	20.15	20.42	0.27	Permian	Overburden	Mudstone, carbonaceous, few penny bands of bright coal	7.55	0.13	0.11	3	14	-11	4.16	7.2	0	0	NAF
WMLB15	OC2	28519	WMLB15-E14	20.42	22.60	2.18	Permian	Overburden	Siltstone, Sandstone fine, few carbonaceous traces	7.66	0.21	0.03	1	7	-6	7.63	7.5	0	0	NAF
WMLB15	OC2	28520	WMLB15-E15	22.60	24.50	1.90	Permian	Overburden	Sandstone some siltstone, few coaly traces and sandy laminae	7.61	0.12	0.02	1	11	-10	17.97	7.7	0	0	NAF
WMLB15	OC2	28521	WMLB15-E16	24.50	27.35	2.85	Permian	Overburden	Siltstone dark, tending to mudstone, few coaly traces and sandy laminae	7.34	0.09	0.04	1	8	-7	6.54	7.8	0	0	NAF
WMLB15	OC2	28522	WMLB15-E17	27.35	29.55	2.20	Permian	Overburden	Sandstone, fine and dark with siltstone, laminated, downwards coarsening	6.87	0.10	0.02	1	14	-13	22.88	7.9	0	0	NAF
WMLB15	OC2	28523	WMLB15-E18	29.55	31.02	1.47	Permian	Overburden	Sandstone, medium fine, blocky	6.91	0.09	0.02	1	94	-93	153.59	8.1	0	0	NAF
WMLB15	OC2	28524	WMLB15-E19	31.02	32.00	0.98	Permian	Overburden	Shale, tending to siltstone, fissile	6.76	0.09	0.03	1	11	-10	11.98	8.2	0	0	NAF
WMLB15	OC2	28525	WMLB15-E20	32.00	34.25	2.25	Permian	Overburden	Sandstone, fine, siltstone, laminated	7.43	0.07	0.02	1	14	-13	22.88	8.1	0	0	NAF

Table 1: Geochemical characterisation results for samples from the proposed open pit.

Hole No	Open Cut Pit No	EGi Code	Moolarben Sample No	Depth (m)			Unit	Material Type	Geological Description	$pH_{1:2}$	$EC_{1:2}$	ACID-BASE ANALYSIS					NAG TEST			ARD Classification
				From	To	Interval						Total %S	MPA	ANC	NAPP	ANC/MPA	NAGpH	$NAG_{(pH4.5)}$	$NAG_{(pH7.0)}$	
WMLB15	OC2	28526	WMLB15-E21	34.25	34.88	0.63	Permian	Overburden	Shale, tending to mudstone, carbonaceous	6.73	0.10	0.05	2	3	-1	1.96	5.7	0	2	NAF
WMLB15	OC2	28527	WMLB15-E22	34.88	36.41	1.53	Permian	Overburden	Sandstone, fine to medium, few silty phases and carbonaceous traces, tending to carbonaceous siltstone at base	6.59	0.13	0.02	1	5	-4	8.17	7.1	0	0	NAF
WMLB15	OC2		Coal	36.41	48.21	11.80	Permian	Coal	Coal - Ulan Seam A - E											
WMLB15	OC2	28528	WMLB15-E23	48.21	49.20	0.99	Permian	Floor	Sandstone, fine, Carbonaceous silty laminae throughout, minor carbonaceous material	7.21	0.09	0.04	1	1	0.2	0.82	3.0	7	25	NAF
WMLB15	OC2	28529	WMLB15-E24	49.20	51.35	2.15	Permian	Floor	Sandstone, medium fine, few silty laminae, tending to massive	7.11	0.19	0.09	3	3	0	1.09	5.6	0	1	NAF
WMLB75	OC3	30374		0.00	2.00	2.00	Quaternary/Tertiary	Overburden	Alluvium/weathered Permian colluvium (close to WMLB5)	7.21	0.09	<0.01	0	1	-1.0	-	6.1	0	6	NAF
WMLB75	OC3	30375		2.00	3.00	1.00	Quaternary/Tertiary	Overburden	Alluvium/weathered Permian colluvium (close to WMLB5)	7.34	0.09	<0.01	0	2	-2.0	-	6.2	0	4	NAF
WMLB75	OC3	30376		3.00	4.00	1.00	Permian	Overburden	Weathered Permian (close to WMLB5)	8.02	0.08	<0.01	0	1	-1.0	-	6.2	0	3	NAF
WMLB75	OC3	30377		4.00	5.00	1.00	Permian	Overburden	Weathered Permian (close to WMLB5)	7.61	0.06	<0.01	0	2	-2.0	-	6.0	0	5	NAF
WMLB75	OC3	30378		5.00	6.00	1.00	Permian	Overburden	Weathered Permian (close to WMLB5)	8.06	0.08	<0.01	0	1	-1.0	-	6.1	0	4	NAF
WMLB75	OC3	30379		6.00	7.00	1.00	Permian	Overburden	Weathered Permian (close to WMLB5)	7.37	0.08	0.02	0	0	0.0	-	6.1	0	2	NAF
WMLB5	OC3		Open Hole	0.00	7.85	7.85	Permian													
WMLB5	OC3	28530	WMLB5-E1	7.85	8.02	0.17	Permian	Overburden	Clay, red brown, moderately soft	7.16	0.11	0.02	1	24	-23	39.22	7.4	0	0	NAF
WMLB5	OC3	28531	WMLB5-E2	8.02	9.10	1.08	Permian	Overburden	Siltstone, dark grey, hard	7.23	0.11	0.14	4	10	-6	2.33	6.5	0	0	NAF
WMLB5	OC3	28532	WMLB5-E3	9.10	9.30	0.20	Permian	Overburden	Tuff, white, moderately hard	6.67	0.12	0.03	1	9	-8	9.80	5.4	0	9	NAF
WMLB5	OC3	28533	WMLB5-E4	9.30	11.00	1.70	Permian	Overburden	Siltstone, grey, hard, minor tuff	6.55	0.11	0.10	3	37	-34	12.09	8.0	0	0	NAF
WMLB5	OC3	28534	WMLB5-E5	11.00	12.04	1.04	Permian	Overburden	Siltstone, grey, hard	6.49	0.14	0.03	1	7	-6	7.63	5.2	0	11	NAF
WMLB5	OC3	28535	WMLB5-E6	12.04	13.37	1.33	Permian	Overburden	Tuff (white sandy) at top and base with friable siltstone in middle	7.32	0.15	0.04	1	21	-20	17.16	7.6	0	0	NAF
WMLB5	OC3	28536	WMLB5-E7	13.37	14.03	0.66	Permian	Overburden	Siltstone, grey, massive, sandy at base, hard	6.46	0.11	0.02	1	2	-1	3.27	3.3	4	22	NAF
WMLB5	OC3	28537	WMLB5-E8	14.03	14.27	0.24	Permian	Overburden	Sandstone, light brown, medium grained, carbonaceous wisps throughout, hard	6.55	0.13	0.03	1	10	-9	10.89	7.3	0	0	NAF
WMLB5	OC3		Coal	14.27	15.47	1.20	Permian	Coal	Coal - Ulan Seam B											
WMLB5	OC3	28538	WMLB5-E9	15.47	16.03	0.56	Permian	Overburden	Siltstone, carbonaceous, tending to very fine sandstone	7.14	0.11	0.07	2	4	-2	1.87	3.9	2	17	UC(NAF)
WMLB5	OC3	28539	WMLB5-E10	16.03	16.62	0.59	Permian	Overburden	Sandstone, fine to coarse, silty laminae, carbonaceous traces and granular conglomerate	7.12	0.17	0.03	1	3	-2	3.27	6.9	0	0	NAF
WMLB5	OC3		Coal	16.62	16.92	0.30	Permian	Coal	Coal - Ulan Seam C											
WMLB5	OC3	28540	WMLB5-E11	16.92	17.10	0.18	Permian	Overburden	Sandstone, fine, carbonaceous	7.16	0.16	0.07	2	1	1	0.47	3.0	8	24	PAF-LC
WMLB5	OC3	28541	WMLB5-E12	17.10	18.01	0.91	Permian	Overburden	Sandstone, fine to very coarse, siltstone, laminated	7.21	0.14	0.04	1	2	-1	1.63	6.6	0	0	NAF
WMLB5	OC3	28542	WMLB5-E13	18.01	19.80	1.79	Permian	Overburden	Intrusion, altered soft greasy chloritic in part, greyish green	7.16	0.11	0.12	4	34	-30	9.26	8.2	0	0	NAF
WMLB5	OC3	28543	WMLB5-E14	19.80	21.37	1.57	Permian	Overburden	Intrusion, altered soft greasy chloritic in part, greyish green	7.29	0.10	0.13	4	33	-29	8.30	8.4	0	0	NAF
WMLB5	OC3	28544	WMLB5-E15	21.37	22.00	0.63	Permian	Overburden	Sandstone, very coarse, tending to conglomerate, few coaly traces	7.21	0.08	0.04	1	1	0.2	0.82	4.6	0	7	NAF
WMLB5	OC3	28545	WMLB5-E16	22.00	22.61	0.61	Permian	Overburden	Shale and sandstone, partly carbonaceous, banded with claystone and stoney coal	7.35	0.09	0.11	3	2	1	0.59	2.8	21	44	PAF-LC
WMLB5	OC3	28546	WMLB5-E17	22.61	24.62	2.01	Permian	Overburden	Sandstone, fine to coarse tending to granular conglomerate, some silty laminae	7.39	0.11	0.03	1	1	0	1.09	5.3	0	5	NAF
WMLB5	OC3	28547	WMLB5-E18	24.62	25.91	1.29	Permian	Overburden	Sandstone (medium-coarse) and carbonaceous shale	7.46	0.12	0.08	2	2	0.4	0.82	3.6	2	13	PAF-LC
WMLB5	OC3		Coal	25.91	29.19	3.28	Permian	Coal	Coal - Ulan Seam D - EBT											
WMLB5	OC3	28548	WMLB5-E19	29.19	30.79	1.60	Permian	Floor	Sandstone (fine) and carbonaceous shale and siderite (inlcudes Ulan Seam ELW)	7.41	0.11	0.14	4	4	0.3	0.93	4.8	0	11	UC(NAF)
WMLB5	OC3	28549	WMLB5-E20	30.79	32.35	1.56	Permian	Floor	Sandstone, fine to medium, few carbonaceous traces	7.11	0.10	0.06	2	2	0	1.09	6.9	0	0	NAF

KEY

$pH_{1:2}$ = pH of 1:2 extract

$EC_{1:2}$ = Electrical Conductivity of 1:2 extract (dS/m)

MPA = Maximum Potential Acidity (kgH_2SO_4/t)

ANC = Acid Neutralising Capacity (kgH_2SO_4/t)

NAPP = Net Acid Producing Potential (kgH_2SO_4/t)

NAGpH = pH of NAG liquor

$NAG_{(pH4.5)}$ = Net Acid Generation capacity to pH 4.5 (kgH_2SO_4/t)

$NAG_{(pH7.0)}$ = Net Acid Generation capacity to pH 7.0 (kgH_2SO_4/t)

[yellow box] = NAG Result Affected by High Organic Carbon in Sample

Table 2: Geochemical characterisation results for samples from hole TB103, drilled close to proposed ventilation shaft and access portals for the underground mine.

EGi Code	Depth (m)			Unit	Material Type	Geological Description	$pH_{1:2}$	$EC_{1:2}$	ACID-BASE ANALYSIS					NAG TEST			ARD Classification
	From	To	Interval						Total %S	MPA	ANC	NAPP	ANC/MPA	NAGpH	$NAG_{(pH4.5)}$	$NAG_{(pH7.0)}$	
30386	0.00	1.00	1.00			Top Soil, w/- Fine Silty Clay	7.66	0.09	<0.01	0	1	-1	-	6.3	0	11	NAF
30387	1.00	5.00	4.00	Quaternary/Tertiary	Overburden	Alluvium, silty clay, Mottled yellow, orange and white	7.71	0.09	<0.01	0	1	-1	-	6.9	0	0	NAF
30388	5.00	10.00	5.00	Quaternary/Tertiary	Overburden	Alluvium, silty clay, Mottled yellow, orange and white	8.11	0.07	<0.01	0	1	-1	-	6.2	0	12	NAF
30389	10.00	14.00	4.00	Quaternary/Tertiary	Overburden	Alluvium, silty clay, yellow	8.21	0.06	<0.01	0	1	-1	-	6.3	0	11	NAF
30390	14.00	17.00	3.00	Quaternary/Tertiary	Overburden	Alluvium, sandy clay, yellow	8.42	0.07	<0.01	0	1	-1	-	6.2	0	12	NAF
30391	17.00	20.00	3.00	Quaternary/Tertiary	Overburden	Alluvium, sandy clay, white	7.91	0.08	<0.01	0	1	-1	-	6.1	0	10	NAF
30392	20.00	22.00	2.00	Quaternary/Tertiary	Overburden	Alluvium, silty clay, brown with black shale	7.14	0.11	0.13	4	1	3	0.25	2.6	18	45	UC(NAF)
30393	22.00	24.00	2.00	Quaternary/Tertiary	Overburden	Alluvium, clay, white with yellow and orange shale	7.16	0.13	0.03	1	1	0	1.09	6.0	0	3	NAF
30394	24.00	25.00	1.00	Permian	Overburden	Silty Clay, light brown	6.71	0.13	0.02	1	2	-1	3.27	7.3	0	0	NAF
30395	25.00	29.00	4.00	Permian	Overburden	Sandstone, grey, coarse grain, some clay	6.65	0.12	0.04	1	1	0	0.82	6.5	0	0	NAF
30396	29.00	30.00	1.00	Permian	Overburden	Sandstone/Shale, mottled	6.78	0.14	0.02	1	2	-1	3.27	6.6	0	0	NAF
30397	30.00	31.00	1.00	Permian	Overburden	Clay, white to grey with mottled shale	7.14	0.09	0.02	1	1	0	1.63	6.9	0	0	NAF
30398	31.00	32.00	1.00	Permian	Overburden	Clay, light brown with shale and qtz sand	6.62	0.11	0.02	1	2	-1	3.27	7.4	0	0	NAF
30399	32.00	35.00	3.00	Permian	Overburden	Clay, light brown with carbonaceous shale	7.21	0.12	0.07	2	2	0.1	0.93	3.9	1	12	PAF-LC
30400	35.00	40.00	5.00	Permian	Overburden	Clay, light brown with carbonaceous shale	6.66	0.10	0.11	3	5	-2	1.49	6.6	0	0	NAF
30401	40.00	41.00	1.00	Permian	Overburden	Sandstone, grey, fine grained	7.14	0.12	0.10	3	6	-3	1.96	6.9	0	0	NAF
30402	41.00	45.00	4.00	Permian	Overburden	Shale and carbonaceous shale, mottled to black	7.23	0.11	0.07	2	10	-8	4.67	7.3	0	0	NAF
30403	45.00	47.00	2.00	Permian	Overburden	Shale and carbonaceous shale, mottled to black	7.27	0.09	0.08	2	11	-9	4.49	7.6	0	0	NAF
30404	47.00	50.00	3.00	Permian	Overburden	Shale and carbonaceous shale, mottled to black	7.32	0.12	0.09	3	18	-15	6.54	7.7	0	0	NAF
30405	50.00	52.00	2.00	Permian	Overburden	Shale and carbonaceous shale, mottled to black	7.39	0.13	0.14	4	14	-10	3.27	7.3	0	0	NAF
30406	52.00	55.00	3.00	Permian	Overburden	Shale and carbonaceous shale, mottled to black	7.49	0.09	0.10	3	17	-14	5.56	7.5	0	0	NAF
30407	55.00	60.00	5.00	Permian	Overburden	Sandstone, dark grey	7.41	0.14	0.09	3	36	-33	13.07	8.3	0	0	NAF
30408	60.00	62.00	2.00	Permian	Overburden	Carbonaceous shale, black	7.55	0.11	0.08	2	10	-8	4.08	7.4	0	0	NAF
30409	62.00	65.00	3.00	Permian	Overburden	Carbonaceous shale, black	6.66	0.11	0.29	9	14	-5	1.58	7.3	0	0	NAF
30410	65.00	68.00	3.00	Permian	Overburden	Carbonaceous shale/Sandstone, black/grey	7.27	0.13	0.09	3	16	-13	5.81	8.0	0	0	NAF
30411	68.00	72.00	4.00	Permian	Overburden	Sandstone, grey	6.63	0.12	0.04	1	24	-23	19.61	8.3	0	0	NAF
30412	72.00	75.00	3.00	Permian	Overburden	Carbonaceous shale, black	7.21	0.11	0.23	7	9	-2	1.28	3.3	7	22	UC(NAF)
30413	75.00	78.00	3.00	Permian	Overburden	Carbonaceous shale, black	6.62	0.12	0.05	2	11	-9	7.19	7.5	0	0	NAF
30414	78.00	80.00	2.00	Permian	Overburden	Carbonaceous shale, black	6.79	0.11	0.05	2	9	-7	5.88	7.8	0	0	NAF
30415	80.00	83.00	3.00	Permian	Overburden	Silty sandstone, grey, very fine grained	6.69	0.13	<0.01	0	6	-6	-	7.3	0	0	NAF
30416	83.00	86.00	3.00	Permian	Overburden	Silty sandstone, grey, with carb shale	7.11	0.13	0.07	2	46	-44	21.48	8.8	0	0	NAF
30417	86.00	90.00	4.00	Permian	Overburden	Sandstone, grey, fine grained	7.22	0.12	0.02	1	17	-16	27.78	8.4	0	0	NAF
30418	90.00	95.00	5.00	Permian	Overburden	Sandstone, grey, fine grained	7.14	0.10	0.02	1	82	-81	133.99	8.4	0	0	NAF
30419	95.00	100.00	5.00	Permian	Overburden	Sandstone, grey, fine grained	6.67	0.12	0.02	1	91	-90	148.69	8.5	0	0	NAF
30420	100.00	101.00	1.00	Permian	Overburden	Sandstone, grey, fine grained, with clay	6.59	0.13	<0.01	0	33	-33	-	8.4	0	0	NAF
30421	101.00	105.00	4.00	Permian	Overburden	Sandstone, grey, with carb shale	7.21	0.13	0.01	0	17	-17	55.56	8.2	0	0	NAF
30422	105.00	108.00	3.00	Permian	Overburden	Carbonaceous shale, black, with minor grey sandstone	6.82	0.12	0.18	6	15	-9	2.72	7.9	0	0	NAF
30423	108.00	111.00	3.00	Permian	Overburden	Carbonaceous shale, black, with minor grey sandstone	7.12	0.11	0.10	3	11	-8	3.59	7.9	0	0	NAF
30424	111.00	114.00	3.00	Permian	Overburden	Carbonaceous shale, black, with minor grey sandstone	6.72	0.12	0.10	3	47	-44	15.36	8.3	0	0	NAF
30425	114.00	115.00	1.00	Permian	Coal	Coal - Ulan Seam	6.81	0.12	0.14	4	11	-7	2.57	8.0	0	0	NAF
30426	115.00	118.00	3.00	Permian	Coal	Coal - Ulan Seam	5.21	1.46	0.30	9	7	2	0.76	6.7	0	0	UC(NAF)
30427	118.00	121.00	3.00	Permian	Coal	Coal - Ulan Seam	5.11	1.31	0.41	13	6	7	0.48	3.0	11	28	PAF-LC
30428	121.00	124.00	3.00	Permian	Coal	Coal - Ulan Seam	4.87	1.88	0.54	17	5	12	0.30	2.8	20	46	PAF
30429	124.00	127.00	3.00	Permian	Coal	Coal - Ulan Seam	4.71	1.91	0.66	20	2	18	0.10	2.2	54	86	PAF
30430	127.00	128.00	1.00	Permian	Coal	Coal - Ulan Seam	4.51	1.97	0.60	18	3	15	0.16	2.4	34	57	PAF
30431	128.00	129.00	1.00	Permian	Floor	Carbonaceous shale, black, with grey sandstone	7.14	0.41	0.11	3	6	-3	1.78	7.5	0	0	NAF
30432	129.00	130.00	1.00	Permian	Floor	Carbonaceous shale, black, with grey sandstone	7.21	0.22	0.17	5	5	0	0.96	6.9	0	0	NAF
30433	130.00	135.00	5.00	Permian	Floor	Sandstone, grey, with some silt and Qtz	7.36	0.32	0.08	2	5	-3	2.04	4.0	0.2	5	UC(NAF)

KEY

$pH_{1:2}$ = pH of 1:2 extract

$EC_{1:2}$ = Electrical Conductivity of 1:2 extract (dS/m)

MPA = Maximum Potential Acidity (kgH_2SO_4/t)

ANC = Acid Neutralising Capacity (kgH_2SO_4/t)

NAPP = Net Acid Producing Potential (kgH_2SO_4/t)

NAGpH = pH of NAG liquor

$NAG_{(pH4.5)}$ = Net Acid Generation capacity to pH 4.5 (kgH_2SO_4/t)

$NAG_{(pH7.0)}$ = Net Acid Generation capacity to pH 7.0 (kgH_2SO_4/t)

[yellow box] = NAG Result Affected by High Organic Carbon in Sample

Table 3: Modified NAG test results for selected overburden samples.

EGi Code	Hole No	Material Type	Geological Description	Acid-Base Analysis				Standard NAG Test			NAGorg TEST		ARD Classification
				Total %S	MPA	ANC	NAPP	NAGpH	$NAG_{(pH4.5)}$	$NAG_{(pH7.0)}$	Extended Boil NAGpH	Calculated NAG	
28490	WMLB24	Overburden	Coal, shaley, banded with mudstone, dark brown	0.19	6	3	3	2.3	76	122	6.8	6	PAF-LC
28493	WMLB24	Overburden	Mudstone, coaly and carbonaceous	0.14	4	2	2	2.2	45	79	6.7	4	PAF-LC
28503	WMLB24	Overburden	Mudstone, carbonaceous, few penny bands of b coal	0.20	6	2	4	2.4	43	73	6.8	5	PAF-LC
28508	WMLB15	Overburden	Coal (Moolarben), Dmb, stoney, minor tuff and sideritic in part	0.21	6	5	1	2.4	68	109	6.8	4	PAF-LC
28514	WMLB15	Overburden	Mudstone, carbonaceous	0.20	6	2	4	2.4	37	68	5.4	3	PAF-LC
28545	WMLB5	Overburden	Shale and sandstone, partly carbonaceous, banded with claystone and stoney coal	0.11	3	2	1	2.8	21	44	6.5	3	PAF-LC
30392	TB103	Overburden	Silty clay, brown with black shale	0.13	4	1	3	2.6	18	45	7.5	-1	NAF
30412	TB103	Overburden	Carbonaceous shale, black	0.23	7	9	-2	3.3	7	22	7.7	-4	NAF

KEY

MPA = Maximum Potential Acidity (kgH_2SO_4/t)

ANC = Acid Neutralising Capacity (kgH_2SO_4/t)

NAPP = Net Acid Producing Potential (kgH_2SO_4/t)

NAGpH = pH of NAG liquor

$NAG_{(pH4.5)}$ = Net Acid Generation capacity to pH 4.5 (kgH_2SO_4/t)

$NAG_{(pH7.0)}$ = Net Acid Generation capacity to pH 7.0 (kgH_2SO_4/t)

Extended Boil NAGpH = pH of NAG liquor after extended heating

Calculated NAG = The net acid potential based on assay of anions and cations released to the NAG solution (kgH_2SO_4/t)

Table 4: Multi-element composition of selected overburden and floor solid samples (mg/kg except where shown).

Element	Detection Limit	EGi Sample Number and Sample Description																
		28491	28494	28495	28497	28503	28508	28513	28514	28542	30377	30386	30390	30403	30412	30418	30422	30431
		Mudstone	Siltstone	Sandstone	Sandstone	Mudstone	Coal (Moolarben Seam)	Tuff	Mudstone	Intrusion	Weathered Permian	Top Soil	Sandy Clay	Shale	Shale	Sandstone	Shale	Shale
Ag	0.1	<0.1	0.3	0.1	0.2	0.2	0.1	0.2	0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Al	0.002%	5.59%	7.92%	3.45%	10.04%	7.23%	3.47%	12.77%	4.01%	4.59%	3.70%	1.99%	1.80%	7.64%	5.39%	5.15%	7.91%	7.87%
As	1	1	2	3	20	8	3	6	1	3	5	1	2	6	3	6	8	3
Ba	0.1	217.9	295	197.8	236.6	159	137.5	75.4	121.6	354	175.5	91.9	91.4	353.5	192.8	217.2	332	265.8
Be	0.1	3.8	3	0.6	2.7	4.2	4.3	2.6	5.2	3.2	2.5	0.5	0.4	3.7	3.5	1.4	3.2	3
Ca	0.001%	0.05%	0.05%	0.02%	0.06%	0.05%	0.09%	0.11%	0.03%	0.16%	0.06%	0.03%	0.03%	0.33%	0.15%	1.69%	0.21%	0.11%
Cd	0.1	0.1	0.2	<0.1	0.2	0.1	<0.1	0.4	0.1	0.2	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	0.2	0.2
Co	0.1	1.9	5.5	1.6	37.5	5.1	4.3	5.4	8.5	6.4	11.2	3.9	1.6	6.8	7	9.9	11.3	8.4
Cr	2.0	24	62	17	88	110	6	5	17	22	80	68	30	28	12	69	96	44
Cu	1.0	17	37	3	32	39	6	4	16	13	12	7	3	26	7	7	34	16
F	50	465	494	158	392	491	394	1073	356	962	229	152	118	447	651	260	295	416
Fe	0.01%	0.40%	0.38%	0.41%	1.29%	0.38%	0.62%	0.16%	0.10%	1.11%	1.43%	0.57%	0.38%	2.20%	1.22%	1.99%	3.42%	1.50%
Hg	0.01	<0.05	0.07	<0.05	0.06	0.08	0.06	0.16	<0.05	<0.05	<0.05	<0.05	<0.05	0.19	<0.05	<0.05	<0.05	<0.05
K	0.002%	0.84%	1.58%	1.03%	1.27%	1.13%	0.36%	0.89%	0.29%	1.20%	0.26%	0.24%	0.18%	1.10%	0.95%	1.34%	2.52%	1.99%
Mg	0.002%	0.15%	0.21%	0.06%	0.20%	0.19%	0.15%	0.28%	0.06%	0.33%	0.13%	0.06%	0.04%	0.34%	0.25%	0.82%	0.45%	0.24%
Mn	1.0	43	31	33	223	37	134	4	8	198	47	81	25	510	150	436	462	221
Mo	0.1	2.7	0.4	0.2	2.6	0.5	2.6	1.7	1.6	2.6	0.6	0.4	0.3	2.4	4.4	0.5	0.9	1.2
Na	0.002%	0.03%	0.04%	0.03%	0.03%	0.03%	0.02%	0.02%	0.02%	0.05%	0.05%	0.03%	0.03%	0.04%	0.03%	0.03%	0.04%	0.04%
Ni	1.0	9	20	5	99	55	24	26	31	26	35	15	11	48	19	53	68	20
P	20	89	70	88	284	111	63	236	80	85	229	95	74	101	47	124	232	142
Pb	2.0	17	24	11	27	20	15	56	16	21	12	8	5	31	22	13	18	23
S	0.001%	0.12%	0.06%	0.01%	0.03%	0.21%	0.27%	0.06%	0.23%	0.14%	0.01%	0.01%	0.01%	0.06%	0.16%	0.01%	0.07%	0.06%
Sb	0.05	1.59	0.85	0.31	0.89	1.31	1.56	0.97	2.17	1.18	0.78	0.49	0.41	1.33	1.11	0.48	0.85	0.52
Se	0.01	0.13	0.09	0.02	0.15	0.33	0.21	0.09	0.25	0.39	0.04	0.04	<0.01	0.34	0.15	0.03	0.26	0.12
Si	0.1%	25.6%	29.2%	38.9%	29.6%	22.5%	18.9%	26.6%	19.1%	28.6%	37.6%	40.4%	40.9%	29.4%	23.1%	32.1%	26.5%	29.8%
Sn	0.1	3.8	3.8	1.2	4.8	2.9	2.2	8.8	2.1	3.6	1.7	0.8	0.8	3.4	3.8	2.3	3	4.4
Sr	0.05	12.59	25.33	29.4	157.33	33.55	20.07	118.99	25.89	38.08	42.66	27.76	22.98	33.44	19.76	109.7	115.16	57.85
Th	0.01	10.54	10.95	3.58	18.97	10.1	9.44	35.09	8.87	12.27	7.48	4.51	3.8	13.75	14.25	6.96	10.61	14.19
U	0.01	4.32	2.93	0.99	4.68	2.74	4.79	11.8	3.43	4.52	2.21	1.11	1.05	5.11	3.76	1.82	2.76	3.99
Zn	1.0	45	99	3	104	34	74	165	51	62	31	9	6	66	48	47	80	104

< element at or below analytical detection limit.

Table 5: Geochemical abundance indices (GAI) of selected overburden and floor solid samples.

Element	Median Soil Abundance*	EGi Sample Number and Sample Description																
		28491	28494	28495	28497	28503	28508	28513	28514	28542	30377	30386	30390	30403	30412	30418	30422	30431
		Mudstone	Siltstone	Sandstone	Sandstone	Mudstone	Coal (Moolarben Seam)	Tuff	Mudstone	Intrusion	Weathered Permian	Top Soil	Sandy Clay	Shale	Shale	Sandstone	Shale	Shale
Ag	0.05	-	2	-	1	1	-	1	-	-	-	-	-	-	-	-	-	-
Al	7.1%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As	6	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Ba	500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Be	0.3	3	3	-	3	3	3	3	4	3	2	-	-	3	3	2	3	3
Ca	1.5%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cd	0.35	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Co	8	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
Cr	70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cu	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
F	200	1	1	-	-	1	-	2	-	2	-	-	-	1	1	-	-	-
Fe	4.0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hg	0.06	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-
K	1.4%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg	0.5%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn	1000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mo	1.2	1	-	-	1	-	1	-	-	1	-	-	-	-	1	-	-	-
Na	0.5%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ni	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P	800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pb	35	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S	0.07%	-	-	-	-	1	1	-	1	-	-	-	-	-	1	-	-	-
Sb	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Se	0.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Si	33.0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sn	4	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Sr	250	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Th	9	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
U	2	1	-	-	1	-	1	2	-	1	-	-	-	1	-	-	-	-
Zn	90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

*Bowen H.J.M.(1979) Environmental Chemistry of the Elements.

Table 6: Chemical composition of water extracts of overburden and floor samples.

Parameter		Detection Limit	EGi Sample Number and Sample Description																
			28491	28494	28495	28497	28503	28508	28513	28514	28542	30377	30386	30390	30403	30412	30418	30422	30431
			Mudstone	Siltstone	Sandstone	Sandstone	Mudstone	Coal (Moolarben Seam)	Tuff	Mudstone	Intrusion	Weathered Permian	Top Soil	Sandy Clay	Shale	Shale	Sandstone	Shale	Shale
pH		0.01	6.83	6.53	7.21	6.63	7.51	7.88	7.89	7.67	7.36	7.67	7.2	8.3	7.3	7.46	7.61	7.11	7.26
EC	dS/m	0.01	0.088	0.049	0.055	0.091	0.119	0.136	0.121	0.139	0.116	0.081	0.096	0.076	0.089	0.122	0.111	0.125	0.416
Ag	mg/l	0.00001	<	<	<	<	<	<	<	<	0.00001	<	<	<	<	<	<	<	<
Al	mg/l	0.01	1.4	1.55	1.35	0.64	0.94	0.99	2.49	0.3	0.2	3.05	3.05	1.87	0.14	3.33	0.84	2.09	0.32
As	mg/l	0.0001	0.0015	0.0041	0.0021	0.0126	0.0044	0.0013	0.0027	0.0025	0.0009	0.0021	0.001	0.0021	0.0027	0.0041	0.0058	0.0102	0.0032
B	mg/l	0.01	0.01	0.01	<	0.01	0.01	0.03	0.01	0.02	<	<	0.01	<	0.01	0.01	0.01	0.02	0.01
Ba	mg/l	0.00005	0.02162	0.02915	0.0431	0.01513	0.01326	0.01901	0.00782	0.03729	0.03581	0.00619	0.02742	0.02786	0.14396	0.13988	0.09798	0.17209	0.04227
Be	mg/l	0.0001	0.0001	0.0002	0.0001	0.0001	0.0003	0.0001	0.0002	<	<	0.0002	0.0001	<	<	0.0002	<	0.0001	<
Ca	mg/l	0.01	3.29	5.13	4.09	9.12	2.57	3.71	9.35	5.11	75.25	1.04	3.07	2.55	14.29	9.68	15.21	12.47	4.64
Cd	mg/l	0.00002	0.00003	0.00007	<	0.00019	0.00004	<	0.00004	0.00003	0.00002	<	0.00002	0.00003	0.00002	<	<	<	<
Cl	mg/l	2	29	29	32	29	28	35	30	32	60	37	55	34	34	32	31	29	29
Co	mg/l	0.0001	0.0016	0.0063	0.0011	0.2701	0.006	0.0026	0.0031	0.0192	0.0116	0.0007	0.0034	0.002	0.0031	0.0007	0.0008	0.001	0.0006
Cr	mg/l	0.01	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Cu	mg/l	0.01	<	<	<	<	<	<	<	<	<	0.02	<	<	<	<	<	<	<
F	mg/l	0.1	0.7	0.9	0.9	0.5	0.5	0.9	1.0	1.0	1.2	1.4	0.6	1.4	0.8	1.6	1.8	2.0	1.8
Fe	mg/l	0.01	0.2	0.1	0.2	0.23	0.09	0.18	0.07	0.03	0.24	1.06	1.05	0.67	0.04	0.22	0.29	0.18	0.04
Hg	mg/l	0.0001	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
K	mg/l	0.1	11.2	15.6	10.8	18.6	9.3	7.7	11.6	6.8	33.4	3.1	4.2	3.8	13.3	12.5	13.4	18.7	13.3
Mg	mg/l	0.01	3.57	5.28	4.5	10.15	3.08	6.81	8.47	6.56	47.93	4.9	4.12	1.68	8.57	4.07	6.89	5.15	2.23
Mn	mg/l	0.01	0.03	<	0.02	0.18	0.08	0.03	<	0.02	0.07	<	0.26	0.02	0.06	<	0.02	<	<
Mo	mg/l	0.00005	0.01539	0.00359	0.00034	0.06118	0.00211	0.01238	0.05514	0.0214	0.00829	0.00062	0.00024	0.00451	0.013	0.02694	0.01047	0.02214	0.01608
Na	mg/l	0.1	22.2	21.4	21.9	23.8	22.4	26	30.7	24.7	52.8	36.9	38.6	40.7	26.1	23.3	24.1	27	32.6
Ni	mg/l	0.01	<	<	<	0.39	0.04	<	<	0.02	0.04	<	<	0.01	0.03	<	<	<	<
P	mg/l	0.1	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Pb	mg/l	0.0005	0.0014	0.0029	0.0018	0.0012	0.0011	0.0012	0.0037	0.0009	0.0008	<	0.002	0.0012	0.001	0.0022	0.001	0.0007	0.0007
SO_4	mg/l	0.3	5.6	18	3.8	64.5	16	12	47.2	13.7	399	4.6	10.5	4.2	38.1	5.9	20.9	22.9	11.4
Sb	mg/l	0.00001	0.00056	0.00055	0.00014	0.0022	0.00045	0.00064	0.00157	0.00119	0.00005	0.00013	0.00012	0.00041	0.00097	0.001	0.00068	0.0023	0.00078
Se	mg/l	0.0005	0.0083	0.0129	0.0012	0.0308	0.02	0.0079	0.0054	0.0211	0.0099	0.001	0.0008	0.0013	0.0019	0.0046	0.002	0.0202	0.0055
Si	mg/l	0.05	6.6	5.63	4	3.89	5.17	3.71	7.13	2.76	1.05	8.47	8.68	12.31	2.94	8.49	2.85	7.36	3.11
Sn	mg/l	0.0001	<	0.0001	0.0002	<	<	0.0002	0.0002	0.0001	0.0001	0.0001	0.0002	0.0002	<	0.0003	<	0.0001	<
Sr	mg/l	0.00002	0.01776	0.02972	0.02662	0.0513	0.01308	0.02523	0.06933	0.03106	0.64967	0.00711	0.02895	0.01665	0.11547	0.07286	0.09399	0.08628	0.04105
Th	mg/l	0.000005	0.000276	0.000468	0.000554	0.000192	0.000288	0.001068	0.00136	0.000153	0.000092	0.000168	0.000488	0.000625	0.000082	0.000691	0.000146	0.000191	0.00009
U	mg/l	0.000005	0.000249	0.000162	0.000157	0.00013	0.000096	0.000268	0.000583	0.000173	0.000152	0.000134	0.000206	0.000371	0.000699	0.000351	0.000211	0.000244	0.000128
Zn	mg/l	0.01	<	<	<	0.02	<	<	<	<	<	<	<	<	<	<	<	<	<

< element at or below analytical detection limit.

Table 7: Soluble/exchangeable cations and EAT classes of selected overburden and floor samples.

EGi Sample Code	Unit	Material Type	Geological Description	EC	sol Na	sol K	sol Ca	sol Mg	ex Na	ex K	ex Ca	ex Mg	ex Al	% ECEC Na (ESP)	% ECEC K	% ECEC Ca	% ECEC Mg	% ECEC Al	ECEC	Ca/Mg ratio	Emerson Aggregate Test Class	
				(dS/m)	(meq%)	(meq%)	(meq%)	(meq%)	(meq%)	(meq%)	(meq%)	(meq%)	(meq%)								Class	Sub-Class
28492	Permian	Overburden	Claystone/Tuff	0.06	0.06	0.06	< 0.08	0.06	0.11	0.55	3.70	5.63	< 0.02	1.1	5.5	37.0	56.4	0.0	10.0	0.70	5	3
28497	Permian	Overburden	Sandstone	0.09	0.07	0.12	0.16	0.22	0.03	0.36	1.27	2.01	< 0.02	0.8	9.8	34.6	54.8	0.0	3.7	0.60	5	1
28502	Permian	Overburden	Mudstone	0.09	0.10	0.08	0.08	0.09	0.08	0.47	1.77	2.78	< 0.02	1.6	9.2	34.7	54.5	0.0	5.1	0.60	5	2
28506	Permian	Overburden	Siltstone Weathered	0.08	0.86	0.12	< 0.08	0.37	0.50	0.51	1.84	8.13	< 0.02	4.6	4.6	16.8	74.0	0.0	11.0	0.20	5	3
28513	Permian	Overburden	Claystone/Tuff	0.11	0.20	0.06	0.11	0.15	0.15	0.42	4.43	5.88	< 0.02	1.4	3.9	40.7	54.0	0.0	10.9	0.80	5	2
28542	Permian	Overburden	Intrusion - chloritic in part	0.11	0.62	0.28	2.12	2.00	0.23	0.79	8.91	7.80	< 0.02	1.3	4.5	50.3	44.0	0.0	17.7	1.10	5	2
30374	Quaternary/Tertiary	Overburden	Alluvium/weathered Permian	0.09	0.20	0.01	< 0.08	0.02	0.63	0.20	0.34	3.98	0.26	11.6	3.7	6.3	73.6	4.8	5.4	0.10	5	2
30377	Permian	Overburden	Weathered Permian	0.06	0.71	0.01	< 0.08	0.16	0.95	0.12	< 0.20	5.16	< 0.02	15.0	1.9	1.4	81.6	0.0	6.3	0.00	3	
30380	Quaternary/Tertiary	Overburden	Alluvium	0.07	0.81	0.06	< 0.08	0.62	0.91	0.15	0.36	3.28	< 0.02	19.4	3.2	7.7	69.8	0.0	4.7	0.10	2	
30383	Quaternary/Tertiary	Overburden	Alluvium	0.08	1.74	0.02	< 0.08	0.07	1.16	0.23	< 0.20	2.91	< 0.02	26.6	5.3	1.4	66.7	0.0	4.4	0.00	5	2
30386			Top Soil	0.09	0.29	0.02	< 0.08	0.06	0.12	0.07	0.61	0.69	< 0.02	8.1	4.7	40.9	46.3	0.0	1.5	0.90	3	
30388	Quaternary/Tertiary	Overburden	Silty Clay	0.07	0.28	0.01	< 0.08	0.02	0.23	0.07	0.39	1.41	< 0.02	11.0	3.3	18.6	67.1	0.0	2.1	0.30	5	2
30394	Permian	Overburden	Weathered Permian Silty Clay	0.13	0.38	0.04	< 0.08	0.04	0.33	0.17	1.39	2.52	< 0.02	7.5	3.9	31.5	57.1	0.0	4.4	0.60	5	2
30399	Permian	Overburden	Clay	0.12	0.14	0.04	< 0.08	0.02	0.23	0.29	1.94	3.79	0.09	3.6	4.6	30.6	59.8	1.4	6.3	0.50	5	2
30403	Permian	Overburden	Carbonaceous Shale	0.09	0.12	0.07	0.20	0.17	0.08	0.35	6.33	4.61	< 0.02	0.7	3.1	55.7	40.5	0.0	11.4	1.40	5	2
30418	Permian	Overburden	Sandstone	0.10	0.07	0.08	0.17	0.11	0.02	0.21	3.15	1.71	< 0.02	0.4	4.1	61.9	33.6	0.0	5.1	1.80	5	2
30422	Permian	Overburden	Carbonaceous Shale	0.12	0.13	0.10	0.11	0.08	0.11	0.78	4.71	2.81	< 0.02	1.3	9.3	56.0	33.4	0.0	8.4	1.70	5	3

Table 8: Geochemical characterisation results for Ulan Coal Seam samples from hole TB103.

EGi Code	Depth (m)			Geological Description	$pH_{1:2}$	$EC_{1:2}$	ACID-BASE ANALYSIS					NAG TEST			NAGorg TEST		ARD Classification
	From	To	Interval				Total %S	MPA	ANC	NAPP	ANC/MPA	NAGpH	$NAG_{(pH4.5)}$	$NAG_{(pH7.0)}$	Extended Boil NAGpH	Calculated NAG	
30425	114.00	115.00	1.00	Coal - Ulan Seam	6.81	0.12	0.14	4	11	-7	2.57	8.0	0	0			NAF
30426	115.00	118.00	3.00	Coal - Ulan Seam	5.21	1.46	0.30	9	7	2	0.76	6.7	0	0			UC(NAF)
30427	118.00	121.00	3.00	Coal - Ulan Seam	5.11	1.31	0.41	13	6	7	0.48	3.0	11	28			PAF-LC
30428	121.00	124.00	3.00	Coal - Ulan Seam	4.87	1.88	0.54	17	5	12	0.30	2.8	20	46	6.9	0	UC(NAF)
30429	124.00	127.00	3.00	Coal - Ulan Seam	4.71	1.91	0.66	20	2	18	0.10	2.2	54	86	7.0	4	PAF-LC
30430	127.00	128.00	1.00	Coal - Ulan Seam	4.51	1.97	0.60	18	3	15	0.16	2.4	34	57			PAF-LC

KEY

$pH_{1:2}$ = pH of 1:2 extract

$EC_{1:2}$ = Electrical Conductivity of 1:2 extract (dS/m)

MPA = Maximum Potential Acidity (kgH_2SO_4/t)

ANC = Acid Neutralising Capacity (kgH_2SO_4/t)

NAPP = Net Acid Producing Potential (kgH_2SO_4/t)

NAGpH = pH of NAG liquor

$NAG_{(pH4.5)}$ = Net Acid Generation capacity to pH 4.5 (kgH_2SO_4/t)

$NAG_{(pH7.0)}$ = Net Acid Generation capacity to pH 7.0 (kgH_2SO_4/t)

[yellow shading] = NAG Result Affected by High Organic Carbon in Sample

Extended Boil NAGpH = pH of NAG liquor after extended heating

Calculated NAG = The net acid potential based on assay of anions and cations released to the NAG solution (kgH_2SO_4/t)

Table 9: Geochemical characterisation results for coal reject samples.

Hole No	Open Cut Pit No	EGi Sample No	Carbon Consulting Sample No	Moolarben Samples Used in Coal Composite	Coal Product Description	$pH_{1:2}$	$EC_{1:2}$	ACID-BASE ANALYSIS					NAG TEST			NAGorg TEST		ARD Classification
								Total %S	MPA	ANC	NAPP	ANC/MPA	NAGpH	$NAG_{(pH4.5)}$	$NAG_{(pH7.0)}$	Extended Boil NAGpH	Calculated NAG	
WMLB24	OC1	30372	39141	WML B24 - 3, 4 & 6	High ash domestic thermal product (Ulan Seams A to C)	5.85	0.31	0.27	8	1	7	0.12	2.8	14	27	9	6	PAF
WMLB24	OC1	30373	39147	WML B24 - 7, 8, 9 & 10	Export thermal product (Ulan Seams D to E)	4.21	0.37	1.06	32	0	32	0.00	2.5	29	32		26	PAF

KEY

$pH_{1:2}$ = pH of 1:2 extract

$EC_{1:2}$ = Electrical Conductivity of 1:2 extract (dS/m)

MPA = Maximum Potential Acidity (kgH_2SO_4/t)

ANC = Acid Neutralising Capacity (kgH_2SO_4/t)

NAPP = Net Acid Producing Potential (kgH_2SO_4/t)

NAGpH = pH of NAG liquor

$NAG_{(pH4.5)}$ = Net Acid Generation capacity to pH 4.5 (kgH_2SO_4/t)

$NAG_{(pH7.0)}$ = Net Acid Generation capacity to pH 7.0 (kgH_2SO_4/t)

[yellow box] = NAG Result Affected by High Organic Carbon in Sample

Extended Boil NAGpH = pH of NAG liquor after extended heating

Calculated NAG = The net acid potential based on assay of anions and cations released to the NAG solution (kgH_2SO_4/t)

Table 10: Total S(%) contents of washed coal from drill testing of the proposed open cut development (data provided by Moolarben Coal).

Seam	Open Cut 1									
Section	wmlb22	dmmld2	dmmld7	dmmld8	dmmlx-1	wmlb23	wmlb24	wmlb25	wmlb28	wmlb29
A-CL	0.43		0.36	0.37		0.44	0.42	0.46	0.41	
DTP-ELR	0.44	0.44	0.47	0.54	0.45	0.48	0.44	0.50	0.45	0.50
A-ELR										

Seam	Open Cut 2						
Section	wmlb11	wmlb13	wmlb14	dmmld3	dmmld5	dmmld4	wmlb16
A-CL	0.40	0.34	0.36		0.44	0.43	
DTP-ELR	0.50	0.47	0.45	0.41	0.36	0.44	0.44
A-ELR							

Seam	Open Cut 3						
Section	wmlb3	wmlb4	wmlb5	wmlb6	wmlb7	wmlb8	wmlb10
A-CL	0.38	0.42		0.39		0.54	0.35
DTP-ELR		0.48		0.37		0.36	0.40
A-ELR			0.44		0.36		

Total S Summary Statistics

Maximum =	0.54%S
Minimum =	0.34%S
90th Percentile =	0.50%S
Median =	0.44%S
10th Percentile =	0.36%S

Table 11: Total S(%) contents of raw coal from drill testing of the proposed underground development (data provided by Moolarben Coal).

No 4 UG Ulan Seam Raw Ply Sulphur						
Drillhole	**Sample No**	**From (m)**	**To (m)**	**Thickness (m)**	**Ply**	**%S**
C200	11321	137.50	138.12	0.62	ULA(part)	0.32
C200	11322	138.12	139.60	1.48	UB	0.32
C200	11323	139.60	141.80	2.20	UC	0.33
C200	11324	141.80	142.10	0.30	CMK	0.60
C200	11325	142.10	142.85	0.75	UCL	0.75
C200	11326	142.85	143.65	0.80	UD	0.45
C200	11327	143.65	144.60	0.95	UD	0.47
C200	11328	144.60	145.50	0.90	UD	1.71
C200	11329	145.50	146.03	0.53	UD	1.10
C200		146.03	146.73	0.70		
C200	11330	146.73	147.37	0.64	UE	0.90
C202	11391	154.40	156.20	1.80	ULA	0.28
C202	1	156.20	158.42	2.22	UB	0.37
C202	2	158.42	160.00	1.58	UC	
C202	3	160.00	160.30	0.30	CMK	
C202	4	160.30	160.70	0.40	UC	0.53
C202	5	160.70	163.25	2.55	UD	0.60
C202	6	163.25	164.25	1.00	UD	0.72
C202	11392	164.25	166.00	1.75	UE	
C204	1	91.10	93.10	2.00	ULA	0.32
C204	2	93.10	94.77	1.67	UB	0.43
C204	3+4	94.77	95.38	0.61	UC1	0.43
C204	5	95.38	95.75	0.37	UC2	0.27
C204	6	95.75	96.94	1.19	UC2	0.51
C204	7	96.94	97.37	0.43	CMK	0.20
C204	8	97.37	98.01	0.64	UCL	0.85
C204	9	98.01	99.28	1.27	DTP+DWS	0.47
C204	10	99.28	100.45	1.17	DWS	0.75
C204	11	100.45	101.44	0.99	DWS	0.51
C204	12	101.44	102.32	0.88	ETP	0.60
C204	13	102.32	103.18	0.86	EBT	0.49
C204	14	103.18	103.45	0.27	ELW	0.47
C204	15	103.45	103.99	0.54	ELW	0.13
C221	10189	141.86	142.92	1.06	ULA	0.29
C221	10190	142.92	143.65	0.73	UB1	0.34
C221	10191	143.65	144.50	0.85	UB2	0.46
C221	10192	144.50	145.05	0.55	UC1	0.40
C221	10193	145.05	146.55	1.50	UC2	0.30
C221		146.55	146.90	0.30	CMK	
C221	10194	146.90	147.66	0.76	UCL	0.44
C221	10195	147.66	148.16	0.50	DTP	0.42
C221	10196	148.16	149.60	1.44	DWS1	0.50
C221	10197	149.60	150.30	0.70	DWS2	0.89
C221	10198	150.30	150.85	0.55	DWS3	0.63
C221	10199	150.85	151.95	1.10	ETP	1.26
C221	10200	151.95	152.70	0.75	EBT	0.54
C223	10001	57.80	59.87	2.00	ULA	0.28
C223	10002	59.87	60.70	0.90	UB1	0.41
C223	10003	60.70	61.50	0.80	UB2	0.35
C223	10004	61.50	62.08	0.58	UC1	0.40
C223	10005	62.08	63.68	1.60	UC2	0.34
C223		63.68	63.96	0.28	CMK	
C223	10006	63.96	64.90	0.94	UCL	0.33
C223	10007	64.90	65.20	0.30	DTP	0.44
C223	10008	65.20	66.50	1.30	DWS1	0.50
C223	10009	66.50	67.05	0.55	DWS2	0.43

Table 11: Total S(%) contents of raw coal from drill testing of the proposed underground development (data provided by Moolarben Coal).

No 4 UG Ulan Seam Raw Ply Sulphur						
Drillhole	Sample No	From (m)	To (m)	Thickness (m)	Ply	%S
C223	10010	67.05	68.05	1.00	DWS3	0.46
C223	10011	68.05	69.00	0.95	ETP	0.39
C223	10012	69.00	69.90	0.90	EBT	0.53
C224	10014	74.90	77.25	2.35	ULA	0.33
C224	10015	77.25	77.90	0.65	UB1	0.41
C224	10016	77.90	78.90	1.00	UB2	0.41
C224	10017	78.90	79.40	0.50	UC1	0.41
C224	10018	79.40	80.90	1.50	UC2	0.40
C224	10019	81.25	82.00	0.75	UCL	0.57
C224		81.90	81.25	0.35	CMK	
C224	10020	82.00	82.25	0.25	DTP	0.58
C224	10021	82.25	82.90	0.65	DWS1	0.59
C224	10022	82.90	84.60	1.70	DWS2	0.64
C224	10023	84.60	85.20	0.60	DWS3	0.47
C224	10024	85.20	85.94	0.74	ETP	0.56
C224	10025	85.94	86.85	0.91	EBT	0.71
C224	10026	86.85	87.45	0.60	ELW	0.67
C225	10027	123.68	124.30	0.62	UCL	0.48
C225	10028	124.30	124.60	0.30	DTP	0.69
C225	10029	124.60	125.60	1.00	DWS1	0.42
C225	10030	125.60	126.70	1.10	DWS2	0.50
C225	10031	126.70	127.65	0.95	DWS3	0.44
C225	10032	127.65	128.60	0.95	ETP	0.54
C225	10033	128.60	129.50	0.90	EBT	0.51
C225	10034	129.50	130.25	0.75	ELW	0.47
C227	10048	138.20	140.65	2.45	ULA	0.29
C227	10049	140.65	141.30	0.65	UB1	0.35
C227	10050	141.30	142.10	0.80	UB2	0.38
C227	10051	142.10	142.80	0.70	UC1	0.40
C227	10052	142.80	144.35	1.55	UC2	0.46
C227		144.35	144.63	0.28	CMK	
C227	10053	144.63	145.40	0.77	UCL	0.38
C227	10054	145.40	145.66	0.26	DTP	0.51
C227	10055	145.66	146.54	0.88	DWS1	0.67
C227	10056	146.54	147.70	1.16	DWS2	0.59
C227	10057	147.70	148.60	0.90	DWS3	0.48
C227	10058	148.60	149.61	1.01	ETP	0.78
C227	10059	149.61	150.45	0.84	EBT	0.65
C229	10087	130.50	131.00	0.50	UB1	0.32
C229	10088	131.00	132.13	1.13	UB2	0.34
C229	10089	132.13	132.75	0.62	UC1	0.32
C229	10090	132.75	134.20	1.45	UC2	0.39
C229		134.20	134.48	0.28	CMK	
C229	10091	134.48	135.30	0.82	UCL	0.58
C229	10092	135.30	135.55	0.25	DTP	2.01
C229	10093	135.55	136.43	0.88	DWS1	0.48
C229	10094	136.43	137.55	1.12	DWS2	0.51
C229	10095	137.55	138.40	0.85	DWS3	0.51
C229	10096	138.40	139.50	1.10	ETP	0.94
C229	10097	139.50	140.35	0.85	EBT	0.62
C229	10098	140.35	140.85	0.50	ELW	0.45
C230	10099	137.35	139.80	2.45	ULA	0.31
C230	10100	139.80	140.55	0.75	UB1	0.36
C230	10179	140.55	141.36	0.81	UB2	0.44
C230	10180	141.36	142.00	0.64	UC1	0.33
C230	11393	142.00	143.55	1.55	UC2	0.40

Table 11: Total S(%) contents of raw coal from drill testing of the proposed underground development (data provided by Moolarben Coal).

No 4 UG Ulan Seam Raw Ply Sulphur						
Drillhole	**Sample No**	**From (m)**	**To (m)**	**Thickness (m)**	**Ply**	**%S**
C230		143.55	143.91	0.28	CMK	
C230	11394	143.91	144.68	0.77	UCL	0.43
C230	11395	144.68	144.90	0.22	DTP	0.97
C230	11396	144.90	146.20	1.30	DWS1	0.67
C230	11397	146.20	147.33	1.13	DWS2	0.74
C230	11398	147.33	147.93	0.60	DWS3	0.49
C230	11399	147.93	148.95	1.02	ETP	0.72
C230	11400	148.95	149.80	0.85	EBT	0.66
C238		169.75	170.09	0.34	dtp	0.38
C238		170.09	171.15	1.06	dws1	0.53
C238		171.15	172.15	1.00	dws2	0.69
C238		172.15	173.10	0.95	dws3	0.60
C238		173.10	173.95	0.85	ETP	0.60
C238		173.95	174.70	0.75	ebt	0.42
C238		174.70	175.65	0.95	ELW	0.38
C239		162.85	163.15	0.30	dtp	0.40
C239		163.15	164.45	1.30	dws1	0.49
C239		164.45	165.10	0.65	dws2	0.50
C239		165.10	166.10	1.00	dws3	0.44
C239		166.10	167.00	0.90	ETP	1.07
C239		167.00	167.80	0.80	ebt	0.75
C240	10346	144.20	146.35	2.15	ULA	0.35
C240	10347	146.35	146.95	0.60	UB1	0.40
C240	10348	146.95	147.85	0.90	UB2	0.39
C240	10349	147.85	148.40	0.55	UC1	0.45
C240	10350	148.40	149.90	1.50	UC2	0.33
C240		149.90	150.20	0.30	CMK	
C240		150.20	151.00	0.80	UCL	
C240		151.00	151.60	0.60	DTP +DWS	
C240		151.60	154.15	2.65	DWS	
C240	10356	154.15	155.10	0.95	ETP	1.06
C240	10357	155.10	155.95	0.85	EBT	0.57
C240	10358	155.95	156.65	0.70	ELW	0.93
C245	10878	113.14	115.61	2.47	ULA	0.34
C245	10879	115.61	116.20	0.59	UB1	0.35
C245	10880	116.20	117.20	1.00	UB2	0.37
C245	10899	117.20	117.70	0.50	UC1	0.55
C245	10900	117.70	119.25	1.55	UC2	0.35
C245	10501	119.57	120.73	1.16	UCL	0.45
C245	10502	120.73	121.03	0.30	DTP	0.45
C245	10503	121.03	122.07	1.04	DWS1	0.59
C245	10504	122.07	123.00	0.93	DWS2	0.46
C245	10505	123.00	123.55	0.55	DWS3	0.62
C245	10506	123.55	124.41	0.86	ETP	1.19
C245	10507	124.41	125.04	0.63	EBT	0.60
C268	11070	205.40	206.30	0.90	DWS1	0.42
C268	11071	206.30	207.21	0.91	DWS2	0.47
C268	11072	207.21	208.09	0.88	DWS3	0.42
C268	11073	208.09	208.38	0.29	DWS4	0.46

Total S Summary Statistics

Maximum =	2.01%S
Minimum =	0.13%S
90th Percentile =	0.75%S
Median =	0.47%S
10th Percentile =	0.33%S

Table 12: Multi-element composition (mg/kg except where shown) and geochemical abundance index (GAI) of coal and reject sample solids.

Element	Detection Limit	EGi Sample Number and Sample Description				Element	Median Soil Abundance*	EGi Sample Number and Sample Description			
		30428	30430	30372	30373			30428	30430	30372	30373
		Coal (Ulan Seam)	Coal (Ulan Seam)	High ash domestic thermal product (Ulan Seams A to C)	Export thermal product (Ulan Seams D to E)			Coal (Ulan Seam)	Coal (Ulan Seam)	High ash domestic thermal product (Ulan Seams A to C)	Export thermal product (Ulan Seams D to E)
Ag	0.1	<0.1	<0.1	<0.7	<0.3	Ag	0.05	-	-	**3**	2
Al	0.002%	2.88%	4.88%	7.40%	14.30%	Al	7.1%	-	-	-	-
As	1	2	3	4	8	As	6	-	-	-	-
Ba	0.1	52	93	57	41	Ba	500	-	-	-	-
Be	0.1	1.5	3.9	1	3	Be	0.3	2	**3**	1	**3**
Ca	0.001%	0.09%	0.05%	0.02%	0.03%	Ca	1.5%	-	-	-	-
Cd	0.1	<0.1	<0.1	<0.6	<0.8	Cd	0.35	-	-	-	1
Co	0.1	2.0	3.4	6.9	3.5	Co	8	-	-	-	-
Cr	2.0	9	17	6	2	Cr	70	-	-	-	-
Cu	1.0	8	12	174	83	Cu	30	-	-	2	1
F	50	228	230	342	534	F	200	-	-	-	1
Fe	0.01%	0.88%	0.59%	0.26%	0.74%	Fe	4.0%	-	-	-	-
Hg	0.01	<0.10	<0.11	<0.13	0.26	Hg	0.06	-	-	1	2
K	0.002%	0.23%	0.55%	0.15%	0.25%	K	1.4%	-	-	-	-
Mg	0.002%	0.08%	0.07%	0.03%	0.03%	Mg	0.5%	-	-	-	-
Mn	1.0	174	65	18	7	Mn	1000	-	-	-	-
Mo	0.1	0.8	1.2	1.3	2.7	Mo	1.2	-	-	-	1
Na	0.002%	0.01%	0.02%	0.01%	0.00%	Na	0.5%	-	-	-	-
Ni	1.0	9	9	4	7	Ni	50	-	-	-	-
P	20	72	76	103	<175	P	800	-	-	-	-
Pb	2.0	10	15	20	<42	Pb	35	-	-	-	-
S	0.001%	0.33%	0.52%	0.28%	1.04%	S	0.07%	2	2	1	**3**
Sb	0.05	0.35	0.61	0.44	0.59	Sb	1	-	-	-	-
Se	0.01	0.31	<0.39	0.6	2.25	Se	0.4	-	-	-	2
Si	0.1%	11.9%	12.7%	27.2%	20.0%	Si	33.0%	-	-	-	-
Sn	0.1	1.4	2.8	19.1	19.2	Sn	4	-	-	2	2
Sr	0.05	19.4	25.1	24.6	51.1	Sr	250	-	-	-	-
Th	0.01	5.56	9.93	11.54	30.88	Th	9	-	-	-	1
U	0.01	1.77	2.96	3.23	6.58	U	2	-	-	-	1
Zn	1.0	19	34	103	118	Zn	90	-	-	-	-

< element at or below analytical detection limit.

*Bowen H.J.M.(1979) Environmental Chemistry of the Elements.

Table 13: Chemical composition of coal and reject sample water extracts.

Parameter		Detection Limit	EGi Sample Number and Sample Description			
			30428	30430	30372	30373
			Coal (Ulan Seam)	Coal (Ulan Seam)	High ash domestic thermal product (Ulan Seams A to C)	Export thermal product (Ulan Seams D to E)
pH		0.01	5.11	5.02	5.9	4.2
EC	dS/m	0.01	1.92	1.99	0.307	0.366
Ag	mg/l	0.00001	<	<	0.00004	0.00003
Al	mg/l	0.01	0.06	0.03	0.16	0.85
As	mg/l	0.0001	0.0012	0.0009	0.1034	0.111
B	mg/l	0.01	0.02	0.01	<	<
Ba	mg/l	0.00005	0.14777	0.07402	0.05102	0.04673
Be	mg/l	0.0001	<	<	0.0004	0.0089
Ca	mg/l	0.01	10.72	16.74	10.28	26.27
Cd	mg/l	0.00002	<	0.00004	0.00091	0.00238
Cl	mg/l	2	29	28	166	121
Co	mg/l	0.0001	0.0002	0.0018	0.2536	0.0760
Cr	mg/l	0.01	<	<	<	<
Cu	mg/l	0.01	<	<	1.00	0.25
F	mg/l	0.1	1.6	1.2	0.1	0.4
Fe	mg/l	0.01	0.01	<	0.48	1.16
Hg	mg/l	0.0001	<	<	0.0003	0.0003
K	mg/l	0.1	7.4	10.5	10.4	9.9
Mg	mg/l	0.01	6.34	8.76	10.00	12.62
Mn	mg/l	0.01	0.02	0.14	0.39	0.43
Mo	mg/l	0.00005	0.00408	0.00151	0.00126	0.00025
Na	mg/l	0.1	26.2	29.5	31.3	28.6
Ni	mg/l	0.01	<	<	0.07	0.13
P	mg/l	0.1	<	<	0.2	0.4
Pb	mg/l	0.0005	<	<	0.0044	0.0525
SO_4	mg/l	0.3	17.2	74.1	31.5	65.5
Sb	mg/l	0.00001	0.00027	0.00032	0.00053	0.00020
Se	mg/l	0.0005	0.004	0.0056	0.4113	0.4466
Si	mg/l	0.05	1.62	1.98	1.97	3.52
Sn	mg/l	0.0001	<	<	0.0022	0.0003
Sr	mg/l	0.00002	0.061	0.0977	0.06838	0.16459
Th	mg/l	0.000005	0.000037	0.000027	0.000472	0.000561
U	mg/l	0.000005	0.00011	0.000085	0.000228	0.000670
Zn	mg/l	0.01	<	<	0.52	0.32

< element at or below analytical detection limit.

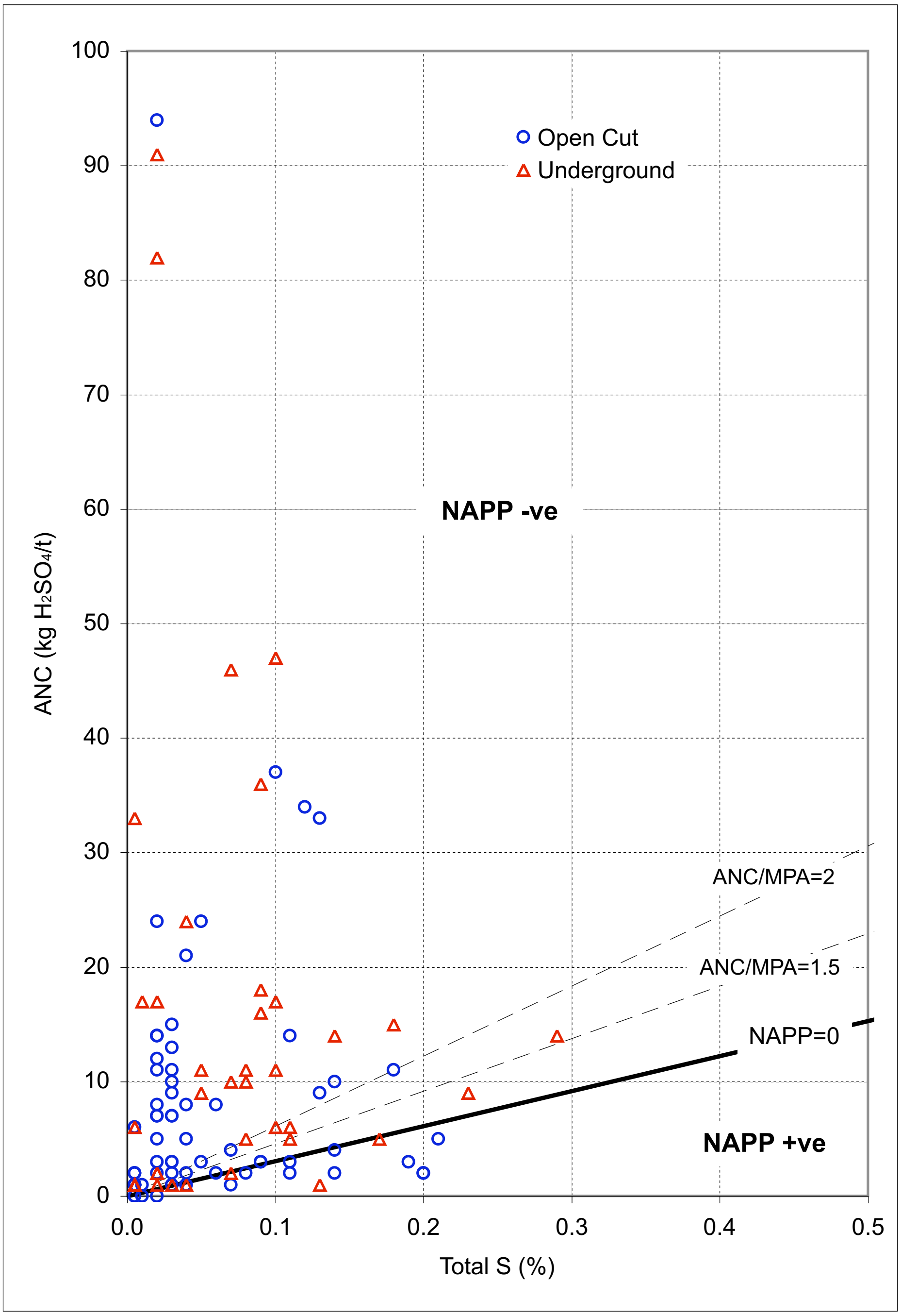


Figure 1: Acid-base account (ABA) plot showing ANC versus total S for overburden and floor samples.

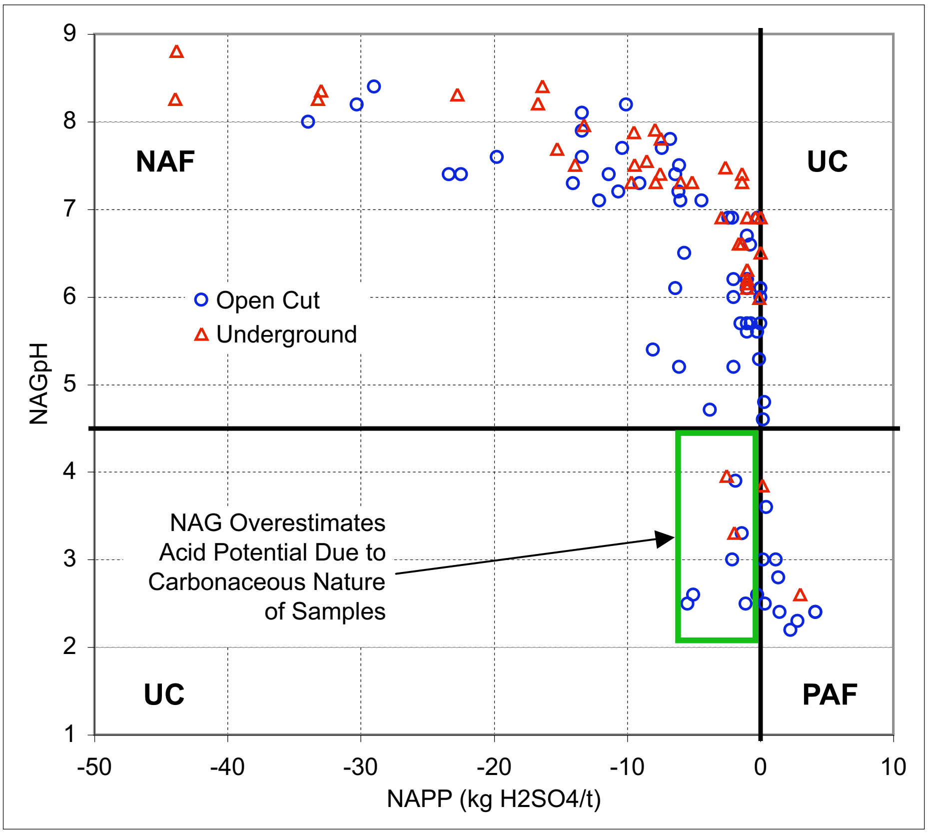


Figure 2: Geochemical classification plot for overburden and floor samples showing NAGpH versus NAPP, with ARD classification domains indicated.

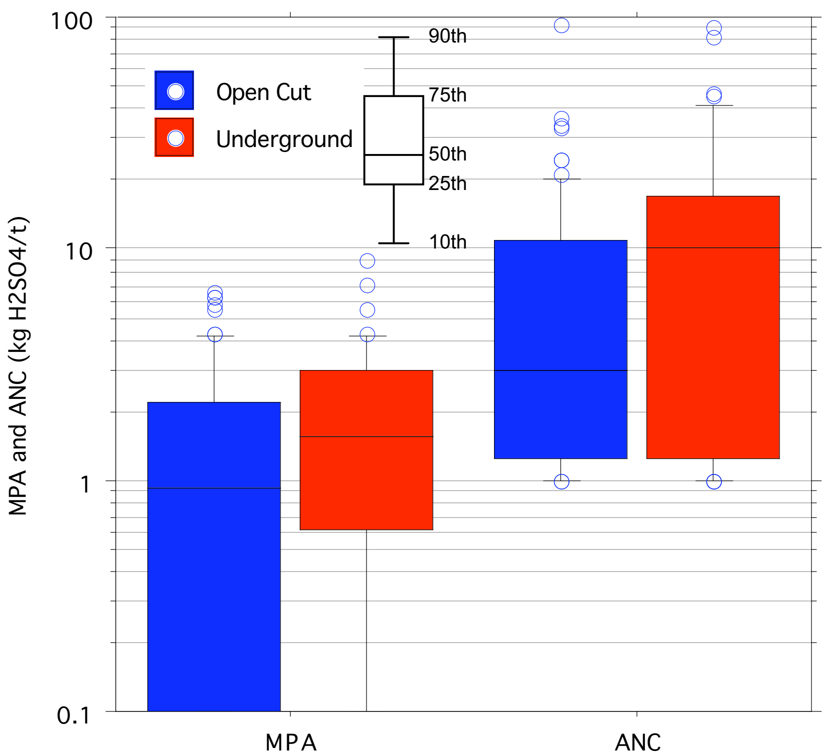


Figure 3: Box plot showing distribution of MPA and ANC values for open cut and underground samples. 10th, 25th, 50th (median), 75th and 90th percentiles are marked.

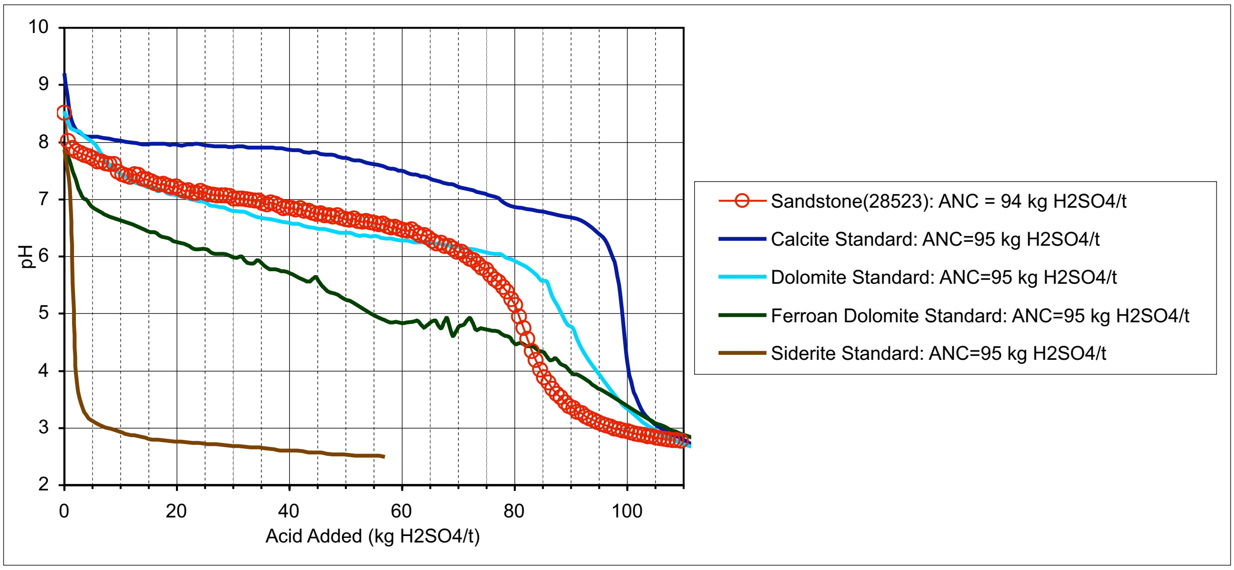


Figure 4: ABCC profile for sandstone sample 28523 with an ANC value of 94 kg H_2SO_4/t. Carbonate standard curves are included for reference.

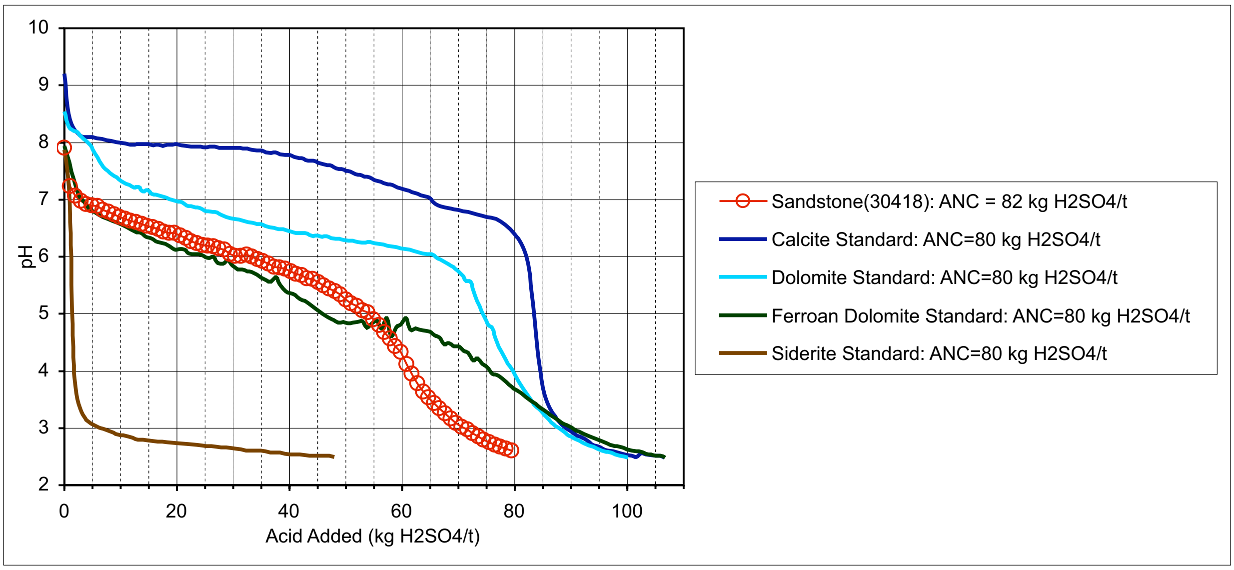


Figure 5: ABCC profile for sandstone sample 30418 with an ANC value of 82 kg H_2SO_4/t. Carbonate standard curves are included for reference.

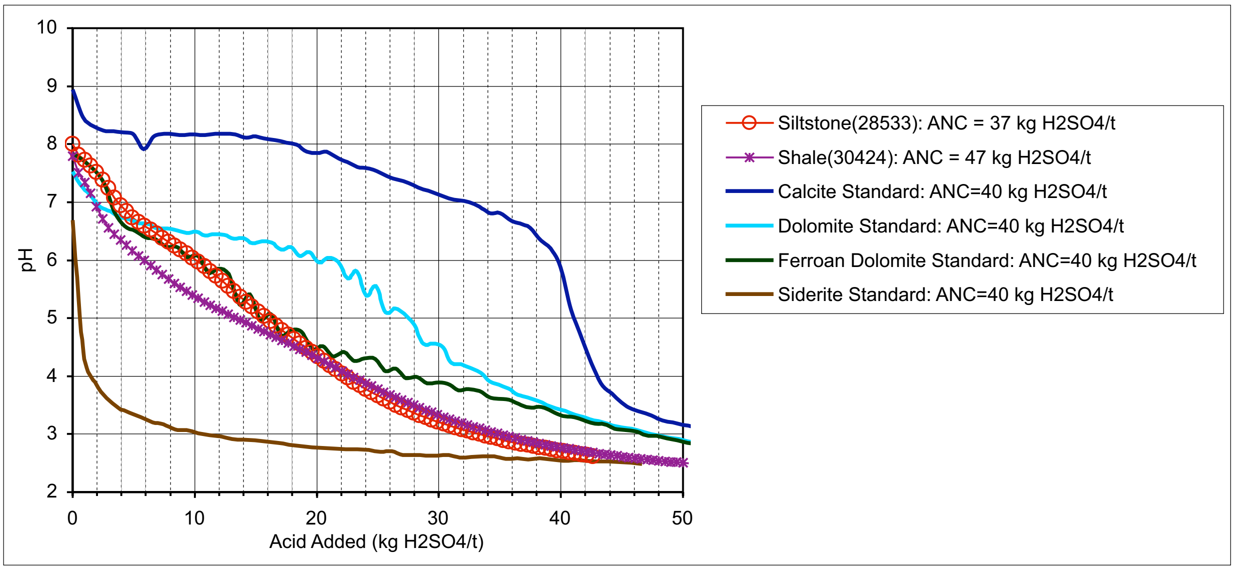


Figure 6: ABCC profile for siltstone sample 28533 with an ANC value of 37 kg H_2SO_4/t, and shale sample 30424 with an ANC value of 47 kg H_2SO_4/t. Carbonate standard curves are included for reference.

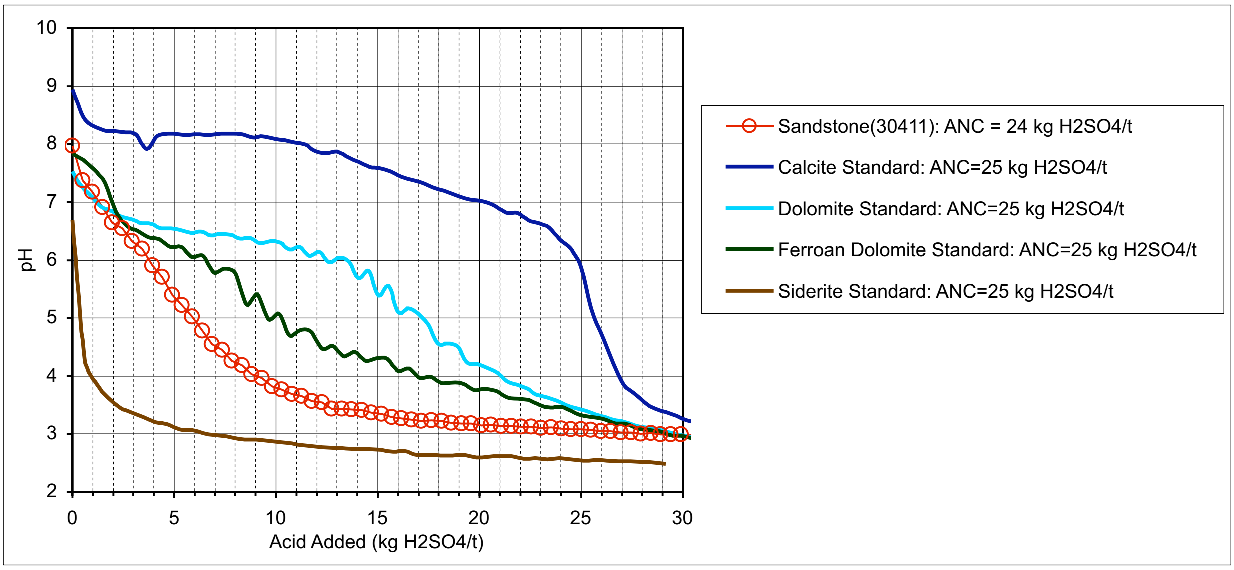


Figure 7: ABCC profile for sandstone sample 30411 with an ANC value of 24 kg H2SO4/t. Carbonate standard curves are included for reference.

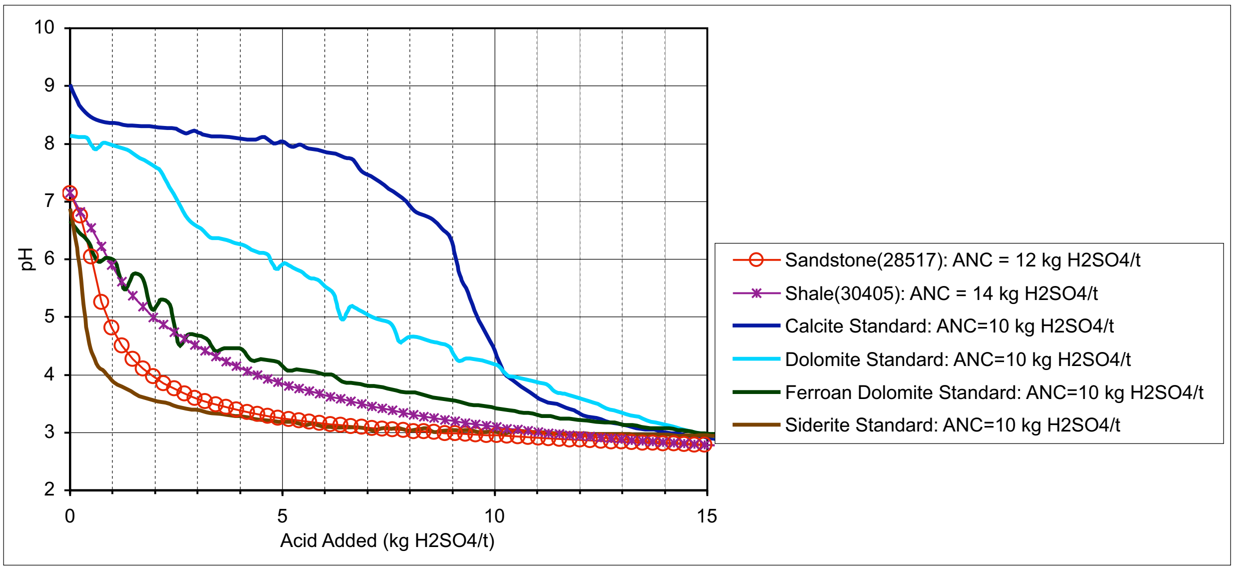


Figure 8: ABCC profile for sandstone sample 28517 with an ANC value of 12 kg H_2SO_4/t, and shale sample 30405 with an ANC value of 14 kg H_2SO_4/t. Carbonate standard curves are included for reference.

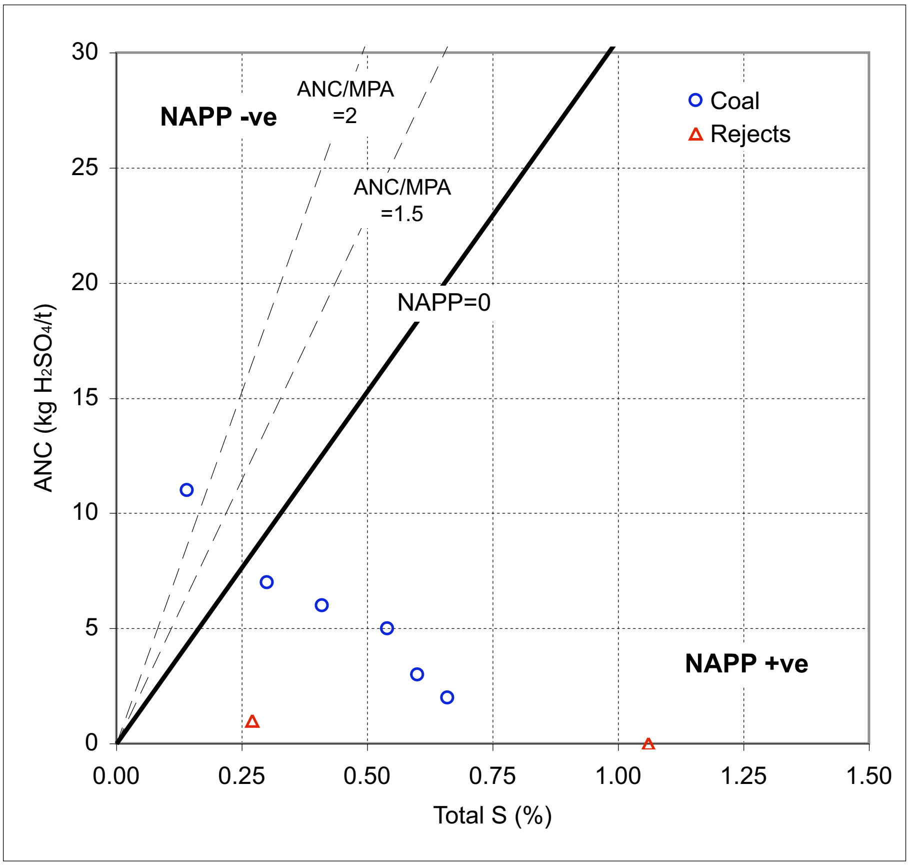


Figure 9: Acid-base account (ABA) plot showing ANC versus total S for coal and reject samples.

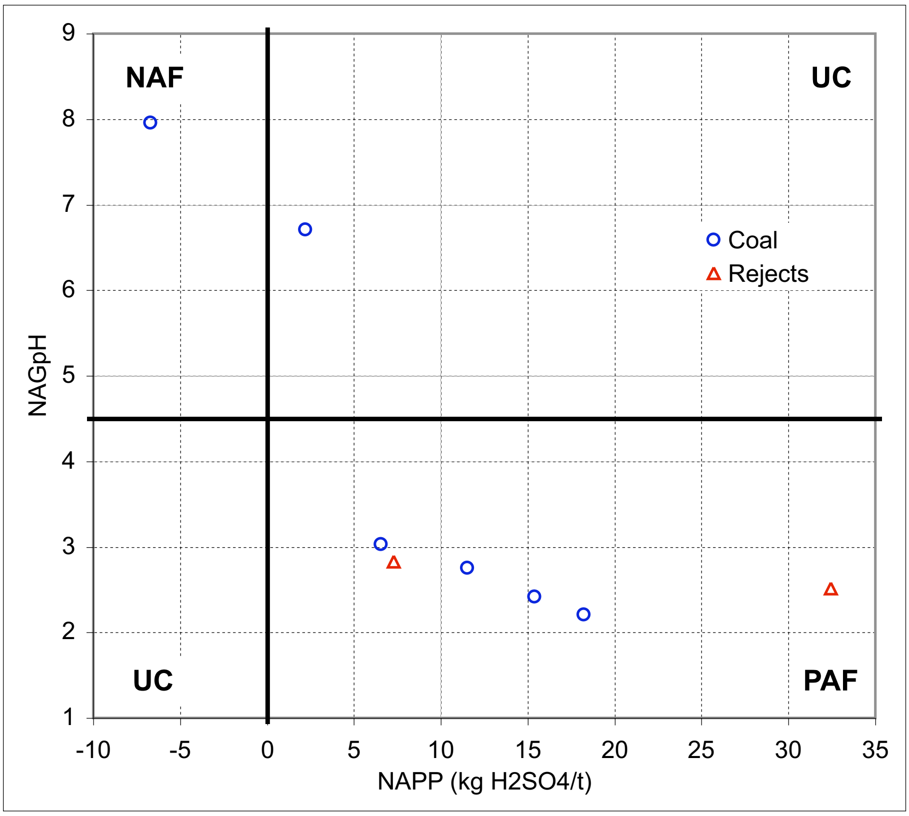
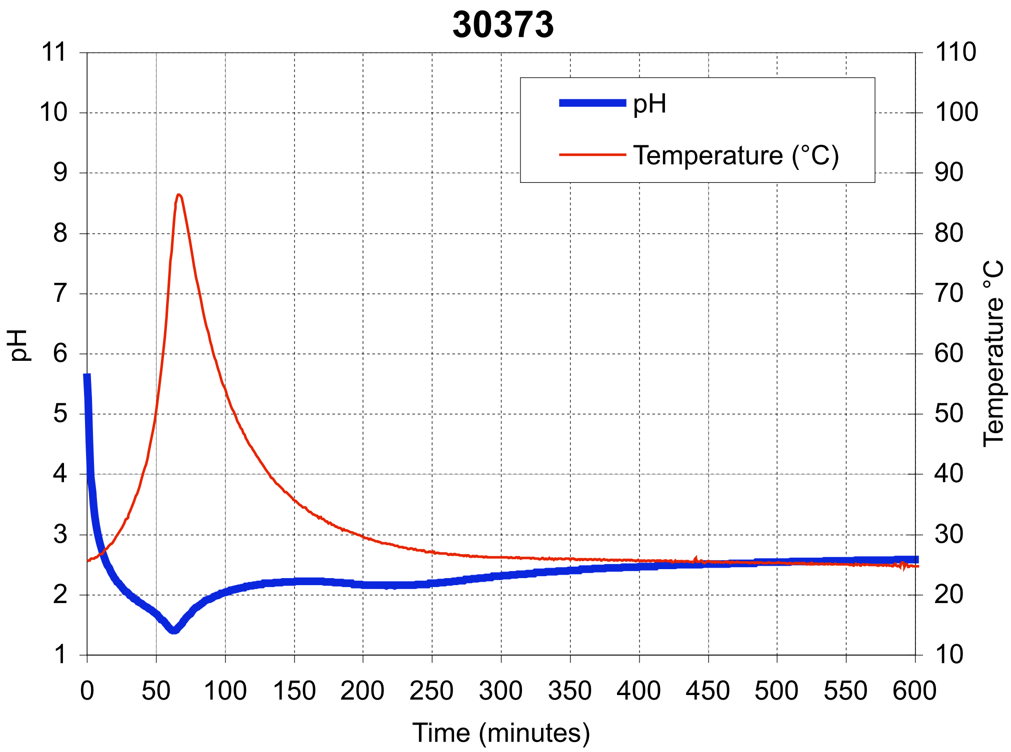


Figure 10: Geochemical classification plot for coal and reject samples showing NAGpH versus NAPP, with ARD classification domains indicated.



Sample Characteristics
%S = 1.06
ANC = 0 kg H2SO4/t
NAPP = 32 kg H2SO4/t
NAGpH = 2.5

Figure 11: Kinetic NAG graph for sample 30373.

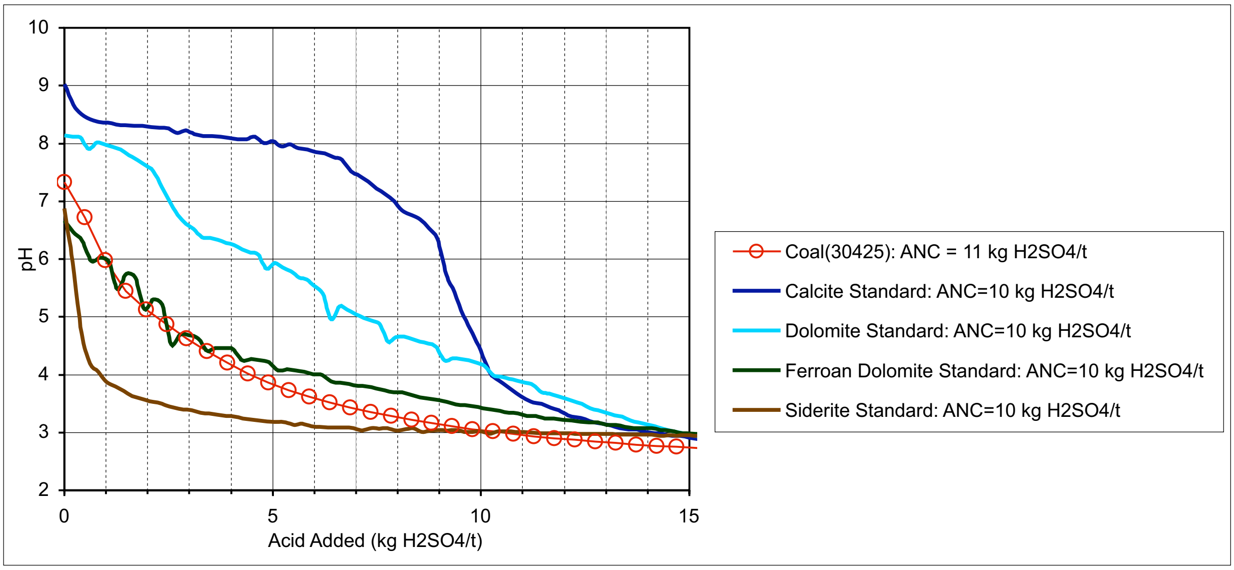


Figure 12: ABCC profile for sandstone sample 30425 with an ANC value of 11 kg H_2SO_4/t. Carbonate standard curves are included for reference.

APPENDIX A

Assessment of Acid Forming Characteristics

Assessment of Acid Forming Characteristics

Introduction

Acid rock drainage (ARD) is produced by the exposure of sulphide minerals such as pyrite to atmospheric oxygen and water. The ability to identify in advance any mine materials that could potentially produce ARD is essential for timely implementation of mine waste management strategies.

A number of procedures have been developed to help assess the acid forming characteristics of mine waste materials. The most widely used assessment methods for ARD characterisation are the Acid-Base Account (ABA) and the Net Acid Generation (NAG) test. These methods are referred to as static procedures because each involves a single measurement in time.

Acid-Base Account

The acid-base account involves static laboratory procedures that evaluate the balance between acid generation processes (oxidation of sulphide minerals) and acid neutralising processes (dissolution of alkaline carbonates, displacement of exchangeable bases, and weathering of silicates).

The values arising from the acid-base account are referred to as the maximum potential acidity (MPA) and the acid neutralising capacity (ANC), respectively. The difference between the MPA and ANC value is referred to as the net acid producing potential (NAPP).

The chemical and theoretical basis of the ABA are discussed below.

Maximum Potential Acidity

The MPA that can be generated by a sample is determined from the sample sulphur content. The total sulphur content of a sample is commonly determined by the Leco high temperature combustion method. The calculation assumes that all the sulphur measured in the sample occurs as pyrite (FeS_2) and that the pyrite reacts under oxidising conditions to generate acid according to the reaction:

$$FeS_2 + 15/4\ O_2 + 7/2\ H_2O \Rightarrow Fe(OH)_3 + 2\ H_2SO_4$$

According to this reaction, the MPA of a sample containing 1 %S as pyrite would be 30.6 kilograms of H_2SO_4 per tonne of material (*i.e.* kg H_2SO_4/t). Hence the MPA of a sample is calculated from the total sulphur content using the following formula:

$$MPA\ (kg\ H_2SO_4/t) = (Total\ \%S) \times 30.6$$

The use of the total sulphur assay to estimate the MPA is a conservative approach because some sulphur may occur in forms other than pyrite. Sulphate-sulphur and native sulphur, for example, are non-acid generating sulphur forms. Also, some sulphur may occur as other metal sulphides (*e.g.* covellite, chalcocite, sphalerite, galena) which yield less acidity than pyrite when oxidised or, in some cases, may be non-acid generating.

The total sulfur content is commonly used to assess MPA because of the difficulty and costs involved in routinely determining the speciation of sulfur forms within samples and determining reactive sulphide-sulfur contents. However, if the sulphide mineral forms are known then allowance can be made for non- and lesser acid generating sulfur forms to provide a better estimate of the MPA.

Acid Neutralising Capacity

The acid formed from pyrite oxidation will to some extent react with acid neutralising minerals contained within the sample. This inherent acid buffering is quantified in terms of the ANC.

The ANC is commonly determined by the Modified Sobek method. This method involves the addition of a known amount of standardised hydrochloric acid (HCl) to an accurately weighed sample, allowing the sample time to react (with heating), then back-titrating the mixture with standardised sodium hydroxide (NaOH) to determine the amount of unreacted HCl. The amount of acid consumed by reaction with the sample is then calculated and expressed in the same units as the MPA, that is kg H_2SO_4/t.

Net Acid Producing Potential

This is a theoretical calculation commonly used to indicate if a material has potential to produce acidic drainage. It represents the balance between the capacity of a sample to generate acid (MPA) and its capacity to neutralise acid (ANC). The NAPP is also expressed in units of kg H_2SO_4/t and is calculated as follows:

$$\text{NAPP} = \text{MPA} - \text{ANC}$$

If the MPA is less than the ANC then the NAPP is negative, which indicates that the sample may have sufficient ANC to prevent acid generation. Conversely, if the MPA exceeds the ANC then the NAPP is positive, which indicates that the material may be acid generating.

ANC/MPA Ratio

The ANC/MPA ratio is frequently used as a means of assessing the risk of acid generation from mine waste materials. The ANC/MPA ratio is another way of looking at the acid base account. A positive NAPP is equivalent to an ANC/MPA ratio less than 1, and a negative NAPP is equivalent to an ANC/MPA ratio greater than 1. A NAPP of zero is equivalent to an ANC/MPA ratio of 1.

The purpose of the ANC/MPA ratio is to provide an indication of the relative margin of safety (or lack thereof) within a material. Various ANC/MPA values are reported in the literature for indicating safe values for prevention of acid generation. These values typically range from 1 to 3. As a general rule, a ANC/MPA ratio of 2 or more generally signifies that there is a high probability that the material will remain circum-neutral in pH and thereby should not be problematic with respect to acid rock drainage.

Acid-Base Account Plot

Sulphur and ANC data are often presented graphically in a format similar to that shown in Figure 1. This figure includes a line indicating the division between NAPP positive samples from NAPP negative samples. Also shown are lines corresponding to ANC/MPA ratios of 2 and 3.

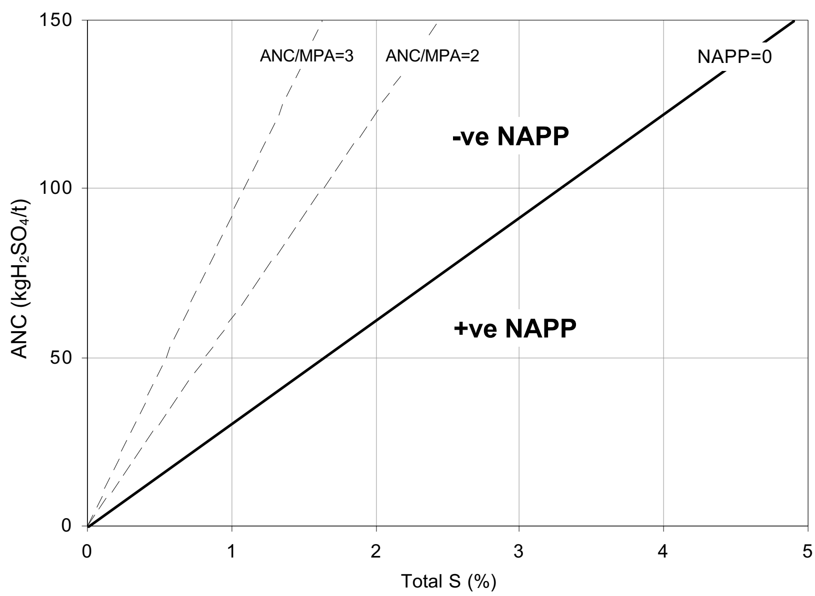


Figure A-1. Acid-base account (ABA) plot

Net Acid Generation (NAG) Test

The NAG test is used in association with the NAPP to classify the acid generating potential of a sample. The NAG test involves reaction of a sample with hydrogen peroxide to rapidly oxidise any sulphide minerals contained within a sample. During the NAG test both acid generation and acid neutralisation reactions can occur simultaneously. Therefore, the end result represents a direct measurement of the net amount of acid generated by the sample. This value is commonly referred to as the NAG capacity and is expressed in the same units as NAPP, that is kg H_2SO_4/t.

Several variations of the NAG test have been developed to accommodate the wide geochemical variability of mine waste materials. The three main NAG test procedures currently used by EGi are the single addition NAG test, the sequential NAG test, and the kinetic NAG test.

Single Addition NAG Test

The single addition NAG test involves the addition of 250 mL of 15% hydrogen peroxide to 2.5 gm of sample. The peroxide is allowed to react with the sample overnight and the following day the sample is gently heated to accelerate the oxidation of any remaining sulphides, then vigorously boiled for several minutes to decompose residual peroxide. When cool, the pH and acidity of the NAG liquor are measured. The acidity of the liquor is then used to estimate the net amount of acidity produced per unit weight of sample.

An indication of the form of the acidity is provided by initially titrating the NAG liquor to pH 4.5, then continuing the titration up to pH 7. The titration value at pH 4.5 includes acidity due to free acid (*i.e.* H_2SO_4) as well as soluble iron and aluminium. The titration value at pH 7 also includes metallic ions that precipitate as hydroxides at pHs between 4.5 and 7.

Sequential NAG Test

When testing samples with high sulphide contents it is not uncommon for oxidation to be incomplete in the single addition NAG test. This can sometimes occur when there is catalytic breakdown of the hydrogen peroxide before it has had a chance to oxidise all of the sulphides in a sample. To overcome this limitation, a multi-stage sequential NAG test is often carried out. This test may also be used to assess the relative geochemical lag of PAF samples with high ANC.

The sequential NAG test is a multi-stage procedure involving a series of single addition NAG tests on the one sample (*i.e.* 2.5 g of sample is reacted two or more times with 250 mL aliquots of 15% hydrogen peroxide). At the end of each stage, the sample is filtered and the solution is used for measurement of NAGpH and NAG capacity. The NAG test is then repeated on the solid residue. The cycle is repeated until such time that there is no further catalytic decomposition of the peroxide, or when the NAGpH is greater than pH 4.5. The overall NAG capacity of the sample is then determined by summing the individual acid capacities from each stage.

Kinetic NAG Test

The kinetic NAG test is the same as the single addition NAG test except that the temperature, pH and sometimes EC of the liquor are recorded. Variations in these parameters during the test provide an indication of the kinetics of sulphide oxidation and acid generation during the test. This, in turn, can provide an insight into the behaviour of the material field under field conditions. For example, the pH trend gives an estimate of relative reactivity and may be related to prediction of lag times and oxidation rates similar to those measured in leach columns. Also, sulphidic samples commonly produce a temperature excursion during the NAG test due to the decomposition of the peroxide solution, catalysed by sulphide surfaces and/or oxidation products.

Sample Classification

The acid forming potential of a sample is classified on the basis of the acid-base and NAG test results into one of the following categories:

- Barren,
- Non-acid forming (NAF),
- Potentially acid forming (PAF), and
- Uncertain (UC).

Barren

A sample classified as barren essentially has no acid generating capacity and no acid buffering capacity. This category is most likely to apply to highly weathered materials. In essence, it represents an 'inert' material with respect to acid generation. The criteria used to classify a sample as barren may vary between sites, but for hard rock mines it generally applies to materials with a total sulfur content ≤ 0.1 %S and an ANC ≤ 5 kg H_2SO_4/t.

Non-acid forming (NAF)

A sample classified as NAF may, or may not, have a significant sulfur content but the availability of ANC within the sample is more than adequate to neutralise all the acid that theoretically could be produced by any contained sulphide minerals. As such, material classified as NAF is considered unlikely to be a source of acidic drainage. A sample is usually defined as NAF when it has a negative NAPP and the final NAG pH ≥ 4.5.

Potentially acid forming (PAF)

A sample classified as PAF always has a significant sulfur content, the acid generating potential of which exceeds the inherent acid neutralising capacity of the material. This means there is a high risk that such a material, even if pH circum-neutral when freshly mined or processed, could oxidise and generate acidic drainage if exposed to atmospheric conditions. A sample is usually defined as PAF when it has a positive NAPP and a final NAGpH < 4.5.

Uncertain (UC)

An uncertain classification is used when there is an apparent conflict between the NAPP and NAG results (*i.e.* when the NAPP is positive and NAGpH > 4.5, or when the NAPP is negative and NAGpH ≤ 4.5). Uncertain samples are generally given a tentative classification that is shown in brackets *e.g.* UC(NAF).

Figure A-2 shows the format of the classification plot that is typically used for presentation of geochemical data. Marked on this plot are the quadrats representing the NAF, PAF and UC classifications.

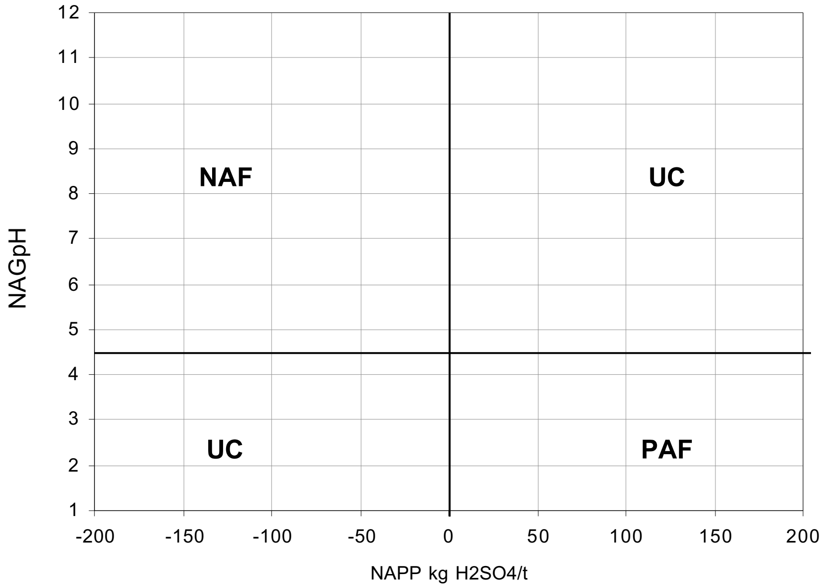


Figure A-2 Geochemical classification plot

Other Methods

Other test procedures may be used to define the acid forming characteristics of a sample.

pH and Electrical Conductivity

The pH and electrical conductivity (EC) of a sample is determined by equilibrating the sample in deionised water for a minimum of 1 hour, typically at a solid to water ratio of 1:2 (w/w). This gives an indication of the inherent acidity and salinity of the waste material when initially exposed in a waste emplacement area.

Acid Buffering Characteristic Curve (ABCC) Test

The ABCC test involves slow titration of a sample with acid while continuously monitoring pH. This data provides an indication of the portion of ANC within a sample that is readily available for acid neutralisation.