

Tarrawonga Coal Mine Modification

APPENDICES A-F

April 2010



ResourceStrategies

Tarrawonga Coal Mine Modification

Appendix A Geochemistry Assessment





**ENVIRONMENTAL GEOCHEMISTRY ASSESSMENT OF
THE TARRAWONGA COAL MINE MODIFICATION,
NEW SOUTH WALES**

March 2010

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Table of Contents

	<i>Page</i>
1.0 Introduction	1
1.1 Background.....	1
1.2 Study Objectives.....	2
2.0 Previous Geochemical Investigations	3
3.0 Geochemical Assessment Program.....	4
3.1 Testing Methodology and Program	4
3.2 Geochemical Classification	7
3.3 Sample Selection and Preparation	9
4.0 Overburden Geochemistry	11
4.1 pH, Salinity and Sodicity.....	11
4.2 Acid Forming Characteristics.....	12
4.3 Metal Enrichment and Solubility.....	13
5.0 Geochemical Implications for Environmental Management of the Proposed Pit Extension	15
5.1 Overburden Management	15
5.2 Water Quality Monitoring	15
5.3 Future Geochemical Assessment Requirements.....	16
6.0 References	17

Table of Contents (Continued)

Tables

	<i>Page</i>
1: Proportion of the major lithologies within the stratigraphic sequence of drill-hole TA31C and the number of overburden samples collected for each lithology	9
2: Concentration ranges and average crustal abundances for slightly enriched elements in selected overburden samples from drill-hole TA31C.....	14
3: Concentration ranges and the ANZECC (2000) Irrigation Water Quality Guideline values for readily soluble elements in the overburden samples from drill-hole TA31C.....	14

Figures

	<i>Page</i>
1: Drill-hole locations for the currently approved pit area and proposed pit extension.....	10
2: Salinity and sodicity ranking for selected overburden samples from drill-hole TA31C.....	11
3: Acid-base account plot for the overburden samples from drill-hole TA31C.....	12
4: Acid rock drainage classification plot for selected overburden samples from drill-hole TA31C.....	13

Attachments

ATTACHMENT A: Geochemical Test Results.

1.0 Introduction

Geo-Environmental Management Pty Ltd (GEM) was commissioned by Tarrawonga Coal Pty Ltd (TCPL) to carry out an environmental geochemical assessment of overburden to be generated by proposed extensions to the open cut mining operations at the Tarrawonga Coal Mine (previously known as the East Boggabri Coal Mine). The Tarrawonga Coal Mine is situated in central northern New South Wales (NSW), approximately 42 kilometres (km) north-west of Gunnedah.

1.1 Background

Improved market conditions since the original Tarrawonga Coal Mine was approved in 2005 have made mining of higher strip ratio coal economically viable. As a result, TCPL is seeking approval to modify the approved open cut boundary to extend up to approximately 600 metres (m) to the east within Mining Lease (ML) 1579 (herein referred to as the proposed Modification). The additional land disturbance associated with the open cut extension would be approximately 38 hectares (ha).

This proposed Modification would enable TCPL to mine approximately 4 million tonnes (Mt) of additional coal, with an increase in overburden of approximately 35 million bank cubic metres (Mbcm). The open cut mining method would remain the same, as would the maximum production rate (i.e. up to 2 Mt per year).

TCPL is also considering the feasibility of mining further to the east (ie. beyond the eastern edge of the proposed Modification), however a decision to proceed would be subject to further feasibility studies and assessments as well as a separate environmental assessment and approval.

Two out-of-pit overburden emplacements are approved and are partially constructed at the Tarrawonga Coal Mine. The emplacements are located to the north-west and south of the open cut pit and are known as the Northern Emplacement and Southern Emplacement. They are approved to maximum heights of 330 m Australian Height Datum (AHD) and 340 m AHD, respectively. As part of the proposed Modification, TCPL is seeking approval to increase the height of the Northern Emplacement to 370 m AHD. The maximum height of the Southern Emplacement would remain at 340 m AHD but it would be extended by approximately 100 to 300 m to the south, into areas previously approved for topsoil stockpiles.

As part of the proposed Modification, TCPL is also seeking to make some modifications to the soil stockpiles and surface water management structures, and coal processing operating hours, as well as install a small additional hardstand/infrastructure area.

1.2 Study Objectives

The Tarrawonga Coal Mine was approved via Development Consent (DA-88-4-2005) by the NSW Minister for Planning in November 2005 under Part 4 of the NSW *Environmental Planning and Assessment Act, 1979* (EP&A Act). This Environmental Geochemistry Assessment report has been compiled in support of an Environmental Assessment for the proposed Modification to the Tarrawonga Coal Mine under Section 75W, Part 3A of the EP&A Act.

The objectives of this study were to:

1. Review the previous geochemical investigations conducted for the Tarrawonga Coal Mine.
2. Review the relevant geological information and available drill-hole logs.
3. Identify and provide TCPL with selected drill-holes to be sampled and the sample depth intervals representative of the major rock type units to be mined as overburden or interburden from the area between the eastern edge of the approved open cut and the eastern boundary of ML 1579 for inclusion in the geochemical testing program.
4. Design a suitable geochemical testing program and identify suitable analytical laboratories to be used to assess the salinity, sodicity and acid forming potential, and metal enrichment and solubility of the samples selected in item 3 above.
5. Provide TCPL with detailed instructions enabling on-site personnel to collect and prepare selected drill-hole samples based on the information provided in item 3, and to dispatch the bagged samples according to the instructions provided in item 4 above.
6. Co-ordinate the testing programs to be conducted by the external laboratories identified in item 4.
7. Receive, tabulate and evaluate all of the test work results.
8. Prepare a geochemistry assessment report which summarises the results of the previous test work (Item 1), and provides a detailed description of the current sampling and analytical programs (items 2 to 7). Using all of the available information the report will evaluate and discuss the environmental impacts and, in particular the acid forming potential, of the overburden to be mined from the proposed additional pit area.

This report provides the results and findings of the geochemical investigations completed for the proposed Modification. Based on the current and previous geochemical investigations, recommendations for operational and long-term environmental management of the overburden are also provided.

2.0 Previous Geochemical Investigations

Previous geochemical characterisation of overburden and interburden (collectively termed overburden) samples from the Tarrawonga Coal Mine was carried out by URS Australia Pty Ltd in May 2005. This geochemical assessment program was required for the *East Boggabri Joint Venture Environmental Impact Statement (2005 EIS)* (R.W Corkery & Co Pty Limited, 2005). For this program, five sample composites were prepared from one drill-hole located within the proposed open pit area. It is understood that the sample composites comprised mixed lithologies from within the major overburden units and that the depth intervals represented ranged from 8 to 20 m.

The results from the geochemical characterisation program indicated that the materials represented had relatively low sulfur (S) contents (0.04 to 0.31 %S) and a range in acid neutralising capacities (ANC) from 8 to 64 kilograms of sulfuric acid per tonne of material (i.e. kg H₂SO₄/t). The corresponding net acid producing potential (NAPP) values were all negative, indicating an excess in acid neutralisation over acid potential. The net acid generation (NAG) test results derived pH of NAG liquor (NAGpH) values all greater than pH 4 (NAGpH range 6.2 to 9.0). Based on these results, the materials represented by the samples tested were all classified as non-acid forming (NAF). This program also indentified a low potential for soluble salt generation, indicating a low salinity risk. The sodicity ratings of the overburden materials were not determined at the time.

3.0 Geochemical Assessment Program

3.1 Testing Methodology and Program

The laboratory program for these investigations included the following tests and procedures:

- pH and Electrical Conductivity (EC) determination (all samples);
- exchangeable cation analysis (all samples);
- acid-base analysis (total S, ANC, NAPP) (all samples);
- sulfur forms analysis (selected samples);
- single addition NAG testing (selected samples); and
- multi-element scans on solids and water extracts (selected samples).

The pH and EC determinations, and deionised water extracts for multi-element analyses were conducted in-house. The sample preparation, exchangeable cation analysis, acid-base analysis, and NAG testing were performed by Australian Laboratory Services Pty Ltd in Brisbane and the multi-element analyses on solids and water extracts were performed by Genalysis Laboratories in Perth.

An overview of the test procedures used for this program is presented below.

pH and Electrical Conductivity Determination

The pH and EC of a sample is determined by equilibrating the sample in deionised water for a minimum of 2 hours at a solid to water ratio of 1:2 weight by weight (w/w). This gives an indication of the inherent acidity and salinity of the material when it is initially exposed. The general salinity ranking based on EC_{1:2} is provided below:

EC _{1:2} (dS/m)	Salinity
< 0.5	Non-Saline
0.5 to 1.5	Slightly Saline
1.5 to 2.5	Moderately Saline
> 2.5	Highly Saline

dS/m = deciSiemens per metre.

Exchangeable Cation Analysis

Exchangeable cation analyses are carried out to determine the sodicity of a sample. Sodicity occurs in materials that have high concentrations of exchangeable sodium (Na) relative to the other major cations (i.e. Calcium [Ca] and Magnesium [Mg]), causing the material to be highly dispersive. The Exchangeable Sodium Percent (ESP) is used to determine the sodicity of a sample by comparing the amount of exchangeable Na to Ca and Mg concentrations. The ESP is used to rank materials according to sodicity and likely dispersion characteristics as shown below:

ESP	Sodicity	Dispersion
< 6	Non-Sodic	Not Dispersive
6 to 15	Slightly Sodic	Slightly Dispersive
15 to 30	Moderately Sodic	Moderately Dispersive
> 30	Highly Sodic	Highly Dispersive

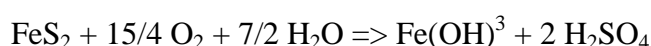
Acid Forming Characteristic Evaluation

A number of test procedures are used to assess the acid forming characteristics of mine waste materials. The most widely used assessment methods are the acid-base account and the 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 laboratory procedures that evaluate the balance between acid generation processes (oxidation of sulfide 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 ANC, respectively. The difference between the MPA and ANC value is referred to as the NAPP.

The MPA is calculated using the total sulfur content of the sample. This calculation assumes that all of the sulfur measured in the sample occurs as pyrite (FeS₂) and that the pyrite reacts under oxidising conditions to generate acid according to the following reaction:



According to this reaction, the MPA of a sample containing 1 %S as pyrite would be 30.6 kg H₂SO₄/t. Hence the MPA of a sample is calculated from the total sulfur content using the following formula:

$$\text{MPA (kg H}_2\text{SO}_4\text{/t)} = (\text{Total \%S}) \times 30.6$$

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

The acid formed from pyrite oxidation would, to some extent, react with acid neutralising minerals contained within the sample. This inherent acid neutralisation is quantified in terms of the ANC and is commonly determined using 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 (kg H₂SO₄/t).

The NAPP is a theoretical calculation commonly used to indicate if a material has the potential to produce acid. 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 H₂SO₄/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.

The ANC/MPA ratio is used as a means of assessing the risk of acid generation from mine waste materials. 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. Generally, an ANC/MPA ratio of 3 or more signifies that there is a high probability that the material is not acid generating.

Net Acid Generation 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 sulfide 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 H₂SO₄/t.

The standard NAG test involves the addition of 250 millilitres (mL) of 15% hydrogen peroxide to 2.5 grams (g) 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 sulfides, 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.

Metal Enrichment and Solubility

Multi-element scans are carried out to identify any elements that are present in a material at concentrations that may be of environmental concern with respect to water quality and revegetation. The assay results from the solid samples are compared to the average crustal abundance for each element to provide a measure of the extent of element enrichment. The extent of enrichment is reported as the Geochemical Abundance Index (GAI). However, identified element enrichment does not necessarily mean that an element would be a concern for revegetation, water quality, or public health and this technique is used to identify any significant element enrichments that warrant further examination.

Multi-element scans are also performed on water extracts from the solid samples (1:2 sample/deionised water) to determine the immediate element solubilities under the existing sample pH conditions of the sample. However, common environmentally important elements that are not identified as significantly enriched or immediately soluble may still present an environmental risk under low pH conditions and where acid forming materials are identified, additional (kinetic) testing is required to develop an understanding of the geochemical behaviour of these materials.

3.2 Geochemical Classification

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

- barren;
- NAF;
- potentially acid forming (PAF);
- acid forming; and
- uncertain.

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 it generally applies to materials with a total sulfur content $\leq 0.1\%$ S and an ANC ≥ 5 kg $\text{H}_2\text{SO}_4/\text{t}$.

Non-Acid Forming

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 sulfide 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 a final NAGpH ≥ 4.5 .

Potentially Acid Forming

A sample classified as PAF always has a significant sulfur content, the acid generating potential of which exceeds the inherent ANC 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 .

Acid Forming

A sample classified as acid forming has the same characteristics as the PAF samples, however, these samples also have an existing pH of less than 4.5. This indicates that acid conditions have already been developed, confirming the acid forming nature of the sample.

Uncertain

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).

3.3 Sample Selection and Preparation

A total of 29 samples were collected by TCPL personnel from drill-hole TA31C which is centrally located between the eastern edge of the approved open cut and the eastern boundary of ML 1579 (Figure 1). The intervals selected for sampling were based on the lithology and proximity to the coal seams using the stratigraphic log for the drill-hole provided by TCPL. Strata that occur as finely interbedded materials of different lithology have been logged as discrete units of mixed lithology (e.g. carbonaceous mudstone and siltstone). The sample intervals selected comprised either discrete lithologies or discrete units of mixed lithology. The selected sample set is therefore considered to be representative of the major overburden rock types within the remaining potential open cut areas within ML 1579. Table 1 provides the proportion of the major lithologies (or mixed lithology units) sampled and the number of samples collected for each lithology.

The samples were sent to Australian Laboratory Services Pty Ltd in Brisbane for preparation where all of the sample was crushed to minus 4 millimetres (mm) and a 200 g split was then pulverised to minus 75 micrometres (μm) prior to testing.

Table 1: Proportion of the major lithologies within the stratigraphic sequence of drill-hole TA31C and the number of overburden samples collected for each lithology.

Lithology	Weathering	Weighted Proportion	Number of Samples
Conglomerate	Highly Weathered	7.7%	1
Conglomerate	Weathered	3.0%	1
Sandstone	Weathered	0.9%	1
Claystone	Weathered	0.2%	1
Conglomerate	Partially Weathered	14.4%	1
Carbonaceous Mudstone	Partially Weathered	0.3%	1
Conglomerate	Fresh	35.7%	6
Sandstone	Fresh	13.7%	4
Sandstone, Siltstone	Fresh	10.7%	4
Carbonaceous Mudstone	Fresh	6.0%	3
Carb. Mudstone, Siltstone	Fresh	2.5%	2
Carb. Mudstone, Sandstone	Fresh	2.3%	2
Carb. Mudstone, Sandstone, Siltstone	Fresh	1.3%	0
Siltstone	Fresh	1.2%	2
TOTAL		*100%	29

* Total may be different due to rounding.



Figure 1: Drill-hole locations for the currently approved pit area and proposed pit extension.

4.0 Overburden Geochemistry

The geochemical test results for the 29 overburden samples, including the $\text{pH}_{(1:2)}$ and $\text{EC}_{(1:2)}$, acid forming characteristic, sodicity assessment and element enrichment and solubility, are provided in Attachment A and discussed below.

4.1 pH, Salinity and Sodicity

The $\text{pH}_{1:2}$ of the overburden samples ranges from 7.4 to 9.3 with a median value of 8.6 (Table A-1 in Attachment A) indicating that the overburden materials represented by the samples tested are likely to be slightly to moderately alkaline. The $\text{EC}_{1:2}$ values range from 0.139 to 0.575 dS/m with a median value of 0.272 (Table A-1 in Attachment A), indicating that the overburden materials are expected to be generally likely non-saline.

Eleven of the overburden samples were selected for exchangeable cation analysis and determination of the ESP in order to assess the sodicity risk presented by the overburden materials (Table A-2 in Attachment A). The range in ESP values for the selected samples is relatively large ranging from 1.8 to 24.8 %. Figure 2 is a plot of the ESP values compared to the $\text{EC}_{1:2}$ for the different lithologies included in the selected samples and provides the salinity and sodicity ranking for these materials. This plot shows that the selected overburden samples are non-saline and range from non-sodic to moderately sodic. The unweathered (fresh) carbonaceous mudstone and siltstone have moderately sodic ESP values ranging from 17.2 to 24.8 while all of the other fresh and weathered lithologies generally have non-sodic ESP values ranging from 1.8 to 6.7 (Table A-2 in Attachment A).

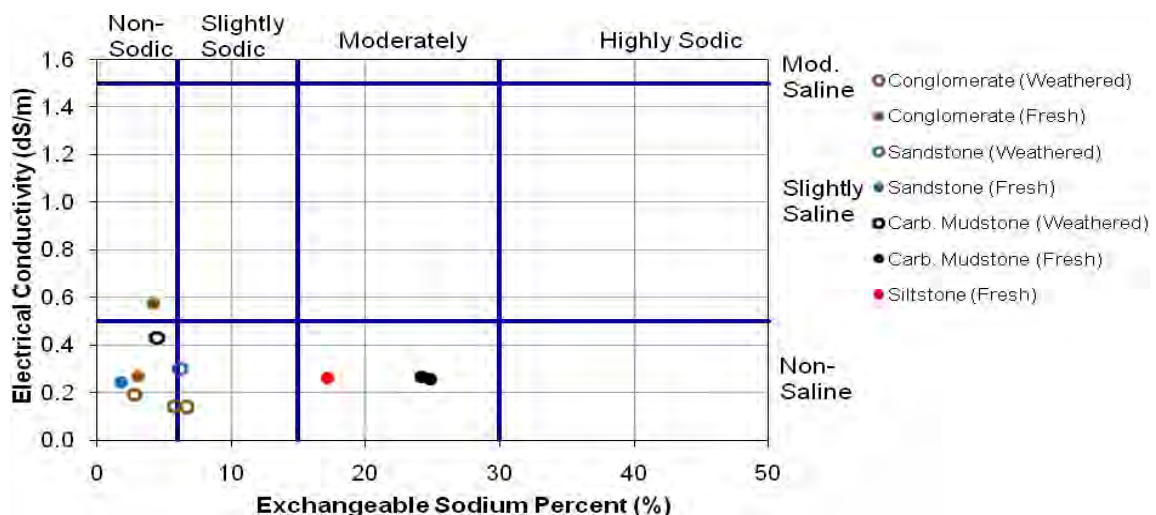


Figure 2: Salinity and sodicity ranking for selected overburden samples from drill-hole TA31C.

4.2 Acid Forming Characteristics

The total sulfur content of these samples is low ranging from <0.01 to 0.11 %S with an average value of 0.03 %S. The majority of the samples (83%) have total sulfur contents of 0.1 %S or below. The three highest sulfur samples, with total sulfur contents ranging from 0.07 to 0.11 %S, were selected for sulfide sulfur analyses. All three samples represented fresh lithologies, including the conglomerate, sandstone and carbonaceous mudstone. The results from these analyses varied between samples indicating that in some of the samples all of the contained sulfur occurs as reactive sulfide, while in other samples a proportion of the sulfur occurs in non-reactive sulfur forms such as sulfate. Based on the total sulfur contents the MPA of these samples is only low, ranging from <0.3 to 3 kg H₂SO₄/t.

The ANC of the overburden samples varies widely, ranging from 5 to 185 kg H₂SO₄/t. However, the majority of the samples have a relatively low ANC, with the overall sample set having an average of only 23 kg H₂SO₄/t and only one sample, representing the fresh sandstone (GEM/11), having an ANC greater than 100 kg H₂SO₄/t.

Figure 3 is a plot of the total sulfur content compared to the ANC of the different major (or predominant) lithologies. Samples that plot above the NAPP = 0 (ANC/MPA = 1) line are NAPP negative, indicating an excess in acid buffering capacity over potential acidity. This plot shows that conservatively, using the total sulfur contents, all of the samples are NAPP negative.

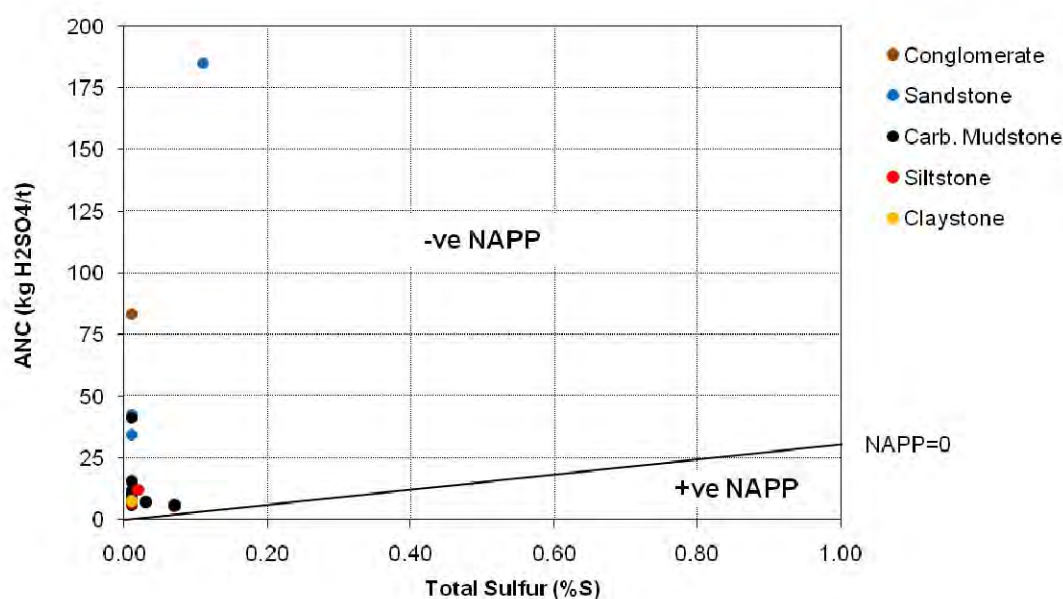


Figure 3: Acid-base account plot for the overburden samples from drill-hole TA31C.

Nine samples, representing the range in geochemical material types within the overburden sample set, were selected for NAG testing to confirm the geochemical classification of these materials. Figure 4 is a plot of the NAPP values of these samples compared to the NAGpH values. Samples that plot in the upper left quadrant are NAPP negative with NAGpH values greater than 4.5, and these samples are confirmed as NAF. Samples that plot in the lower right quadrant are NAPP positive with NAGpH values less than 4.5, and these samples are confirmed as PAF. Samples that plot in the lower left or upper right quadrants have an uncertain geochemical classification. This plot shows that all of the samples are confirmed as NAF. Additionally, the high ANC sandstone sample (GEM/11) has an NAPP of minus 185 kg H₂SO₄/t with a NAGpH of 10.4 and materials represented by this sample are expected to be significantly acid consuming.

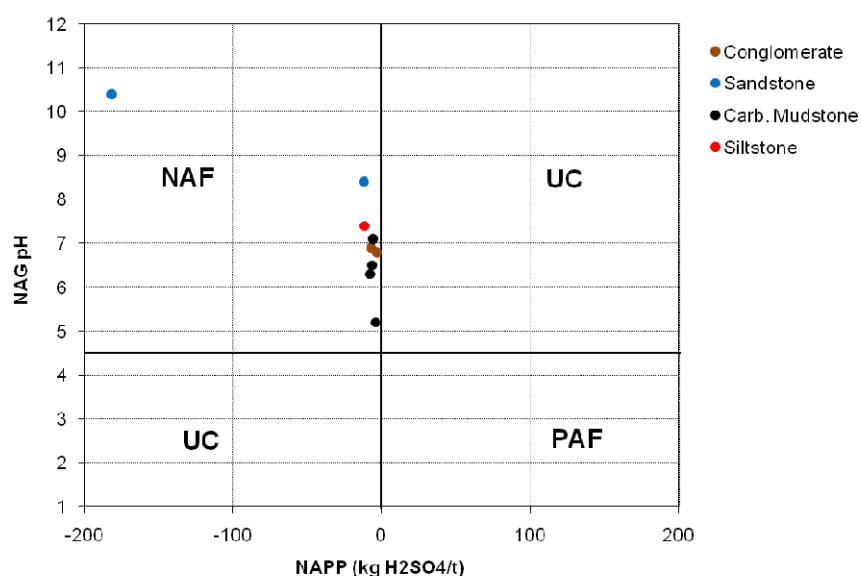


Figure 4: Acid rock drainage classification plot for selected overburden samples from drill-hole TA31C.

Based on the samples tested, these results indicate that all of the major lithology types comprising the overburden from the area between the eastern edge of the approved open cut and the eastern boundary of ML 1579 are expected to be NAF and, apart from the high ANC sandstone sample (GEM/11), are considered to be geochemically barren with low sulfur contents and relatively low ANC.

4.3 Metal Enrichment and Solubility

Eight samples, including three conglomerate, two sandstone, one siltstone and two carbonaceous mudstone samples, were selected for multi-element analysis based on their stratigraphic location, lithology and geochemical characteristics (Table A-4 in Attachment A). The results from these analyses and the geochemical abundances indices for the selected samples are provided in Attachment A.

These results show only minor enrichment of Arsenic (As) in all samples and of Antimony (Sb) and Selenium (Se) in some of the samples compared to the average crustal abundance. The enrichment of As, Sb and Se compared to the average crustal abundance is a relatively common characteristic of coal deposits of this region. The concentration ranges and average crustal abundance of these elements are summarised in Table 2.

Table 2: Concentration ranges and average crustal abundances for slightly enriched elements in selected overburden samples from drill-hole TA31C.

Element	Concentration Range	Average Crustal Abundance
As	4 - 12 mg/kg	1.5 mg/kg
Sb	0.35 – 0.80 mg/kg	0.2 mg/kg
Se	<0.01 - 0.33 mg/kg	0.05 mg/kg

The high ANC sandstone sample (GEM/11) also has significant enrichment of Barium (Ba) compared to the average abundance, and compared to the other overburden samples has high concentrations of Ca, Iron (Fe), Mg and Manganese (Mn).

Multi-element scans were performed on water extracts (1 part sample/2 parts deionised water) from these samples in order to provide an indication of relative element solubility. The results from these scans are presented in Attachment A. These results indicate that As, Molybdenum (Mo) and Se are relatively soluble in a number of the samples tested. The concentration range of these elements is compared to Australian and New Zealand Environment Conservation Council (ANZECC) irrigation water quality guidelines (ANZECC, 2000) in Table 3 in order to provide an indication of their relative solubility.

Table 3: Concentration ranges and the ANZECC (2000) Irrigation Water Quality Guideline values for readily soluble elements in the overburden samples from drill-hole TA31C.

Element	Concentration Range	Irrigation Water Quality Guideline (ANZECC, 2000)	
		Long-Term	Short-Term
As	2.7 – 112.8 µg/L	100 µg/L	2,000 µg/L
Mo	3.25 – 219.7 µg/L	10 µg/L	50 µg/L
Se	0.6 – 84.2 µg/L	20 µg/L	50 µg/L

Although slightly enriched in some of the overburden samples, Sb was not found to be readily soluble in the samples tested.

5.0 Geochemical Implications for Environmental Management of the Proposed Pit Extension

5.1 Overburden Management

Previous geochemical investigations, conducted by URS Australia Pty Ltd (2005) as part of the 2005 EIS for the current operations (R.W Corkery & Co Pty Limited, 2005), reported the geochemical characteristics of the overburden from the current pit area. The results from these investigations indicated that the overburden was likely to be NAF and, due to the low sulfur content, it was likely to only have a low potential for soluble salt generation, indicating that the material had a low salinity risk. Due to the relatively inert nature of the overburden, it was recommended that no specific constraints relating to the handling and storage of the overburden would be required for geochemically secure disposal of the overburden.

The results of the current geochemical investigations indicate that overburden from the area between the eastern edge of the approved open cut and the eastern boundary of ML 1579 is geochemically consistent with overburden from the current pit in that it is expected to be relatively barren (non-reactive) with a consistently low sulfur content and a moderately low ANC. Based on this, it is expected that no changes to the management practices of the overburden would be required. However, a sodicity assessment performed on a limited number of samples during the current investigations, indicates that some of the overburden materials, including the carbonaceous mudstone and siltstone, have the potential to be moderately sodic. Sodic materials have a tendency to be highly dispersive and can therefore cause problems with stability and erosion if left exposed on the outer dump surfaces.

Multi-element scans, performed on selected solid samples and water extracts from the solids during the current investigations, indicates that the overburden is not likely to contain any significantly enriched elements of potential environmental concern and also indicates no significantly soluble elements of environmental concern. However, a number of elements were identified that should be included in the site water quality monitoring program. These are discussed below.

5.2 Water Quality Monitoring

The multi-element scans on the solids and water extracts, discussed above, indicate the minor enrichment of As, Sb and Se in the solids and the relative solubility of As, Mo and Se. Because of this it is recommended that these elements be included in the site water quality monitoring program on an occasional basis (such as 3-monthly) in order to confirm that the release of these elements from the stockpiled overburden does not adversely impact the water quality of the receiving environment.

5.3 Future Geochemical Investigation Requirements

It is recommended that similar detailed geochemical investigations be conducted on overburden in the future if the mining operations expand or move into new areas not covered by the previous or current investigations.

There may be a requirement to further investigate the distribution of sodic materials throughout the overburden sequence in order to ensure that sodic materials are not left exposed on the final dump surfaces, in particular within the batters. However, a less labor-intensive approach may be to monitor the final dump surfaces and batters, and if required, conduct a program to sample and test the outer surfaces of the final dumps, primarily targeting the batters, to determine the sodicity risk. Any identified sodic materials would either need to be excavated and buried within the dump or covered sufficiently to ensure direct rainfall would not be able to cause dispersion and erosion of the dump surfaces and/or batters.

6.0 References

Australian and New Zealand Environment Conservation Council (2000) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Canberra, October.

R.W.Corkery and Co. Pty Ltd (2005) *East Boggabri Joint Venture Environmental Impact Statement*.

URS Australia Pty Ltd (2005) *Acid Mine Drainage and Salinity Potential Assessment for the proposed Boggabri Coal Mine*. Prepared on behalf of the East Boggabri Joint Venture.

Attachment A

Geochemical Test Results

Table A-1: pH, EC and acid forming characteristics of the overburden samples from drill-hole TA31C.

Table A-2: Exchangeable cations, cation exchange capacity and exchangeable sodium percent for selected overburden samples from drill-hole TA31C.

Table A-3: Multi-element composition and geochemical abundance indices of selected overburden samples from drill-hole TA31C.

Table A-4: Chemical composition of water extracts from selected overburden samples from drill-hole TA31C.

Table A-1: pH, EC, and acid forming characteristics of the overburden samples from drill-hole TA31C.

Sample Code	Sample Description	pH _{1:2}	EC _{1:2}	ACID-BASE ANALYSIS						NAG TEST			ARD Classification
				Total %S	Sulfide %S	MPA	ANC	NAPP	ANC/MPA	NAGpH	NAG _(pH4.5)	NAG _(pH7.0)	
GEM/1	Conglomerate - Highly Weathered	8.4	0.193	<0.01	-	0	7	-7	22.5	6.9	0	0	NAF
GEM/2	Conglomerate - Weathered	8.7	0.143	<0.01	-	0	8	-8	24.8	-	-	-	NAF
GEM/3	Claystone - Weathered	8.2	0.470	<0.01	-	0	8	-8	24.8	-	-	-	NAF
GEM/4	Sandstone - Weathered	7.8	0.300	<0.01	-	0	11	-11	34.6	-	-	-	NAF
GEM/5	Conglomerate - Partially Weathered	8.6	0.140	<0.01	-	0	11	-11	35.6	-	-	-	NAF
GEM/6	Carbonaceous Mudstone - Partially Weathered	7.5	0.430	0.01	-	0	10	-9	31.4	-	-	-	NAF
GEM/8	Conglomerate	7.4	0.575	0.04	0.01	1	5	-4	2.5	6.8	0	0	NAF
COAL SEAM (BR)													
GEM/9	Siltstone	8.7	0.213	<0.01	-	0	7	-7	21.6	-	-	-	NAF
GEM/10	Sandstone, Siltstone	8.1	0.237	0.01	-	0	8	-7	25.2	-	-	-	NAF
GEM/11	Sandstone	8.3	0.244	0.11	0.06	3	185	-182	55.0	10.4	0	0	NAF
GEM/12	Carbonaceous Mudstone, Siltstone	8.3	0.180	0.01	-	0	6	-6	19.6	7.1	0	0	NAF
COAL SEAM (BC)													
GEM/13	Conglomerate	8.7	0.268	<0.01	-	0	83	-83	272.5	-	-	-	NAF
GEM/14	Sandstone	8.9	0.188	<0.01	-	0	8	-8	27.5	-	-	-	NAF
GEM/15	Carbonaceous Mudstone, Sandstone	8.9	0.235	0.01	-	0	12	-11	37.6	-	-	-	NAF
GEM/16	Conglomerate	8.7	0.232	0.01	-	0	10	-9	31.4	-	-	-	NAF
GEM/17	Conglomerate	9.1	0.266	<0.01	-	0	43	-42	138.9	-	-	-	NAF
GEM/18	Sandstone, Siltstone	9.3	0.346	<0.01	-	0	35	-34	112.7	-	-	-	NAF
GEM/19	Conglomerate	9.0	0.294	0.01	-	0	16	-15	51.3	-	-	-	NAF
COAL SEAM (JE)													
GEM/20	Carbonaceous Mudstone	9.2	0.295	<0.01	-	0	15	-15	50.3	-	-	-	NAF
COAL SEAM (JEL)													
GEM/21	Siltstone	8.5	0.262	0.02	-	1	12	-11	19.8	7.4	0	0	NAF
GEM/22	Carbonaceous Mudstone, Sandstone	9.1	0.291	<0.01	-	0	41	-41	135.3	-	-	-	NAF
GEM/23	Conglomerate	9.0	0.297	0.01	-	0	42	-42	137.3	-	-	-	NAF
GEM/24	Sandstone	8.9	0.269	<0.01	-	0	43	-42	138.9	-	-	-	NAF
COAL SEAM (MN)													
GEM/26	Carbonaceous Mudstone	8.9	0.266	0.03	-	1	7	-6	7.8	6.5	0	0	NAF
COAL SEAM (MNL)													
GEM/28	Sandstone, Siltstone	9.1	0.381	0.01	-	0	12	-12	39.5	8.4	0	0	NAF
COAL SEAM (VY)													
GEM/29	Carbonaceous Mudstone	8.5	0.258	0.08	0.07	2	6	-4	2.8	5.2	0	4	NAF
GEM/30	Sandstone, Siltstone	8.6	0.209	<0.01	-	0	9	-9	30.7	-	-	-	NAF
GEM/31	Sandstone	9.0	0.278	<0.01	-	0	10	-10	31.4	-	-	-	NAF
GEM/32	Carbonaceous Mudstone, Siltstone	8.7	0.139	0.01	-	0	8	-8	26.8	6.3	0	1	NAF
COAL SEAM (NG)													
KEY										ARD Classification Key			
pH _{1:2} = pH of 1:2 extract				NAGpH = pH of NAG liquor						NAF = Non-Acid Forming			
EC _{1:2} = Electrical Conductivity of 1:2 extract (dS/m)				NAG _(pH4.5) = Net Acid Generation capacity to pH 4.5 (kgH ₂ SO ₄ /t)									
MPA = Maximum Potential Acidity (kgH ₂ SO ₄ /t)				NAG _(pH7.0) = Net Acid Generation capacity to pH 7.0 (kgH ₂ SO ₄ /t)									
ANC = Acid Neutralising Capacity (kgH ₂ SO ₄ /t)				ARD = Acid Rock Drainage									
NAPP = Net Acid Producing Potential (kgH ₂ SO ₄ /t)				S = Sulfur									

Table A-2: Exchangeable cations, cation exchange capacity and exchangeable sodium percent for selected overburden samples from drill-hole TA31C.

Sample Code	Sample Description	Exchangeable Cations (meq/100g)				CEC	ESP
		Ca	Mg	K	Na		
GEM/1	Conglomerate - Highly Weathered	12.6	2.6	1.1	0.5	16.8	2.8
GEM/2	Conglomerate - Weathered	7.4	3.1	1.6	0.7	12.8	5.8
GEM/4	Sandstone - Weathered	3.7	6.2	4.4	0.9	15.3	6.2
GEM/5	Conglomerate - Partially Weathered	6.5	3.7	1.1	0.8	12.2	6.7
GEM/6	Carbonaceous Mudstone - Partially Weathered	5.6	12.4	4.4	1.0	23.5	4.5
GEM/8	Conglomerate	5.9	7.7	2.2	0.7	16.5	4.2
GEM/11	Sandstone	27.8	3.2	1.0	0.6	32.5	1.8
GEM/13	Conglomerate	27.2	2.4	1.0	1.0	31.6	3.1
GEM/21	Siltstone	2.6	5.8	1.5	2.1	12.1	17.2
GEM/26	Carbonaceous Mudstone	4.5	5.3	1.7	3.6	15.1	24.2
GEM/29	Carbonaceous Mudstone	3.1	3.9	1.1	2.7	10.8	24.8
<p>KEY meq = Milliequivalent CEC = Cation Exchange Capacity (meq/100g). ESP = Exchangeable Sodium Percent (%).</p>							

Table A-3: Multi-element composition and geochemical abundance indices of selected overburden samples from drill-

Element	Unit	Detection Limit	Sample Description/Code								*Mean Crustal Abundance	Sample Descr				
			Conglomerate			Sandstone		Siltstone	Carb. Mudstone			Conglomerate			Sandst	
			GEM/2	GEM/8	GEM/19	GEM/11	GEM/24	GEM/21	GEM/26	GEM/29		GEM/2	GEM/8	GEM/19	GEM/11	GEM/24
Ag	mg/kg	0.2	<	<	<	<	<	<	<	<	0.07	<1	<1	<1	<1	
Al	%	0.005%	6.04%	8.50%	6.82%	5.90%	6.71%	8.99%	9.02%	7.87%	8.2%	-	-	-	-	
As	mg/kg	2	7	12	5	10	4	8	4	5	1.5	2	2	1	2	
B	mg/kg	50	59	53	<	<	<	<	<	<	10	2	2	<2	<2	
Ba	mg/kg	0.1	664.5	495.8	613.8	4713.4	804.2	593.6	535.9	718.0	500	-	-	-	3	
Be	mg/kg	0.1	1.8	2.2	1.8	1.2	1.4	2.1	1.9	2.5	2.6	-	-	-	-	
Ca	%	0.005%	0.23%	0.20%	0.36%	6.40%	1.74%	0.13%	0.12%	0.09%	4.0%	-	-	-	-	
Cd	mg/kg	0.1	<	<	<	<	<	0.1	0.2	<	0.11	-	-	-	-	
Co	mg/kg	0.1	4.0	12.0	5.0	4.1	4.0	12.6	12.3	5.9	20	-	-	-	-	
Cr	mg/kg	5	15	13	16	12	13	35	45	54	100	-	-	-	-	
Cu	mg/kg	1	7	4	10	4	4	17	27	24	50	-	-	-	-	
Fe	%	0.01%	1.11%	1.12%	0.74%	3.60%	0.86%	1.81%	0.87%	1.22%	4.1%	-	-	-	-	
Hg	mg/kg	0.01	0.02	0.05	0.02	0.01	0.02	0.04	0.06	0.03	0.05	-	-	-	-	
K	%	0.002%	3.03%	3.47%	2.69%	1.61%	2.34%	2.85%	2.40%	2.05%	2.1%	-	-	-	-	
Mg	%	0.002%	0.15%	0.34%	0.26%	1.11%	0.41%	0.46%	0.41%	0.33%	2.3%	-	-	-	-	
Mn	mg/kg	1	154	101	116	520	111	91	49	148	950	-	-	-	-	
Mo	mg/kg	0.1	0.7	0.8	0.7	1.4	0.7	1.5	1.3	0.5	1.5	-	-	-	-	
Na	%	0.002%	0.96%	0.57%	0.76%	0.79%	0.23%	0.29%	0.16%	0.13%	2.3%	-	-	-	-	
Ni	mg/kg	1	11	22	12	14	6	27	24	22	80	-	-	-	-	
P	mg/kg	50	147	156	165	140	148	312	372	303	1000	-	-	-	-	
Pb	mg/kg	2	13	12	13	10	14	20	22	17	14	-	-	-	-	
Sb	mg/kg	0.05	0.80	0.74	0.59	0.35	0.44	0.65	0.76	0.71	0.2	1	1	1	-	
Se	mg/kg	0.01	<	0.02	0.01	<	<	0.09	0.11	0.33	0.05	-	-	-	-	
Si	%	0.1%	36.5%	34.1%	36.6%	26.0%	33.5%	32.0%	30.8%	27.7%	27.7%	-	-	-	-	
Sn	mg/kg	0.1	2.4	4.6	2.4	1.4	1.7	2.7	3.5	3.4	2.2	-	-	-	-	
Th	mg/kg	0.01	8.47	8.23	8.77	5.91	8.79	9.77	11.20	9.62	12	-	-	-	-	
U	mg/kg	0.01	1.98	1.46	1.96	1.59	1.90	3.02	2.71	2.20	2.4	-	-	-	-	
V	mg/kg	2	35	48	38	26	31	86	111	98	160	-	-	-	-	
Zn	mg/kg	1	42	124	39	24	32	183	104	46	75	-	-	-	-	

< element at or below analytical detection limit. *Bowen H.J.M.(1979) Environmental Chemistry of the Elements.

Table A-4: Chemical composition of water extracts from selected overburden samples from drill-hole TA31C.

Parameter	Detection Limit	Sample Description/Code							
		Conglomerate			Sandstone		Siltstone	Carb. Mudstone	
		GEM/2	GEM/8	GEM/19	GEM/11	GEM/24	GEM/21	GEM/26	GEM/29
pH	0.1	8.7	7.4	9.0	8.3	8.9	8.5	8.9	8.5
EC dS/m	0.001	0.143	0.575	0.294	0.244	0.269	0.262	0.266	0.258
Al mg/l	0.01	0.26	0.03	0.99	0.28	0.11	0.44	0.88	0.67
B mg/l	0.01	<	0.01	<	<	<	<	<	<
Ca mg/l	0.01	3.38	46.19	1.99	18.04	2.52	0.48	0.47	0.42
Cr mg/l	0.01	<	<	<	<	<	<	<	<
Cu mg/l	0.001	0.011	0.005	0.009	0.002	0.006	0.005	0.021	0.011
Fe mg/l	0.01	0.03	<	0.37	<	<	0.05	0.08	0.08
K mg/l	0.1	6.3	14.2	2.3	11.6	3.5	2.9	2.1	2.1
Mg mg/l	0.01	3.66	42.17	1.02	10.99	2.71	0.70	0.47	0.44
Mn mg/l	0.001	0.002	0.171	0.007	0.005	0.002	<	<	<
Na mg/l	0.1	26.4	39.7	81.9	27.1	75.5	67.7	77.5	77.7
Ni mg/l	0.001	<	0.032	<	<	<	<	0.002	0.002
P mg/l	0.05	<	<	<	<	<	<	<	<
Si mg/l	0.05	5.94	4.9	1.58	2.79	2.31	2.78	4.23	4.04
SO ₄ mg/l	0.3	12.5	341.3	71.1	35.2	50.4	120.7	76.8	59.7
V mg/l	0.01	<	<	<	<	<	<	0.03	0.02
Zn mg/l	0.01	<	0.02	<	0.01	<	0.01	0.02	<
Ag ug/l	0.01	<	<	0.01	0.02	<	0.02	<	<
As ug/l	0.1	2.7	4.4	54.7	10.7	21.6	37.2	112.8	62.8
Ba ug/l	0.05	13.44	44.57	84.78	155.63	25.09	18.85	18.60	19.43
Be ug/l	0.1	0.2	<	<	0.1	0.2	0.3	0.2	0.3
Cd ug/l	0.02	0.05	0.05	0.10	0.08	1.09	0.05	0.11	0.95
Co ug/l	0.1	0.1	17.8	0.8	0.5	0.3	1.3	3.2	0.8
Hg ug/l	0.1	<	<	<	<	<	<	<	<
Mo ug/l	0.05	3.25	16.95	90.88	70.34	32.63	104.30	219.71	48.34
Pb ug/l	0.5	<	<	0.5	0.8	<	0.5	2.1	7.0
Sb ug/l	0.01	0.86	0.64	2.86	1.56	1.88	6.94	9.56	3.39
Se ug/l	0.5	0.6	5.2	8.1	2.8	4.2	32.2	63.7	84.2
Sn ug/l	0.1	0.2	0.2	0.3	0.2	0.5	0.2	0.2	0.1
Th ug/l	0.005	0.032	0.008	0.022	0.006	0.009	0.036	0.059	0.078
U ug/l	0.005	0.760	0.063	0.346	0.151	0.098	0.125	0.201	0.118

< element at or below analytical detection limit.