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Stuart Colliery Geochemical Assessment

First Draft Report

Version - 1

March 2012

Clean Stream Environmental Consultants
GCS Project Number: 11-365

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EXECUTIVE SUMMARY

GCS (Pty) Ltd was appointed by Clean Stream Environmental Consultants for the environmental geochemical assessment of the Stuart Colliery. Based on the results of the geochemical assessment, the following conclusions could be made:

Sampling

- Based on the distribution of sampling points and analytical results received it was concluded that the rock and waste samples are representative of the backfill material in terms of its environmental geochemical character;
- Enough samples were taken from each lithology in order to observe the geochemical characteristics;

Mineralogy

- The mineralogical test results show that pyrite is present in various rock samples. Oxidation of pyrite will release products of acid mine drainage (AMD), including metals, sulphate and acidity;
- The presence of carbonate minerals will contribute to neutralisation AMD to some degree. However, the test results indicated that all rock material (including coal, discard, clastic rocks like sandstone) have very low carbonate mineral content;

Acid-base Accounting (ABA) and Net Acid Generation (NAG) test

- The *coal and discard* have a very high %S (> 0.3 %) and most of these samples are likely to generate acidic drainage based on their %S and NP/AP ratio. From the limited number of samples taken it seems as if the potential for acid generating for different coal seams increase as follows: No. 3/4 < No. 2 < No. 5 < No. 6. The No. 3/4 coal seam samples have the lowest %S; while the No. 2 coal seam samples have a higher neutralising potential (NP) than the other coal seams;
- The NAG test results confirmed the high potential for acidification for coal and discard. Most samples were classified as having a low to high capacity for acid generation;
- The *sandstone* samples from the opencast have almost no neutralisation potential, however, the %S is also low with about 73% of the samples having a %S below 0.1. Only the sandstone samples between the No. 5 and No. 6 coal seams in the Weltevreden Pit have a %S of between 0.1 - 0.3. The sandstone will in general not produce acid drainage but also do not have any neutralisation potential to neutralise the acidity from other rock types;

- The *shale* interburden between the No. 2 and No. 3/4 coal seams in the East Pit has a %S below 0.3 and has no net acid generating potential. The shale directly overlying the No. 5 coal seam in the Weltevreden Pit has a high %S and has some potential to generate acidic drainage. The %S decreases, however, upwards in the shale sequence, probably due to the distance from the seam and due to weathering. Forty-three (43) % of the shale samples have a high potential to generate acidic drainage;

Potential impact on drainage quality

- Without consideration of mitigation measures the drainage from the opencast backfill is expected to become acidic over the long-term as the ABA results show that the material has a significant potential to generate acid-mine drainage. Clastic rocks that will be backfilled also have a low neutralisation potential. The future geochemical model will be used to predict the pH and salt load in the drainage water from the mine;
- The discard will have a significant impact on pit water quality if disposed above the decant or equilibrium elevation. Discard above the decant or equilibrium elevation will significantly contribute to acid drainage and the salt load of the mine;
- Discard below the decant or equilibrium elevation will have a much smaller impact on the pit water quality. However, it will be necessary to determine whether enough volume is present below the decant or equilibrium elevation for the co-disposal of the discard. The time that the mine will take to flood is also important as discard below the decant or equilibrium level will still be subjected to oxidation if the mine is unflooded;
- It is not foreseen that significant elevation in metals will occur at near-neutral conditions. After acidification non-compliance for Al, Fe, Mn will occur. Other metals like As, Cd, Cr, Ni, Pb, Sb and V (as identified through peroxide extraction) may also leach out at elevated concentrations; however, significant non-compliance of these metals are unlikely to occur under field conditions.

Management measures

- Several mitigation measures were recommended in the report. Most of the measures relates to 1) containment of seepage/drainage, and 2) flooding or capping of material in order to minimise oxygen infiltration. The effectiveness of the mitigation measures must first be investigated through groundwater and/or geochemical modelling;
- An important management measure relates to the monitoring of mine, surface and groundwater quality; and

- It is recommended that the geochemical model is updated during the life of mine in order to validate and calibrate its results and to construct an effective closure plan.

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1 INTRODUCTION

1.1 Terms of reference

The *Stuart Colliery* is located in the north-western Witbank Coalfield, outside the town of Delmas. GCS (Pty) Ltd was appointed by Clean Stream Environmental Consultants for the environmental geochemical assessment of the *Stuart Colliery*. The scope of work was as follows:

- To determine the geochemical nature of material backfilled in the opencast mines;
- To determine the long-term net acid generation potential of the opencast pits;
- To identify metals that may be present in drainage from the opencast pits; and
- To determine the water quality trends in the pits.

Based on the geochemical assessment, mitigation measures will be recommended in order to minimize any impact on drainage quality from the opencast pits.

This report is an interim data report with a first order impact assessment included. Geochemical modelling will be performed once the mine model data has been finalised. This data includes the actual coal discard volumes at the mine, pit floor contours, coal resource estimation, and spatial thicknesses of coal seams and overburden. From this data the following will be calculated: decant level, pit volume below the decant level, thickness of unsaturated zone of pits after flooding, and estimated time for pits to flood. This data is especially important as discard is co-disposed in the mining pit. The following would be included in the final report:

1) Best localities for in-pit discard disposal;

2) The volume of discard that could be disposed off below the closure pit water level.

3) Predicted pit water quality without co-disposal of discard; and

4) Predicted pit water quality with the co-disposal of discard.

1.2 Regional geological setting

The regional geological setting of the *Stuart Colliery* is given in Figure 1 below. From the geological map the following comments could be made:

- The mine is situated in the north-western Witbank Coalfield. The sedimentary rock in the coalfield had been deposited on top of a pre-Karoo basement comprising of the Transvaal Supergroup or the Bushveld Igneous Complex. At the mine the basement rocks comprise of the Chuniespoort and Pretoria Group of the Transvaal Supergroup;

- On base of the Karoo Supergroup comprises of the Dwyka Group tillite, which is of fluvio-glacial origin. The Dwyka Group is overlain by the Ecca Group. The coal is hosted in the Vryheid Formation of the lower Ecca Group. Regionally, the basement had a significant influence on the nature, distribution and thickness of the overlying sedimentary rocks, especially the coal seam thickness and the coal quality; and
- Five coal seams are recognized in the Vryheid Formation with the No. 1 coal seam at the bottom and the No. 5 coal seam at the top. The No. 2 and No. 4 coal seams are regionally of the largest economical interest. The other coal seams, although often mined, are thinner and more sporadically developed. At the mine the No. 2 to No. 5 coal seams are present and currently mined. A much localised No. 6 coal seam is developed in one part of the Weltevreden Pit. Although rarely mined, the No. 6 coal seam sampled in September 2011 was at least 1 m in thickness and was actually mined during the site visit. The No. 6 seam is also erratically present at the nearby Leeuwpan Mine although it is only a few centimetres thick where present.

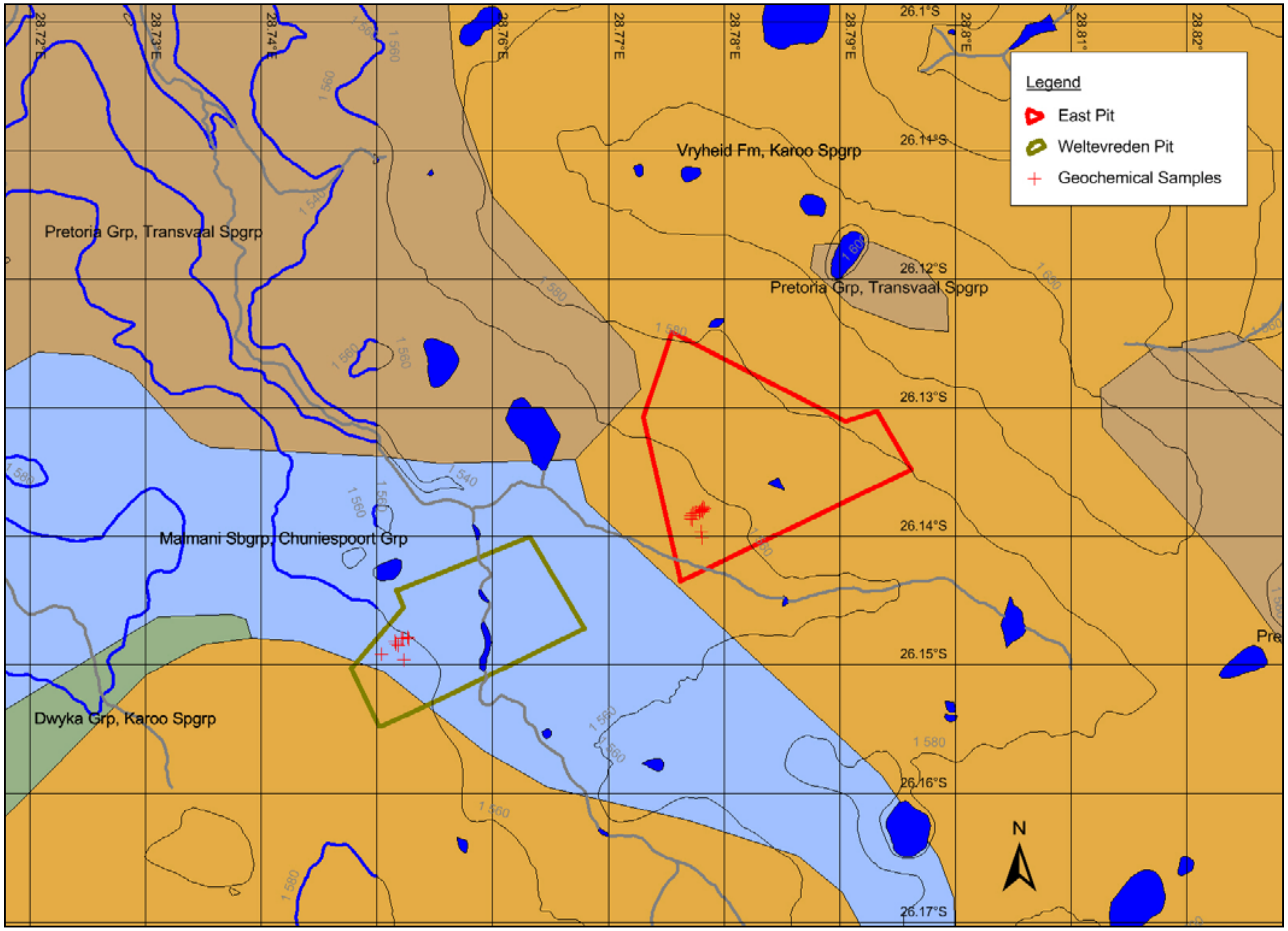

Figure 1: Regional geological setting of the Stuart Colliery and location of geochemical pit samples (simplified from 1:250 000 geological map)

2 ANALYTICAL RESULTS AND INTERPRETATION

2.1 Sampling

A total of 48 samples were taken for geochemical testing. A description of the samples is given in Table 1 below. The distribution of the sampling sites is shown in Figure 1 above. The samples were collected from the following sites:

- 21 coal samples from the two opencast pits;
- 7 shale and 1 siltstone sample from the two opencast pits;
- 11 sandstone samples from the two opencast pits;
- 3 fine spiral discard samples from the plant; and
- 5 coarse discard samples from the plant.

With regard to the representativeness of the sampling the following comments could be made:

- All coal seams and overburden litho-stratigraphical units were sampled in the pit areas accessible for sampling;
- It could be concluded that the samples are representative of the sampled material for the purpose of determining its environmental geochemical character; and
- For quality control about 8% of the samples were analysed in duplicate for certain parameters.

Table 1: Description of geochemical samples

Sample Nr.	Sample name	*	Lithology	Level	Description	Site
D1	Discard 1		Coal discard	Surface	Coarse	Plant
D2	Discard 2		Coal discard	Surface	Coarse	Plant
D3	Discard 3		Coal discard	Surface	Coarse	Plant
D4	Discard 4		Coal discard	Surface	Coarse	Plant
D5	Discard 5		Coal discard	Surface	Coarse	Plant
FD1	Fine Discard 1		Fine Discard	Surface	Fine spiral discard	Plant
FD2	Fine Discard 2		Fine Discard	Surface	Fine spiral discard	Plant
FD3	Fine Discard 3		Fine Discard	Surface	Fine spiral discard	Plant
EP19	Sandstone		Sandstone	Above No.5	Highly weathered	East Pit

Sample Nr.	Sample name	*	Lithology	Level	Description	Site
EP18	Shale		Shale	Above No.5	Soft, Highly Weathered	East Pit
EP17	Siltstone		Siltstone	Above No.5	Weathered	East Pit
EP16	Shale		Shale	Above No.5	-	East Pit
EP15	Shale		Shale	Above No.5	-	East Pit
EP14	Shale		Shale	Above No.5	-	East Pit
EP13	Shale		Shale	Above No.5	-	East Pit
EP12	No. 5 coal seam	5	Coal	No. 5 coal seam	-	East Pit
EP11	No. 5 coal seam	5	Coal	No. 5 coal seam	-	East Pit
EP10	No. 5 coal seam	5	Coal	No. 5 coal seam	-	East Pit
EP9	No. 3/4 coal seam	4	Coal	No. 3/4 coal seam	-	East Pit
EP8	No. 3/4 coal seam	4	Coal	No. 3/4 coal seam	-	East Pit
EP7	No. 3/4 coal seam	4	Coal	No. 3/4 coal seam	-	East Pit
EP6	Shale interburden		Shale	No. 2/3 coal seam interburden	-	East Pit
EP5	Shale interburden		Shale	No. 2/3 coal seam interburden	-	East Pit
EP4	No. 2 coal seam	2	Coal	No. 2 coal seam	-	East Pit
EP3	No. 2 coal seam	2	Coal	No. 2 coal seam	-	East Pit
EP2	No. 2 coal seam	2	Coal	No. 2 coal seam	-	East Pit
EP1	No. 2 coal seam	2	Coal	No. 2 coal seam	-	East Pit
EP0	No. 2 coal seam	2	Coal	No. 2 coal seam	-	East Pit
WP19	Sandstone above Red Sandstone above No.6		Sandstone	Above No. 6	-	Weltevreden pit
WP18	Red Sandstone above No. 6		Sandstone	Above No. 6	Red	Weltevreden pit
WP17	White/Red Sandstone		Sandstone	Above No. 6	White/Red	Weltevreden pit
WP16	Sandstone directly above No.6		Sandstone	Above No. 6	-	Weltevreden pit
WP15	Sandstone directly above No.6		Sandstone	Overlying No. 6 coal seam		Weltevreden pit
WP14	Sandstone directly above No.6		Sandstone	Overlying No. 6 coal seam	-	Weltevreden pit
WP13	White sandstone		Sandstone	Overlying No.6 coal seam	White	Weltevreden pit

Sample Nr.	Sample name	*	Lithology	Level	Description	Site
WP12	White Sandstone		Sandstone	Overlying No.6 coal seam	White	Weltevreden pit
WP11	No.6 coal seam	6	Coal	No.6 coal seam	-	Weltevreden pit
WP10	No.6 coal seam	6	Coal	No.6 coal seam	-	Weltevreden pit
WP9	No.6 coal seam	6	Coal	No.6 coal seam	-	Weltevreden pit
WP8	Sandstone directly below No.6		Sandstone	Underlying No.6 coal seam	-	Weltevreden pit
WP7	Sandstone overlying No. 5		Sandstone	Overlying No. 5 coal seam	-	Weltevreden pit
WP6	No. 5 coal seam	5	Coal	No. 5 coal seam	-	Weltevreden pit
WP5	No. 5 coal seam	5	Coal	No. 5 coal seam	-	Weltevreden pit
WP4	No 3/4 below No 5	4	Coal	No. 3/4 below No. 5 coal seam		Weltevreden pit
WP3	No.3/4 below No. 5	4	Coal	No. 3/4 below No. 5 coal seam		Weltevreden pit
WP2	No. 2 coal seam	2	Coal	No. 2 coal seam	-	Weltevreden pit
WP1	No. 2 coal seam	2	Coal	No. 2 coal seam	-	Weltevreden pit
WP0	No. 2 coal seam	2	Coal	No. 2 coal seam	-	Weltevreden pit

***Black/dark grey = Coal, Orange = Sandstone, Light grey = Shale, Green = Siltstone, Brown = Discard, Light green - Fine discard**

2.2 Mineralogical composition

The mineralogical composition of the rock samples was determined by means of X-ray Diffraction (XRD). The XRD was performed at *XRD Analytical and Consulting*, *Pretoria*. The total element analyses were performed by means of X-ray Fluorescence (XRF) at the *Council for Geoscience*, *Pretoria*. The results are given in Table 2 to 4 below.

The following pertains to the XRD method used:

- The samples were prepared for XRD analysis using a back loading preparation method. They were analysed with a PANalytical X'Pert Pro powder diffractometer with X'Celerator detector and variable divergence- and fixed receiving slits with Fe filtered Co-K radiation. The phases were identified using X'Pert Highscore plus software;
- Amorphous phases were not taken into account in the quantification;
- Trace minerals at concentrations below ±1% are often not detected by means of XRD testing on whole rock samples as the error might become larger than the analyses reported; and

- The weight percentages of the minerals were determined using the Rietveld method (Autoquan Software).

The following comments could be made with regard to the minerals identified in the rock material:

- Quartz (SiO_2) is present as a minor to major mineral in the shale, coal and discard samples. The quartz grains generally have a detrital origin and originate from the felsic mother rock;
- Kaolinite ($Al_2Si_2O_5(OH)_4$) is present as a major to dominant mineral in the shale, coal and discard samples. In most of the samples kaolinite is the dominant mineral instead of quartz. Generally a good correlation between the ash and the kaolinite content in the coal is present in the Vryheid Formation coal. Kaolinite is generally precipitated by authigenic processes during coal formation;
- Mica (muscovite - $KAl_2(Si_3Al)O_{10}(OH,F)_2$) and K-feldspar ($KAlSi_3O_8$) are present as trace to minor minerals in most of the tested samples. K-feldspar forms an incomplete solution series with albite, and will often contain small amounts of Na. These minerals have a detrital origin and originate from the felsic mother rock;
- Plagioclase ($(Na,Ca)(Si,Al)_4O_8$) is present as a trace to minor mineral in some of the rock samples. Previous studies have shown that the plagioclase in the Vryheid Formation is richer in Na than in Ca and have an oligoclase composition;
- Calcite ($CaCO_3$) was present as a trace to minor mineral in most of the samples. No dolomite ($CaMg(CO_3)_2$) or siderite ($FeCO_3$) was detected in the samples. However, these minerals are generally frequently present in the Vryheid Formation rock bearing strata. If more samples were analysed these minerals would most likely be present at least as trace minerals. Siderite may contribute to Mn in the mine water as Mn often replaces some of the Fe in the siderite. Siderite does not contribute to neutralization of acid rock drainage as it only neutralizes the acid generated by the oxidation of its own Fe;
- Rutile and anatase (both TiO_2) are Ti-oxides and has a detrital origin; and
- Pyrite is generally elevated in coal with respect to clastic rocks as it forms under reducing conditions. Pyrite is present as a trace to minor mineral in all samples tested. Pyrite can form during or very shortly after peat accumulation (autigenic) or as veins later in the coal's burial history (epigenetic). Pyrite is elevated in the coal discard as it is concentrated during the beneficiation process.

The following comments could be made with regard to the elemental composition of the rock material:

- SiO_2 is below the average upper earth crust of Rudnick and Gao (2003) especially because of the low quartz content of the tested samples;
- Al_2O_3 is elevated above the average upper crust in most samples where kaolinite is the dominant mineral;
- TiO_2 is often related to the Al_2O_3 content of the clastic rocks and TiO_2 may often even replace the Al in the crystal structure of several minerals;
- CaO is elevated in the fine discard sample that has a high calcite content;
- Several trace elements were elevated above the average upper earth crust. However, very few were elevated more than 2 or 3 times above this reference. Some important exceptions are the elevated As in the No. 6 coal seam sample and the elevated Se in the discard, fine discard and some coal samples. This elevation is however not an indication of the leachability of the trace elements and metals. The leachability was assessed through leaching tests in Section 2.4 and 2.5.

Table 2: XRD results (weight % with error given in brackets)

Sample Nr.	Lithology	*	Anatase	Calcite	Graphite	Kaolinite	K-feldspar	Muscovite	Plagioclase	Pyrite	Quartz	Rutile	Smectite	Total
D1	Discard		1.26 (0.42)	2.67 (0.48)	18.1 (7.5)	64.7 (5.7)	0.98 (0.78)	5.62 (0.81)	0.68 (0.57)	1.71 (0.29)	3.38 (0.45)	0.85 (0.24)	-	99.95
D1	Discard		0.78 (0.45)	2.13 (0.57)	-	76.79 (1.41)	4.04 (0.87)	7.54 (0.84)	0.6 (0.48)	2.04 (0.3)	4.96 (0.48)	1.11 (0.3)	-	99.99
D4	Discard		0.76 (0.36)	1.58 (0.3)	25.1 (6.3)	58.7 (4.8)	1.31 (0.63)	4.86 (0.72)	0.94 (0.6)	0.4 (0.15)	5.22 (0.84)	1.08 (0.25)	-	99.95
D4	Discard		0.27 (0.3)	1.62 (0.54)	-	75.63 (1.41)	5.24 (0.99)	7.46 (0.81)	1.24 (0.84)	0.45 (0.22)	6.45 (0.54)	1.64 (0.33)	-	100
FD1	Fine Discard		3.81 (0.72)	10.55 (1.05)	42.9 (4.8)	34.17 (2.76)	0.46 (0.39)	2.31 (0.39)	0.35 (0.33)	1.66 (0.23)	3.45 (0.39)	0.34 (0.2)	-	100
FD1	Fine Discard		7.16 (1.17)	16.6 (0.87)	-	53.72 (1.5)	5.49 (0.9)	6.18 (0.96)	1 (0.9)	2.68 (0.36)	6.06 (0.63)	1.11 (0.33)	-	100
WP11	Coal	6	0 (0)	0(0)	68.12 (1.2)	6.74 (0.48)	0 (0)	0.22 (0.24)	0.64 (0.29)	5.99 (0.26)	7.38 (0.45)	0 (0)	10.9 (1.11)	99.99
WP11	Coal	6	0 (0)	0 (0)	-	19.36 (2.04)	6.1 (1.53)	0.7 (1.08)	6.69 (1.41)	17.4 (0.96)	21.62 (1.77)	0 (0)	28.18 (2.76)	100.05

Sample Nr.	Lithology	*	Anatase	Calcite	Graphite	Kaolinite	K-feldspar	Muscovite	Plagioclase	Pyrite	Quartz	Rutile	Smectite	Total
EP11	Coal	5	0 (0)	0.26 (0.25)	34.6 (5.7)	44.9 (3.9)	0.74 (0.6)	5.1 (0.75)	0.48 (0.48)	0.24 (0.14)	12.94 (1.32)	0.74 (0.24)	-	100
EP11	Coal	5	0 (0)	0.21 (0.42)	-	65.13 (1.65)	3.45 (1.11)	8.92 (0.96)	1.68 (1.08)	0.29 (0.24)	18.8 (1.29)	1.5 (0.39)	-	100
EP9	Coal	4	1.91 (0.51)	0.99 (0.3)	49.5 (3.6)	35.04 (2.46)	1.2 (0.78)	5 (0.63)	0.59 (0.48)	0.37 (0.12)	4.69 (0.72)	0.67 (0.18)	-	99.96
EP9	Coal	4	1.33 (0.63)	1.17 (0.57)	-	66.65 (1.71)	5.71 (1.14)	10.81 (1.14)	2.25 (1.35)	0.47 (0.3)	9.73 (0.81)	1.88 (0.42)	-	100
EP6	Shale		0 (0)	0.32 (0.25)	18.5 (6.3)	72.8 (5.4)	1.28 (1.05)	3.89 (0.48)	0.5 (0.51)	0.23 (0.15)	1.75 (0.63)	0.76 (0.23)	-	100
EP6	Shale		0 (0)	0.12 (0.3)	-	85.04 (1.47)	3.24 (0.75)	6.75 (0.75)	0.47 (0.42)	0.22 (0.18)	3.06 (0.9)	1.09 (0.26)	-	99.99
EP5	Shale		1.46 (0.36)	2.27 (0.25)	67.55 (1.62)	24.03 (1.05)	0.57 (0.39)	1.69 (0.33)	0.72 (0.39)	0.18 (0.07)	1.3 (0.18)	0.22 (0.16)	-	99.99
EP5	Shale		0.61 (0.57)	6.44 (1.23)	-	66.3 (5.7)	3.4 (7.8)	6.88 (1.32)	5.91 (1.5)	0.15 (0.3)	8.57 (1.05)	1.67 (0.51)	-	100.01

***Black/dark grey = Coal, Orange = Sandstone, Light grey = Shale, Green = Siltstone, Brown = Discard, Light green - Fine discard**

Table 3: XRF major element results (ppm)

Sample name	D1	D4	FD1	W11	EP11	EP9	EP6	EP5	Average Upper Crust (Rudnick and Gao, 2003)
Oxide (%)				6	5	4			
SiO_2	27.22	28	14.43	10.59	34.2	20.96	34.51	9.4	66.6
TiO_2	**1.01**	**1.27**	0.57	0.15	**0.95**	**0.92**	**0.87**	0.28	0.64
Al_2O_3	**20.63**	**20.4**	9.52	3.86	**19.3**	13.84	**27.4**	7.01	15.4
Fe_2O_3(t)	1.35	0.43	1.76	8.86	0.61	0.55	0.35	0.1	11.2
MnO	0.017	0.015	0.097	<0.001	0.003	0.006	0.004	0.011	0.1
MgO	0.45	0.36	0.72	0.11	0.36	0.55	0.16	0.28	2.48
CaO	1.23	0.97	**6.85**	0.15	0.2	0.99	0.2	1.27	3.59
Na_2O	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.03	<0.01	3.27
K_2O	0.27	0.31	0.22	0.18	0.68	0.68	0.34	0.11	2.8
P_2O_5	0.052	0.124	0.053	0.023	0.038	0.038	0.032	0.027	0.15
Cr_2O_3	0.009	0.011	0.007	<0.001	0.01	0.009	0.018	0.002	**See trace**
Total	52.238	51.89	34.227	23.923	56.361	38.543	63.914	18.49	

***Black/dark grey = Coal, Orange = Sandstone, Light grey = Shale, Green = Siltstone, Brown = Discard, Light green - Fine discard**

Table 4: XRF trace element results (ppm)

Sample name	D1	D4	FD1	W11	EP11	EP9	EP6	EP5	Average Upper Crust (Rudnick and Gao, 2003)
Trace				6	5	4			
As	6.4	<4	6.8	36	<4	<4	<4	<4	4.8
Ba	166	201	305	128	152	186	213	75	628
Bi	<3	3.2	<3	<3	<3	<3	<3	<3	0.16
Br	<2	<2	<2	<2	<2	<2	<2	<2	1.6
Ce	123	143	89	56	111	60	84	50	63
Co	4.1	4.1	7.3	10	4.2	3.2	2.9	3.1	17.3
Cr	67	80	62	22	74	67	121	27	92
Cs	7	8.7	5.8	<5	13	31	8.7	<5	4.9
Cu	22	25	16	5.9	15	23	21	4.7	28
Ga	28	30	16	10	26	24	39	9.8	17.5
Ge	<1	1.1	1.5	19	<1	1.8	<1	<1	1.4
Hf	6.9	6.8	<3	<3	6.1	4.9	8.5	<3	5.3
La	74	82	59	35	63	30	44	33	31
Mo	<2	<2	<2	2.2	<2	<2	<2	<2	1.1
Nb	24	30	13	6.8	23	20	24	6	12
Nd	56	63	41	23	49	32	35	22	27
Ni	17	23	20	7.6	16	12	15	8.9	47
Pb	33	43	30	18	31	33	56	45	17

Sample name	D1	D4	FD1	W11	EP11	EP9	EP6	EP5	Average Upper Crust (Rudnick and Gao, 2003)
Trace				6	5	4			
Rb	20	22	11	13	50	67	24	6.2	82
Sc	14	17	14	6.4	15	14	20	5.9	14
Se	1.6	1.3	2.3	<1	1.7	<1	<1	<1	0.09
Sm	11	12	<10	<10	<10	<10	<10	<10	4.7
Sr	101	253	367	54	53	115	66	133	320
Ta	<2	<2	<2	<2	<2	<2	<2	<2	0.9
Th	16	21	7.7	<3	16	14	30	3.8	10.5
Tl	<3	<3	<3	<3	<3	<3	<3	<3	0.9
U	8.4	9.6	5.4	2.8	7.2	6.8	6.2	3.9	2.7
V	71	78	57	30	80	54	63	16	97
W	4.8	4.6	<3	<3	3.3	3.1	<3	<3	1.9
Y	37	49	31	11	37	27	35	17	21
Yb	4.3	5.9	4.9	<3	4.6	3.8	5.1	3	2
Zn	17	17	13	7.9	9.7	8.2	8.1	7.9	67
Zr	209	295	150	72	249	214	282	90	193

*Black/dark grey = Coal, Orange = Sandstone, Light grey = Shale, Green = Siltstone, Brown = Discard, Light green - Fine discard

2.3 ABA and NAG tests

2.3.1 ABA terminology and screening methods

Acid-Base Accounting (ABA) is a static test where the net potential of the rock to produce acidic drainage is assessed. This test provides an important first order assessment of the potential drainage that could be expected from the rock material. A description of the different ABA components is given below:

- AP (Acid Potential) is determined by multiplying %S with a factor of 31.25. The unit of AP is kg $CaCO_3$/t rock and indicates the theoretical amount of calcite that could be neutralized by the acid produced; and
- The NP (Neutralization Potential) is determined by treating a sample with a known excess of standardized hydrochloric or sulfuric acid (the sample and acid are heated to insure reaction completion). The paste is then back-titrated with standardized sodium hydroxide in order to determine the amount of unconsumed acid. NP is also expressed as kg $CaCO_3$/t rock as to represent the amount of calcite theoretically available to neutralize the acidic drainage.

In order for the material to be classified in terms of their ARD potential, the ABA results could be screened in terms of its NNP (Net Neutralization Potential), %S and NP:AP ratio as follows:

- NNP is determined by subtracting AP from NP. Therefore, a rock with NNP < 0 kg $CaCO_3$/t will have a net potential for acidic drainage and a rock with NNP > 0 kg $CaCO_3$/t rock will have a net potential for the neutralization of acidic drainage. Because of the uncertainty related to the exposure of the carbonate minerals or the pyrite for reaction, the interpretation of whether a rock will actually be net acid generating or neutralizing is more complex. Research has shown that a range from -20 kg $CaCO_3$/t to 20 kg $CaCO_3$/t exists that is defined as a "grey" area in determining the net acid generation or neutralization potential of a rock. Material with a NNP above this range is classified as Rock Type IV - No Potential for Acid Generation and with a NNP below this range as Rock Type I - Likely Acid Generating;
- Further screening criteria could be used that attempts to classify the rock in terms of its net potential for acid production or neutralization. The following screening methods given in Table below, as proposed by Price (1997), use the NP:AP ratio to classify the rock in terms of its potential for acid generation; and
- Soregaroli and Lawrence (1998) further states that samples with less than 0.3% sulphide sulphur are regarded as having insufficient oxidisable sulphides to sustain

long term acid generation. Material with a %S below 0.3% is therefore classified as Rock Type IV - No Potential for Acid Generation, and material with a %S of above 0.3%, as Rock Type I - Likely Acid Generating.

Table 5: Screening methods using the NP:AP ratio (Price, 1997)

Potential for Acid Generation	NP:AP screening criteria	Comments
Rock Type I. Likely Acid Generating.	< 1:1	Likely AMD generating.
Rock Type II. Possibly Acid Generating.	1:1 – 2:1	Possibly AMD generating if NP is insufficiently reactive or is depleted at a faster rate than sulphides.
Rock Type III. Low Potential for Acid Generation.	2:1 – 4:1	Not potentially AMD generating unless significant preferential exposure of sulphides along fracture planes, or extremely reactive sulphides in combination with insufficient reactive NP.
Rock Type IV. No Potential for Acid Generation.	>4:1	No further AMD testing required unless materials are to be used as a source of alkalinity.

2.3.2 NAG test terminology and screening methods

In the Net-acid Generating (NAG) test hydrogen peroxide (H_2O_2) is used to oxidize sulfide minerals in order to predict the acid generation potential of the sample. The NAG test provides a direct assessment of the potential for a material to produce acid after a period of exposure (to a strong oxidant) and weathering. The test can be used to refine the results of the ABA predictions.

In general, the static NAG test involves the addition of 250 ml of 15% H_2O_2 to 2.5 g of sample in a 500 ml wide mouth conical flask, or equivalent. The sample is covered with a watch glass, and placed in a fumehood or well ventilated area. Once "boiling" or effervescing ceases, the solution is allowed to cool to room temperature and the final pH (NAG pH) is determined. A quantitative estimation of the amount of net acidity remaining (the NAG capacity) in the sample is determined by titrating it with NaOH to pH 4.5 (and/or pH 7.0) to obtain the NAG Value.

In order to determine the acid generation potential of a sample, the screening method given in Table 6 of Miller et al. (1997) is used.

Table 6: NAG test screening method (edited from Miller et al., 1997)

Rock Type	NAG pH	NAG Value (H_2SO_4 kg/t)	NNP ($CaCO_3$ kg/t)
Rock Type Ia. High Capacity Acid Forming.	< 4	> 10	Negative
Rock Type Ib. Lower Capacity Acid Forming.	< 4	≤ 10	-
Uncertain, possibly Ib.	< 4	> 10	Positive
Uncertain.	≥ 4	0	Negative (Reassess mineralogy)*
Rock Type IV. Non-acid Forming.	≥ 4	0	Positive

* If non- or low acid forming sulphides is dominant then Rock Type IV.

2.3.3 ABA and NAG test results

Acid-base Accounting (ABA) and Net-Acid Generating (NAG) tests were performed by Waterlab (Pty) Ltd. The test results are presented as follows:

- The ABA results are presented in Table 7 below;
- The classification in terms of %S and NP/AP is depicted in Figure 2;
- A summary of the ABA results are given in Table 8;
- The potential of the different lithologies to generate acid-mine drainage is summarized in Table 9; and
- The NAG test results are presented in Table 10 below.

From the ABA and NAG test results the following observations could be made:

- The NP/AP indicates the potential for the rock to generate acid drainage, whereas the %S indicates whether this drainage will be sustained over the long term. In Figure 2 the red lines assess the acid production potential, while the yellow line assesses the long term acid generation potential;
- The total S% (determined by means of a *Leco* analyser) was used to determine the Acid Potential (AP) of the rock. This is an overestimation as it assumes that all the sulphur in the rock will be acid-producing. Pyrite was the only sulphide detected in the rock through means of XRD. It was assumed that oxidation of pyrite will be the only contributor to acidity;
- The sandstone samples from the opencast has almost no neutralisation potential and about 73% of the sandstone has a %S of below 0.1 %S. Only the sandstone

samples between the No. 5 and No. 6 coal seams in the Weltevreden Pit have a %S between 0.1 - 0.3. The sandstone will not produce acid drainage but also do not have any neutralisation potential to neutralise the acidity from other rock types;

- The shale interburden between the No.2 and No. 3/4 coal seams in the East Pit has a %S of below 0.3 and is not classified as having any potential to generate net acidity. The shale directly overlying the No. 5 coal seam in the Weltevreden Pit has a high %S and has some potential to generate acidic drainage. The %S decreases however upwards in the shales, probably due to both the distance from the seam and due to weathering. Forty-three (43) % of the shale samples has a high potential to generate acidic drainage;
- The one siltstone sample overlying the No. 5 coal seam has no potential to generate acidic drainage due to the low %S;
- The coal discard and fine discard samples have a high potential for acid generation. The %S is higher in the discard than in the average raw coal due to the concentration of pyrite in discard during beneficiation. The %S in the discard is however comparable to the %S in the No. 5 coal seam;
- The coal samples all have a high potential to generate acidic drainage. From the limited number of samples taken it seems as if the potential for acid generating increases as follows: No. 3/4 < No. 2 < No. 5 < No. 6. The No. 3/4 coal seam samples have relatively lower %S; while the No. 2 coal seam samples have a higher NP compared to other coal seams (see Table 8); and
- The NAG test results in Table 10 confirmed the high potential for acidification of the coal and coarse discard samples. It seems from the NAG test results that the fine spiral discard may just have enough neutralisation potential to prevent acidification.

Table 7: Acid-base accounting results

Sample Nr.	Lithology	*	Paste pH	Total %S	AP CaCO3 kg/t	NP CaCO3 kg/t	NNP CaCO3 kg/t	NP/AP	Rock Type NNP	Rock Type %S	Rock Type NP/AP
D1	Discard 1		**7.8**	0.98	30.54	19.67	-10.88	0.64	Uncertain	I	I
D2	Discard 2		**8.2**	0.39	12.24	14.33	2.09	1.17	Uncertain	I	II
D3	Discard 3		**7.7**	1.88	58.61	19.42	-39.18	0.33	I	I	I
D4	Discard 4		**8**	0.24	7.37	7.06	-0.32	0.96	Uncertain	IV	I
D5	Discard 5		**7.5**	3.55	110.81	18.21	-92.60	0.16	I	I	I
FD1	Fine Discard 1		**7.6**	1.21	37.79	61.66	23.87	1.63	IV	I	II
FD3	Fine Discard 3		**7.9**	1.16	36.32	63.12	26.80	1.74	IV	I	II
EP19	Sandstone		**7.9**	0.01	0.31	0.00	-0.31	0.00	Uncertain	IV	I
EP18	Shale		**6.6**	0.01	0.31	0.00	-0.31	0.00	Uncertain	IV	I
EP18D	Shale		**6.4**	0.01	0.31	0.00	-0.31	0.00	Uncertain	IV	I
EP17	Siltstone		**6.7**	0.01	0.35	2.21	1.86	6.34	Uncertain	IV	IV
EP16	Shale		**4.7**	0.18	5.58	0.00	-5.58	0.00	Uncertain	IV	I
EP16D	Shale		**4.1**	0.18	5.58	0.00	-5.58	0.00	Uncertain	IV	I
EP15	Shale		**3.6**	0.88	27.49	0.75	-26.74	0.03	I	I	I
EP14	Shale		**4.9**	0.47	14.64	0.51	-14.14	0.03	Uncertain	I	I
EP13	Shale		**3.6**	0.72	22.64	1.96	-20.68	0.09	I	I	I
EP12	No. 5 coal seam	5	**7.1**	0.25	7.69	0.00	-7.69	0.00	Uncertain	IV	I

Sample Nr.	Lithology	*	Paste pH	Total %S	AP CaCO3 kg/t	NP CaCO3 kg/t	NNP CaCO3 kg/t	NP/AP	Rock Type NNP	Rock Type %S	Rock Type NP/AP
EP11	No. 5 coal seam	5	**6.8**	0.18	5.55	0.00	-5.55	0.00	Uncertain	IV	I
EP10	No. 5 coal seam	5	**7.3**	0.17	5.18	0.99	-4.19	0.19	Uncertain	IV	I
EP9	No. 3/4 coal seam	4	**8.1**	0.28	8.74	17.73	8.98	2.03	Uncertain	IV	III
EP8	No. 3/4 coal seam	4	**7.4**	0.35	11.02	30.23	19.20	2.74	Uncertain	I	III
EP7	No. 3/4 coal seam	4	**6.8**	0.37	11.49	0.00	-11.49	0.00	Uncertain	I	I
EP7D	No. 3/4 coal seam	4	**6.9**	0.37	11.49	0.00	-11.49	0.00	Uncertain	I	I
EP6	Shale interburden		**7.1**	0.03	0.94	0.00	-0.94	0.00	Uncertain	IV	I
EP6D	Shale interburden		**6.5**	0.09	2.96	0.00	-2.96	0.00	Uncertain	IV	I
EP5	Shale interburden		**7.9**	0.22	6.76	13.01	6.24	1.92	Uncertain	IV	II
EP3	No. 2 coal seam	2	**7.7**	3.25	101.58	66.51	-35.07	0.65	I	I	I
EP2	No. 2 coal seam	2	**7.9**	0.34	10.48	17.00	6.52	1.62	Uncertain	I	II
EP1	No. 2 coal seam	2	**8.1**	0.18	5.51	0.00	-5.51	0.00	Uncertain	IV	I
EP0	No. 2 coal seam	2	**8.1**	0.16	5.09	0.00	-5.09	0.00	Uncertain	IV	I
WP19	Sandstone		**7.3**	0.01	0.31	0.00	-0.31	0.00	Uncertain	IV	I
WP18	Sandstone		**6.5**	0.01	0.31	0.00	-0.31	0.00	Uncertain	IV	I
WP17	Sandstone		**6.4**	0.01	0.31	0.00	-0.31	0.00	Uncertain	IV	I
WP16	Sandstone		**7.9**	0.01	0.31	0.00	-0.31	0.00	Uncertain	IV	I
WP15	Sandstone		**6.9**	0.01	0.31	0.00	-0.31	0.00	Uncertain	IV	I

Sample Nr.	Lithology	*	Paste pH	Total %S	AP CaCO3 kg/t	NP CaCO3 kg/t	NNP CaCO3 kg/t	NP/AP	Rock Type NNP	Rock Type %S	Rock Type NP/AP
WP14	Sandstone		**6.9**	0.01	0.31	0.00	-0.31	0.00	Uncertain	IV	I
WP13	Sandstone		**7.4**	0.01	0.31	0.00	-0.31	0.00	Uncertain	IV	I
WP12	Sandstone		**7.4**	0.01	0.31	0.00	-0.31	0.00	Uncertain	IV	I
WP11	Coal	6	**3.3**	7.16	223.88	0.00	-223.88	0.00	I	I	I
WP10	Coal	6	**7**	0.44	13.90	0.00	-13.90	0.00	Uncertain	I	I
WP9	Coal	6	**6.5**	0.37	11.64	0.00	-11.64	0.00	Uncertain	I	I
WP8	Sandstone		**7.6**	0.16	4.92	0.00	-4.92	0.00	Uncertain	IV	I
WP7	Sandstone		**3.5**	0.18	5.74	0.00	-5.74	0.00	Uncertain	IV	I
WP7D	Sandstone		**3.6**	0.18	5.74	0.00	-5.74	0.00	Uncertain	IV	I
WP6	Coal	5	**2.6**	4.47	139.82	0.27	-139.55	0.00	I	I	I
WP5	Coal	5	**3.7**	3.03	94.74	0.00	-94.74	0.00	I	I	I
WP4	Coal	4	**7.7**	0.29	9.09	0.00	-9.09	0.00	Uncertain	IV	I
WP3	Coal	4	**7.2**	0.20	6.11	0.00	-6.11	0.00	Uncertain	IV	I
WP2	Coal	2	**7.5**	1.43	44.76	0.75	-44.01	0.02	I	I	I
WP1	Coal	2	**8.2**	0.42	13.21	42.75	29.54	3.24	IV	I	III
WP0	Coal	2	**7.5**	0.62	19.24	10.45	-8.79	0.54	Uncertain	I	I

***Black/dark grey = Coal, Orange = Sandstone, Light grey = Shale, Green = Siltstone, Brown = Discard, Light green - Fine discard**

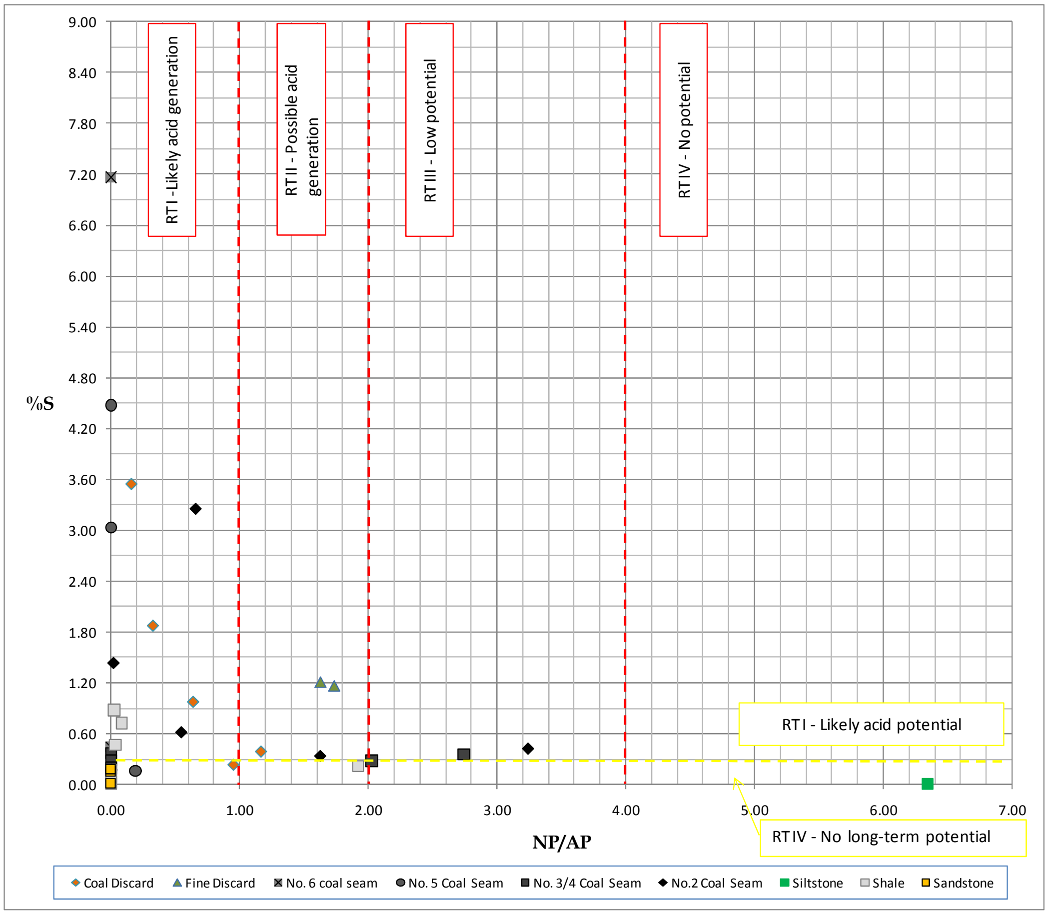

Figure 2: Classification of samples in terms of %S and NP/AP (only samples with NP/AP < 7 are shown)

Table 8: Acid-base accounting (ABA) results - average for various lithologies

Lithology	Number of Samples	Total %S	AP $CaCO_3$ kg/t	NP $CaCO_3$ kg/t	NNP $CaCO_3$ kg/t	NP/AP	Rock Type NNP	Rock Type %S	Rock Type NP/AP
Coal Discard	5	1.41	43.91	15.74	-28.18	0.65	I	I	I
Fine Discard	2	1.19	37.06	62.39	25.33	1.68	IV	I	II
No. 6 Coal Seam	3	2.66	83.14	0.00	-83.14	0.00	I	I	I
No. 5 coal seam	5	1.62	50.59	0.25	-50.34	0.00	I	I	I
No. 3/4 coal seam	5	0.30	9.29	9.59	0.30	1.03	Uncertain	IV	II
No. 2 coal seam	7	0.91	28.55	19.64	-8.92	0.69	Uncertain	I	I
Sandstone	11	0.04	1.23	0.00	-1.23	0.00	Uncertain	IV	I
Shale	7	0.29	9.07	1.80	-7.27	0.23	Uncertain	IV	I
Siltstone	1	0.01	0.35	2.21	1.86	6.34	Uncertain	IV	IV

Table 9: Potential for rock units to generate acidic drainage (% of samples)

Criteria	Number of samples	Rock Type (%S) I Rock Type (NP/AP) I or II	Rock Type (%S) I Rock Type (NP/AP) III or IV	%S 0.1 - 0.3 Rock Type (NP/AP) I or II	%S 0.1 - 0.3 Rock Type (NP/AP) III or IV	%S <0.1 Rock Type (NP/AP) I or II	%S <0.1 Rock Type (NP/AP) III or IV
Coal Discard	5	80%		20%			
Fine Discard	2	100%					
No. 6 Coal Seam	3	100%					
No. 5 Coal Seam	5	60%		40%			
No. 3/4 Coal Seam	5	40%		40%	20%		
No. 2 Coal Seam	7	40%	29%	29%			
Sandstone	11			27%		73%	
Shale	7	43%		29%		29%	
Siltstone	1						100%
Potential for acid mine drainage		HIGH	MEDIUM/ LOW	MEDIUM/ LOW	NO	NO	NO
		Likely/ possibly acid generating High salt load	Low to medium potential for acid generation Low to medium salt load	Low to medium potential for acid generation Low to medium salt load	No potential for acid generation Low to medium salt load	No potential for acidic drainage Very low salt load over short term	No potential for acidic drainage Very low/no salt load

Table 10: Net acid generation (NAG) test results

Sample Nr.	*	NAG pH (H_2O_2)	NAG value (kg H_2SO_4/t)	NNP ($CaCO_3$ kg/t)	Rock Type NAG
D1		3.9	4.31	-10.88	1a
D2		2.6	80.95	2.09	Uncertain, possibly Ib.
D3		2.3	54.88	-39.18	1a
D4		6.6	<0.01	-0.32	Uncertain

Sample Nr.	*	NAG pH (H_2O_2)	NAG value (kg H_2SO_4/t)	NNP ($CaCO_3$ kg/t)	Rock Type NAG
D5		2.2	39.2	-92.60	1a
FD1		4.4	1.37	23.87	IV
FD3		4	9.8	26.80	IV
WP11	6	1.9	66.64	-223.88	Ia
EP11	5	3	18.42	-5.55	Ia
EP9	4	4.5	<0.01	8.98	IV
EP6		5.3	<0.01	-0.94	IV
EP5		2.6	95.06	6.24	Uncertain, possibly Ib.

***Black/dark grey = Coal, Orange = Sandstone, Light grey = Shale, Green = Siltstone, Brown = Discard, Light green - Fine discard**

2.4 Static leaching test

Selected material was submitted for leach testing. System parameters and anions measured in the leachate are listed in Table 11, with the ICP-OES analytical results listed in Table 12. The following pertain to the leaching test methods used:

- Leaching tests identify the elements that will leach out of waste but do not reflect the site-specific concentration of these elements in actual seepage as a different water/rock ratio and contact time will be present in the field;
- The material was leached with a peroxide extraction; and
- For the peroxide extraction a rock/water ratio of 1:100 was used where 2.5 g of the sample was reacted with 250 ml of 15% hydrogen peroxide;

From the leaching test results the following observations could be made:

- It is important to note that the peroxide extraction simulates extreme conditions where all the sulphide minerals are oxidised at once, which will never happen under field conditions. Under field conditions 1) not all sulphides will be oxidised as some minerals are physically shielded by the rock matrix, and 2) oxidation will occur over a longer period of time;
- In the extraction tests the elevation of SO_4 is a direct result of the sulphide oxidation; and
- It is not foreseen that any metals will leach at non-compliant concentrations from near-neutral mine water, except for Al, Fe and Mn that may leach at variable complaint concentrations. If the mine water acidifies other metals like As, Cd, Cr, Ni, Pb, Sb and V (as identified through peroxide extraction) may also leach out. However, significant non-compliance of these metals is unlikely to occur under field conditions.

Table 11: System parameters and major anions in leachate

Sample Id	Description/ Rock Type	*	pH (value)	EC mS/m	TDS (mg/l)	Total Alk (mg/l)	SO_4 (mg/l)	Cl (mg/l)	NO_3 (mg/l)	F (mg/l)
Discard 1	Discard		3.9	138	925	<5	302	16	36	<0.2
Discard 4	Discard		6.5	96.3	645	132	83	<5	3.1	<0.2
Fine discard	Fine discard		4.4	139	931	<5	315	15	33	<0.2
W11	Coal	6	2.1	427	2861	<5	848	<5	5.1	<0.2
EP11	Coal	5	3.3	90.2	604	<5	74	6	<0.2	<0.2
EP9	Coal	4	4.5	120	804	<5	114	<5	<0.2	<0.2
EP6	Shale		5.3	70.7	474	<5	31	<5	<0.2	<0.2
EP5	Shale		2.6	173	1159	<5	<5	15	<0.2	<0.2
SANS 241:2011	0-50% of limit		6 - 8.4	<85	<600	-	<250	<150	<5.5	<0.75
	50-100% of limit		5-6; 8.4-9.7	85-170	600-1200	-	250-500	150-300	5.5-11	0.75-1.5
	Outside limit		<5; >9.7	>170	>1200	-	>500	>300	>11	>1.5

*Black/dark grey = Coal, Orange = Sandstone, Light grey = Shale, Green = Siltstone, Brown = Discard, Light green - Fine discard

Table 12: ICP-OES results of peroxide extraction test

Sample	D1	D4	FD1	W11	EP11	EP9	EP6	EP5	SANS 241: 2011		
Description	Discard	Discard	Fine Discard	Coal	Coal	Coal	Shale	Shale			
Parameters (ppm)				6	5	4			0-50% of limit	50-100% of limit	Outside limit
Ag	1.430	0.369	0.077	<0.025	1.432	2.830	0.511	1.909	-	-	-
Al	9.065	2.59	1.445	1.290	15.036	6.035	9.731	4.152	<0.15	0.15-0.3	>0.3
As	0.034	<0.010	<0.010	0.141	<0.010	0.015	<0.010	<0.010	<0.005	0.005-0.01	>0.01
B	0.086	0.036	0.123	<0.025	0.192	0.152	0.049	0.061	-	-	-
Ba	0.064	<0.025	0.03	0.053	0.324	0.079	0.084	0.37	-	-	-
Be	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	-	-	-
Bi	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	-	-	-
Ca	79	41	119	3	10	58	7	75	-	-	-
Cd	<0.005	<0.005	<0.005	0.01	<0.005	<0.005	<0.005	<0.005	<0.0015	0.0015-0.003	>0.003
Co	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.25	0.25-0.5	>0.5
Cr	0.173	0.190	0.206	<0.025	0.331	0.271	0.394	0.117	<0.025	0.025-0.05	>0.05
Cu	0.288	0.133	0.109	0.079	0.105	0.242	0.152	0.132	<1	1-2	>2
Fe	39.113	0.04	2.987	252	7.292	7.65	0	3	<1	1-2	>2
K	<1.0	<1.0	<1.0	<1.0	2.6	2.1	1.4	<1.0	-	-	-
Li	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	-	-	-
Mg	18	10	32	<2	4	16	3	11	-	-	-
Mn	1.222	0.375	4.981	0.323	0.075	0.370	0.092	0.742	<0.25	0.25-0.5	>0.5
Mo	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	-	-	-
Na	<2	<2	<2	<2	<2	<2	<2	<2	<100	100-200	>200
Ni	0.073	0.063	0.086	0.049	0.087	0.060	0.040	0.044	<0.035	0.035-0.07	>0.07
P	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	-	-	-
Pb	<0.020	<0.020	<0.020	<0.020	0.033	0.020	<0.020	0.413	<0.005	0.005-0.01	>0.01
Sb	0.172	0.094	0.067	<0.010	<0.010	0.013	0.071	0.052	<0.01	0.01-0.02	>0.02
Se	<0.020	0.024	<0.020	<0.020	0.025	<0.020	<0.020	<0.020	<0.005	0.005-0.01	>0.01

Sample	D1	D4	FD1	W11	EP11	EP9	EP6	EP5	SANS 241: 2011		
Description	Discard	Discard	Fine Discard	Coal	Coal	Coal	Shale	Shale			
Parameters (ppm)				6	5	4			0-50% of limit	50-100% of limit	Outside limit
Si	6.5	8.4	1.7	1.4	12.4	5.4	15.5	2.8	-	-	-
Sn	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	-	-	-
Sr	0.529	0.200	1.426	0.028	0.160	0.397	0.138	0.61	-	-	-
Ti	1.334	0.344	0.06	<0.025	1.445	2.877	0.438	1.89	-	-	-
V	**0.201**	**0.266**	**0.174**	<0.025	**0.309**	**0.183**	**0.260**	0.069	<0.1	**0.1-0.2**	**>0.2**
W	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	-	-	-
Zn	0.101	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.041	<2.5	**2.5-5.0**	**>5**
Zr	<0.025	<0.025	<0.025	<0.025	0.029	<0.025	<0.025	0.166	-	-	-

***Black/dark grey = Coal, Orange = Sandstone, Light grey = Shale, Green = Siltstone, Brown = Discard, Light green - Fine discard**

2.5 Kinetic leaching test

The following pertains to the kinetic leach test:

- The aim of the test was to 1) observe what chemicals will leach from the sampled rock over time, and to 2) determine the pyrite oxidation rate;
- 2000 g of the sample was leached weekly with 1000 ml deionised water and the leachate was analysed for several parameters;
- The following samples were subjected to column leach testing:
  - Discard Sample 1 (Crushed)
  - Discard Sample 1 (Not crushed)
  - Discard Sample 4 (Crushed)
  - Discard Sample 4 (Not crushed)
  - Fine Discard (FD1)
  - EP9 No. 3/4 Coal Seam
  - EP4 No. 2 Coal Seam.

Changes in parameters in the weekly leachate are provided in Table 13 to 19. The following observations relate to the kinetic leaching test results:

- The leachate was neutral in all samples over the tested period. Leachate from Discard Sample 1 is likely to become acidic over time based on the ABA test results;
- TDS and SO_4 decreased significantly from a maximum during the first few weeks. The higher initial salt load could be attributed to leaching of secondary minerals (already oxidised), especially sulphate minerals. There would typically more sulphate minerals in discard than in raw coal - therefore the discard (even if it has a similar %S than the raw coal) would initially have leachate with a larger salt load;
- The salt load from the Crushed Discard 1 Sample was 2 - 3 times higher than for the sample that had not been crushed. The salt load from the Crushed Discard 4 Sample was 20 - 25 times higher than for the sample that had not been crushed. The salt load from the fine discard was initially also much higher than for the coarse discard. The salt load from the coal samples were much lower than for the discard samples; and
- Metals in secondary minerals are more readily released into solution than those in the primary minerals. Therefore, metals will be higher in leachate during the first few weeks. The leaches were not acidic and very few metals were present at the near neutral conditions. Al, Fe, Mn, Ni and Se were erratically elevated in the leach of various of the samples.

Table 13: Analyses of weekly leach - Discard Sample 1 (Crushed)

Sample	Discard 1 (Crushed)						SANS 241:2011		
Date	Week 0	Week 1	Week 2	Week 7	Week 10	Week 15	Class I	Class II	Non-compliant
pH (value)	8.16	8.14	8.05	7.79	7.79	7.54	6.-8.4	5-6; 8.4-9.7	<5; >9.7
EC mS/m	83.2	40.5	71.30	39.80	37.50	30.70	<85	85-170	>170
TDS (mg/l)	624	258	512.58	235.42	219.65	180.05	<600	600-1200	>1200
Ca (mg/l)	115.0	47.0	94.10	48.43	45.66	38.91	-	-	-
Mg (mg/l)	39.3	15.1	30.10	13.77	11.32	10.67	-	-	-
Na (mg/l)	13.9	10.00	11.30	8.02	6.74	2.64	<100	100-200	>200
K (mg/l)	5.13	2.54	4.04	2.47	2.09	1.43	-	-	-
Si (mg/l)	4.4	4.81	5.66	2.51	2.18	2.04	-	-	-
Total Alk (mg/l)	83	72	72.70	81.80	82.30	70.70	-	-	-
SO_4 (mg/l)	385	124.9	316	102.00	91.90	80.50	<250	250-500	>500
Cl (mg/l)	10.36	9.68	8.21	5.87	5.98	0.67	<150	150-300	>300
NO_3 as N (mg/l)	0.97	1.297	1.04	0.87	1.02	0.91	<5.5	5.5-11	>11
F (mg/l)	0.113	0.144	0.12	0.16	0.15	0.16	<0.75	0.75 - 1.5	>1.5
Suspended solids	76.80	24.40	79.20	-	-	-	-	-	-
Al (mg/l)	0.020	0.020	0.03	<0.01	<0.01	0.01	<0.15	0.15-0.3	>0.3
Fe (mg/l)	<0.01	<0.01	<0.01	0.01	0.01	<0.01	<1	1-2	>2
Mn (mg/l)	0.220	<0.01	<0.01	0.14	0.25	0.27	<0.25	0.25-0.5	>0.5
Hg (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.003	0.003	>0.006
NH_4 as N (mg/l)	0.447	0.02	0.02	0.09	0.05	0.11	<0.75	0.75-1.5	>1.5
Ag (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
As (mg/l)	0.006	<0.005	<0.005	0.01	0.01	<0.005	<0.005	0.005-0.01	>0.01
Au (mg/l)	0.039	0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
B (mg/l)	0.061	0.04	0.06	0.09	0.10	0.08	-	-	-
Ba (mg/l)	0.239	0.210	0.20	0.14	0.14	0.13	-	-	-
Be (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Bi (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Cd (mg/l)	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.0015	0.0015	>0.003
Cr (mg/l)	<0.01	<0.01	<0.01	0.02	0.02	0.02	<0.025	0.025-0.05	>0.05
Co (mg/l)	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.25	0.25-0.5	>0.5
Cu (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<1	1-2	>2
Dy (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-

Sample	Discard 1 (Crushed)						SANS 241:2011		
Date	Week 0	Week 1	Week 2	Week 7	Week 10	Week 15	Class I	Class II	Non-compliant
Er (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Eu (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Ga (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Gd (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
In (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
La (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Li (mg/l)	0.02	<0.01	0.01	<0.01	<0.01	<0.01	-	-	-
Lu (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
P (mg/l)	<0.01	<0.01	<0.01	0.48	0.51	0.7	-	-	-
Pb (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.005	0.005-0.1	>0.01
Mo (mg/l)	<0.01	0.01	0.02	<0.01	<0.01	<0.01	-	-	-
Ni (mg/l)	0.07	<0.01	<0.01	0.074	0.059	0.066	<0.035	0.035-0.07	>0.07
S (mg/l)	131	38.9	105	26.1	22.5	19.6	-	-	-
Sb (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01-0.02	>0.02
Sc (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Se (mg/l)	0.04	0.02	0.04	<0.005	<0.005	<0.005	<0.005	0.005-0.01	>0.01
Sr (mg/l)	0.640	0.279	0.50	0.427	0.648	0.488	-	-	-
Sn (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Te (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Tb (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Tl (mg/l)	<0.01	<0.01	<0.01	<0.01	0.016	<0.01	-	-	-
Th (mg/l)	0.09	0.04	0.08	0.044	0.041	0.034	-	-	-
Ti (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
U (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.0075	0.0075-0.015	<0.015
V (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.2	0.1-0.2	>0.2
W (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Y (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Yb (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Zn (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<2.5	2.5-5	>5
Zr (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-

Table 14: Analyses of weekly leach - Discard Sample 1 (Not Crushed)

Sample	Discard 1 (Not crushed)						SANS 241:2011		
Date	Week 0	Week 1	Week 2	Week 7	Week 10	Week 15	Class I	Class II	Non-compliant
pH (value)	7.52	7.26	7.19	4.55	7.17	6.86	6 - 8.4	5-6; 8.4-9.7	<5; >9.7
EC mS/m	43.7	23.3	43.1	20.50	17.4	11.3	<85	85-170	>170
TDS (mg/l)	295	146.17	287.68	116.50	96.42	56.85	<600	600-1200	>1200
Ca (mg/l)	54.1	23.2	51.4	15.20	16.2	11.76	-	-	-
Mg (mg/l)	13.8	8.54	15.30	5.77	5.06	3.9	-	-	-
Na (mg/l)	12.3	12.6	10.9	4.04	6.27	1.172	<100	100-200	>200
K (mg/l)	2.9	1.7	2.2	1.27	1.47	0.656	-	-	-
Si (mg/l)	1.8	**2.36**	**1.81**	1.30	1.12	0.65	-	-	-
Total Alk (mg/l)	36.3	29.50	25.90	0.36	34.9	17.6	-	-	-
SO_4 (mg/l)	176	64.99	**179.86**	65.80	31.1	26.25	<250	250-500	>500
Cl (mg/l)	9.04	11.1	8	6.33	5.66	0.39	<150	150-300	>300
NO_3 as N (mg/l)	0.974	1.4	1	1.93	1.69	0.01	<5.5	5.5-11	>11
F (mg/l)	0.032	0.1	0.0	0.17	0.13	0.14	<0.75	0.75 - 1.5	>1.5
Suspended solids	144	134	325	-	-	-	-	-	-
Al (mg/l)	0.020	0.03	0.07	<0.01	<0.01	0.01	<0.15	0.15-0.3	>0.3
Fe (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	0.017	<1	1-2	>2
Mn (mg/l)	0.200	0.02	0.05	7.40	0.333	0.127	<0.25	0.25-0.5	>0.5
Hg (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.003	0.003	>0.006
NH_4 as N (mg/l)	0.341	0.04	0.067	0.05	0.06	0.11	<0.75	0.75-1.5	>1.5
Ag (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
As (mg/l)	<0.005	<0.005	0.005	0.01	0.008	0.005	<0.005	0.005-0.01	>0.01
Au (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
B (mg/l)	0.029	<0.01	0.032	0.05	0.04	0.014	-	-	-
Ba (mg/l)	0.136	0.127	0.141	0.11	0.09	0.07	-	-	-
Be (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Bi (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Cd (mg/l)	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.0015	0.0015 - 0.003	>0.003
Cr (mg/l)	<0.01	<0.01	<0.01	0.02	0.019	0.018	<0.025	0.025-0.05	>0.05
Co (mg/l)	0.029	<0.01	0.0	<0.01	<0.01	<0.01	<0.25	0.25-0.5	>0.5
Cu (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<1	1-2	>2
Dy (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-

Sample	Discard 1 (Not crushed)						SANS 241:2011		
Date	Week 0	Week 1	Week 2	Week 7	Week 10	Week 15	Class I	Class II	Non-compliant
Er (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Eu (mg/l)	<0.01	<0.01	<0.01	-	-	-	-	-	-
Ga (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Gd (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
In (mg/l)	<0.001	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
La (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Li (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Lu(mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
P (mg/l)	<0.01	<0.01	<0.01	0.54	0.54	0.54	-	-	-
Pb (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.005	0.005-0.1	>0.01
Mo (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Ni (mg/l)	0.161	0.106	0.241	0.088	0.053	0.05	<0.035	0.035-0.07	>0.07
S (mg/l)	58.200	20.6	58.5	10	7.98	8	-	-	-
Sb (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01-0.02	>0.02
Sc (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Se (mg/l)	0.008	<0.005	0.013	<0.005	<0.005	<0.005	<0.005	0.005-0.01	>0.01
Sr (mg/l)	0.30	0.121	0.261	0.243	0.244	0.223	-	-	-
Sn (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Te (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Tb (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Tl (mg/l)	<0.01	<0.01	<0.01	0.011	<0.01	<0.01	-	-	-
Th (mg/l)	0.032	0.007	0.032	0.021	0.017	0.011	-	-	-
Ti (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
U (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.0075	0.0075-0.015	<0.015
V (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.2	0.1-0.2	>0.2
W (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Y (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Yb (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Zn (mg/l)	<0.01	<0.01	0.011	<0.01	<0.01	<0.01	<2.5	2.5-5	>5
Zr (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-

Table 15: Analyses of weekly leach - Discard Sample 4 (Crushed)

Sample	Stuart Discard Sample 4 (Crushed)					SANS 241:2011		
Date	Week 0	Week 1	Week 2	Week 6	Week 10	Class I	Class II	Non-compliant
pH (value)	7.82	7.75	7.55	7.90	7.80	6.-8.4	5-6; 8.4-9.7	<5; >9.7
EC mS/m	87.5	41.6	46.40	51.00	33.70	<85	85-170	>170
TDS (mg/l)	655	271	312.27	301.82	203.91	<600	600-1200	>1200
Ca (mg/l)	113.0	53.6	59.00	50.10	42.73	-	-	-
Mg (mg/l)	48.6	18.0	19.50	32.37	10.49	-	-	-
Na (mg/l)	12.4	8.93	8.10	4.53	2.261	<100	100-200	>200
K (mg/l)	5.61	3.11	2.26	2.06	1.83	-	-	-
Si (mg/l)	7.5	4.73	3.89	2.99	1.97	-	-	-
Total Alk (mg/l)	136	89	82.50	116.00	92.80	-	-	-
SO_4 (mg/l)	374	110.4	155.04	122.00	77.10	<250	250-500	>500
Cl (mg/l)	12.54	13.19	11.04	6.91	0.59	<150	150-300	>300
NO_3 as N (mg/l)	1.48	2.269	1.68	1.45	0.01	<5.5	5.5-11	>11
F (mg/l)	0.191	0.186	0.09	0.17	0.16	<0.75	0.75 - 1.5	>1.5
Suspended solids	766.00	38.40	129.00	-	-	-	-	-
Al (mg/l)	0.030	0.04	0.02	<0.01	<0.01	<0.15	0.15-0.3	>0.3
Fe (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<1	1-2	>2
Mn (mg/l)	0.200	0.090	0.10	5.72	10.40	<0.25	0.25-0.5	>0.5
Hg (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.003	0.003	>0.006
NH_4 as N (mg/l)	0.129	0.07	0.07	0.07	0.13	<0.75	0.75-1.5	>1.5
Ag (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
As (mg/l)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005-0.01	>0.01
Au (mg/l)	<0.01	0.01	<0.01	<0.01	<0.01	-	-	-
B (mg/l)	0.081	0.07	<0.01	0.08	0.06	-	-	-
Ba (mg/l)	0.331	0.240	0.16	0.11	0.10	-	-	-
Be (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Bi (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Cd (mg/l)	<0.003	<0.003	<0.003	<0.003	<0.003	<0.0015	0.0015	>0.003
Cr (mg/l)	<0.01	<0.01	<0.01	0.021	0.02	<0.025	0.025-0.05	>0.05
Co (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.25	0.25-0.5	>0.5
Cu (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<1	1-2	>2
Dy (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-

Sample	Stuart Discard Sample 4 (Crushed)					SANS 241:2011		
Date	Week 0	Week 1	Week 2	Week 6	Week 10	Class I	Class II	Non-compliant
Er (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Eu (mg/l)	<0.01	<0.01	<0.01	-	-	-	-	-
Ga (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Gd (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
In (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
La (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Li (mg/l)	0.02	<0.01	<0.01	0.026	0.02	-	-	-
Lu(mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
P (mg/l)	0.02	0.03	0.02	0.59	0.79	-	-	-
Pb (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.005	0.005-0.1	>0.01
Mo (mg/l)	0.02	0.01	0.01	<0.01	<0.01	-	-	-
Ni (mg/l)	0.03	0.102	0.05	0.069	0.058	<0.035	0.035-0.07	>0.07
S (mg/l)	125.00	38.700	47.80	32.7	18.7	-	-	-
Sb (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01-0.02	>0.02
Sc (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Se (mg/l)	0.08	0.03	0.04	<0.005	<0.005	<0.005	0.005-0.01	>0.01
Sr (mg/l)	0.754	0.312	0.33	0.412	0.041	-	-	-
Sn (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Te (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Tb (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Th (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Tl (mg/l)	0.10	0.04	0.04	0.056	0.04	-	-	-
Ti (mg/l)	0.014	<0.01	<0.01	<0.01	<0.01	-	-	-
U (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.0075	0.0075-0.015	<0.015
V (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.2	0.1-0.2	>0.2
W (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Y (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Yb (mg/l)	0.051	0.014	0.018	<0.01	<0.01	-	-	-
Zn (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<2.5	2.5-5	>5
Zr (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-

Table 16: Analyses of weekly leach - Discard Sample 4 (Not Crushed)

Sample	Stuart Discard Sample 4 (Not Crushed)					SANS 241:2011		
Date	Week 0	Week 1	Week 2	Week 6	Week 10	Class I	Class II	Non-compliant
pH (value)	7.42	7.41	7.27	7.15	7.10	6.-8.4	5-6; 8.4-9.7	<5; >9.7
EC mS/m	14.0	17.6	11.40	7.46	5.31	<85	85-170	>170
TDS (mg/l)	87	107	72.47	37.09	29.21	<600	600-1200	>1200
Ca (mg/l)	16.1	18.5	10.50	7.61	5.34	-	-	-
Mg (mg/l)	3.8	5.8	3.93	2.56	2.18	-	-	-
Na (mg/l)	6.8	9.80	7.90	2.06	1.263	<100	100-200	>200
K (mg/l)	1.30	1.84	1.26	0.85	0.56	-	-	-
Si (mg/l)	1.4	1.96	1.63	0.71	0.44	-	-	-
Total Alk (mg/l)	32	51	29.80	25.70	20.70	-	-	-
SO_4 (mg/l)	19	15.3	10.86	3.53	4.02	<250	250-500	>500
Cl (mg/l)	10.59	13.06	10.90	0.62	0.25	<150	150-300	>300
NO_3 as N (mg/l)	2.19	2.560	1.97	0.17	0.01	<5.5	5.5-11	>11
F (mg/l)	0.012	0.029	0.02	0.14	0.16	<0.75	0.75 - 1.5	>1.5
Suspended solids	494.00	2.00	9.20	-	-	-	-	-
Al (mg/l)	0.240	0.03	0.16	0.04	0.053	<0.15	0.15-0.3	>0.3
Fe (mg/l)	0.02	<0.01	<0.01	<0.01	<0.01	<1	1-2	>2
Mn (mg/l)	0.020	0.040	<0.01	0.974	0.406	<0.25	0.25-0.5	>0.5
Hg (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.003	0.003	>0.006
NH_4 as N (mg/l)	0.091	0.11	0.16	0.09	0.14	<0.75	0.75-1.5	>1.5
Ag (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
As (mg/l)	<0.005	<0.005	0.01	<0.005	<0.005	<0.005	0.005-0.01	>0.01
Au (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
B (mg/l)	<0.01	0.04	<0.01	0.03	0.01	-	-	-
Ba (mg/l)	0.519	0.504	0.22	0.08	0.05	-	-	-
Be (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Bi (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Cd (mg/l)	<0.003	<0.003	<0.003	<0.003	<0.003	<0.0015	0.0015	>0.003
Cr (mg/l)	<0.01	<0.01	<0.01	0.02	0.02	<0.025	0.025-0.05	>0.05
Co (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.25	0.25-0.5	>0.5
Cu (mg/l)	<0.01	<0.01	<0.01	0.01	<0.01	<1	1-2	>2
Dy (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Er (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-

Sample	Stuart Discard Sample 4 (Not Crushed)					SANS 241:2011		
Date	Week 0	Week 1	Week 2	Week 6	Week 10	Class I	Class II	Non-compliant
Eu (mg/l)	<0.01	<0.01	<0.01	-	-	-	-	-
Ga (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Gd (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
In (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
La (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Li (mg/l)	<0.01	<0.01	<0.01	0.021	0.02	-	-	-
Lu(mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
P (mg/l)	0.02	0.03	0.03	0.78	0.75	-	-	-
Pb (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.005	0.005-0.1	>0.01
Mo (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Ni (mg/l)	<0.01	<0.01	<0.01	0.036	0.026	<0.035	0.035-0.07	>0.07
S (mg/l)	6.73	6.130	3.53	1.9	1.23	-	-	-
Sb (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01-0.02	>0.02
Sc (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Se (mg/l)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005-0.01	>0.01
Sr (mg/l)	0.147	0.138	0.06	0.493	0.581	-	-	-
Sn (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Te (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Tb (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Th (mg/l)	<0.01	<0.01	<0.01	0.007	0.006	-	-	-
Tl (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Ti (mg/l)	0.011	<0.01	<0.01	<0.01	<0.01	-	-	-
U (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.0075	0.0075-0.015	<0.015
V (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.2	0.1-0.2	>0.2
W (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Y (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Yb (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Zn (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<2.5	2.5-5	>5
Zr (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-

Table 17: Analyses of weekly leach - Fine discard Sample 1

Sample.	Stuart Fine Discard Sample 1					SANS 241:2011		
Date	Week 0	Week 1	Week 2	Week 6	Week 10	Class I	Class II	Non-compliant
pH (value)	7.51	7.42	7.77	7.95	7.56	6 - 8.4	5-6; 8.4-9.7	<5; >9.7
EC mS/m	152.0	159.0	126.00	44.40	22.80	<85	85-170	>170
TDS (mg/l)	1471	1535	1145.18	261.42	146.81	<600	600-1200	>1200
Ca (mg/l)	291.0	294.0	234.00	65.29	32.41	-	-	-
Mg (mg/l)	85.9	95.6	60.70	10.67	4.97	-	-	-
Na (mg/l)	13.4	14.40	11.20	7.76	2.69	<100	100-200	>200
K (mg/l)	4.92	5.32	4.02	2.38	1.09	-	-	-
Si (mg/l)	2.5	3.03	2.91	2.17	1.20	-	-	-
Total Alk (mg/l)	44	57	59.00	119.00	64.80	-	-	-
SO_4 (mg/l)	1040	1081.7	789.53	91.90	51.87	<250	250-500	>500
Cl (mg/l)	5.41	5.97	6.69	8.61	1.57	<150	150-300	>300
NO_3 as N (mg/l)	0.94	0.836	0.71	0.12	0.01	<5.5	5.5-11	>11
F (mg/l)	0.029	0.029	0.02	0.15	0.18	<0.75	0.75 - 1.5	>1.5
Suspended solids	11.00	4.40	30.40	-	-	-	-	-
Al (mg/l)	0.030	0.03	0.04	<0.01	0.015	<0.15	0.15-0.3	>0.3
Fe (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<1	1-2	>2
Mn (mg/l)	0.080	0.130	0.21	0.92	10.20	<0.25	0.25-0.5	>0.5
Hg (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.003	0.003	>0.006
NH_4 as N (mg/l)	0.039	0.13	0.13	0.09	0.08	<0.75	0.75-1.5	>1.5
Ag (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
As (mg/l)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005-0.01	>0.01
Au (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
B (mg/l)	0.017	0.044	0.025	0.09	0.05	-	-	-
Ba (mg/l)	0.163	0.108	0.07	0.13	0.08	-	-	-
Be (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Bi (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Cd (mg/l)	<0.003	<0.003	<0.003	<0.003	<0.003	<0.0015	0.0015	>0.003
Cr (mg/l)	<0.01	<0.01	<0.01	0.02	0.02	<0.025	0.025-0.05	>0.05
Co (mg/l)	0.02	0.01	<0.01	<0.01	0.01	<0.25	0.25-0.5	>0.5
Cu (mg/l)	<0.01	<0.01	<0.01	<0.01	0.02	<1	1-2	>2
Dy (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-

Sample.	Stuart Fine Discard Sample 1					SANS 241:2011		
Date	Week 0	Week 1	Week 2	Week 6	Week 10	Class I	Class II	Non-compliant
Er (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Eu (mg/l)	<0.01	<0.01	<0.01	-	-	-	-	-
Ga (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Gd (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
In (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
La (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Li (mg/l)	0.02	0.02	0.01	0.016	0.05	-	-	-
Lu(mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
P (mg/l)	<0.01	0.02	<0.01	0.54	0.90	-	-	-
Pb (mg/l)	<0.01	<0.01	0.01	<0.01	<0.01	<0.005	0.005-0.01	>0.01
Mo (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Ni (mg/l)	0.12	0.069	0.09	0.064	0.118	<0.035	0.035-0.07	>0.07
S (mg/l)	472.00	472.000	324.00	22.8	10.5	-	-	-
Sb (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01-0.02	>0.02
Sc (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Se (mg/l)	0.01	0.01	<0.005	<0.01-	<0.01	<0.005	0.005-0.01	>0.01
Sr (mg/l)	2.548	2.548	1.65	0.094	0.085	-	-	-
Sn (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Te (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Tb (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Tl (mg/l)	<0.01	<0.01	<0.01	<0.01	0.012	-	-	-
Th (mg/l)	0.16	0.18	0.13	0.036	0.018	-	-	-
Ti (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
U (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.0075	0.0075-0.015	<0.015
V (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.2	0.1-0.2	>0.2
W (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Y (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Yb (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Zn (mg/l)	0.03	0.02	0.02	<0.01	<0.01	<2.5	2.5-5	>5
Zr (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-

Table 18: Analyses of weekly leach - Sample EP9 No. 3/4 Coal Seam

Sample.	EP9 No. 3/4 Coal Seam					SANS 241:2011		
Date	Week 0	Week 1	Week 2	Week 6	Week 10	Class I	Class II	Non-compliant
pH (value)	8.07	7.99	7.77	7.87	7.85	6.-8.4	5-6; 8.4-9.7	<5; >9.7
EC mS/m	29.3	23.2	22.70	37.80	26.80	<85	85-170	>170
TDS (mg/l)	176	138	135.42	218.40	144.88	<600	600-1200	>1200
Ca (mg/l)	33.2	26.0	26.10	39.97	29.32	-	-	-
Mg (mg/l)	13.6	10.4	10.50	13.87	10.43	-	-	-
Na (mg/l)	10.6	9.78	8.49	10.21	2.84	<100	100-200	>200
K (mg/l)	4.93	3.68	3.36	3.78	2.43	-	-	-
Si (mg/l)	4.3	3.66	4.77	2.33	1.69	-	-	-
Total Alk (mg/l)	97	84	88.60	119.00	101.00	-	-	-
SO_4 (mg/l)	41	21.4	11.74	63.29	31.58	<250	250-500	>500
Cl (mg/l)	6.77	7.73	11.06	6.40	0.48	<150	150-300	>300
NO_3 as N (mg/l)	1.49	1.68	2.30	1.47	0.01	<5.5	5.5-11	>11
F (mg/l)	1.030	0.563	0.48	0.07	0.07	<0.75	0.75 - 1.5	>1.5
Suspended solids	971.00	178.00	128.00	-	-	-	-	-
Al (mg/l)	0.200	0.05	0.04	<0.01	<0.01	<0.15	0.15-0.3	>0.3
Fe (mg/l)	0.01	<0.01	<0.01	<0.01	<0.01	<1	1-2	>2
Mn (mg/l)	<0.01	<0.01	<0.01	1.03	4.94	<0.25	0.25-0.5	>0.5
Hg (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.003	0.003	>0.006
NH_4 as N (mg/l)	0.211	0.36	0.16	0.05	0.10	<0.75	0.75-1.5	>1.5
Ag (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
As (mg/l)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005-0.01	>0.01
Au (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
B (mg/l)	0.162	0.10	0.08	0.15	0.13	-	-	-
Ba (mg/l)	1.082	0.903	0.83	0.38	0.21	-	-	-
Be (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Bi (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Cd (mg/l)	<0.003	<0.003	<0.003	<0.003	<0.003	<0.0015	0.0015	>0.003
Cr (mg/l)	<0.01	<0.01	<0.01	0.02	0.02	<0.025	0.025-0.05	>0.05
Co (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.25	0.25-0.5	>0.5
Cu (mg/l)	<0.01	<0.01	<0.01	0.01	0.01	<1	1-2	>2
Dy (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-

Sample.	EP9 No. 3/4 Coal Seam					SANS 241:2011		
Date	Week 0	Week 1	Week 2	Week 6	Week 10	Class I	Class II	Non-compliant
Er (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Eu (mg/l)	<0.01	<0.01	<0.01	-	-	-	-	-
Ga (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Gd (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
In (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
La (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Li (mg/l)	<0.01	<0.01	<0.01	0.049	0.03	-	-	-
Lu(mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
P (mg/l)	0.02	0.02	0.02	0.51	0.58	-	-	-
Pb (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.005	0.005-0.1	>0.01
Mo (mg/l)	0.03	0.03	0.02	<0.01	<0.01	-	-	-
Ni (mg/l)	**<0.01**	**<0.01**	**<0.01**	**0.081**	**0.112**	<0.035	0.035-0.07	>0.07
S (mg/l)	11.70	5.220	4.05	15.5	8.63	-	-	-
Sb (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01-0.02	>0.02
Sc (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Se (mg/l)	**0.05**	**0.03**	**0.02**	**<0.005**	**<0.005**	<0.005	0.005-0.01	>0.01
Sr (mg/l)	0.741	0.551	0.54	0.216	0.586	-	-	-
Sn (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Te (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Tb (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Th (mg/l)	0.02	0.01	0.01	0.05	0.038	-	-	-
Tl (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Ti (mg/l)	0.031	<0.01	<0.01	<0.01	<0.01	-	-	-
U (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.0075	0.0075-0.015	<0.015
V (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.2	0.1-0.2	>0.2
W (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Y (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Yb (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Zn (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<2.5	2.5-5	>5
Zr (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-

Table 19: Analyses of weekly leach - Sample Stuart EP4 No. 2 Coal Seam

Sample	EP4 No. 2 Coal Seam					SANS 241:2011		
Date	Week 0	Week 1	Week 2	Week 6	Week 10	Class I	Class II	Non-compliant
pH (value)	7.83	7.86	7.81	7.97	7.81	6.-8.4	5-6; 8.4-9.7	<5; >9.7
EC mS/m	32.4	25.1	22.90	32.20	22.60	<85	85-170	>170
TDS (mg/l)	200	147	136.93	199.07	116.44	<600	600-1200	>1200
Ca (mg/l)	40.4	29.8	27.30	38.95	27.45	-	-	-
Mg (mg/l)	10.8	8.0	7.30	19.54	8.17	-	-	-
Na (mg/l)	9.0	9.00	8.36	8.85	1.9	<100	100-200	>200
K (mg/l)	2.75	2.09	1.74	2.05	0.91	-	-	-
Si (mg/l)	2.9	3.16	2.78	2.38	1.24	-	-	-
Total Alk (mg/l)	91	87	83.20	134.00	106.00	-	-	-
SO_4 (mg/l)	71	31.7	30.64	35.50	6.66	<250	250-500	>500
Cl (mg/l)	5.96	7.65	6.68	5.98	0.48	<150	150-300	>300
NO_3 as N (mg/l)	1.02	1.208	1.06	1.22	0.01	<5.5	5.5-11	>11
F (mg/l)	0.229	0.170	0.13	0.1	0.15	<0.75	0.75 - 1.5	>1.5
Suspended solids	860.00	487.00	184.00	-	-	-	-	-
Al (mg/l)	0.150	0.11	0.03	<0.01	<0.01	<0.15	0.15-0.3	>0.3
Fe (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<1	1-2	>2
Mn (mg/l)	0.050	0.010	<0.01	0.80	4.73	<0.25	0.25-0.5	>0.5
Hg (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.003	0.003	>0.006
NH_4 as N (mg/l)	0.217	0.18	0.03	0.08	0.08	<0.75	0.75-1.5	>1.5
Ag (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
As (mg/l)	<0.005	<0.005	<0.005	<0.005	0.01	<0.005	0.005-0.01	>0.01
Au (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
B (mg/l)	0.032	0.02	<0.01	0.13	0.08	-	-	-
Ba (mg/l)	0.402	0.564	0.51	0.73	0.52	-	-	-
Be (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Bi (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Cd (mg/l)	<0.003	<0.003	<0.003	<0.003	<0.003	<0.0015	0.0015	>0.003
Cr (mg/l)	<0.01	<0.01	<0.01	0.02	0.02	<0.025	0.025-0.05	>0.05
Co (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.25	0.25-0.5	>0.5
Cu (mg/l)	<0.01	<0.01	<0.01	0.01	0.01	<1	1-2	>2
Dy (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Er (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Eu (mg/l)	<0.01	<0.01	<0.01	-	-	-	-	-
Ga (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-

Sample	EP4 No. 2 Coal Seam					SANS 241:2011		
Date	Week 0	Week 1	Week 2	Week 6	Week 10	Class I	Class II	Non-compliant
Gd (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
In (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
La (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Li (mg/l)	<0.01	<0.01	<0.01	0.037	0.03	-	-	-
Lu(mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
P (mg/l)	<0.01	0.02	0.01	0.53	0.72	-	-	-
Pb (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.005	0.005-0.1	>0.01
Mo (mg/l)	0.02	0.02	0.03	<0.01	<0.01	-	-	-
Ni (mg/l)	0.02	<0.01	<0.01	0.033	0.06	<0.035	0.035-0.07	>0.07
S (mg/l)	29.60	9.070	6.67	5.26	3.39	-	-	-
Sb (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01-0.02	>0.02
Sc (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Se (mg/l)	0.01	0.01	0.01	<0.005	<0.005	<0.005	0.005-0.01	>0.01
Sr (mg/l)	0.540	0.399	0.35	0.065	0.434	-	-	-
Sn (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Te (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Tb (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Th (mg/l)	0.02	0.01	0.01	0.037	0.03	-	-	-
Ti (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
U (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
V (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.0075	0.0075-0.015	<0.015
W (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.2	0.1-0.2	>0.2
Y (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Yb (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Zn (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-
Zr (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<2.5	2.5-5	>5

3 IMPACT ASSESSMENT

From the interim results of the study a first order impact assessment was performed. An environmental impact assessment is inherently a prediction of eventualities which could possibly/probably occur in future, based on an interpretation/assessment of data/information available at the time of compilation of such an assessment.

3.1 Conditions required for acid mine drainage

The question that must be answered is: what are the general conditions required for acid mine drainage and will it be met at the mine. The following comments relate to acid mine drainage in general:

- The impact on drainage from a mine or mining waste depends on the interaction between the 1) solid, 2) water, and 3) air phase;
- The degree of acid-mine drainage will depend on the minerals present in order to generate or neutralize acidic drainage, as well as the interaction of the minerals with the oxygen and water;
- Without any of these three phases no acid mine drainage will be possible. For instance, if waste rock material is sealed off from the atmosphere (e.g. through water saturation) then no oxygen ingress is possible with no resultant oxidation of sulphides;

The following comments relate to the water and oxygen ingress into the backfilled opencast pits:

- During the operational phase, water is pumped from the pits in order to keep mine workings dry. The pumped-out water has a low residence time in the pit (short contact period with rock) and no significant increase in the salt load will occur in the pit water;
- After closure the pit water level will rises until it reaches the surface decant elevation or equilibrium level (point at which inflow equals groundwater outflow);
- The pit backfill above the decant or equilibrium elevation will be unsaturated after closure;
- Sulphide oxidation will occur in the unsaturated zone as a result of oxygen infiltration. According to the ABA test results these rocks have a significant potential to generate net acidity;
- A conceptual model of the physico-chemical processes that occur in mining waste in contact with atmosphere is depicted in Figure 3 below:

- Consumption of oxygen will lead to a gradient in oxygen fugacity in the material that initiates oxygen diffusion (flow from high concentration to low concentration). The oxygen concentration will be at its highest in material directly in contact with the atmosphere, and due to its consumption, the oxygen concentration will gradually become depleted within only a few meters;
- Initially only the upper part of the material will be situated in the oxidation zone. The oxidation zone will shift deeper into the material as sulphide minerals are depleted. The temperature in the material will eventually rise due to the oxidation of sulphides. Temperature differences will result in differences in gas pressure that initiate the process of oxygen advection.

From the above discussion the following conclusions could be made:

- With no mitigation acid-mine drainage will occur in the opencast mines as the material contains inadequate neutralisation potential and sufficient sulphides for oxidation. This will especially the case if discard is co-disposed with waste rock in the pits; and
- Discard must be disposed off below the decant or equilibrium level to minimise potential AMD impacts.

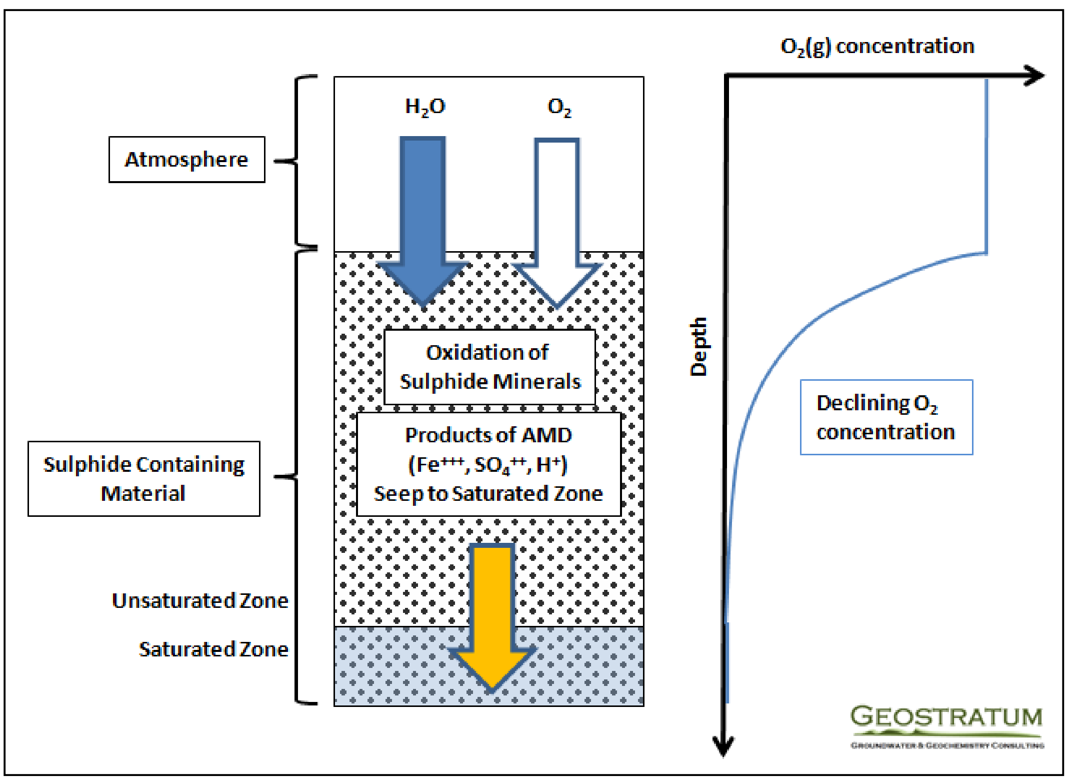

Figure 3: Conceptual model of the physico-chemical processes in a backfilled pit

3.2 Geochemical reactions

The following observations relate to the geochemical reactions in the waste rock and discard material:

- Fe is inherently associated with the pyrite. The reaction of Fe^{2+} in solution under the presence of oxygen at neutral to alkaline conditions is presented in Equation 1 below. Fe^{2+} produced from the sulphide oxidation will hydrolize to form $Fe(OH)_3$ and 2 mol acidity (Equation 1):

$$Fe^{2+} + 2.5H_2O + 0.25O_2(aq) \rightarrow Fe(OH)_3(ppd) + 2H^+ \quad \text{Equation 1}$$

- Pyrite (FeS_2) is present in several of the rock material tested. The net dissolution reaction of pyrite under neutral to alkaline oxidising conditions will form 4 mol of acidity (Equation 3). The intermediate reaction where Fe^{2+} is first formed is also shown below (Equation 2).

$$\text{pyrite} + 3.5O_2(aq) + H_2O \rightarrow Fe^{++} + 2SO_4^{2-} + 2H^+ \quad \text{Equation 2}$$

$$\text{pyrite} + 3.75O_2(aq) + 3.5H_2O \rightarrow Fe(OH)_3(ppd) + 2SO_4^{2-} + 4H^+ \quad \text{Equation 3}$$

- Water serves as the transport medium for the products of acid mine drainage (AMD) as it percolates through the mine/waste material. The water phase also serves as the medium in which dissolution of neutralizing minerals can take place. The acid produced by the oxidation of the sulphide minerals will be consumed by calcite ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$) present in the rock. The neutralisation reactions under neutral to alkaline conditions are given in Equation 4 and 5 below:

$$\text{calcite} + H^+ \rightarrow HCO_3^- + Ca^{++} \quad \text{Equation 4}$$

$$\text{dolomite} + 2H^+ \rightarrow 2HCO_3^- + Ca^{2+} + Mg^{2+} \quad \text{Equation 5}$$

  - Under increasing acid production ($pH < 6.3$) calcite and dolomite will consume additional acidity according to Equation 6 and 7 below:

$$\text{calcite} + 2H^+ \rightarrow CO_2(g) + Ca^{2+} + H_2O \quad \text{Equation 6}$$

$$\text{dolomite} + 4H^+ \rightarrow 2CO_2(g) + Ca^{2+} + Mg^{2+} + 2H_2O \quad \text{Equation 7}$$

- Together with SO_4 the Ca^{2+} produced will form gypsum ($CaSO_4.2H_2O$) as follows:

$$Ca^{2+} + 2H_2O + SO_4^{2-} \rightarrow \text{gypsum} \quad \text{Equation 8}$$

- The formation of gypsum will help to keep SO_4 values below ±2 200 mg/l in drainage water. However, if Ca is produced too slowly, the SO_4 concentration may reach even higher values;
- If all the carbonate minerals are depleted then the seepage from the mine material becomes acidic. Silicate minerals can also consume some of the acidity. However,

silicate minerals react too slowly to prevent acidification in material with a significant potential to generate acidic drainage; and

- In acidic seepage, metals will also be leached out at elevated concentrations and the final stage of AMD would have been reached.

3.3 Impact on pit water quality

The following methodology was followed in order to determine the expected impact on pit water quality:

- The results from the ABA and leaching tests were used in order to determine expected non-compliance that may occur in drainage from the mine;
- Generally, good correlation could be found between leaching test results and drainage from mine material. However, care must always be taken to interpret leaching test results for the following reasons:
  - o The same water:rock ratio is not present in leaching tests than under field conditions;
  - o The same water/rock contact time is not present in leaching tests than under field conditions; and
  - o It is assumed that the samples tested are representative of the mine material.
- It is important that all parameters that are expected to leach at marginal to non-complaint concentrations be included in the monitoring plan. A full spectrum of metal analyses must be included in the monitoring at least twice a year on drainage/seepage/pit water samples.

The following comments relate to the opencast water quality:

- Water quality standards used to determine compliance:
  - o The SANS241:2011 (South African National Standard) was used in order to compare the leaching test results in the report. This standard was used rather as a reference for indicating elevation of parameters than a limit that the mine water must comply with. The actual compliance limits will depend on the end-use/fate of the contaminated water;
- Opencast pits:
  - o Without consideration of mitigation measures the drainage from the opencast' backfill is expected to become acidic over the long-term as the ABA results show that the material has a significant potential to generate acid-mine

drainage. Clastic rocks that will be backfilled also have a low neutralisation potential. The future geochemical model will be used to predict the pH and salt load in the drainage water from the mine;

- The discard will have a significant impact on pit water quality if disposed above the decant elevation. Discard above the decant elevation will significantly contribute to acid drainage and the salt load of the mine;
- Discard below the decant elevation will have a much smaller impact on the pit water quality. However, it will be necessary to determine whether enough volume is present below the decant elevation for the co-disposal of the discard. The time that the mine will take to flood is also important as discard below the decant level will still be subjected to oxidation while the mine is still unflooded;
- It is not foreseen that significant elevation in metals will occur at near-neutral conditions. After acidification non-compliance for Al, Fe, Mn will occur. Other metals like As, Cd, Cr, Ni, Pb, Sb and V (as identified through peroxide extraction) may also leach out at elevated concentrations; however, significant non-compliance of these metals are unlikely to occur under field conditions.

3.4 Management measures

The economical and practical viability, as well as effectiveness of mitigation measures still need to be assessed in further detail, using geochemical modelling. The following general mitigation measures are however proposed:

- During the operational phase mine water must be used or pumped to dirty water dams or pollution control facilities in order to avoid deterioration of the mine water. The longer the mine water resides in the pit the higher its TDS will be. It is not foreseen that mine water in contact with the pit material (and with a short residence time <3 months) will acidify during the operational phase of future mining;
- As much as possible coal must be removed from the opencast mines during the operational phase;
- Carbonaceous clastic rocks should be placed in the deepest part of the pit (as far as practical possible) and below the decant elevation in order to ensure that it is flooded and that pyrite oxidation is minimized;
- Backfilling with discard will prevent the potential impact of a surface discard dump, but will increase the potential AMD from the opencast areas. Discard in the

unsaturated zone of the pits will contribute to additional acidity and salt load from the pit;

- If possible, pits must not be connected with adjacent mining as this will lower the decant elevation and increase the unsaturated zone subjected to oxidation. Connection with adjacent mining may also increase the time to flood. The thickness of the unsaturated zone above the decant elevation must be kept to the minimum and the mine must be allowed to flood as soon as possible;
- Soft overburden and weathered rock must be placed at the top of the backfill in order to minimize oxygen diffusion into the pit;
- The mined out sections of the pit must be backfilled, compacted and rehabilitated as soon as possible. Rehabilitation must include covering with a topsoil layer as well as vegetation thereof. Installation of a soil cover will significantly decrease water infiltration and contamination of water resulting in smaller decant from the pit. If less water is infiltrating it will not have a negative effect on mine water quality (increasing in TDS) as the salt content is controlled by mineral saturation rather than straightforward dilution;
- An important management measure relates to the monitoring of the mine water. The following parameters need to be included into the monitoring program:

Major Parameters	**Metals and Trace Elements**
pH, EC, TDS, Ca, Mg, Na, K, SO_4, F, Total Alkalinity, Cl, NO_3, NH_4	Al, Mn, Fe and metal ICP scan

An ICP-OES scan must be performed in order to identify any trace elements present in seepage from the mine. Elevated trace metals identified with ICP during monitoring should also be included into the monitoring program; and

- It is recommended that the geochemical model is updated during the life of the mine in order to calibrate and validate its results and to construct an effective closure plan. Monitoring of mine water is critical in order to validate and calibrate the geochemical model. The geochemical model must assess the effectiveness of potential mitigation measures before closure.

4 CONCLUSIONS

Based on the results of the geochemical assessment, the following conclusions could be made:

Sampling

- Based on the distribution of sampling points and analytical results received it was concluded that the rock and waste samples are representative of the backfill material in terms of its environmental geochemical character;
- Enough samples were taken from each lithology in order to observe the geochemical characteristics;

Mineralogy

- The mineralogical test results show that pyrite is present in various rock samples. Oxidation of pyrite will release products of acid mine drainage (AMD), including metals, sulphate and acidity;
- The presence of carbonate minerals will contribute to neutralisation AMD to some degree. However, the test results indicated that all rock material (including coal, discard, clastic rocks like sandstone) have very low carbonate mineral content;

Acid-base Accounting and Net Acid Generation test

- The *coal and discard* have a very high %S (> 0.3 %) and most of these samples are likely to generate acidic drainage based on their %S and NP/AP ratio. From the limited number of samples taken it seems as if the potential for acid generating for different coal seams increase as follows: No. 3/4 < No. 2 < No. 5 < No. 6. The No. 3/4 coal seam samples have the lowest %S; while the No. 2 coal seam samples have a higher neutralising potential (NP) than the other coal seams;
- The NAG test results confirmed the high potential for acidification for coal and discard. Most samples were classified as having a low to high capacity for acid generation;
- The *sandstone* samples from the opencast have almost no neutralisation potential, however, the %S is also low with about 73% of the samples having a %S below 0.1. Only the sandstone samples between the No. 5 and No. 6 coal seams in the Weltevreden Pit have a %S of between 0.1 - 0.3. The sandstone will in general not produce acid drainage but also do not have any neutralisation potential to neutralise the acidity from other rock types;
- The *shale* interburden between the No. 2 and No. 3/4 coal seams in the East Pit has a %S below 0.3 and has no net acid generating potential. The shale directly overlying the No. 5 coal seam in the Weltevreden Pit has a high %S and has some

potential to generate acidic drainage. The %S decreases, however, upwards in the shale sequence, probably due to the distance from the seam and due to weathering. Forty-three (43) % of the shale samples have a high potential to generate acidic drainage;

Potential impact on drainage quality

- Without consideration of mitigation measures the drainage from the opencast backfill is expected to become acidic over the long-term as the ABA results show that the material has a significant potential to generate acid-mine drainage. Clastic rocks that will be backfilled also have a low neutralisation potential. The future geochemical model will be used to predict the pH and salt load in the drainage water from the mine;
- The discard will have a significant impact on pit water quality if disposed above the decant or equilibrium elevation. Discard above the decant or equilibrium elevation will significantly contribute to acid drainage and the salt load of the mine;
- Discard below the decant or equilibrium elevation will have a much smaller impact on the pit water quality. However, it will be necessary to determine whether enough volume is present below the decant or equilibrium elevation for the co-disposal of the discard. The time that the mine will take to flood is also important as discard below the decant or equilibrium level will still be subjected to oxidation if the mine is unflooded;
- It is not foreseen that significant elevation in metals will occur at near-neutral conditions. After acidification non-compliance for Al, Fe, Mn will occur. Other metals like As, Cd, Cr, Ni, Pb, Sb and V (as identified through peroxide extraction) may also leach out at elevated concentrations; however, significant non-compliance of these metals are unlikely to occur under field conditions;

Management measures

- Several mitigation measures were recommended in the report. Most of the measures relates to 1) containment of seepage/drainage, and 2) flooding or capping of material in order to minimise oxygen infiltration. The effectiveness of the mitigation measures must first be investigated through groundwater and/or geochemical modelling;
- An important management measure relates to the monitoring of mine, surface and groundwater quality; and
- It is recommended that the geochemical model is updated during the life of mine in order to validate and calibrate its results and to construct an effective closure plan.

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