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**18 March 2019**

ANGLO AMERICAN LIMITED

## DER BROCHEN PROJECT PRE-FEASIBILITY B GEOCHEMICAL ASSESSMENT

### 1. BACKGROUND

As part of the outcome of the Der Brochen Project Pre-Feasibility-A (PFS- A) study completed in 2017, further geochemical characterization including the evaluation of potential Acid Rock Drainage (ARD) and Metal Leaching (ML) of all formations foreseen to be disturbed or otherwise exposed by the mining project was recommended.

The results of the geochemical test work, specifically the total and leachable concentrations of mine residues, will also be used to classify the waste in accordance to the NEMWA – Norms and Standards as specified in the Government Notices R. 63, 635 and 636 (Government Gazette No. 36784, 23/08/2013) pertaining to the National Environmental Management: Waste Act (Act No. 59 of 2008) by the Department of Environmental Affairs. Recent amendment to the regulations regarding the Planning and Management of Residue Stockpiles and Residue Deposits (Government Gazette No. 41920, 21/09/2018), ‘allow for the pollution control measure, to be determined on a case by case basis, based on a risk analysis conducted by a competent person’. “Competent person” is defined in the existing regulations. The amendments also provide for textual amendments to provide clarity, consequential amendments and transitional arrangements.

The current geochemical study augments earlier studies (i.e. Delta-H, 2014) by assessing the geochemical characteristics of expected hoisted reef, floor and roof rocks in addition to the Dense Medium Separation (DMS) stockpile as part of the Der Brochen Expansion Project.

Representative core samples were retrieved from the newly drilled North Portal exploration hole to represent material being potentially exposed during underground mining (e.g. roof and/floor) and material going to the concentrator for processing. In order to characterise the stockpile material exiting the proposed Dense Medium Separation (DMS) process, samples from the Booyensdal DMS Plant feed were collected over a few days by the Northam Platinum Mine Metallurgist in July 2018 and again in August 2018. These two composite samples were then submitted for static geochemical testing, with one sample to undergo further kinetic (humidity cell) leach testing to supplement the static test results and to determine the likely long-term leachate quality. This geochemical characterisation report is based on the static test results/analysis received from the laboratory (WaterLab) for the samples shown in Table 1-1. The general stratigraphy used for the sample’s selection is shown in Figure 1-1<sup>1</sup>.

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<sup>1</sup> E-mail correspondence 30 August 2018 – Stephan van As (Resource Geologist)

Table 1-1: Waste type classification by total and leachable concentration thresholds (TCT and LCT) for landfill disposal.

Type	Sample	Lab ID	Lithology	Comments
DMS Stockpile	DMS Plant	36513	-	Booyesendal DMS Feed
	DMS Plant D	36513D	-	
	DMS Plant #2	38547	-	
	DMS Plant #2D	38547D	-	
	DMS Plant Nr2	50532	-	
Ore	DB N Portal Reef	44022	UG2	North Portal Core
Waste Rock	DB N Portal Floor	44023	Norite and Pyroxenite	North Portal Core
	DB N Portal Roof	44024	Norite and Pyroxenite	
	Split Reef Waste #1	44025	Norite (above Chromitite)	
	Split Reef Roof	44026	Norite and Pyroxenite (above Chromitite)	

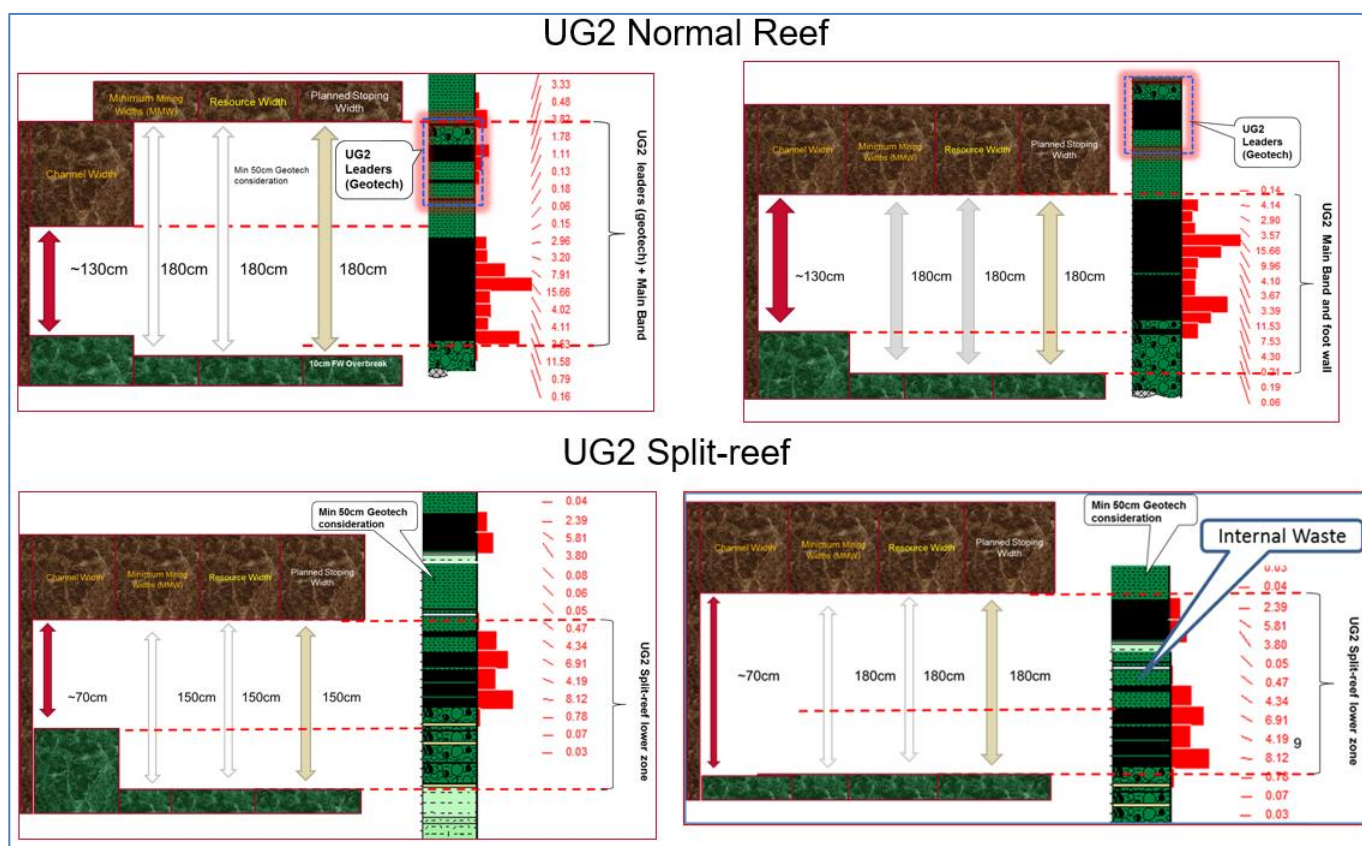


Figure 1-1: Neutralising potential ratio versus total sulphur content.

## 2. GEOCHEMICAL CLASSIFICATION METHODOLOGY

### 2.1. BACKGROUND

The geochemical test work was carried out by Waterlab (Pty) Ltd, a SANAS (South African National Accreditation System) accredited laboratory and included the following:

- Acid-Base Accounting (ABA), Net Acid Generation (NAG), Sulphur (S)-speciation and Paste pH.
- Determination of total concentrations on solids using Aqua regia digestion with analysis for 15 metals, Hg, F and CrVI
- Determination of leachable concentrations using distilled water extraction (for waste to be disposed of with non-putrescible waste) at a liquid-to-solid ratio of 1:20 with analysis for 15 metals, Hg, F, CrVI, TDS, Cl, SO<sub>4</sub>, NO<sub>3</sub> to enable a formal waste classification
- Determination of leachable concentrations using distilled water extraction at a liquid-to-solid ratio of 1:4 to facilitate a more realistic estimation of source terms for the solute transport model (NB: The waste classification requires a liquid-to-solid ratio of 1:20, which accounts for dilution in the aquifer but is unrealistic for a transport model source term derivation).
- XRD mineralogy

### 2.2. ACID ROCK DRAINAGE POTENTIAL

Acid rock drainage is a process whereby contaminants (especially metals and sulphate) are released from solid to liquid phase under acidic pH conditions due to the oxidation of sulphide minerals in the presence of oxygen (or other oxidants like ferric iron or manganese) and water, potentially accelerated by bacteria. Heat may be generated in the process. The term acid rock drainage is also used to refer to saline and neutral mine drainage, which are characterised by neutral to alkaline pH conditions and more moderate metal and sulphate contents.

The laboratory tests to determine the potential of rock samples to produce Acid Rock Drainage (ARD) are generally grouped into two categories: static and kinetic tests. The static tests are relatively simple, inexpensive and rapid, whereas kinetic tests may take several months. Kinetic tests are typically carried out if the results of the static tests are inconclusive or kinetic reaction rates (of acid production and neutralisation) are required for geochemical models.

The current test work reported upon here comprises of static tests.

#### 2.2.1. Acid-Base Accounting (ABA)

Acid-base accounting (ABA) by Sobek et al. (1978) is a screening procedure whereby the acid-neutralising potential (assets) and acid-generating potential (liabilities) of rock samples are determined and the difference (net neutralising potential, equity) is calculated. It is a static procedure and provides no information on the rate with which acid generation or neutralisation will proceed. Reaction rates are usually determined by kinetic weathering or leaching tests. It must be noted that acid-neutralising (or buffer) reaction rates of most minerals (apart from the carbonates) are typically slower than the sulphide oxidation rates in the rocks.

ABA tests calculate the acid potential (AP) of a sample due to the theoretical oxidation of the total sulphur content of the sample to sulphuric acid. As the AP is usually expressed in kg CaCO<sub>3</sub> per tonne of rock, the conversion factor is 31.25 kg CaCO<sub>3</sub>/tonne:

$$AP = \frac{\text{Sulphur content (\%)} * 1000\text{kg}}{100} * \frac{\text{molecular weight of CaCO}_3}{\text{atomic weight of sulphur}}$$
$$= \text{sulphur content (\%)} * 31.25\text{kg CaCO}_3 \text{ per tonne}$$

The total sulphur content of a sample is hereby commonly determined by LECO. The AP can be converted into the Maximum Potential Acidity (MPA, expressed as kg H<sub>2</sub>SO<sub>4</sub>/tonne), which is commonly used in Australia by simply multiplying the AP with 0.98.

The neutralisation potential (NP) of a sample, mostly provided by carbonates hydroxides and silicates, is determined according to Sobek et al. (1978) by digestion of hydrochloric acid. The NP is expressed in kg CaCO<sub>3</sub> per tonne of rock, but can be converted into the Acid Neutralising Capacity (ANC, expressed as kg H<sub>2</sub>SO<sub>4</sub>/tonne), used in Australia by simply multiplying the NP with 0.98.

It must be noted that this theoretical and widely used neutralisation potential does not necessarily represent the real neutralisation potential that would occur in the field as it is site-specific to environmental conditions, mineralogy, kinetic reactions and dissolution rates (Morin and Hutt 2001). Two key indicators are used to assess the risk of acid drainage:

1. The Net Neutralisation Potential (NNP) is calculated by subtracting the Acid Potential (AP) from the Neutralising Potential (NP):

$$NNP = NP - AP,$$

with negative NNP values indicating the potential to generate acidity and therefore a predicted net acid drainage water quality from the rock. Positive values indicate acid-neutralising potential or a predicted net alkaline drainage water quality from a rock sample, though some authorities (Canada) request NNP values larger than 20 before non-acid generation can be assumed.

2. The Neutralisation Potential Ratio (NPR) is calculated by dividing NP by the AP:

$$NPR = NP / AP,$$

with the following assessment criteria for a sample:

- NPR larger than 2 generally indicates non-acid generation (NAG), i.e. neutral or alkaline leachate, but in case of preferential exposure or reactivity of sulphides NPR larger than 4 is needed for complete acid neutralisation (Price et al., 1997).
- NPR between 1 and 2 is considered inconclusive or uncertain with regard to acid generation.
- NPR below 1 indicates potentially acid generating (PAG) material.

#### 2.2.1. Paste pH

As part of the ABA procedure according to Sobek et al. (1978), the paste pH of a mixture of the pulverized rock sample and distilled water (pH typically 5.3) is determined. The measured pH value indicates whether a sample was at the time of analysis acidic (paste pH<5), near neutral (5<paste pH<10) or alkaline (paste pH>10). Acidic paste pH values indicate a non-reactive or absent neutralisation potential.

#### 2.2.2. Sulphur speciation

ABA assumes conservatively that all sulphur in the sample will react to form sulphuric acid, while in fact some of the sulphur may be present in non-acid producing sulphates (e.g. gypsum, barite), organic or elemental sulphur. If a significant part of the total sulphur occurs as sulphate sulphur instead of sulphide sulphur, the overall risk of acid generation is reduced. Furthermore, acid generation of samples with sulphide sulphur content below 0.3 % is considered short term (Price and Errington 1995, Soregaroli and Lawrence 1998) due to limited sulphur supply. The sulphide acid potential (SAP) of a sample is then calculated according to:

$$SAP = \text{Sulphide sulphur content (\%)} * 31.25 \text{ kg CaCO}_3 \text{ per tonne}$$

In general, the use of total sulphur for the determination of the maximum potential acidity is considered more conservative (Brady 1990), but is obviously overly conservative for oxidised ore bodies.

### 2.2.3. Net Acid Generation (NAG) test

Net acid generation tests directly determine the acid generating potential of sulphide minerals in a rock sample by oxidation with hydrogen peroxide ( $H_2O_2$ ). Acid generation and acid neutralization reactions occur simultaneously and the test provides therefore a net result of the amount of acid generated.

After complete oxidation of the sample, the final NAG pH is used as a screening criterion for the acid generation potential:

- NAG pH below 3.5 indicates a high risk of acid generation,
- NAG pH value larger than 5.5 indicates no risk of acid generation, and
- NAG pH value between 3.5 and 5.5 indicates a low risk of acid generation.

The supernatant of the test is titrated to a pH of 4.5 and 7.0 and the net acid potential in the form of kilograms of sulphuric acid produced per tonne of waste rock sample ( $kg\ H_2SO_4/t$ ) calculated.

### 2.3. LEACH TESTING AND WASTE CLASSIFICATION

Leach tests are commonly used as a preliminary screening process to identify potential constituents of concern based on a comparison against relevant water quality and effluent standards or other specified limits. In the context of this study, the total and leachable concentrations will be used to classify the mine residues in accordance to the NEMWA – Norms and Standards as specified in the Government Notices R. 63, 635 and 636 (Government Gazette No. 36784, 23/08/2013) pertaining to the National Environmental Management: Waste Act (Act No. 59 of 2008) by the Department of Environmental Affairs. According to the Government Notices, the leachable concentrations are determined using the Australian Standard Leaching Procedure (AS 4439.3-1997, bottle leaching procedure) and the total concentrations using aqua regia digestion. The applicable leachable or total concentration thresholds used by the authorities to classify the waste into several categories are given in Table 2-1.

**Table 2-1: Waste type classification by total and leachable concentration thresholds (TCT and LCT) for landfill disposal.**

Total concentration threshold	Link between TCT and LCT	Leachable concentration threshold	Waste Type	Landfill design
< TCT0	and	< LCT0	Type 4	Class D
< TCT1	and	< LCT1	Type 3	Class C
< TCT1	and	< LCT2	Type 2	Class B
< TCT2	or	< LCT3	Type 1	Class A
> TCT2	or	> LCT3	Type 0	Not allowed

### 3. GEOCHEMICAL TEST RESULTS

#### 3.1. QUALITY CONTROL

##### 3.1.1. Intra-Laboratory quality control

Two sample analyses (sulphur speciation, NAG pH, paste pH, AP and NP) were run in duplicate for internal quality control purposes by the laboratory and are highlighted in **Error! Reference source not found.** To assess the data quality, the Relative Percentage Difference (RPD) of the analysis were calculated as follows:

$$RPD = \frac{|a - b|}{average(a, b)} * 100\%$$

The following criteria were used to assess the RPD values:

- RPD < 1%            Excellent
- RPD < 2.5%        Good
- RPD < 5%          Average
- RPD > 5%          Poor

The internal quality control showed an excellent (RPD < 1%) reproducibility of the following parameter:

- Total sulphur (DMS Plant#2D, Split Reef Roof)
- Sulphide sulphur (DMS PlantD, DMS Plant#2D, Split Reef Roof)
- Sulphate sulphur (DMS PlantD, DMS Plant#2D, Split Reef Roof)
- NAG pH 4.5 (DMS Plant#2D)
- NAG pH 7 (DMS Plant#2D)
- Paste pH (DMS PlantD, DMS Plant#2D, Split Reef Roof)

An average (RPD < 5%) reproducibility is recognised for:

- Neutralisation potential (Split Reef Roof)
- NAG pH 4.5 (Split Reef Roof)
- NAG pH 7 (Split Reef Roof)

A poor (RDP > 5%) reproducibility is recognised for:

- Total sulphur (DMS PlantD)
- Acid potential (DMS PlantD, DMS Plant#2D)
- Neutralisation potential (DMS PlantD, DMS Plant#2D)
- NAG pH 4.5 (DMS PlantD)
- NAG pH 7 (DMS PlantD)

While the observed poor reproducibility of several parameters, most of which border their limit of detection, is of concern, they do not change the overall classification of these samples and the data are therefore considered acceptable for the purpose of the acid rock drainage assessment. No ionic charge balances were determined for the leach test analysis due to missing major elements (predominantly cations) in the leach test results, as they are not required for the waste classification process.

##### 3.1.1. Inter-Laboratory quality control

The DMS Plant #2 (August 2018) sample was submitted for analysis to a different laboratory (Aquatico Laboratory, sample ID: DMS Plant Nr2) to enable an inter-laboratory quality control of the analysis. The inter-laboratory revealed

- a poor (RDP > 5%) reproducibility of the pH 4.5 and 7 NAG (pH) values, but these do not change the absence of the derived NAG values in kg H<sub>2</sub>SO<sub>4</sub>/t as all pH values are circumneutral with no net acid generation potential.

A general poor (RDP > 5%) reproducibility is observed for the remainder of the analysed parameter, with expect for the paste pH values (RDP = 7.2%) all RDP values above 10%, and the total and sulphate sulphur contents reaching RDP values above 100%.

While these inter-laboratory quality control results are of major concern, it can at this point in time not be ascertained whether the differing results are due to – unlikely - sample heterogeneity or which laboratory analysis are actually correct (a third analysis would be required). However, as stated already above, the determined sulphur contents are very low and (regardless of which NP values are chosen) far outweighed by their neutralisation potentials, so the glaring discrepancies between the laboratory analyses do **not** affect the overall classification of this sample and can therefore be accepted for the current assessment, but certainly not as a general condonation of the quality of the laboratory analyses. An inter-laboratory comparison of a third overseas laboratory to establish which laboratory results can actually be depend upon is proposed for future assessments.

### **3.2. ACID ROCK DRAINAGE POTENTIAL**

The ABA, sulphur speciation and calculated SAP, NNP and NPR values for the different tailings and DMS samples from Der Brochen are summarised in Table 3-1 while the original laboratory certificates are provided in Appendix A.

Table 3-1: ABA, NAG and S-Speciation results for the samples and calculated NP, NNP and NPR values (duplicate sample results highlighted in grey).

Sample ID	Lab ID	SULPHUR SPECIATION			NET ACID GENERATION						ACID BASE ACCOUNTING					
		Total Sulphur (%)	Sulphate Sulphur as S (%)	Sulphide Sulphur (%)	pH 4.5 NAG (pH)	pH 4.5 NAG (kg H <sub>2</sub> SO <sub>4</sub> /t)	pH 7 NAG (pH)	pH 7 NAG (kg H <sub>2</sub> SO <sub>4</sub> /t)	Paste pH	Acid Potential (AP) (kg/t)	Sulphide Acid Potential SAP (calc) (kg/t)	Neut Potential (NP) (kg/t)	Net Neut Potential (NNP)	Neut Potential Ratio (NPR)	NNP_S2	NPR_S2
DMS Plant	36513	0.01	0.01	0.01	7.3	<0.01	7.3	<0.01	9.4	0.313	0.3	7.2	6.8	23.0	6.8	22.91
DMS PlantD	36513D	0.02	0.01	0.01	7.9	<0.01	7.9	<0.01	9.4	0.625	0.3	7.7	7.0	12.0	7.4	24.54
DMS Plant #2	38547	0.01	0.01	0.01	7.9	<0.01	7.9	<0.01	9.4	0.425	0.3	13.0	12.0	30.0	12.7	41.60
DMS Plant #2D	38547D	0.01	0.01	0.01	7.9	<0.01	7.9	<0.01	9.4	0.391	0.3	14.0	13.0	35.0	13.7	44.80
DMS Plant Nr2	50532	0.053	0.044	0.009	6.4	<0.01	6.4	<0.01	10.1	0.3125	0.3	21.7	21.4	69.4	21.4	77.16
DB N Portal Reef	44022	0.13	0.09	0.04	6.8	<0.01	6.8	<0.01	8.75	4.06	1.3	8.4	4.4	2.1	7.2	6.74
DB N Portal Floor	44023	0.01	0.01	0.01	7.4	<0.01	7.4	<0.01	8.95	0.313	0.3	7.3	7.0	23.0	7.0	23.30
DB N Portal Roof	44024	0.06	0.03	0.03	7.9	<0.01	7.9	<0.01	9.01	1.88	0.9	10.0	8.5	5.6	9.1	10.67
Split Reef Waste	44025	0.01	0.01	0.01	7.6	<0.01	7.6	<0.01	8.9	0.313	0.3	9.5	9.2	30.0	9.2	30.43
Split Reef Roof	44026	0.01	0.01	0.01	7.6	<0.01	7.6	<0.01	9.13	0.313	0.3	9.2	8.9	29.0	8.8	29.31
Split Reef Roof	44026 D	0.01	0.01	0.01	7.8	<0.01	7.8	<0.01	9.13	0.313	0.3	9.4	9.1	30.0	9.1	30.11
RPD	36513D	66.7%	0.0%	0.0%	7.9%	0.0%	7.9%	0.0%	0.0%	66.5%	0.0%	6.9%	2.9%	62.9%	7.2%	6.9%
	38547D	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	8.3%	0.0%	7.4%	8.0%	15.4%	7.6%	7.4%
	44026 D	0.0%	0.0%	0.0%	2.6%	0.0%	2.6%	0.0%	0.0%	0.0%	0.0%	2.7%	2.8%	3.4%	2.8%	2.7%



### 3.2.1. Paste pH results

The paste pH values of the tested samples range from pH 8.75 to pH 10.1 (Table 3-1). The alkaline paste pH range at the time of analysis suggests that the samples do not contain any acidity, but ample alkalinity that may be readily released upon deposition.

### 3.2.2. ABA results

The majority of tested samples show positive NNP values; NPR ratios larger than 4 and low sulphide sulphur content below or at the limit of detection (0.01 %). These samples are therefore classified as non-acid generating (Figure 3-1). However, the DB N Portal Reef sample shows a total sulphur content of 0.13 % which in conjunction with a relatively low neutralisation potential results in an inconclusive classification of the sample (i.e. potentially acid generating if preferentially exposed). This was also observed for the Mototolo contractor ore stockpile sample in 2014 by Delta-H.

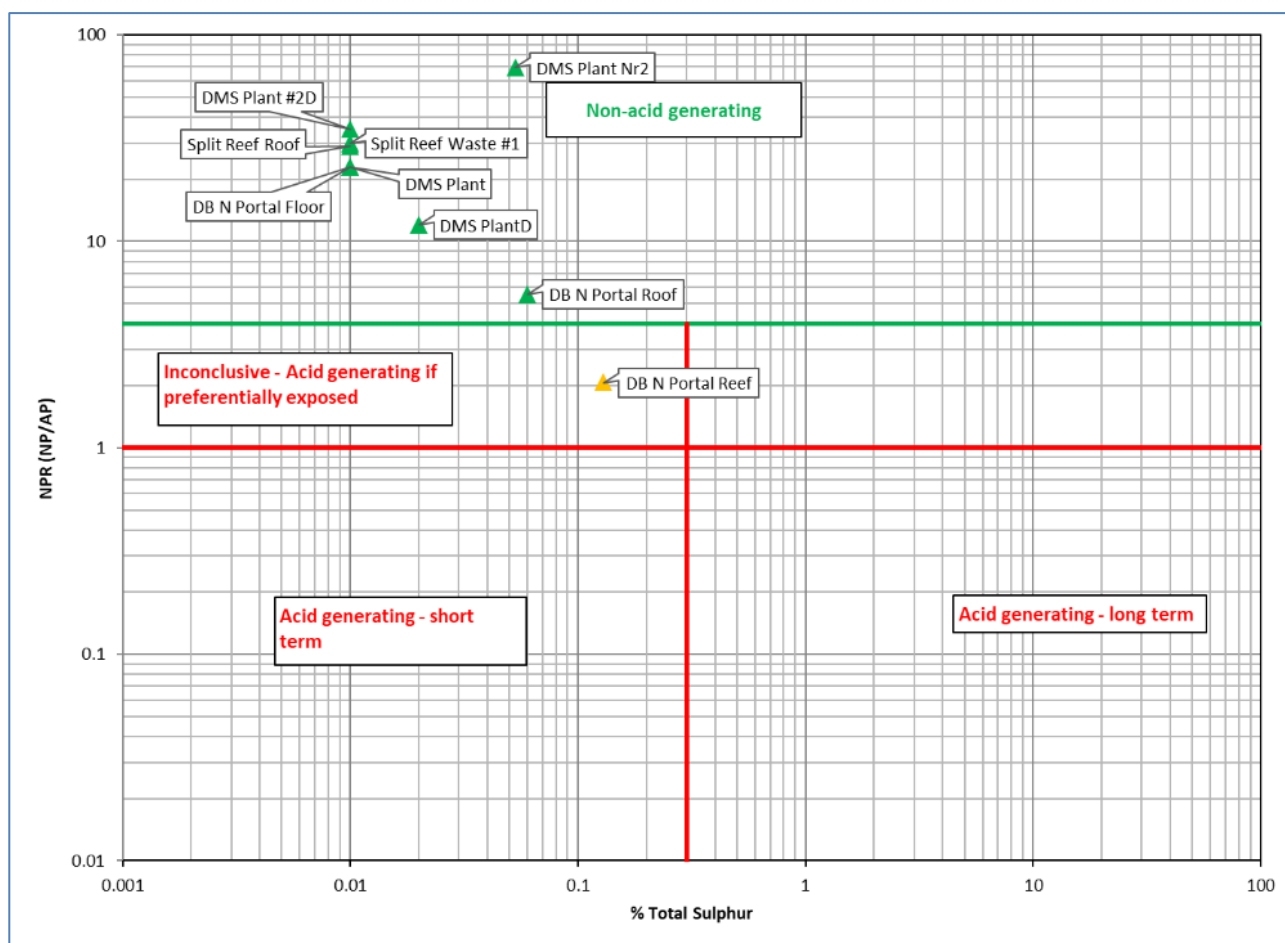


Figure 3-1: Neutralising potential ratio versus total sulphur content.

### 3.2.3. ABA results under consideration of sulphur speciation

The sulphur speciation results show that in all of the tested samples at least half of sulphur occurs as non-acid generating sulphate sulphur. As stated earlier, the ABA methodology assumes conservatively that all sulphur in the sample will react to form sulphuric acid; while a significant part of the total sulphur may occur as non-acid producing sulphate sulphur, reducing potentially the overall risk of acid generation further. Based on a plot of the sulphide neutralising potential ratio ( $\text{NPR-S}^{2-}$ , calculated using the sulphide acid potential (SAP) versus the sulphide sulphur instead of total sulphur content (Figure 3-2), all samples are now classified as non-acid generating. Sample DB N Portal Reef, which was previously classified as inconclusive, moved now to the non-acid generating field as half of its sulphur content is already oxidised to sulphate sulphur.

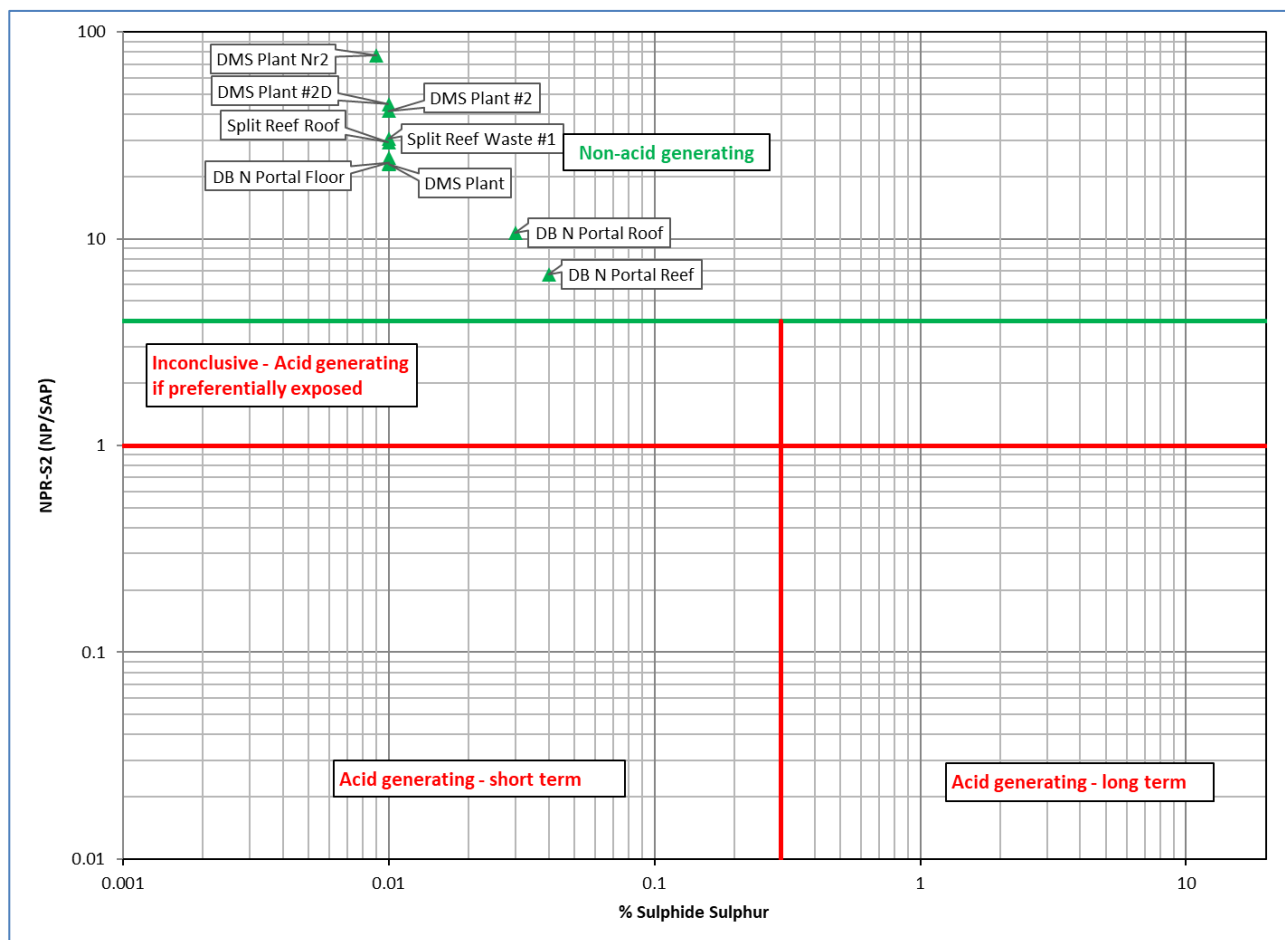


Figure 3-2: Sulphide neutralising potential ratio versus sulphide sulphur content.

#### 3.2.4. NAG test results

The NAG pH is the result of oxidation of sulphide minerals in the samples by hydrogen peroxide ( $H_2O_2$ ). The NAG test would also be expected to oxidise iron/manganese carbonate minerals in the samples and release the residual acidity associated with these minerals if present. Samples with a NAG pH value less than 3.5 are considered to indicate potentially acid generating (PAG) material, while samples with a NAG pH larger than 5.5 are considered to indicate non-acid generating (NAG) material, with intermediate values between 3.5 and 5.5 indicating a low risk of acid generation. The NAG results (Table 3-1 **Error! Reference source not found.**) for the samples range from pH 6.4 to 7.9 and do not suggest any acidity release of the samples, confirming in general the earlier classification.

The evaluation of the NAG pH and NPR values (Figure 3-3), with a lower NPR screening criteria for samples with NAG pH values larger 5.5, show complete agreement to the initial ABA assessment, with all samples being clearly classified as non-acid generating except for the uncertain classification of sample DB N Portal Reef.

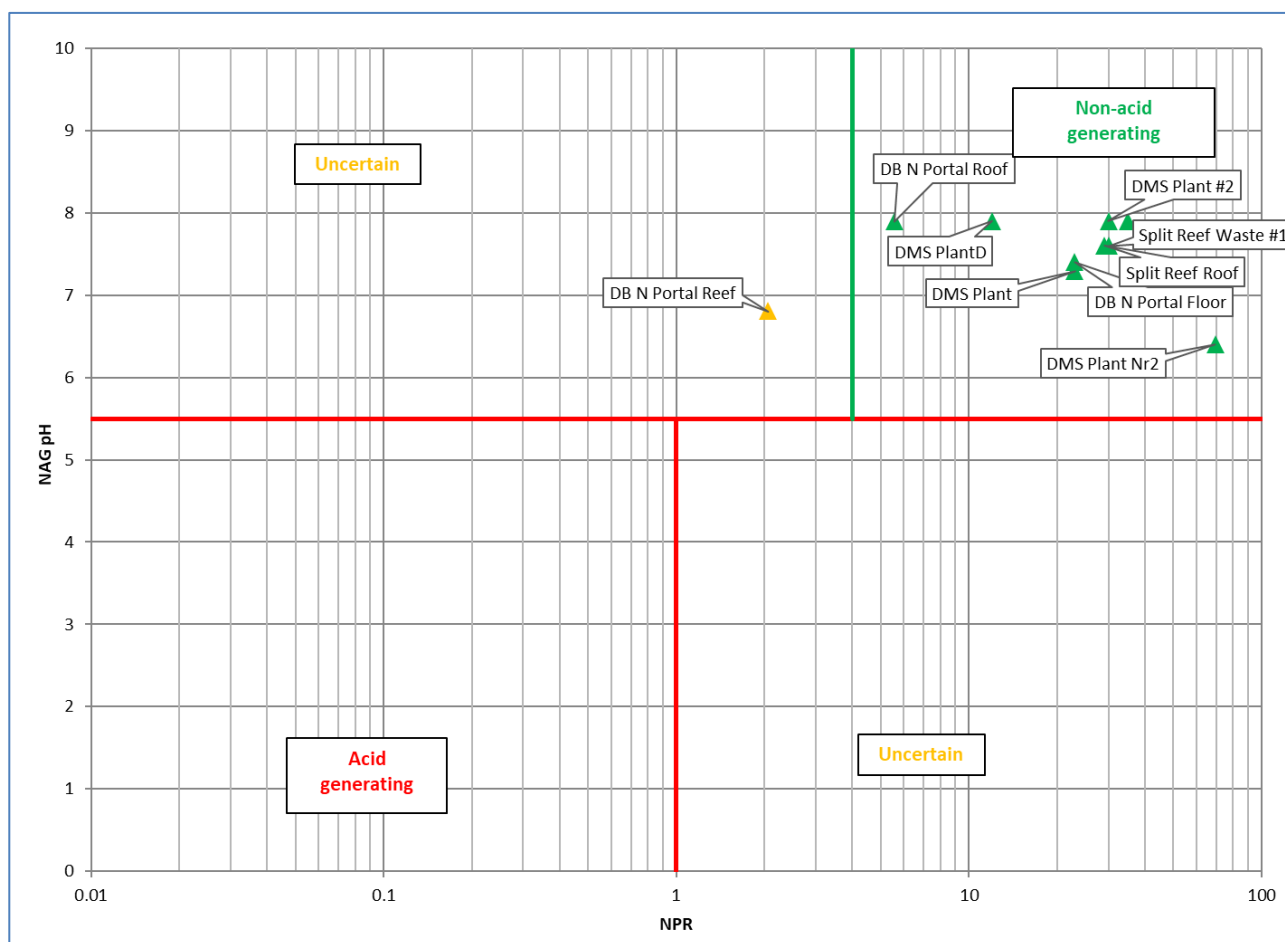


Figure 3-3: NAG pH versus neutralisation potential ratio.

### 3.2.5. Summary of ARD test results

All tested tailings and DMS plant samples are classified as non-acid generating (NAG) and provide actually acid buffer capacity, with the net neutralising (or buffer) potentials of the tested samples ranging from 4.4 to 21.4 kg/t. All roof and floor material samples are classified as non-acid generating based on their absent or limited sulphide sulphur content and subsequently calculated sulphide acid potential. The reef sample is formally classified as non-acid generating based on its limited sulphide sulphur content and subsequently calculated sulphide acid potential. The ARD assessment shows limited or no potential of the tested DMS stockpile and roof and floor material samples for acid generation and a neutral to alkaline leachate quality is therefore expected.

### 3.3. WASTE CLASSIFICATION

The leachable and total concentrations along with the applicable thresholds used for the classification of the samples are presented in Table 3-2, Table 3-3 and Table 3-4. It is important to note that according to the Government Notices R. 634, 635 and 636 (Government Gazette No. 36784, 23/08/2013), the exceedance of a threshold value for **any element** or chemical substance determines the overall waste classification of the sample.

No exceedances were noted for the distilled water (1:20 ratio) leachable concentration of the samples (Table 3-2).

- The leachable concentrations of the DMS Plant samples as well as the roof, reef and floor material are all **within the LCT0 thresholds**.

The following exceedances were noted for the distilled water (1:4 ratio) leachable concentrations (Table 3-3).

- The DMS Plant sample as well the Split Reef Roof sample with total chromium concentrations of 0.132 mg/l and 170 mg/l respectively, exceed the LCT0 threshold of 0.1 mg/l, but not the LCT1 threshold of 5 mg/l.
- The DB N Portal Reef sample exceeds with a mercury concentration of 0.014 mg/l the LCT0 threshold of 0.006 mg/l, but not the LCT1 threshold of 0.3 mg/l.

It must be noted that the 1:4 leach ratio was done for comparison purposes (and for the estimation of modelling source terms) only and does not form any part of the formal waste classification.

The following exceedances were noted for the total concentrations (Aqua Regia digestion) (Table 3-4).

- Total concentration of barium exceeds in sample Split Reef Roof the TCT0 threshold, but not the TCT1 threshold.
- Total concentrations of cobalt exceed in samples DB N Portal Roof and Split Reef Waste #1 the TCT0 threshold, but not the TCT1 threshold.
- Total concentrations of copper exceed in all samples the TCT0 threshold, but not the TCT1 threshold.
- Total concentrations of nickel exceed in all samples (except the DMS Plant Nr 2 sample) the TCT0 threshold, but not the TCT1 threshold.
- Total concentration of vanadium exceeds in sample DB N Portal Roof the TCT0 threshold, but not the TCT1 threshold.
- Total concentrations of fluoride exceed in the DMS Plant, DB N Portal Reef, DB Portal Roof, Split Reef Waste and the Split Reef roof samples the TCT0 threshold, but not the TCT1 threshold.
- Total concentrations of manganese exceed in samples DB N Portal Roof and Split Reef Waste #1 the TCT0 threshold, but not the TCT1 threshold.

Although leachable concentrations for all constituents analysed are within their LCT0 thresholds, the exceedances of the total concentration threshold TCT0 for copper alone (i.e.  $TCT0 < TC < TCT1$ ) strictly classifies all samples formally as **Type 3 Waste**.

The inter-laboratory comparison of the waste classification shows discrepancies, with most analyses by Aquatico laboratory being under their comparably high limits of detection (LoD). Duplicate analysis of e.g. total arsenic or nickel concentrations by Waterlab show for example concentrations an order of magnitude above Aquatico's LoD.

Table 3-2: Leachate (distilled water 1:20 ratio) test concentrations for the samples (exceedances highlighted).

Leachable 1:20	DMS Plant	DMS Plant #2	DMS Plant Nr2	DB N Portal Reef	DB N Portal Floor	DB N Portal Roof	Split Reef Waste #1	Split Reef Roof	Threshold			
Sample Number	36513	38547	50532	44022	44023	44024	44025	44026	LCT0	LCT1	LCT2	LCT3
Units	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ
As, Arsenic	<0.001	0.002	<0.01	<0.001	<0.001	<0.001	<0.001	0.001	0.01	0.5	1	4
B, Boron	<0.025	<0.025	<0.50	<0.025	<0.025	<0.025	<0.025	<0.025	0.5	25	50	200
Ba, Barium	<0.025	<0.025	<0.70	<0.025	<0.025	<0.025	<0.025	<0.025	0.7	35	70	280
Cd, Cadmium	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.003	0.15	0.3	1.2
Co, Cobalt	<0.025	<0.025	<0.4	<0.025	<0.025	<0.025	<0.025	<0.025	0.5	25	50	200
Cr <sub>Total</sub> , Chromium Total	0.033	<0.025	<0.1	<0.025	<0.025	<0.025	<0.025	<0.025	0.1	5	10	40
Cr(VI), Chromium (VI)	<0.010	<0.010	<0.02	<0.010	<0.010	<0.010	<0.010	<0.010	0.05	2.5	5	20
Cu, Copper	<0.010	<0.025	<1	<0.025	<0.025	<0.025	<0.025	<0.025	2.0	100	200	800
Hg, Mercury	<0.001	<0.001	<0.006	0.008	<0.001	<0.001	<0.001	<0.001	0.006	0.3	0.6	2.4
Mn, Manganese	<0.025	<0.025	<0.5	<0.025	<0.025	<0.025	<0.025	<0.025	0.5	25	50	200
Mo, Molybdenum	<0.025	<0.025	<0.07	<0.025	<0.025	<0.025	<0.025	<0.025	0.07	3.5	7	28
Ni, Nickel	<0.025	<0.025	<0.07	<0.025	<0.025	<0.025	<0.025	<0.025	0.07	3.5	7	28
Pb, Lead	<0.010	<0.010	<0.01	<0.010	<0.010	<0.010	<0.010	<0.010	0.01	0.5	1	4
Sb, Antimony	0.001	0.002	<0.020	0.001	0.001	0.001	<0.001	0.001	0.02	1.0	2	8
Se, Selenium	0.001	0.003	<0.010	<0.001	<0.001	<0.001	<0.001	0.003	0.01	0.5	1	4
V, Vanadium	<0.025	<0.025	<0.20	<0.025	<0.025	<0.025	<0.025	<0.025	0.2	10	20	80
Zn, Zinc	<0.025	<0.025	<2.00	<0.025	<0.025	<0.025	<0.025	<0.025	5.0	250	500	2000
<b>Inorganic Anions</b>	<b>mg/ℓ</b>	<b>mg/ℓ</b>	<b>mg/ℓ</b>	<b>mg/ℓ</b>	<b>mg/ℓ</b>	<b>mg/ℓ</b>	<b>mg/ℓ</b>	<b>mg/ℓ</b>	<b>mg/ℓ</b>	<b>mg/ℓ</b>	<b>mg/ℓ</b>	<b>mg/ℓ</b>
Total Dissolved Solids*	30	24	<100	48	40	74	62	48	1000	12 500	25 000	100 000
Chloride as Cl	<2	<2	<50.0	<2	<2	<2	<2	<2	300	15 000	30 000	120 000
Sulphate as SO <sub>4</sub>	<2	<2	<50.0	7	<2	<2	<2	<2	250	12 500	25 000	100 000
Nitrate as N	0.30	0	<10.0	<0.1	<0.1	<0.1	<0.1	<0.1	11	550	1100	4400
Fluoride as F	<0.2	0	<1.0	<0.2	<0.2	<0.2	<0.2	<0.2	1.5	75	150	600

Table 3-3: Leachate (distilled water 1:4 ratio) test concentrations for the samples (exceedances highlighted).

Leachable 1:20	DMS Plant	DMS Plant #2	DMS Plant Nr2	DB N Portal Reef	DB N Portal Floor	DB N Portal Roof	Split Reef Waste #1	Split Reef Roof	Threshold			
Sample Number	36513	38547	50532	44022	44023	44024	44025	44026	LCT0	LCT1	LCT2	LCT3
Units	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ
As, Arsenic	0.001	<0.001	<0.01	<0.001	<0.001	0.002	<0.001	<0.001	0.01	0.5	1	4
B, Boron	<0.025	<0.025	<0.50	<0.025	<0.025	<0.025	<0.025	<0.025	0.5	25	50	200
Ba, Barium	<0.025	<0.025	<0.70	<0.025	<0.025	<0.025	<0.025	0.032	0.7	35	70	280
Cd, Cadmium	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.003	0.15	0.3	1.2
Co, Cobalt	<0.025	<0.025	<0.4	<0.025	<0.025	<0.025	<0.025	<0.025	0.5	25	50	200
Cr <sub>Total</sub> , Chromium Total	0.132	<0.025	<0.1	<0.025	<0.025	<0.025	<0.025	0.170	0.1	5	10	40
Cr(VI), Chromium (VI)	<0.010	<0.010	<0.02	<0.010	<0.010	<0.010	<0.010	<0.010	0.05	2.5	5	20
Cu, Copper	<0.010	<0.025	<1	<0.010	<0.010	<0.010	<0.010	<0.010	2.0	100	200	800
Hg, Mercury	<0.001	<0.001	<0.006	0.014	<0.001	<0.001	<0.001	<0.001	0.006	0.3	0.6	2.4
Mn, Manganese	0.165	<0.025	<0.5	<0.025	<0.025	<0.025	<0.025	0.123	0.5	25	50	200
Mo, Molybdenum	<0.025	<0.025	<0.07	<0.025	<0.025	<0.025	<0.025	<0.025	0.07	3.5	7	28
Ni, Nickel	0.046	<0.025	<0.07	<0.025	<0.025	<0.025	<0.025	0.050	0.07	3.5	7	28
Pb, Lead	<0.010	<0.010	<0.01	<0.010	<0.010	<0.010	<0.010	<0.010	0.01	0.5	1	4
Sb, Antimony	0.001	0.002	<0.020	0.001	0.001	0.001	0.001	<0.001	0.02	1.0	2	8
Se, Selenium	<0.001	<0.001	<0.010	<0.001	<0.001	<0.001	<0.001	<0.001	0.01	0.5	1	4
V, Vanadium	<0.025	<0.025	<0.20	<0.025	<0.025	<0.025	<0.025	<0.025	0.2	10	20	80
Zn, Zinc	<0.025	<0.025	<2.00	<0.025	<0.025	<0.025	<0.025	0.029	5.0	250	500	2000
<b>Inorganic Anions</b>	<b>mg/ℓ</b>	<b>mg/ℓ</b>	<b>mg/ℓ</b>	<b>mg/ℓ</b>	<b>mg/ℓ</b>	<b>mg/ℓ</b>	<b>mg/ℓ</b>	<b>mg/ℓ</b>	<b>mg/ℓ</b>	<b>mg/ℓ</b>	<b>mg/ℓ</b>	<b>mg/ℓ</b>
Total Dissolved Solids*	122	68	<100	186	98	110	106	22	1000	12 500	25 000	100 000
Chloride as Cl	5	<2	<50.0	3	2	<2	<2	4	300	15 000	30 000	120 000
Sulphate as SO <sub>4</sub>	<2	2	<50.0	69	2	3	<2	8	250	12 500	25 000	100 000
Nitrate as N	2	2	<10.0	<0.1	<0.1	<0.1	<0.1	<0.1	11	550	1100	4400
Fluoride as F	<0.2	<0.2	<1.0	<0.2	<0.2	<0.2	<0.2	0.4	1.5	75	150	600

Table 3-4: Totals (aqua regia digestion) for the samples (exceedances highlighted).

Total	DMS Plant	DMS Plant #2	DMS Plant Nr2	DB N Portal Reef	DB N Portal Floor	DB N Portal Roof	Split Reef Waste #1	Split Reef Roof	Threshold		
Sample Number	36513	38547	50532	44022	44023	44024	44025	44026	TCT0	TCT1	TCT2
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
As, Arsenic	<0.400	0.4	<0.058	<0.400	<0.400	<0.400	<0.400	<0.400	5.80	500.00	2 000
B, Boron	<10	<10	<150	10.4	12.8	12.4	26.0	25.2	150	15 000	6 000
Ba, Barium	52.0	59.6	<62.5	42.0	59.6	48.0	33.6	86.4	62.50	6 250	25 000
Cd, Cadmium	4.8	4.8	<7.5	3.6	2.8	6.4	4.0	4.0	7.5	260.00	1 040
Co, Cobalt	42	47	<50	53	27	79.2	72.4	32	50	5 000	20 000
Cr <sub>Total</sub> , Chromium Total	2156	2020	<1000	24000	860	2524	1692	2768	46 000	800 000	N/A
Cu, Copper	49.0	20.4	25.6	204.0	26.4	55.2	16.8	28.0	16	19 500	78 000
Hg, Mercury	<0.400	<0.400	<0.9	<0.400	<0.400	<0.400	<0.400	<0.400	0.93	160.00	640
Mn, Manganese	736	904	<1000	656	592	1 660	1 476	820	1 000	25 000	100 000
Mo, Molybdenum	<10	<10	<10	<10	<10	<10	<10	<10	40	1 000	4 000
Ni, Nickel	340	365	<50	956	265	624	516	264	91	10 600	42 400
Pb, Lead	<4.00	14.4	<20	<4.00	<4.00	<4.00	<4.00	<4.00	20	1 900	7 600
Sb, Antimony	<0.400	<0.400	<10	<0.400	<0.400	<0.400	<0.400	<0.400	10	75	300
Se, Selenium	<0.400	<0.400	<10	<0.400	<0.400	<0.400	<0.400	<0.400	10	50	200
V, Vanadium	13	<0.401	<100	170	<10	54	42	<10	150	2 680	10 720
Zn, Zinc	222	51	<220	93	39	96	78	39	240	160 000	640 000
<b>Inorganic Anions</b>	<b>mg/kg</b>	<b>mg/kg</b>		<b>mg/kg</b>	<b>mg/kg</b>		<b>mg/kg</b>		<b>mg/kg</b>	<b>mg/kg</b>	<b>mg/kg</b>
Cr(VI), Chromium (VI) Total [s]	<5	<5	<5	<5	<5	<5	<5	<5	6.5	500.00	2 000
Total Fluoride [s] mg/kg	112.0	99.5	93.8	87.2	71.8	110.1	110.2	110.1	100	10 000	40 000

### 3.4. MINERALOGICAL ANALYSIS

The samples underwent additional analysis to gain a better understanding of their mineralogical make-up. The relative phase amounts or mineral groups in weight-% of the samples were determined using XRD analysis (Table 3-5). The mineral composition of the samples is generally made up by plagioclase feldspars and the magnesium rich pyroxene silicate mineral enstatite and for the DMS plant samples to a minor degree iron oxides (magnetite). The DB N Portal Reef sample shows furthermore significant chromite amounts. While Plagioclase provides buffer (acid neutralising) capacity, it does so to a lesser extent and at a slower reaction rate than carbonate minerals such as calcite. Expectedly, no measurable amounts of sulphide bearing minerals were detected in the XRD analysis, confirming the low potential of acid generation from the tested materials.

**Table 3-5: Major mineral composition of the Tailings Pool and DMS Plant samples (XRD Analysis) (weight %).**

Compound Name	Ideal Chemical Formula	DMS Plant	DMS Plant #2	DMS Plant Nr2	DB N Portal Reef	DB N Portal Floor	DB N Portal Roof	Split Reef Waste	Split Reef Roof
Hornblende	$\text{Ca}_2[\text{Mg}_4(\text{Al},\text{Fe})]\text{Si}_7\text{AlO}_{22}(\text{OH})_2$	0.68	0	0					
Quartz low	$\text{SiO}_2$	0.25	0.41	1.2	0.55	0.71	1.23	2.71	1.88
Magnetite	$\text{Fe}_3\text{O}_4$	1.37	0	0.07					
Plagioclase	$(\text{Na},\text{Ca})(\text{Si},\text{Al})_4\text{O}_8$	84.84	80.98	57.62	27.01	53.17	16.77	40.98	21.62
Muscovite	$\text{K Al}_2 ((\text{OH})_2 \text{ Al Si}_3 \text{ O}_{10})$	0	0.06		1.72	0	0.58	0	0.59
Augite	$\text{Ca}(\text{Mg},\text{Fe})\text{Si}_2\text{O}_6$	1.01	0	4.39					
Lizardite	$\text{Mg}_3\text{Si}_2\text{O}_5(\text{OH})_4$	0	0.01	0					
Talc	$\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$	0.67	0.64	4.57	3.9	2.54	7.11	5.82	2.64
Enstatite	$(\text{Mg},\text{Fe})\text{SiO}_3$	11.18	17.85	32	41.24	30.64	68.12	26.06	59.11
Diopside	$\text{CaMgSi}_2\text{O}_6$				5.86	5.79	6.02	6.87	7.33
Smectite	$(\text{Na},\text{Ca})_0.3(\text{Al},\text{Mg})_2\text{Si}_4\text{O}_{10}(\text{OH})_2 \cdot n(\text{H}_2\text{O})$				0.37	0.97	0	0.75	1.04
Kaolinite	$\text{Mg}_3\text{Si}_2\text{O}_5(\text{OH})_4$				0.24	0.19	0.17	0.39	0.09
Actinolite	$\text{Ca}_2(\text{Mg},\text{Fe})_5\text{Si}_8\text{O}_{22}(\text{OH})_2$				trace	trace	trace	trace	trace
Chlorite	$(\text{Mg},\text{Fe})_5\text{Al}(\text{AlSi}_3\text{O}_{10})(\text{OH})_8$				2.95	5.99	0	16.42	5.71
Chromite	$\text{Fe}^{++}\text{Cr}_2\text{O}_4$				16.17	0	0	0	0



### 3.5. KINETIC LEACHING

Kinetic leaching, which is a sequential leach procedure according to the ASTM D5744 standard (20 weeks of leaching using humidity cells) was performed on samples DMS plant and Tailings Pool 2 to determine the elemental release rates. A summary of the leaching rate results for each sample is presented in the following sections.

#### 3.5.1. DMS plant

The DMS plant sample was classified as non-acid generating according to ABA and NAG tests (Figure 3-1 and Figure 3-3), however, the salt load potential released during weathering from the material was not determined in the static assessment. Therefore, a kinetic leach test was performed on one DMS plant sample to estimate the potential salt load and elemental release rates from the DMS stockpile. Figure 3-4 presents the sulphate production rate and carbonate NP consumption over the leaching period of 20 weeks. The weekly leachate remained neutral, being consistent with the ABA findings, with an overall constant sulphate production rate and declining carbonate NP consumption. An elevated sulphate production rate and carbonate NP consumption was observed at the beginning of the leach test. This can be caused by the rinsing of soluble primary and the accumulation of secondary sulphide and carbonate minerals initially present in the sample during the first weeks. Small peaks in the sulphate production rate and carbonate NP consumption were observed at week 9 and week 14. This can possibly be attributed to the biological acclimation in the humidity cell since the physical and chemical conditions were otherwise constant.

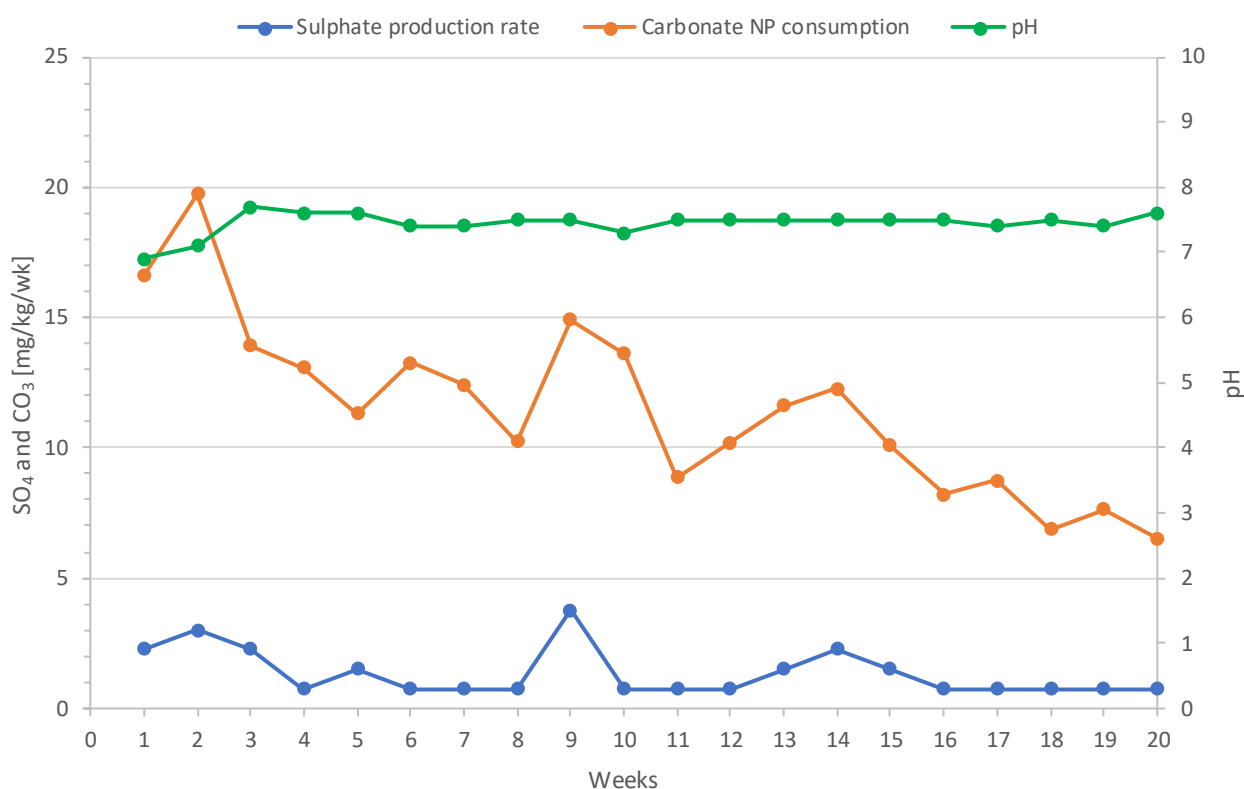


Figure 3-4: pH and relative rates of sulphate production and carbonate consumption of sample DMS plant over 20 weeks.

The calculated sulphate production rate indicated that the neutralizing potential (NP) exceeds the sulphide oxidation, resulting in a continuous neutral pH (Figure 3-4). The total sulphur concentration decreased at a faster rate compared to the remaining NP. Therefore, acid generation is therefore unlikely if the available NP and sulphate production rate of the test sample persist in the long term (Figure 3-5).

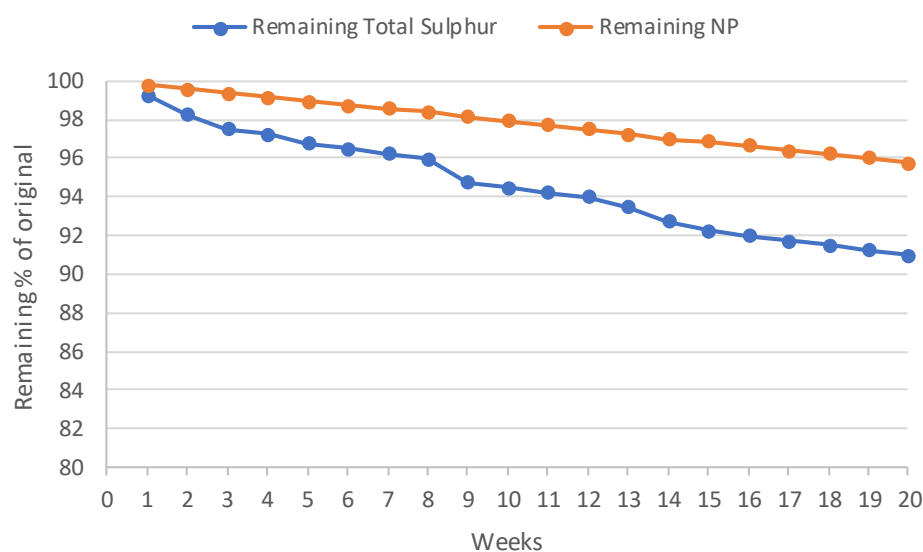


Figure 3-5: Depletion of sulphur and NP of sample DMS plant over 20 weeks.

Metal leaching rates of most metals presented in Figure 3-6 showed only small variations, likely due to the neutral pH values throughout the test. Initial leaching rates of Al and Fe were elevated due to rinsing of soluble primary minerals. Observed peaks in leaching rates at weeks 4 and 9 could be caused by biological acclimation as mentioned above. Strontium had a constant leaching rate, suggesting that its dissolution and precipitation has reached a dynamic steady state in the system and that its leaching rate is controlled by the dissolution of the mineral phase.

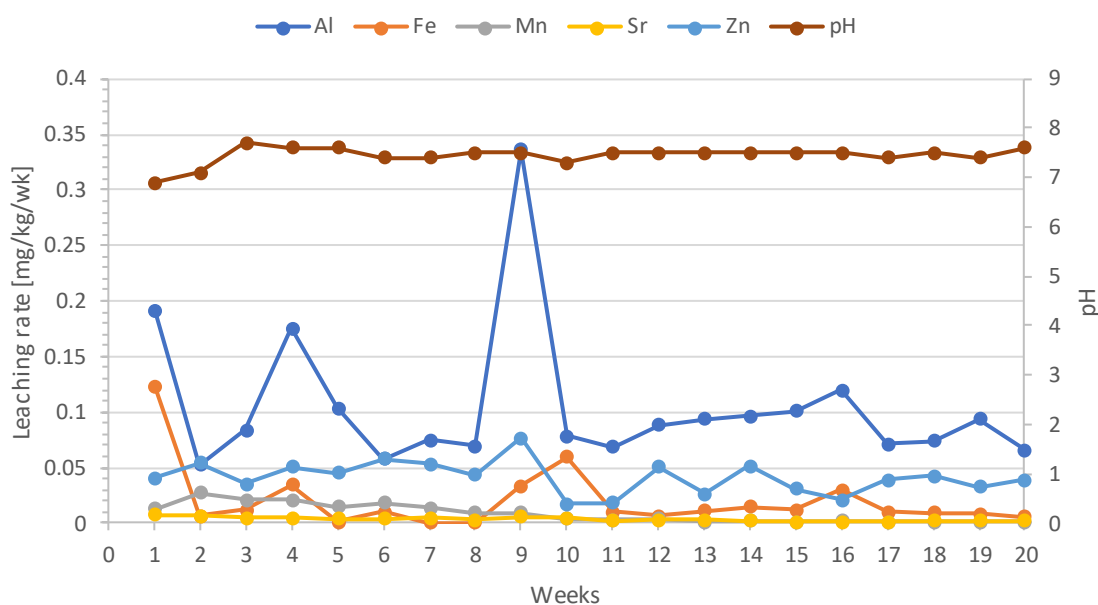


Figure 3-6: Leaching rates of selected metals of sample DMS plant over 20 weeks.

Speciation modelling of the weekly leachate solutions with the software PHREEQC highlighted the following (Figure 3-7):

- Gibbsite ( $\text{Al}(\text{OH})_3$ ), kaolinite ( $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$ ) and partly ferrihydrite ( $\text{Fe}(\text{OH})_3$ ) were supersaturated (saturation index (SI) greater than zero), with exception to weeks 7 and 8;
- Calcite, siderite, dolomite and gypsum were undersaturated (SI less than zero).

Based on the SI calculations, aluminium and iron minerals (oxy-hydroxides) may have precipitated in the humidity cell and the elemental leaching rates for Al and Fe may thus be underestimated for the system.

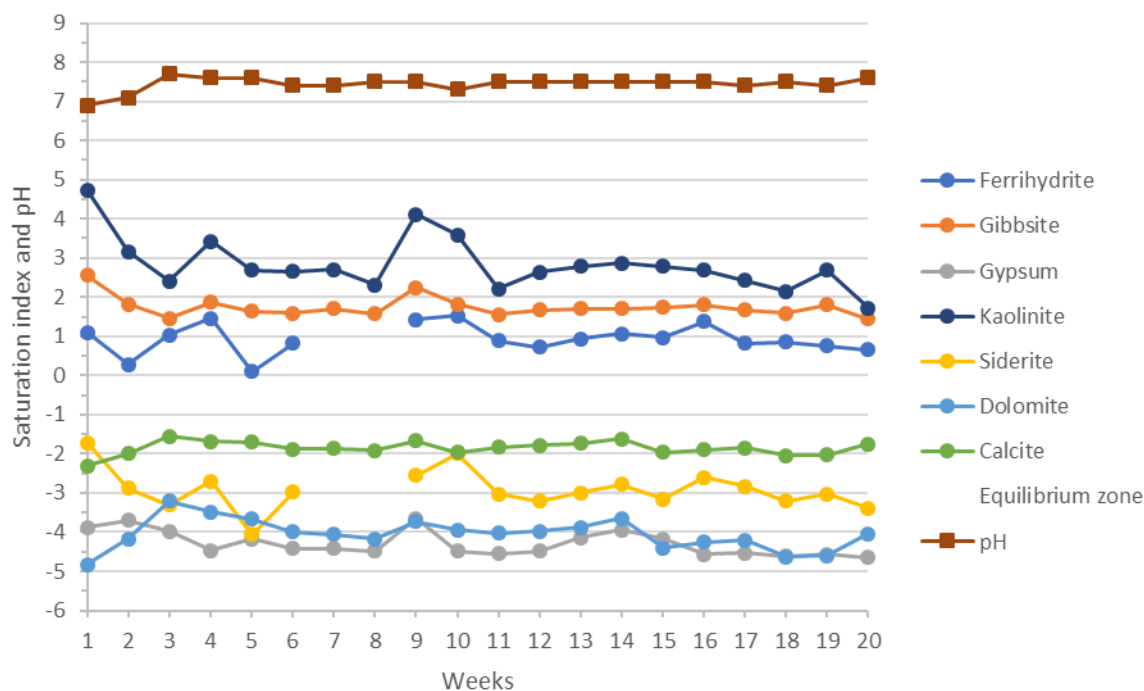


Figure 3-7: Saturation indices of selected minerals of sample DMS plant over 20 weeks.

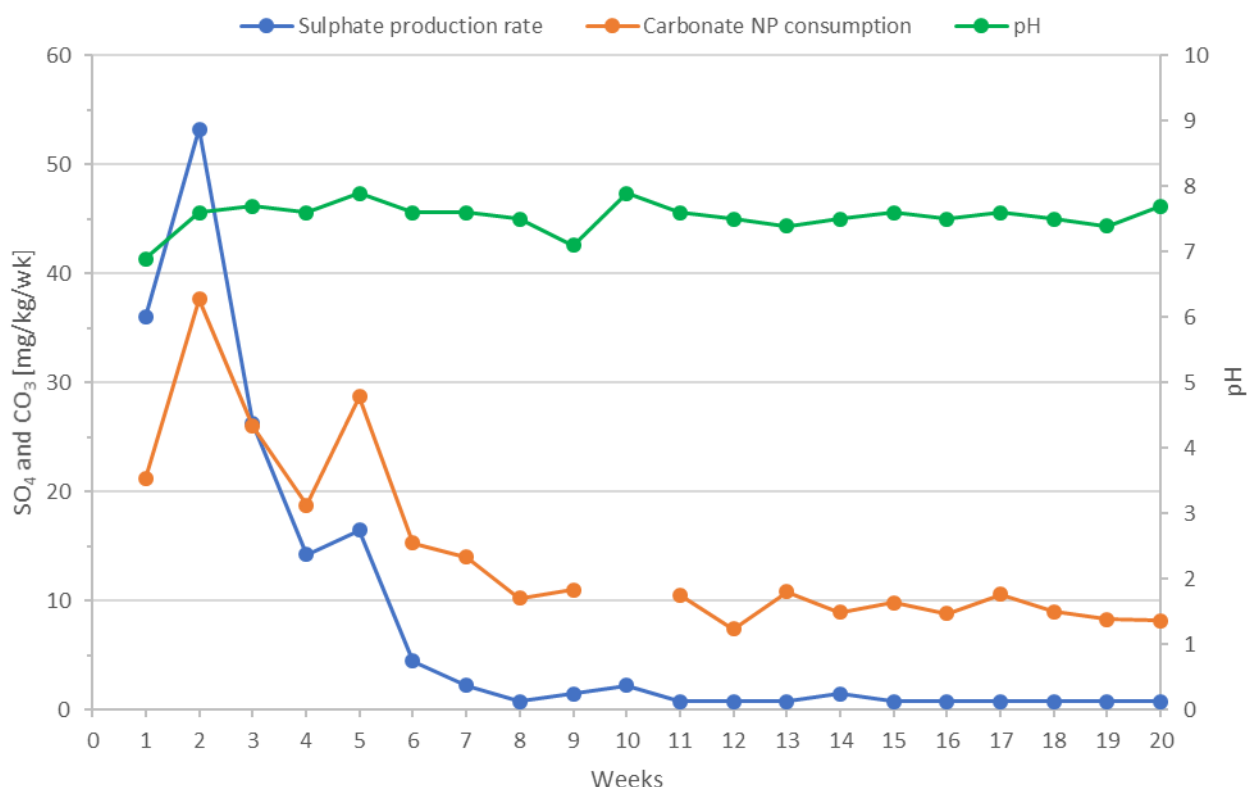
Table 3-6 presents the calculated leaching rates for all elements tested for, averaged over the final three weeks of the kinetic test.

Table 3-6: Calculated elemental leaching rates for sample DMS plant.

Parameter	Units	Leaching rate (average of weeks 18-20)
Alkalinity	mg/kg/wk as CaCO <sub>3</sub>	15.250
NH <sub>3</sub>	mg/kg/wk as N	<0.075
NO <sub>3</sub>	mg/kg/wk as N	<0.075
NO <sub>2</sub>	mg/kg/wk as N	<0.0375
Cl	mg/kg/wk	<1.5
SO <sub>4</sub>	mg/kg/wk	<1.5
F	mg/kg/wk	0.175
Cr(VI)	mg/kg/wk	<0.0075
Ag	mg/kg/wk	0.0003
Al	mg/kg/wk	0.0778
As	mg/kg/wk	0.0003
B	mg/kg/wk	0.0034
Ba	mg/kg/wk	0.0072
Ca	mg/kg/wk	2.3115
Cd	mg/kg/wk	0.0007
Co	mg/kg/wk	0.0001
Cs	mg/kg/wk	0.0001
Cu	mg/kg/wk	0.0014
Fe	mg/kg/wk	0.0075
K	mg/kg/wk	0.6743
Li	mg/kg/wk	0.0001
Mg	mg/kg/wk	0.2973
Mn	mg/kg/wk	0.0008
Mo	mg/kg/wk	0.0001
Na	mg/kg/wk	0.6088
Ni	mg/kg/wk	0.0021
Pb	mg/kg/wk	0.0009
Sb	mg/kg/wk	0.0002
Se	mg/kg/wk	0.0006
Si	mg/kg/wk	0.5535
Sn	mg/kg/wk	0.0193
Sr	mg/kg/wk	0.0020
Ti	mg/kg/wk	0.0008
V	mg/kg/wk	0.0001
W	mg/kg/wk	0.0001
Zn	mg/kg/wk	0.0380

### 3.5.2. Tailings Pool 2

A kinetic test was conducted of the Tailings Pool 2 sample to determine its salt load potential during mineral weathering as well as leaching rates of particular constituents. Figure 3-8 indicates the kinetic test results of the sulphate production rate and carbonate NP consumption over a leaching period of 20 weeks. The weekly leachate remained neutral with a constant sulphate production and carbonate NP consumption after week 7. An initial high sulphate production rate and carbonate NP consumption can be attributed to the rinsing of soluble primary and accumulation of secondary sulphide and carbonate minerals during the first weeks. The elevated carbonate NP consumption at week 10 is most likely an analytical error and was excluded from the interpretation.



**Figure 3-8: pH and relative rates of sulphate production and carbonate consumption of sample Tailings Pool 2 over 20 weeks.**

The calculated sulphate production rate indicated that the neutralizing potential (NP) exceeds the sulphide oxidation, resulting in a continuous neutral pH (Figure 3-8). In addition, the remaining NP decreased at a much slower rate than the remaining total sulphur content of the sample (Figure 3-9). Therefore, acid generation is unlikely if the NP rates and available NP of the sample persist in the long term.

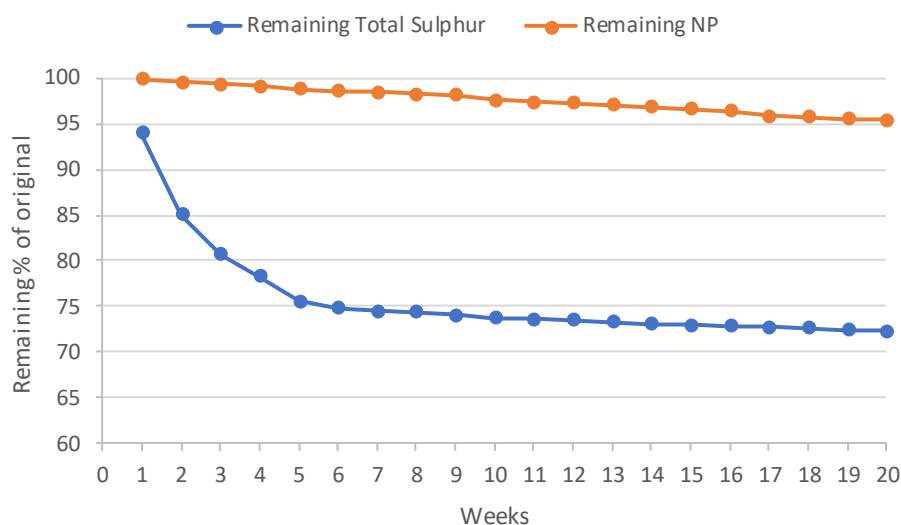


Figure 3-9: Depletion of sulphur and NP of sample Tailings Pool 2 over 20 weeks.

Leaching rates of selected metals are presented in Figure 3-10. During the first 12 weeks of leaching, no consistent trend was observed, possibly caused by biological acclimation of the humidity cell. An initial elevated leaching rate of Al and Fe can be attributed to the rinsing of soluble primary minerals. A constant leaching rate was observed for all selected metals after week 12 in the presence of neutral and steady pH values. This suggests that the system has reached a dynamic equilibrium of precipitation and dissolution of the secondary mineral phases.

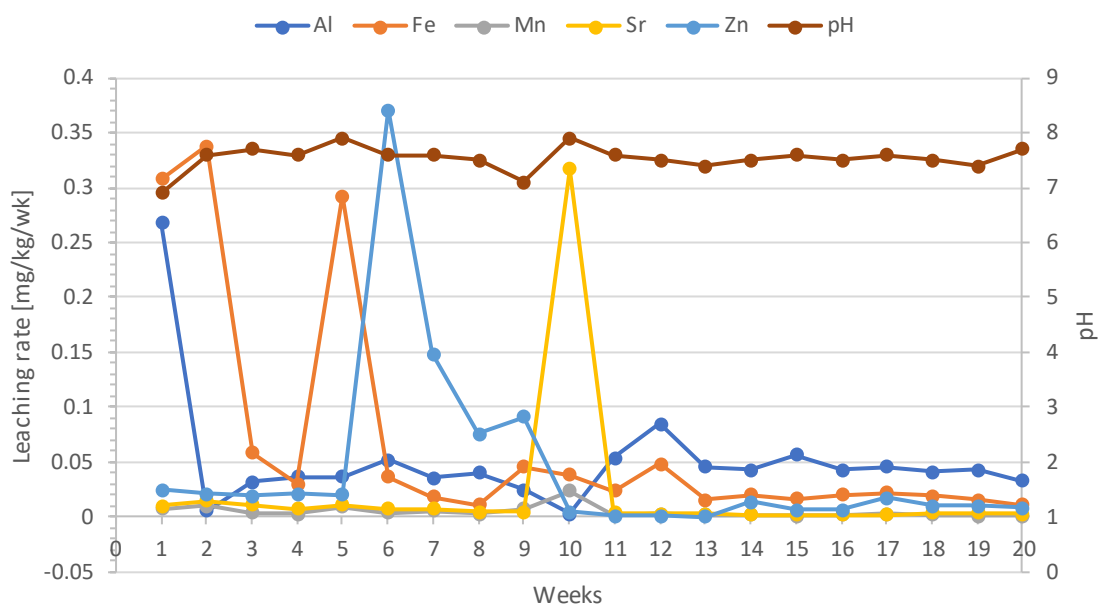


Figure 3-10: Leaching rates of selected metals of sample Tailings Pool 2 over 20 weeks.

Speciation modelling of the weekly leachate solutions obtained from sample Tailings Pool 2 with the software PHREEQC highlighted the following (Figure 3-11):

- Supersaturation (saturation index (SI) greater than zero) with respect to kaolinite ( $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$ ), gibbsite ( $\text{Al}(\text{OH})_3$ ) and ferrihydrite ( $\text{Fe}(\text{OH})_3$ ), with the exception at week 10;
- Undersaturation (SI less than zero) with respect to calcite, siderite, dolomite and gypsum, with the exception at week 10;
- Gibbsite, calcite, and dolomite are in equilibrium at week 10.

Based on the SI calculations, aluminium and iron (oxy-hydroxide) mineral may have precipitated in the humidity cell. Therefore, the elemental leaching rates for Al and Fe may be underestimated for the system.

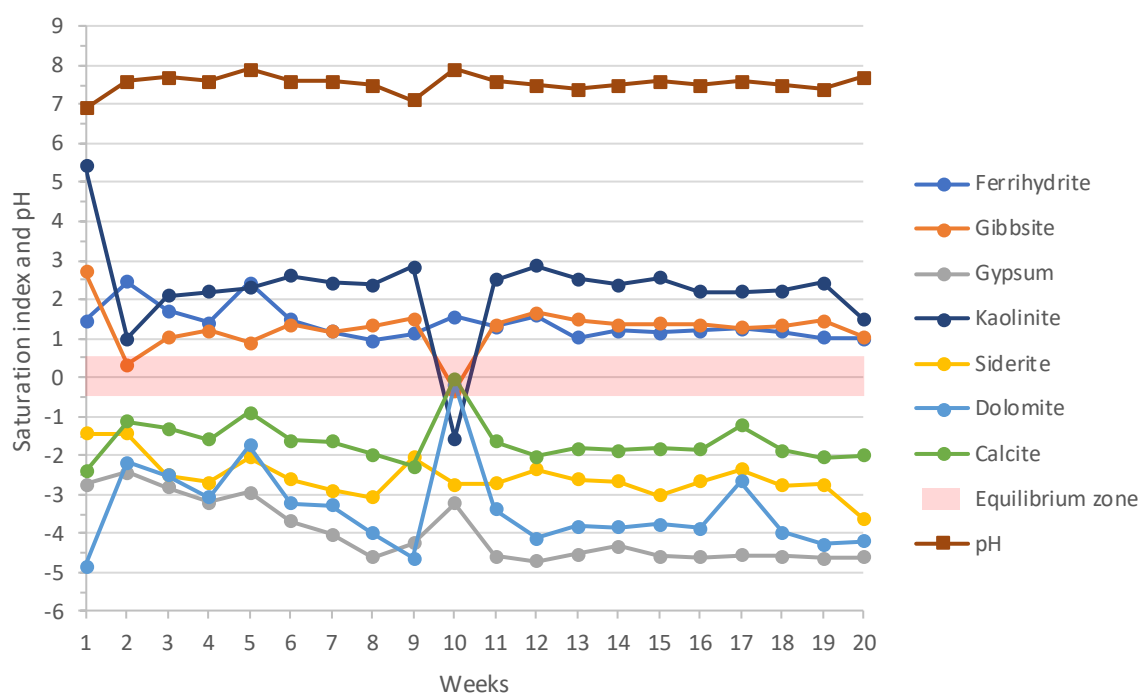


Figure 3-11: Saturation indices of selected minerals of sample Tailings Pool 2 over 20 weeks.

The average leaching rates of the final three weeks of all elements tested for are presented in Table 3-7.

**Table 3-7: Calculated elemental leaching rates of sample Tailings Pool 2.**

Parameter	Units	Leaching rate (average of weeks 18-20)
Alkalinity	mg/kg/wk as CaCO <sub>3</sub>	13.000
NH <sub>3</sub>	mg/kg/wk as N	<0.075
NO <sub>3</sub>	mg/kg/wk as N	<0.075
NO <sub>2</sub>	mg/kg/wk as N	<0.0375
Cl	mg/kg/wk	<1.5
SO <sub>4</sub>	mg/kg/wk	<1.5
F	mg/kg/wk	0.2
Cr(VI)	mg/kg/wk	<0.0075
Al	mg/kg/wk	0.0385
As	mg/kg/wk	0.0001
B	mg/kg/wk	0.0035
Ba	mg/kg/wk	0.0048
Ca	mg/kg/wk	2.3350
Cr	mg/kg/wk	0.0004
Cs	mg/kg/wk	0.0001
Cu	mg/kg/wk	0.0004
Fe	mg/kg/wk	0.0150
K	mg/kg/wk	1.0430
Li	mg/kg/wk	0.0001
Mg	mg/kg/wk	0.6475
Mn	mg/kg/wk	0.0010
Mo	mg/kg/wk	0.0001
Na	mg/kg/wk	0.8120
Ni	mg/kg/wk	0.0028
Pb	mg/kg/wk	0.0003
Sb	mg/kg/wk	0.0003
Se	mg/kg/wk	0.0002
Si	mg/kg/wk	1.0310
Sn	mg/kg/wk	0.0054
Sr	mg/kg/wk	0.0032
V	mg/kg/wk	0.0002
W	mg/kg/wk	0.0001
Zn	mg/kg/wk	0.0094



#### 4. CONCLUSION

The tested DMS plant samples are clearly classified as non-acid generating, with excess buffer capacity to neutralise potential acidity. The exceedances of total concentration thresholds (TCT0) for nickel, copper and fluoride, but not the TCT 1 thresholds alone classify (according to NEMWA 2013) the DMS Plant samples as **Type 3 Waste**, regardless of their leachable concentrations being below the LCT0 threshold.

Based on the preliminary static leachate quality tests conducted on the DMS samples, none of the constituents exceed their LCT0 thresholds at the prescribed 1:20 liquid to solid ratio. An exceedance of the LCT0 threshold for total chromium is however noted for the DMS Plant sample at the 1:4 liquid to solid ratio leach test and flags chromium as a potential constituent of concern. The minimal exceedances of the TCT0 thresholds for total concentrations of copper, nickel, manganese and fluoride don't necessarily suggest a potential impact on the receiving environment, as they are mostly non-leachable. The concentrations of these elements in the leach test results are less than 0.1 percent of the total concentration. This indicates that these elements represent a low environmental risk.

Suitable mitigation measures for the DMS stockpile should be based on a risk analysis, i.e. considering the source (stockpile), groundwater pathway and risk to offsite receptors (e.g. streams and rivers and other groundwater users). Such source-pathway-receptor assessment should also consider the salt load potentially released from the weathering of the material, specifically the plagioclase feldspars and pyroxene silicate mineral enstatite.

Kinetic leach tests of samples DMS plant and Tailings Pool 2 showed a constant neutral pH during the 20-week leach period with a lower sulphate production rate compared to NP consumption. If this relationship is maintained over the long term, both samples are unlikely to become acidic. In addition, the salt load potential released from weathering of the material remained low during kinetic leaching from both the DMS stockpile and Tailings Pool 2 sample.

Should you need to discuss any aspect of this technical memo please do not hesitate to contact us:

PROF. KAI WITTHÜSER

PRINCIPAL HYDROGEOLOGIST

Dr Martin Holland (Pr.Sci.Nat)

PROJECT HYDROGEOLOGIST



## Appendix – A (Lab Certificates)

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**CERTIFICATE OF ANALYSES**  
**NET ACID GENERATION**

Date received: 2018-07-30  
Project number: 1000

Report number: 76210

Date completed: 2018-08-29  
Order number: Delh.2018.049-6

Client name: Delta H  
Address: PO Box 11465, Silver Lakes, 0054  
Telephone: ---

Contact person: Dr. Martin Holland  
Email: martin@delta-h.co.za  
Cell: 082 497 9088

Net Acid Generation	Sample Identification: pH 4.5		
	Tailings Pool	DMS Plant	DMS Plant
Sample Number	36512	36513	36513 D
NAG pH: (H <sub>2</sub> O <sub>2</sub> )	7.5	7.3	7.9
NAG (kg H <sub>2</sub> SO <sub>4</sub> / t)	<0.01	<0.01	<0.01

Net Acid Generation	Sample Identification: pH 7		
	Tailings Pool	DMS Plant	DMS Plant
Sample Number	36512	36513	36513 D
NAG pH: (H <sub>2</sub> O <sub>2</sub> )	7.5	7.3	7.9
NAG (kg H <sub>2</sub> SO <sub>4</sub> / t)	<0.01	<0.01	<0.01

Notes:

- Samples analysed with Single Addition NAG test as per Prediction Manual For Drainage Chemistry from Sulphidic Geological Materials MEND Report 1.20.1.
- Please let me know if results do not correspond to other data.

S. Laubscher  
Assistant Geochemistry Project Manager



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### **CERTIFICATE OF ANALYSES ACID – BASE ACCOUNTING EPA-600 MODIFIED SOBEK METHOD**

Date received: 2018-07-30  
Project number: 1000

Report number: 76210

Date completed: 2018-08-28  
Order number: Delh.2018.049-6

Client name: Delta H  
Address: PO Box 11465, Silver Lakes, 0054  
Telephone: ---

Contact person: Dr. Martin Holland  
Email: [martin@delta-h.co.za](mailto:martin@delta-h.co.za)  
Cell: 082 497 9088

Acid – Base Accounting Modified Sobek (EPA-600)	Sample Identification		
	Tailings Pool	DMS Plant	DMS Plant
Sample Number	36512	36513	36513 D
Paste pH	9.4	9.4	9.4
Total Sulphur (%) (LECO)	0.02	0.01	0.02
Acid Potential (AP) (kg/t)	0.625	0.313	0.625
Neutralization Potential (NP)	8.99	7.16	7.67
Nett Neutralization Potential (NNP)	8.37	6.84	7.04
Neutralising Potential Ratio (NPR) (NP : AP)	14	23	12
Rock Type	III	III	III

\* Negative NP values are obtained when the volume of NaOH (0.1N) titrated (pH: 8.3) is greater than the volume of HCl (1N) to reduce the pH of the sample to 2.0 – 2.5 Any negative NP values are corrected to 0.00.

Please refer to Appendix (p.2) for a Terminology of terms and guidelines for rock classification

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Assistant Geochemistry Project Manager

**CERTIFICATE OF ANALYSES**  
**ACID – BASE ACCOUNTING**  
**EPA-600 MODIFIED SOBEK METHOD**

Date received: 2018-07-30  
Project number: 1000

Report number: 76210

Date completed: 2018-08-28  
Order number: Delh.2018.049-6

Client name: Delta H  
Address: PO Box 11465, Silver Lakes, 0054  
Telephone: ---

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Cell: 082 497 9088

**APPENDIX: TERMINOLOGY AND ROCK CLASSIFICATION**

**TERMINOLOGY (SYNONYMS)**

- Acid Potential (AP) ; *Synonyms:* Maximum Potential Acidity (MPA)  
**Method:** Total S(%) (Leco Analyzer) x 31.25
- Neutralization Potential (NP) ; *Synonyms:* Gross Neutralization Potential (GNP) ; *Syn:* Acid Neutralization Capacity (ANC) (The capacity of a sample to consume acid)  
**Method:** Fizz Test ; Acid-Base Titration (Sobek & Modified Sobek (Lawrence) Methods)
- Nett Neutralization Potential (NNP) ; *Synonyms:* Nett Acid Production Potential (NAPP)  
**Calculation:**  $NNP = NP - AP$  ;  $NAPP = ANC - MPA$
- Neutralising Potential Ratio (NPR)  
**Calculation:**  $NPR = NP : AP$

**CLASSIFICATION ACCORDING TO NETT NEUTRALISING POTENTIAL (NNP)**

If  $NNP (NP - AP) < 0$ , the sample has the potential to generate acid  
If  $NNP (NP - AP) > 0$ , the sample has the potential to neutralise acid produced

Any sample with  $NNP < 20$  is potential acid-generating, and any sample with  $NNP > -20$  might not generate acid (Usher *et al.*, 2003)

**ROCK CLASSIFICATION**

<b>TYPE I</b>	Potentially Acid Forming	Total S(%) > 0.25% and NP:AP ratio 1:1 or less
<b>TYPE II</b>	Intermediate	Total S(%) > 0.25% and NP:AP ratio 1:3 or less
<b>TYPE III</b>	Non-Acid Forming	Total S(%) < 0.25% and NP:AP ratio 1:3 or greater

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### **CERTIFICATE OF ANALYSES ACID – BASE ACCOUNTING EPA-600 MODIFIED SOBEK METHOD**

Date received: 2018-07-30  
Project number: 1000

Report number: 76210

Date completed: 2018-08-28  
Order number: Delh.2018.049-6

Client name: Delta H  
Address: PO Box 11465, Silver Lakes, 0054  
Telephone: ---

Contact person: Dr. Martin Holland  
Email: [martin@delta-h.co.za](mailto:martin@delta-h.co.za)  
Cell: 082 497 9088

#### **CLASSIFICATION ACCORDING TO NEUTRALISING POTENTIAL RATIO (NPR)**

Guidelines for screening criteria based on ABA (Price *et al.*, 1997 ; Usher *et al.*, 2003)

Potential for ARD	Initial NPR Screening Criteria	Comments
Likely	< 1:1	Likely AMD generating
Possibly	1:1 – 2:1	Possibly AMD generating if NP is insufficiently reactive or is depleted at a faster rate than sulphides
Low	2:1 – 4:1	Not potentially AMD generating unless significant preferential exposure of sulphides along fracture planes, or extremely reactive sulphides in combination with insufficiently reactive NP
None	>4:1	No further AMD testing required unless materials are to be used as a source of alkalinity

#### **CLASSIFICATION ACCORDING TO SULPHUR CONTENT (%S) AND NEUTRALISING POTENTIAL RATIO (NPR)**

For sustainable long-term acid generation, at least 0.3% Sulphide-S is needed. Values below this can yield acidity but it is likely to be only of short-term significance. From these facts, and using the NPR values, a number of rules can be derived:

- 1) Samples with less than 0.3% Sulphide-S are regarded as having insufficient oxidisable Sulphide-S to sustain acid generation.
- 2) NPR ratios of >4:1 are considered to have enough neutralising capacity.
- 3) NPR ratios of 3:1 to 1:1 are considered inconclusive.
- 4) NPR ratios below 1:1 with Sulphide-S above 3% are potentially acid-generating. (Soregaroli & Lawrence, 1998 ; Usher *et al.*, 2003)

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### **CERTIFICATE OF ANALYSES ACID – BASE ACCOUNTING EPA-600 MODIFIED SOBEK METHOD**

Date received: 2018-07-30  
Project number: 1000

Report number: 76210

Date completed: 2018-08-28  
Order number: Delh.2018.049-6

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#### **REFERENCES**

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ENVIRONMENT AUSTRALIA. 1997. **Managing Sulphidic Mine Wastes and Acid Drainage.**

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### **CERTIFICATE OF ANALYSES** **SULPHUR SPECIATION**

Methods from: Prediction Manual For Drainage Chemistry from Sulphidic Geological Materials MEND Report 1.20.1

Date received: 2018-07-30  
Project number: 1000

Report number: 76210

Date completed: 2018-08-27  
Order number: Delh.2018.049-6

Client name: Delta H  
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Contact person: Dr. Martin Holland  
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Cell: 082 497 9088

Sulphur Speciation*	Sample Identification		
	Tailings Pool	DMS Plant	DMS Plant
Sample Number	36512	36513	36513 D
Total Sulphur (%) (LECO)	0.02	0.01	0.02
Sulphate Sulphur as S (%)	0.01	0.01	0.01
Sulphide Sulphur (%)	<0.01	<0.01	<0.01

Notes:

- Samples analysed with Pyrolysis at 550°C as per Prediction Manual For Drainage Chemistry from Sulphidic Geological Materials MEND Report 1.20.1. Multiply Sulphate Sulphur to calculate SO<sub>4</sub> % by 2.996. Please see the method for interferences.
- Organic Sulphur is not taken into account and may be included in the results.
- Please let me know if results do not correspond to other data.

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## CERTIFICATE OF ANALYSES X-RAY DIFFRACTION

Date received: 2018-07-30  
Project number: 1000

Report number: 76210

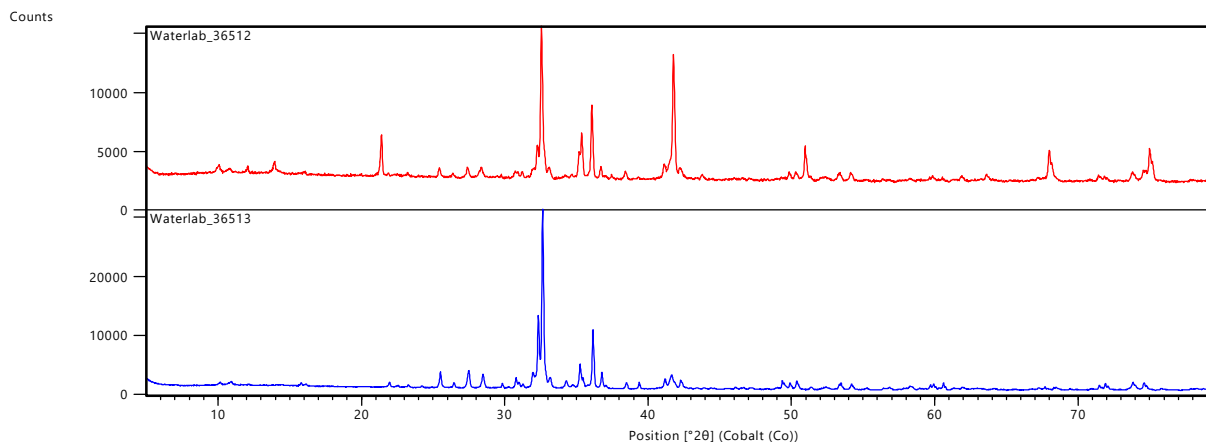
Date completed: 2018-08-16  
Order number: Delh.2018.049-6

Client name: Delta H  
Address: PO Box 11465, Silver Lakes, 0054  
Telephone: ---

Contact person: Dr. Martin Holland  
Email: martin@delta-h.co.za  
Cell: 082 497 9088

Composition (%) [s]			
Tailings Pool		DMS Plant	
36512		36513	
Mineral	Amount (weight %)	Mineral	Amount (weight %)
Magnetite	29.56	Magnetite	1.37
Enstatite	32.41	Enstatite	11.18
Plagioclase	34.02	Plagioclase	84.84
Hornblende	1.65	Hornblende	0.68
Muscovite	0.18	Muscovite	0
Lizardite	0.34	Lizardite	0
Quartz	0.1	Quartz	0.25
Augite	0.72	Augite	1.01
Talc	1.02	Talc	0.67

### [s] Results obtained from sub-contracted laboratory



Peak List
Magnetite; Fe3 O4
Enstatite; ferroan; Fe0.3 Mg0.7 O3 Si1
Anorthite; sodian; Al1.66 Ca0.66 Na0.34 O8 Si3.34
Magnesianhornblende; ferrian; H2 Al1.33 Ca1.81 Fe1.63 K0.03 Mg3.14 Mn0.03 Na0.08 O24 Si6.92 Ti0.15
Muscovite; 2M1; H5.6 Al3.03 N0.9 O12 Si4.67
Lizardite 1T; H4 Mg8 O9 Si2
Quartz; O2 Si1
Augite; Al0.07 Ca0.85 Cr0.02 Fe0.12 Mg0.98 Na0.01 O6 Si1.95
Talc 1A; H2 Mg3 O12 Si4

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Assistant Geochemistry Project Manager

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### CERTIFICATE OF ANALYSES X-RAY DIFFRACTION

Date received: 2018-07-30  
Project number: 1000

Report number: 76210

Date completed: 2018-08-16  
Order number: Delh.2018.049-6

Client name: Delta H  
Address: PO Box 11465, Silver Lakes, 0054  
Telephone: ---

Contact person: Dr. Martin Holland  
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Cell: 082 497 9088

#### Note:

The material was prepared for XRD analysis using a backloading preparation method. It was analysed with a PANalytical AERIS diffractometer with PIXcel detector and fixed slits with Fe filtered Co-K $\alpha$  radiation. The phases were identified using X'Pert Highscore plus software. The relative phase amounts (weight %) were estimated using the Rietveld method.

#### Comment:

- In case the results do not correspond to results of other analytical techniques, please let me know for further fine tuning of XRD.
- Mineral names may not reflect the actual compositions of minerals identified, but rather the mineral group.
- Due to preferred orientation and crystallite size effects, results may not be as accurate as shown in the table.
- Traces of additional phases may be present.
- Amorphous phases, if present, were not taken into consideration during quantification

#### Ideal Mineral compositions:

Compound Name	Ideal Chemical Formula
Hornblende	$\text{Ca}_2[\text{Mg}_4(\text{Al}, \text{Fe})]\text{Si}_7\text{AlO}_{22}(\text{OH})_2$
Quartz low	$\text{SiO}_2$
Magnetite	$\text{Fe}_3\text{O}_4$
Plagioclase	$(\text{Na}, \text{Ca})(\text{Si}, \text{Al})_4\text{O}_8$
Muscovite	$\text{K Al}_2 ((\text{OH})_2 \text{ Al Si}_3 \text{ O}_{10})$
Augite	$\text{Ca}(\text{Mg}, \text{Fe})\text{Si}_2\text{O}_6$
Lizardite	$\text{Mg}_3\text{Si}_2\text{O}_5(\text{OH})_4$
Talc	$\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$
Enstatite	$(\text{Mg}, \text{Fe})\text{SiO}_3$

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## CERTIFICATE OF ANALYSES EXTRACTIONS AS 4439.3

Date received: 2018/07/30 Date completed: 2018/08/28  
Project number: 1000 Report number: 76210 Order number: Delh.2018.049-6

Client name: Delta H Contact person: Dr. Martin Holland  
Address: PO Box 11465, Silver Lakes, 0054 Email: martin@delta-h.co.za  
Telephone: --- Cell: 082 497 9088

Analyses	Tailings Pool	DMS Plant				
Sample Number	36512	36513				
TCPLP / Borax / Distilled Water	Distilled Water	Distilled Water				
Ratio*	1:20	1:20				
Units	mg/ℓ	mg/ℓ	LCT0 mg/l	LCT1 mg/l	LCT2 mg/l	LCT3 mg/l
As, Arsenic	<0.001	<0.001	0.01	0.5	1	4
B, Boron	<0.025	<0.025	0.5	25	50	200
Ba, Barium	<0.025	<0.025	0.7	35	70	280
Cd, Cadmium	<0.003	<0.003	0.003	0.15	0.3	1.2
Co, Cobalt	<0.025	<0.025	0.5	25	50	200
Cr <sub>total</sub> , Chromium Total	2.39	0.033	0.1	5	10	40
Cr(VI), Chromium (VI)	<0.010	<0.010	0.05	2.5	5	20
Cu, Copper	<0.010	<0.010	2.0	100	200	800
Hg, Mercury	0.002	<0.001	0.006	0.3	0.6	2.4
Mn, Manganese	0.065	<0.025	0.5	25	50	200
Mo, Molybdenum	<0.025	<0.025	0.07	3.5	7	28
Ni, Nickel	0.051	<0.025	0.07	3.5	7	28
Pb, Lead	<0.010	<0.010	0.01	0.5	1	4
Sb, Antimony	<0.001	0.001	0.02	1.0	2	8
Se, Selenium	<0.001	<0.001	0.01	0.5	1	4
V, Vanadium	<0.025	<0.025	0.2	10	20	80
Zn, Zinc	<0.025	<0.025	5.0	250	500	2000
Inorganic Anions	mg/ℓ	mg/ℓ				
Total Dissolved Solids*	50	30	1000	12 500	25 000	100 000
Chloride as Cl	4	<2	300	15 000	30 000	120 000
Sulphate as SO <sub>4</sub>	2	<2	250	12 500	25 000	100 000
Nitrate as N	<0.1	0.3	11	550	1100	4400
Fluoride as F	<0.2	<0.2	1.5	75	150	600
Paste pH	9.4	9.4				
Moisture %	10.6	0				
% Solids	---	---				
Acid Base Accounting	See attached report 76210 ABA					
Net Acid Generation	See attached report 76210 NAG					
Sulphur Speciation	See attached report 76210 SS					
X-ray Diffraction [s]	See attached report 76210 XRD					

\*Please note: 1. The sample  
2. A moisture  
3. In cases where  
Moisture  
4. The result

Analyses	Tailings Pool	DMS Plant				
Sample Number	36512	36513				
TCPLP / Borax / Distilled Water	Distilled Water	Distilled Water				
Ratio*	1:4	1:4				
Units	mg/ℓ	mg/ℓ	LCT0 mg/l	LCT1 mg/l	LCT2 mg/l	LCT3 mg/l
As, Arsenic	0.002	0.001	0.01	0.5	1	4
B, Boron	<0.025	<0.025	0.5	25	50	200
Ba, Barium	<0.025	<0.025	0.7	35	70	280
Cd, Cadmium	<0.003	<0.003	0.003	0.15	0.3	1.2
Co, Cobalt	<0.025	<0.025	0.5	25	50	200
Cr <sub>total</sub> , Chromium Total	0.431	0.132	0.1	5	10	40
Cr(VI), Chromium (VI)	<0.010	<0.010	0.05	2.5	5	20
Cu, Copper	<0.010	<0.010	2.0	100	200	800
Hg, Mercury	0.006	<0.001	0.006	0.3	0.6	2.4
Mn, Manganese	<0.025	0.165	0.5	25	50	200
Mo, Molybdenum	<0.025	<0.025	0.07	3.5	7	28
Ni, Nickel	<0.025	0.046	0.07	3.5	7	28
Pb, Lead	<0.010	<0.010	0.01	0.5	1	4
Sb, Antimony	0.001	0.001	0.02	1.0	2	8
Se, Selenium	0.004	<0.001	0.01	0.5	1	4
V, Vanadium	<0.025	<0.025	0.2	10	20	80
Zn, Zinc	<0.025	<0.025	5.0	250	500	2000
Inorganic Anions	mg/ℓ	mg/ℓ				
Total Dissolved Solids*	132	122	1000	12 500	25 000	100 000
Chloride as Cl	11	5	300	15 000	30 000	120 000
Sulphate as SO <sub>4</sub>	23	<2	250	12 500	25 000	100 000
Nitrate as N	<0.1	1.5	11	550	1100	4400
Fluoride as F	<0.2	<0.2	1.5	75	150	600
% Solids	---	---				

[s] = Subcontracted

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## CERTIFICATE OF ANALYSES

Digestion AS 4439.3

Date received:	2018/07/30	Date completed:	2018/08/28
Project number:	1000	Report number:	76210
Order number:	Delh.2018.049-6		
Client name:	Delta H	Contact person:	Dr. Martin Holland
Address:	PO Box 11465, Silver Lakes, 0054	Email:	martin@delta-h.co.za
Telephone:	---	Cell:	082 497 9088

Analyses							
	Tailings Pool		DMS Plant				
Sample Number	36512		36513		TCT0 mg/kg	TCT1 mg/kg	TCT2 mg/kg
Digestion	HNO3 : HF		HNO3 : HF				
Dry Mass Used (g)	0.25		0.25				
Volume Used (mℓ)	100		100				
Units	mg/ℓ	mg/kg	mg/ℓ	mg/kg			
As, Arsenic	0.002	0.800	<0.001	<0.400	5.8	500	2000
B, Boron	<0.025	<10	<0.025	<10	150	15000	6000
Ba, Barium	0.070	28	0.130	52	62.5	6250	25000
Cd, Cadmium	0.020	8.00	0.012	4.80	7.5	260	1040
Co, Cobalt	0.205	82	0.104	42	50	5000	20000
Cr <sub>Total</sub> , Chromium Total	92	36800	5.39	2156	46000	800000	N/A
Cu, Copper	0.068	27	0.123	49	16	19500	78000
Hg, Mercury	<0.001	<0.400	<0.001	<0.400	0.93	160	640
Mn, Manganese	2.24	896	1.84	736	1000	25000	100000
Mo, Molybdenum	<0.025	<10	<0.025	<10	40	1000	4000
Ni, Nickel	1.53	612	0.850	340	91	10600	42400
Pb, Lead	<0.010	<4.00	<0.010	<4.00	20	1900	7600
Sb, Antimony	<0.001	<0.400	<0.001	<0.400	10	75	300
Se, Selenium	0.004	1.60	<0.001	<0.400	10	50	200
V, Vanadium	0.712	285	0.032	13	150	2680	10720
Zn, Zinc	0.404	162	0.554	222	240	160000	640000
Inorganic Anions	mg/ℓ	mg/kg	mg/ℓ	mg/kg			
Cr(VI), Chromium (VI) Total [s]	---	<5	---	<5	6.5	500	2000
Total Fluoride [s] mg/kg	---	104	---	112	100	10000	40000

[s] = subcontracted

UTD = Unable to determine

S. Laubscher  
Assistant Geochemistry Project Manager

**CERTIFICATE OF ANALYSES**  
**NET ACID GENERATION**

Date received: 2018-08-21  
Project number: 1000

Report number: 76722

Date completed: 2018-09-07  
Order number: Delh.2018.049-6

Client name: Delta H  
Address: PO Box 11465, Silver Lakes, 0054  
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Contact person: Dr. Martin Holland  
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Email: [theo@delta-h.co.za](mailto:theo@delta-h.co.za)

Net Acid Generation	Sample Identification: pH 4.5	
	DMS Plant #2	DMS Plant #2
Sample Number	38547	38547 D
NAG pH: (H <sub>2</sub> O <sub>2</sub> )	7.9	7.9
NAG (kg H <sub>2</sub> SO <sub>4</sub> / t)	<0.01	<0.01

Net Acid Generation	Sample Identification: pH 7	
	DMS Plant #2	DMS Plant #2
Sample Number	38547	38547 D
NAG pH: (H <sub>2</sub> O <sub>2</sub> )	7.9	7.9
NAG (kg H <sub>2</sub> SO <sub>4</sub> / t)	<0.01	<0.01

Notes:

- Samples analysed with Single Addition NAG test as per Prediction Manual For Drainage Chemistry from Sulphidic Geological Materials MEND Report 1.20.1.
- Please let me know if results do not correspond to other data.

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Assistant Geochemistry Project Manager



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### **CERTIFICATE OF ANALYSES ACID – BASE ACCOUNTING EPA-600 MODIFIED SOBEK METHOD**

Date received: 2018-08-21  
Project number: 1000

Report number: 76722

Date completed: 2018-09-07  
Order number: Delh.2018.049-6

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Acid – Base Accounting Modified Sobek (EPA-600)	Sample Identification	
	DMS Plant #2	DMS Plant #2
Sample Number	38547	38547 D
Paste pH	9.4	9.4
Total Sulphur (%) (LECO)	0.01	0.01
Acid Potential (AP) (kg/t)	0.425	0.391
Neutralization Potential (NP)	13	14
Nett Neutralization Potential (NNP)	12	13
Neutralising Potential Ratio (NPR) (NP : AP)	30	35
Rock Type	III	III

\* Negative NP values are obtained when the volume of NaOH (0.1N) titrated (pH: 8.3) is greater than the volume of HCl (1N) to reduce the pH of the sample to 2.0 – 2.5 Any negative NP values are corrected to 0.00.

Please refer to Appendix (p.2) for a Terminology of terms and guidelines for rock classification

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### **CERTIFICATE OF ANALYSES** **ACID – BASE ACCOUNTING** **EPA-600 MODIFIED SOBEK METHOD**

Date received: 2018-08-21  
Project number: 1000

Report number: 76722

Date completed: 2018-09-07  
Order number: Delh.2018.049-6

Client name: Delta H  
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### **APPENDIX: TERMINOLOGY AND ROCK CLASSIFICATION**

#### **TERMINOLOGY (SYNONYMS)**

- Acid Potential (AP) ; *Synonyms:* Maximum Potential Acidity (MPA)  
**Method:** Total S(%) (Leco Analyzer) x 31.25
- Neutralization Potential (NP) ; *Synonyms:* Gross Neutralization Potential (GNP) ; *Syn:* Acid Neutralization Capacity (ANC) (The capacity of a sample to consume acid)  
**Method:** Fizz Test ; Acid-Base Titration (Sobek & Modified Sobek (Lawrence) Methods)
- Nett Neutralization Potential (NNP) ; *Synonyms:* Nett Acid Production Potential (NAPP)  
**Calculation:**  $NNP = NP - AP$  ;  $NAPP = ANC - MPA$
- Neutralising Potential Ratio (NPR)  
**Calculation:**  $NPR = NP : AP$

#### **CLASSIFICATION ACCORDING TO NETT NEUTRALISING POTENTIAL (NNP)**

If  $NNP (NP - AP) < 0$ , the sample has the potential to generate acid

If  $NNP (NP - AP) > 0$ , the sample has the potential to neutralise acid produced

Any sample with  $NNP < 20$  is potential acid-generating, and any sample with  $NNP > -20$  might not generate acid (Usher *et al.*, 2003)

#### **ROCK CLASSIFICATION**

TYPE I	Potentially Acid Forming	Total S(%) > 0.25% and NP:AP ratio 1:1 or less
TYPE II	Intermediate	Total S(%) > 0.25% and NP:AP ratio 1:3 or less
TYPE III	Non-Acid Forming	Total S(%) < 0.25% and NP:AP ratio 1:3 or greater

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**CERTIFICATE OF ANALYSES  
ACID – BASE ACCOUNTING  
EPA-600 MODIFIED SOBEK METHOD**

Date received: 2018-08-21  
Project number: 1000

Report number: 76722

Date completed: 2018-09-07  
Order number: Delh.2018.049-6

Client name: Delta H  
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**CLASSIFICATION ACCORDING TO NEUTRALISING POTENTIAL RATIO (NPR)**

Guidelines for screening criteria based on ABA (Price *et al.*, 1997 ; Usher *et al.*, 2003)

Potential for ARD	Initial NPR Screening Criteria	Comments
Likely	< 1:1	Likely AMD generating
Possibly	1:1 – 2:1	Possibly AMD generating if NP is insufficiently reactive or is depleted at a faster rate than sulphides
Low	2:1 – 4:1	Not potentially AMD generating unless significant preferential exposure of sulphides along fracture planes, or extremely reactive sulphides in combination with insufficiently reactive NP
None	>4:1	No further AMD testing required unless materials are to be used as a source of alkalinity

**CLASSIFICATION ACCORDING TO SULPHUR CONTENT (%S) AND NEUTRALISING POTENTIAL RATIO (NPR)**

For sustainable long-term acid generation, at least 0.3% Sulphide-S is needed. Values below this can yield acidity but it is likely to be only of short-term significance. From these facts, and using the NPR values, a number of rules can be derived:

- 1) Samples with less than 0.3% Sulphide-S are regarded as having insufficient oxidisable Sulphide-S to sustain acid generation.
- 2) NPR ratios of >4:1 are considered to have enough neutralising capacity.
- 3) NPR ratios of 3:1 to 1:1 are considered inconclusive.
- 4) NPR ratios below 1:1 with Sulphide-S above 3% are potentially acid-generating. (Soregaroli & Lawrence, 1998 ; Usher *et al.*, 2003)

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### **CERTIFICATE OF ANALYSES ACID – BASE ACCOUNTING EPA-600 MODIFIED SOBEK METHOD**

Date received: 2018-08-21  
Project number: 1000

Report number: 76722

Date completed: 2018-09-07  
Order number: Delh.2018.049-6

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#### **REFERENCES**

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### **CERTIFICATE OF ANALYSES** **SULPHUR SPECIATION**

Methods from: Prediction Manual For Drainage Chemistry from Sulphidic Geological Materials MEND Report 1.20.1

Date received: 2018-08-21

Project number: 1000

Report number: 76722

Date completed: 2018-09-10

Order number: Delh.2018.049-6

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Sulphur Speciation*	Sample Identification	
	DMS Plant #2	DMS Plant #2
Sample Number	38547	38547 D
Total Sulphur (%) (LECO)	0.01	0.01
Sulphate Sulphur as S (%)	0.01	0.01
Sulphide Sulphur (%)	<0.01	<0.01

Notes:

- Samples analysed with Pyrolysis at 550°C as per Prediction Manual For Drainage Chemistry from Sulphidic Geological Materials MEND Report 1.20.1. Multiply Sulphate Sulphur to calculate SO<sub>4</sub> % by 2.996. Please see the method for interferences.
- Organic Sulphur is not taken into account and may be included in the results.
- Please let me know if results do not correspond to other data.

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## CERTIFICATE OF ANALYSES X-RAY DIFFRACTION

Date received: 2018-08-21  
Project number: 1000

Report number: 76722

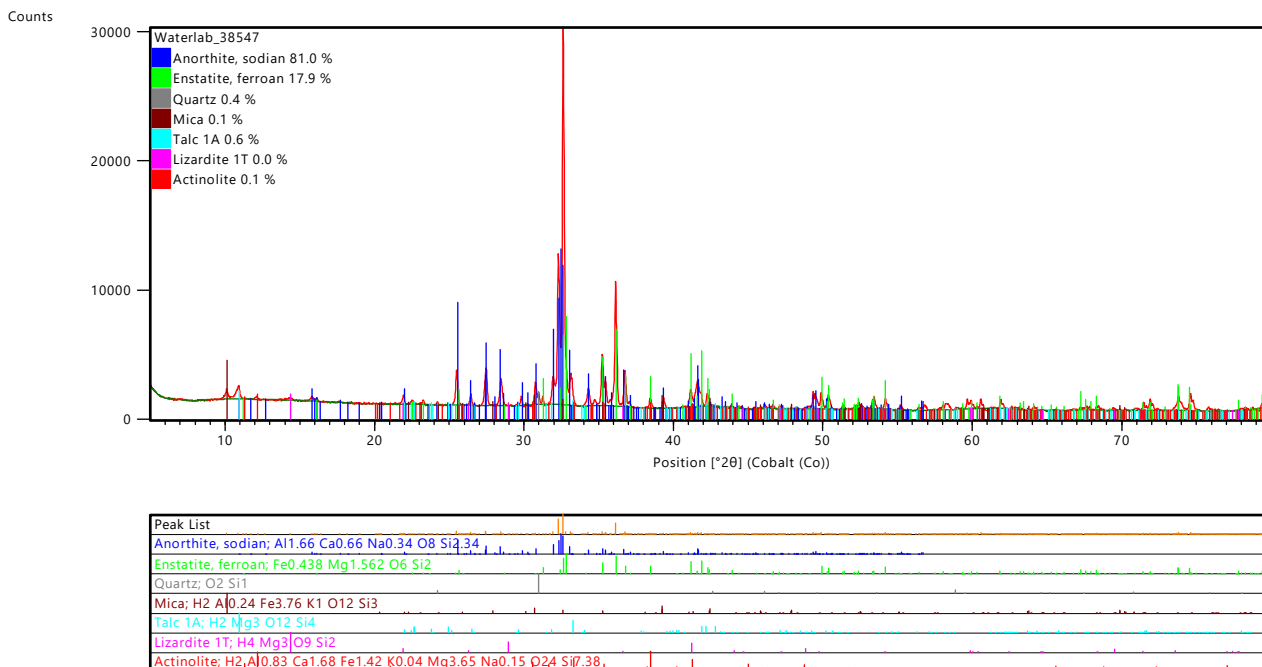
Date completed: 2018-09-04  
Order number: Delh.2018.049-6

Client name: Delta H  
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Contact person: Dr. Martin Holland  
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Composition (%) [s]	
DMS Plant #2	
38547	
Mineral	Amount (weight %)
Plagioclase	80.98
Enstatite	17.85
Quartz	0.41
Muscovite	0.06
Talc	0.64
Lizardite	0.01
Actinolite	0.06

### [s] Results obtained from sub-contracted laboratory



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Assistant Geochemistry Project Manager

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### CERTIFICATE OF ANALYSES X-RAY DIFFRACTION

Date received: 2018-08-21  
Project number: 1000

Report number: 76722

Date completed: 2018-09-04  
Order number: Delh.2018.049-6

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Email: [theo@delta-h.co.za](mailto:theo@delta-h.co.za)

#### Note:

The material was prepared for XRD analysis using a backloading preparation method.  
It was analysed with a PANalytical Aeris diffractometer with PIXcel detector and fixed slits with Fe filtered Co-K $\alpha$  radiation.  
The phases were identified using X'Pert Highscore plus software.  
The relative phase amounts (weight %) were estimated using the Rietveld method.

#### Comment:

- In case the results do not correspond to results of other analytical techniques, please let me know for further fine tuning of XRD.
- Mineral names may not reflect the actual compositions of minerals identified, but rather the mineral group. Muscovite may represent muscovite and /or illite.
- Due to preferred orientation and crystallite size effects, results may not be as accurate as shown in the table.
- Traces of additional phases may be present.
- Amorphous phases, if present, were not taken into consideration during quantification

#### Ideal Mineral compositions:

Compound Name	Ideal Chemical Formula
Talc	$\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$
Quartz	$\text{SiO}_2$
Actinolite	$\text{Ca}_2(\text{Mg,Fe})_5\text{Si}_8\text{O}_{22}(\text{OH})_2$
Lizardite	$\text{Mg}_3\text{Si}_2\text{O}_5(\text{OH})_4$
Muscovite	$\text{K Al}_2 ((\text{OH})_2 \text{ Al Si}_3 \text{ O}_{10})$
Enstatite	$(\text{Mg,Fe})\text{SiO}_3$
Plagioclase	$(\text{Na,Ca})(\text{Si,Al})_4\text{O}_8$

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**CERTIFICATE OF ANALYSES**  
**X-RAY FLUORESCENCE**

Date received: 2018-08-21  
Project number: 1000

Report number: 76722

Date completed: 2018-09-12  
Order number: Delh.2018.049-6

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Email: [theo@delta-h.co.za](mailto:theo@delta-h.co.za)

Major Elements		Major Element Concentration (wt %)[s]
		DMS Plant #2
		38547
Silica	SiO <sub>2</sub>	50.36
Titanium	TiO <sub>2</sub>	0.26
Aluminium	Al <sub>2</sub> O <sub>3</sub>	15.16
Iron	Fe <sub>2</sub> O <sub>3</sub>	9.21
Manganese	MnO	0.17
Magnesium	MgO	13.38
Calcium	CaO	8.26
Sodium	Na <sub>2</sub> O	1.05
Potassium	K <sub>2</sub> O	0.31
Phosphorous	P <sub>2</sub> O <sub>5</sub>	0.04
Chromium	Cr <sub>2</sub> O <sub>3</sub>	0.66
Sulphur	SO <sub>3</sub>	<0.01
Loss on Ignition (1000 °C)	LOI	0.46
Loss of Moisture (105 °C)	H <sub>2</sub> O-	0.05
Total		99.35

[s] =Results obtained from sub-contracted laboratory

**Notes:** % g/g is equivalent to wt %; mg/kg is equivalent to ppm; n.d. = not determined; bold italicised font represents semi-quantitative data; \* represents measurements reported in % g/g or wt%.

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**CERTIFICATE OF ANALYSES**  
**X-RAY FLUORESCENCE**

Date received: 2018-08-21  
Project number: 1000

Report number: 76722

Date completed: 2018-09-12  
Order number: Delh.2018.049-6

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Contact person: Dr. Martin Holland  
Email: martin@delta-h.co.za  
Email: theo@delta-h.co.za

Trace Element		Trace Element Concentration (ppm) [s]	
		DMS Plant #2	
		38547	
Arsenic	As	<0.43	
Barium	Ba	60.6	
Bismuth	Bi	<0.68	
Cadmium	Cd	<3.04	
Cerium	Ce	<3.08	
Chlorine	Cl	<2.59	
Cobalt	Co	18.7	
Caesium	Cs	0.65	
Copper	Cu	57.7	
Galium	Ga	11.8	
Germanium	Ge	<0.50	
Hafnium	Hf	12.2	
Mercury	Hg	<1.00	
Lanthanum	La	21.4	
Lutetium	Lu	2.82	
Molybdenum	Mo	2.48	
Niobium	Nb	<2.15	
Neodymium	Nd	71.6	
Nickel	Ni	467	
Lead	Pb	<2.03	
Rubidium	Rb	3.28	
Antimony	Sb	9.03	
Scandium	Sc	16.1	
Selenium	Se	<0.36	
Samarium	Sm	3.66	
Tin	Sn	<0.08	
Strontium	Sr	246	
Tantalum	Ta	1.41	
Tellurium	Te	29.3	
Thorium	Th	<0.88	
Thallium	Tl	1.6	
Uranium	U	2.27	
Vanadium	V	149	
Tungsten	W	1.7	
Yttrium	Y	7.35	
Ytterbium	Yb	<1.05	
Zinc	Zn	41.9	
Zirconium	Zr	27.1	

[s] = Results obtained from sub-contracted laboratory

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### **CERTIFICATE OF ANALYSES** **X-RAY FLUORESCENCE**

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**Date received: 2018-08-21**  
**Project number: 1000**

**Report number: 76722**

**Date completed: 2018-09-12**  
**Order number: Delh.2018.049-6**

---

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**Email: [theo@delta-h.co.za](mailto:theo@delta-h.co.za)**

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#### **XRF: Major Element Analysis (Geological)**

The samples were prepared by first drying the samples at 100°C for ~3 hours in order to determine loss of moisture content (H<sub>2</sub>O-), followed by ashing of the sample at 1000°C until completely ashed, to determine the loss on ignition (LOI). XRF analyses were performed using a PANalytical Epsilon 3 XL ED-XRF spectrometer, equipped with a 50kV Ag-anode X-ray tube, 6 filters, a helium purge facility and a high resolution silicon drift detector, calibrated using a number of international and national certified reference materials (CRMs).

#### **XRF: Trace Element Analysis (Geological)**

XRF analyses were performed using a PANalytical Epsilon 3 XL ED-XRF spectrometer, equipped with a 50kV Ag-anode X-ray tube, 6 filters, a helium purge facility and a high resolution silicon drift detector, calibrated using international and national certified reference materials (CRMs).

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**CERTIFICATE OF ANALYSES**  
**EXTRACTIONS AS 4439.3**

Date received:	2018/08/21	Report number:	76722	Date completed:	2018/09/18
Project number:	1000	Order number:	Delh.2018.049-6		
Client name:	Delta H	Contact person:	Dr. Martin Holland		
Address:	PO Box 11465, Silver Lakes, 0054	Email:	martin@delta-h.co.za		
Cell:	082 497 9088	Email:	theo@delta-h.co.za		

Analyses	DMS Plant #2				
Sample Number	38547				
TCLP / Borax / Distilled Water	Distilled Water				
Ratio*	1:20				
Units	mg/l	LCT0 mg/l	LCT1 mg/l	LCT2 mg/l	LCT3 mg/l
As, Arsenic	0.002	0.01	0.5	1	4
B, Boron	<0.025	0.5	25	50	200
Ba, Barium	<0.025	0.7	35	70	280
Cd, Cadmium	<0.003	0.003	0.15	0.3	1.2
Co, Cobalt	<0.025	0.5	25	50	200
Cr <sub>total</sub> , Chromium Total	<0.025	0.1	5	10	40
Cr(VI), Chromium (VI)	<0.010	0.05	2.5	5	20
Cu, Copper	<0.025	2.0	100	200	800
Hg, Mercury	<0.001	0.006	0.3	0.6	2.4
Mn, Manganese	<0.025	0.5	25	50	200
Mo, Molybdenum	<0.025	0.07	3.5	7	28
Ni, Nickel	<0.025	0.07	3.5	7	28
Pb, Lead	<0.010	0.01	0.5	1	4
Sb, Antimony	0.002	0.02	1.0	2	8
Se, Selenium	0.003	0.01	0.5	1	4
V, Vanadium	<0.025	0.2	10	20	80
Zn, Zinc	<0.025	5.0	250	500	2000
Inorganic Anions	mg/l				
Total Dissolved Solids*	24	1000	12 500	25 000	100 000
Chloride as Cl	<2	300	15 000	30 000	120 000
Sulphate as SO <sub>4</sub>	<2	250	12 500	25 000	100 000
Nitrate as N	0.3	11	550	1100	4400
Fluoride as F	0.2	1.5	75	150	600
Paste pH	9.4				
Moisture %	0.3				
% Solids	---				
Acid Base Accounting	See attached report 76722 ABA				
Net Acid Generation	See attached report 76722 NAG				
Sulphur Speciation	See attached report 76722 SS				
X-ray Diffraction [s]	See attached report 76722 XRD				
X-ray Fluorescence [s]	See attached report 76722 XRF				

\*Please note: 1. The samples were used as received.  
2. A moisture content were determined  
3. In cases where the sample were a slt  
Moisture content were determined  
4. The results are reported as received.

Analyses	DMS Plant #2				
Sample Number	38547				
TCLP / Borax / Distilled Water	Distilled Water				
Ratio*	1:4				
Units	mg/l	LCT0 mg/l	LCT1 mg/l	LCT2 mg/l	LCT3 mg/l
As, Arsenic	<0.001	0.01	0.5	1	4
B, Boron	<0.025	0.5	25	50	200
Ba, Barium	<0.025	0.7	35	70	280
Cd, Cadmium	<0.003	0.003	0.15	0.3	1.2
Co, Cobalt	<0.025	0.5	25	50	200
Cr <sub>total</sub> , Chromium Total	<0.025	0.1	5	10	40
Cr(VI), Chromium (VI)	<0.010	0.05	2.5	5	20
Cu, Copper	<0.025	2.0	100	200	800
Hg, Mercury	<0.001	0.006	0.3	0.6	2.4
Mn, Manganese	<0.025	0.5	25	50	200
Mo, Molybdenum	<0.025	0.07	3.5	7	28
Ni, Nickel	<0.025	0.07	3.5	7	28
Pb, Lead	<0.010	0.01	0.5	1	4
Sb, Antimony	0.002	0.02	1.0	2	8
Se, Selenium	<0.001	0.01	0.5	1	4
V, Vanadium	<0.025	0.2	10	20	80
Zn, Zinc	<0.025	5.0	250	500	2000
Inorganic Anions	mg/l				
Total Dissolved Solids*	68	1000	12 500	25 000	100 000
Chloride as Cl	<2	300	15 000	30 000	120 000
Sulphate as SO <sub>4</sub>	2	250	12 500	25 000	100 000
Nitrate as N	2.4	11	550	1100	4400
Fluoride as F	<0.2	1.5	75	150	600
% Solids	---				

[s] = Subcontracted





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## CERTIFICATE OF ANALYSES

Digestion AS 4439.3

Date received:	2018/08/21	Report number: 76722	Date completed:	2018/09/18
Project number:	1000		Order number:	Delh.2018.049-6
Client name:	Delta H		Contact person:	Dr. Martin Holland
Address:	PO Box 11465, Silver Lakes, 0054		Email:	martin@delta-h.co.za
Cell:	082 497 9088		Email:	theo@delta-h.co.za

Analyses					
	DMS Plant #2				
Sample Number	38547		TCT0 mg/kg	TCT1 mg/kg	TCT2 mg/kg
Digestion	HNO3 : HF				
Dry Mass Used (g)	0.25				
Volume Used (mℓ)	100				
Units	mg/ℓ	mg/kg			
As, Arsenic	0.001	0.400	5.8	500	2000
B, Boron	<0.025	<10	150	15000	6000
Ba, Barium	0.149	60	62.5	6250	25000
Cd, Cadmium	0.012	4.80	7.5	260	1040
Co, Cobalt	0.117	47	50	5000	20000
Cr <sub>Total</sub> , Chromium Total	5.05	2020	46000	800000	N/A
Cu, Copper	0.051	20	16	19500	78000
Hg, Mercury	<0.001	<0.400	0.93	160	640
Mn, Manganese	2.26	904	1000	25000	100000
Mo, Molybdenum	<0.025	<10	40	1000	4000
Ni, Nickel	0.912	365	91	10600	42400
Pb, Lead	0.036	14	20	1900	7600
Sb, Antimony	<0.001	<0.400	10	75	300
Se, Selenium	<0.001	<0.400	10	50	200
V, Vanadium	0.035	14	150	2680	10720
Zn, Zinc	0.127	51	240	160000	640000
<b>Inorganic Anions</b>	<b>mg/ℓ</b>	<b>mg/kg</b>			
Cr(VI), Chromium (VI) Total [s]	---	<5	6.5	500	2000
Total Fluoride [s] mg/kg	---	99.5	100	10000	40000

[s] = subcontracted

UTD = Unable to determine

S. Laubscher  
Assistant Geochemistry Project Manager

**CERTIFICATE OF ANALYSES**  
**NET ACID GENERATION**

Date received: 2018-10-10  
Project number: 1000

Report number: 77991

Date completed: 2018-11-09  
Order number: Delh.2018.049-6

Client name: Delta H  
Address: PO Box 11465, Silver Lakes, 0054

Contact person: Dr. Martin Holland  
Email: martin@delta-h.co.za  
Cell: 082 497 9088

Net Acid Generation	Sample Identification: pH 4.5		
	DB N Portal Reef	DB N Portal Floor	DB N Portal Roof
Sample Number	44022	44023	44024
NAG pH: (H <sub>2</sub> O <sub>2</sub> )	6.8	7.4	7.9
NAG (kg H <sub>2</sub> SO <sub>4</sub> / t)	<0.01	<0.01	<0.01

Net Acid Generation	Sample Identification: pH 4.5		
	Split Reef Waste #1	Split Reef Roof	Split Reef Roof
Sample Number	44025	44026	44026 D
NAG pH: (H <sub>2</sub> O <sub>2</sub> )	7.6	7.6	7.8
NAG (kg H <sub>2</sub> SO <sub>4</sub> / t)	<0.01	<0.01	<0.01

S. Laubscher  
Assistant Geochemistry Project Manager

**CERTIFICATE OF ANALYSES**  
**NET ACID GENERATION**

Date received: 2018-10-10  
Project number: 1000

Report number: 77991

Date completed: 2018-11-09  
Order number: Delh.2018.049-6

Client name: Delta H  
Address: PO Box 11465, Silver Lakes, 0054

Contact person: Dr. Martin Holland  
Email: martin@delta-h.co.za  
Cell: 082 497 9088

Net Acid Generation	Sample Identification: pH 7		
	DB N Portal Reef	DB N Portal Floor	DB N Portal Roof
Sample Number	44022	44023	44024
NAG pH: (H <sub>2</sub> O <sub>2</sub> )	6.8	7.4	7.9
NAG (kg H <sub>2</sub> SO <sub>4</sub> / t)	<0.01	<0.01	<0.01

Net Acid Generation	Sample Identification: pH 7		
	Split Reef Waste #1	Split Reef Roof	Split Reef Roof
Sample Number	44025	44026	44026 D
NAG pH: (H <sub>2</sub> O <sub>2</sub> )	7.6	7.6	7.8
NAG (kg H <sub>2</sub> SO <sub>4</sub> / t)	<0.01	<0.01	<0.01

Notes:

- Samples analysed with Single Addition NAG test as per Prediction Manual For Drainage Chemistry from Sulphidic Geological Materials MEND Report 1.20.1.
- Please let me know if results do not correspond to other data.

S. Laubscher  
Assistant Geochemistry Project Manager

**CERTIFICATE OF ANALYSES**  
**ACID – BASE ACCOUNTING**  
**EPA-600 MODIFIED SOBEK METHOD**

Date received: 2018-10-10  
Project number: 1000

Report number: 77991

Date completed: 2018-11-09  
Order number: Delh.2018.049-6

Client name: Delta H  
Address: PO Box 11465, Silver Lakes, 0054

Contact person: Dr. Martin Holland  
Email: martin@delta-h.co.za  
Cell: 082 497 9088

Acid – Base Accounting Modified Sobek (EPA-600)	Sample Identification		
	DB N Portal Reef	DB N Portal Floor	DB N Portal Roof
Sample Number	44022	44023	44024
Paste pH	8.75	8.95	9.01
Total Sulphur (%) (LECO)	0.13	0.01	0.06
Acid Potential (AP) (kg/t)	4.06	0.313	1.88
Neutralization Potential (NP)	8.42	7.28	10
Nett Neutralization Potential (NNP)	4.36	6.97	8.52
Neutralising Potential Ratio (NPR) (NP : AP)	2.07	23	5.55
Rock Type	III	III	III

Acid – Base Accounting Modified Sobek (EPA-600)	Sample Identification		
	Split Reef Waste #1	Split Reef Roof	Split Reef Roof
Sample Number	44025	44026	44026 D
Paste pH	8.9	9.13	9.13
Total Sulphur (%) (LECO)	0.01	0.01	0.01
Acid Potential (AP) (kg/t)	0.313	0.313	0.313
Neutralization Potential (NP)	9.51	9.16	9.41
Nett Neutralization Potential (NNP)	9.20	8.85	9.10
Neutralising Potential Ratio (NPR) (NP : AP)	30	29	30
Rock Type	III	III	III

\* Negative NP values are obtained when the volume of NaOH (0.1N) titrated (pH: 8.3) is greater than the volume of HCl (1N) to reduce the pH of the sample to 2.0 – 2.5 Any negative NP values are corrected to 0.00.

Please refer to Appendix (p.2) for a Terminology of terms and guidelines for rock classification

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**CERTIFICATE OF ANALYSES**  
**ACID – BASE ACCOUNTING**  
**EPA-600 MODIFIED SOBEK METHOD**

Date received: 2018-10-10  
Project number: 1000

Report number: 77991

Date completed: 2018-11-09  
Order number: Delh.2018.049-6

Client name: Delta H  
Address: PO Box 11465, Silver Lakes, 0054

Contact person: Dr. Martin Holland  
Email: [martin@delta-h.co.za](mailto:martin@delta-h.co.za)  
Cell: 082 497 9088

**APPENDIX: TERMINOLOGY AND ROCK CLASSIFICATION**

**TERMINOLOGY (SYNONYMS)**

- Acid Potential (AP) ; *Synonyms:* Maximum Potential Acidity (MPA)  
**Method:** Total S(%) (Leco Analyzer) x 31.25
- Neutralization Potential (NP) ; *Synonyms:* Gross Neutralization Potential (GNP) ; *Syn:* Acid Neutralization Capacity (ANC) (The capacity of a sample to consume acid)  
**Method:** Fizz Test ; Acid-Base Titration (Sobek & Modified Sobek (Lawrence) Methods)
- Nett Neutralization Potential (NNP) ; *Synonyms:* Nett Acid Production Potential (NAPP)  
**Calculation:**  $NNP = NP - AP$  ;  $NAPP = ANC - MPA$
- Neutralising Potential Ratio (NPR)  
**Calculation:**  $NPR = NP : AP$

**CLASSIFICATION ACCORDING TO NETT NEUTRALISING POTENTIAL (NNP)**

If  $NNP (NP - AP) < 0$ , the sample has the potential to generate acid

If  $NNP (NP - AP) > 0$ , the sample has the potential to neutralise acid produced

Any sample with  $NNP < 20$  is potential acid-generating, and any sample with  $NNP > -20$  might not generate acid (Usher *et al.*, 2003)

**ROCK CLASSIFICATION**

<b>TYPE I</b>	Potentially Acid Forming	Total S(%) > 0.25% and NP:AP ratio 1:1 or less
<b>TYPE II</b>	Intermediate	Total S(%) > 0.25% and NP:AP ratio 1:3 or less
<b>TYPE III</b>	Non-Acid Forming	Total S(%) < 0.25% and NP:AP ratio 1:3 or greater

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**CERTIFICATE OF ANALYSES**  
**ACID – BASE ACCOUNTING**  
**EPA-600 MODIFIED SOBEK METHOD**

Date received: 2018-10-10  
Project number: 1000

Report number: 77991

Date completed: 2018-11-09  
Order number: Delh.2018.049-6

Client name: Delta H  
Address: PO Box 11465, Silver Lakes, 0054

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**CLASSIFICATION ACCORDING TO NEUTRALISING POTENTIAL RATIO (NPR)**

Guidelines for screening criteria based on ABA (Price *et al.*, 1997 ; Usher *et al.*, 2003)

Potential for ARD	Initial NPR Screening Criteria	Comments
Likely	< 1:1	Likely AMD generating
Possibly	1:1 – 2:1	Possibly AMD generating if NP is insufficiently reactive or is depleted at a faster rate than sulphides
Low	2:1 – 4:1	Not potentially AMD generating unless significant preferential exposure of sulphides along fracture planes, or extremely reactive sulphides in combination with insufficiently reactive NP
None	>4:1	No further AMD testing required unless materials are to be used as a source of alkalinity

**CLASSIFICATION ACCORDING TO SULPHUR CONTENT (%S) AND NEUTRALISING POTENTIAL RATIO (NPR)**

For sustainable long-term acid generation, at least 0.3% Sulphide-S is needed. Values below this can yield acidity but it is likely to be only of short-term significance. From these facts, and using the NPR values, a number of rules can be derived:

- 1) Samples with less than 0.3% Sulphide-S are regarded as having insufficient oxidisable Sulphide-S to sustain acid generation.
- 2) NPR ratios of >4:1 are considered to have enough neutralising capacity.
- 3) NPR ratios of 3:1 to 1:1 are considered inconclusive.
- 4) NPR ratios below 1:1 with Sulphide-S above 3% are potentially acid-generating. (Soregaroli & Lawrence, 1998 ; Usher *et al.*, 2003)

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### **CERTIFICATE OF ANALYSES ACID – BASE ACCOUNTING EPA-600 MODIFIED SOBEK METHOD**

Date received: 2018-10-10  
Project number: 1000

Report number: 77991

Date completed: 2018-11-09  
Order number: Delh.2018.049-6

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Cell: 082 497 9088

#### **REFERENCES**

LAWRENCE, R.W. & WANG, Y. 1997. **Determination of Neutralization Potential in the Prediction of Acid Rock Drainage.** Proc. 4<sup>th</sup> International Conference on Acid Rock Drainage. Vancouver. BC. pp. 449 – 464.

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Assistant Geochemistry Project Manager

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**CERTIFICATE OF ANALYSES**  
**SULPHUR SPECIATION**

Methods from: Prediction Manual For Drainage Chemistry from Sulphidic Geological Materials MEND Report 1.20.1

Date received: 2018-10-10  
Project number: 1000

Report number: 77991

Date completed: 2018-11-09  
Order number: Delh.2018.049-6

Client name: Delta H  
Address: PO Box 11465, Silver Lakes, 0054

Contact person: Dr. Martin Holland  
Email: martin@delta-h.co.za  
Cell: 082 497 9088

Sulphur Speciation*	Sample Identification		
	DB N Portal Reef	DB N Portal Floor	DB N Portal Roof
Sample Number	44022	44023	44024
Total Sulphur (%) (LECO)	0.13	0.01	0.06
Sulphate Sulphur as S (%)	0.09	0.01	0.03
Sulphide Sulphur (%)	0.04	<0.01	0.03

Sulphur Speciation*	Sample Identification		
	Split Reef Waste #1	Split Reef Roof	Split Reef Roof
Sample Number	44025	44026	44026 D
Total Sulphur (%) (LECO)	0.01	0.01	0.01
Sulphate Sulphur as S (%)	0.01	0.01	0.01
Sulphide Sulphur (%)	<0.01	<0.01	<0.01

Notes:

- Samples analysed with Pyrolysis at 550°C as per Prediction Manual For Drainage Chemistry from Sulphidic Geological Materials MEND Report 1.20.1. Multiply Sulphate Sulphur to calculate SO<sub>4</sub> % by 2.996. Please see the method for interferences.
- Organic Sulphur is not taken into account and may be included in the results.
- Please let me know if results do not correspond to other data.

S. Laubscher  
Assistant Geochemistry Project Manager



**CERTIFICATE OF ANALYSES**  
**X-RAY DIFFRACTION**

Date received: 2018-10-10  
Project number: 1000

Report number: 77991

Date completed: 2018-10-19  
Order number: Delh.2018.049-6

Client name: Delta H  
Address: PO Box 11465, Silver Lakes, 0054

Contact person: Dr. Martin Holland  
Email: martin@delta-h.co.za  
Cell: 082 497 9088

Composition (%) [s]					
DB N Portal Reef		DB N Portal Floor		DB N Portal Roof	
44022		44023		44024	
Mineral	Amount (weight %)	Mineral	Amount (weight %)	Mineral	Amount (weight %)
Enstatite	41.24	Enstatite	30.64	Enstatite	68.12
Quartz	0.55	Quartz	0.71	Quartz	1.23
Diopside	5.86	Diopside	5.79	Diopside	6.02
Smectite	0.37	Smectite	0.97	Smectite	0
Plagioclase	27.01	Plagioclase	53.17	Plagioclase	16.77
Muscovite	1.72	Muscovite	0	Muscovite	0.58
Talc	3.9	Talc	2.54	Talc	7.11
Kaolinite	0.24	Kaolinite	0.19	Kaolinite	0.17
Actinolite	trace	Actinolite	trace	Actinolite	trace
Chlorite	2.95	Chlorite	5.99	Chlorite	0
Chromite	16.17	Chromite	0	Chromite	0

Composition (%) [s]			
Split Reef Waste #1		Split Reef Roof	
44025		44026	
Mineral	Amount (weight %)	Mineral	Amount (weight %)
Enstatite	26.06	Enstatite	59.11
Quartz	2.71	Quartz	1.88
Diopside	6.87	Diopside	7.33
Smectite	0.75	Smectite	1.04
Plagioclase	40.98	Plagioclase	21.62
Muscovite	0	Muscovite	0.59
Talc	5.82	Talc	2.64
Kaolinite	0.39	Kaolinite	0.09
Actinolite	trace	Actinolite	trace
Chlorite	16.42	Chlorite	5.71
Chromite	0	Chromite	0

[s] Results obtained from sub-contracted laboratory

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Assistant Geochemistry Project Manager

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**CERTIFICATE OF ANALYSES**  
**X-RAY DIFFRACTION**

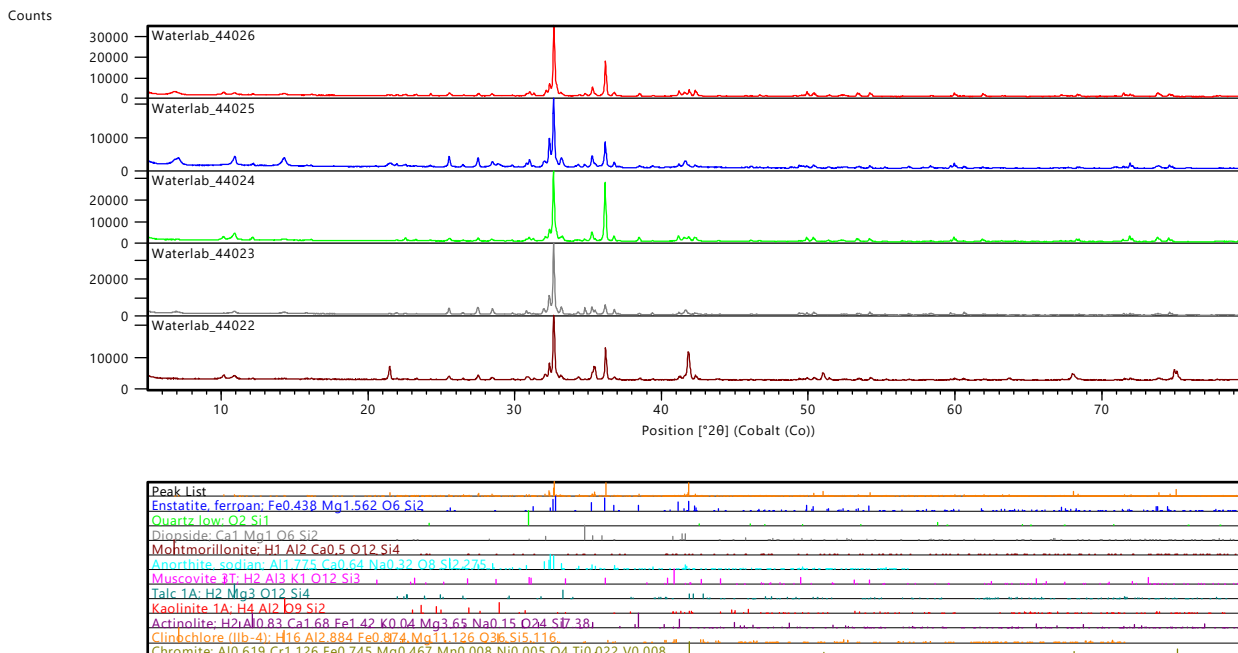
Date received: 2018-10-10  
Project number: 1000

Report number: 77991

Date completed: 2018-10-19  
Order number: Delh.2018.049-6

Client name: Delta H  
Address: PO Box 11465, Silver Lakes, 0054

Contact person: Dr. Martin Holland  
Email: [martin@delta-h.co.za](mailto:martin@delta-h.co.za)  
Cell: 082 497 9088



**Note:**

The material was prepared for XRD analysis using a backloading preparation method. It was analysed with a PANalytical Aeries diffractometer with PIXcel detector and fixed slits with Fe filtered Co-K $\alpha$  radiation. The phases were identified using X'Pert Highscore plus software. The relative phase amounts (weight %) were estimated using the Rietveld method.

**Comment:**

- In case the results do not correspond to results of other analytical techniques, please let me know for further fine tuning of XRD.
- Mineral names may not reflect the actual compositions of minerals identified, but rather the mineral group.
- Due to preferred orientation and crystallite size effects, results may not be as accurate as shown in the table. Smectite may be underestimated.
- Traces of additional phases may be present.
- Amorphous phases, if present, were not taken into consideration during quantification

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### CERTIFICATE OF ANALYSES X-RAY DIFFRACTION

Date received: 2018-10-10  
Project number: 1000

Report number: 77991

Date completed: 2018-10-19  
Order number: Delh.2018.049-6

Client name: Delta H  
Address: PO Box 11465, Silver Lakes, 0054

Contact person: Dr. Martin Holland  
Email: [martin@delta-h.co.za](mailto:martin@delta-h.co.za)  
Cell: 082 497 9088

#### Ideal Mineral compositions:

Compound Name	Ideal Chemical Formula
Talc	$\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$
Quartz	$\text{SiO}_2$
Actinolite	$\text{Ca}_2(\text{Mg,Fe})_5\text{Si}_8\text{O}_{22}(\text{OH})_2$
Kaolinite	$\text{Mg}_3\text{Si}_2\text{O}_5(\text{OH})_4$
Muscovite	$\text{K Al}_2 ((\text{OH})_2 \text{ Al Si}_3 \text{ O}_{10})$
Enstatite	$(\text{Mg,Fe})\text{SiO}_3$
Plagioclase	$(\text{Na,Ca})(\text{Si,Al})_4\text{O}_8$
Smectite (Montmorillonite)	$(\text{Na,Ca})_{0,3}(\text{Al,Mg})_2\text{Si}_4\text{O}_{10}(\text{OH})_2 \cdot n(\text{H}_2\text{O})$
Diopside	$\text{CaMgSi}_2\text{O}_6$
Chromite	$\text{Fe}^{++}\text{Cr}_2\text{O}_4$
Chlorite	$(\text{Mg,Fe})_5\text{Al}(\text{AlSi}_3\text{O}_{10})(\text{OH})_8$

S. Laubscher  
Assistant Geochemistry Project Manager

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