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TWIN HILLS MINE, NAMIBIA

TWIN HILLS FEED STUDY GEOCHEMISTRY TESTING

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EXECUTIVE SUMMARY

Geochemical testing undertaken for the PFS studies of the Twin Hills Mine project (Prime resources, 2022) have shown that the altered and mineralised waste rock and tailings material is potentially acid generating. The tailings material also leached heavy metals including arsenic, aluminium and iron and recommendations for the lining design of the TSF were provided.

As per the DFS studies undertaken by KP in 2022, the tailings liner requirement was revised to include the underlying in-situ but compacted calcrete in the design, providing it could be shown that this geological formation can provide sufficient neutralisation potential in the unlikely event of seepage through the TSF and underdrainage system. The geochemical testing included trickle down column leach through the laboratory scaled TSF and underlying calcrete layer using a mild acid solution (distilled water) to simulate rainfall through the waste facility.

Although most of the waste rock materials tested in 2022 was shown to be non acid generating, to simulate the potential leachate through the low-grade ore stockpile and the lesser volume of waste rock that has minor mineralisation close to the ore body, a similar geochemical trickle-down test was undertaken. The PAG waste rock samples were selected from core samples provided to the laboratory and placed on top of crushed and compacted calcrete. An additional column comprising PAG waste rock, with a thin layer of marble chips sourced from the nearby quarry, and calcrete was also tested. The purpose of the latter is that the Karibib Marble Formation could be used in mitigation to bolster the buffering of the calcrete by incorporating it into the waste rock deposition model as and when zones with higher PAG rock will be mined.

Knight Piésold Consulting (KP) was appointed by Osino Resources (Osino) to undertake the additional geochemical testing in 2023. The scaled down columns were constructed to mimic as close as possible the volumes representing the 35 m high tailings/waste rock overlying 30 m of in-situ calcrete in an approximately 1:1 ratio for the tailings and 2:1 ratio for the waste rock. The columns were flushed with a 1:20 distilled water solution, with pH of 5.5 to simulate slightly acidic rain filtering through the tailings material and waste rock dump. The leachate samples were collected and analysed weekly for a period of 6 weeks. This was extended for the waste rock columns as the large core pieces were crushed at Week 6 to simulate more rapid weathering of the waste rock and were leached for an additional six weeks.

The XRD results as well as ABA static testing of the calcrete and marble samples confirm high composition of carbonate minerals (dolomite plus calcite) of 57% and 98% respectively. These minerals provide the most rapid and effective neutralising minerals to acid generation.

TAILINGS COLUMN TEST RESULTS

The static test results for the tailings material sample indicated that the sample was classified as Uncertain due to the NPR slightly higher than 2 and lower acid generating potential of 4 Kg H₂SO₄/t compared with the 2022 tailings sample of 88 Kg H₂SO₄/t. This could be due to different test trial laboratories and processing of the tailings material, and due to heterogeneity of the ore that was processed in the tailings trials.

The leach testing confirmed that after the initial flush in the first week, the sulphate in the leachate drops accompanied by a rapid drop off of the metals due to the neutralisation provided by the calcrete layer below, through which the tailings seepage passes. However, the low concentration of arsenic that spiked in week 5 before dropping to undetected, confirms that there is a potential short-term risk of

contamination to the groundwater once scaled up and assuming the TSF to be unlined. The planned liner above the calcrete is therefore considered necessary in the TSF design with the compacted calcrete providing assurance that if there is deterioration and tears in the liner, risks to the underlying groundwater will be further minimised.

The leach results were used in a PHREEQC mixing model, with the background brackish groundwater as per monitoring concentrations which have elevated chloride (Cl), sodium (Na) and sulphate (SO₄) which exceed the Namibian discharge limits. The mix model results show that the heavy metals were neutralised by groundwater and are below limits and shows that the pH will remain neutral.

PAG WASTE ROCK COLUMN TEST RESULTS

The static test results of the waste rock samples selected visually (i.e. as worst-case scenario with abundant sulphides visible) had high Sulphur of 1.35% with most of the sulphur as sulphides (1.05%). The NAG pH was 2.6 and NPR was 0.4, classifying the sample as PAG.

Two columns were set up: one with waste and calcrete in a 2:1 ratio and the other included a thin layer of marble rock chips (sourced from near the site) if additional buffering capacity may be needed.

Following six weeks of flushing with slightly acidic water, all the analytes were very low and inspection of the core samples in the column showed very few reactive surfaces, and this was the reason that there was no liberation of metals and the pH remaining neutral. The samples were crushed into smaller sizes to expose more reactive surfaces and the tests were extended for a further six weeks.

To represent the worst-case scenario kinetic test results for the PAG waste rock results (RGS, 2022) were used in the equilibrium mix model as inputs together with the background groundwater and minerals from the calcrete were allowed to dissolve so as to provide additional buffering capacity.

The results of the model were compared to the Namibian discharge limits and the IFC effluent standards. The pH increases to 7.4 and due to the higher alkalinity (increased from 40 to 561 mg/L). The sulphate (SO₄) concentrations are elevated above the Namibian effluent limits (340 mg/L) due to the background groundwater concentrations. Aluminium, iron, nickel, and arsenic were above the Namibian limits for the PAG waste rock leachate but when mixed with background groundwater and an addition of calcrete these parameters were then below the effluent limits.

Based on the results of the mix model, there is no requirement to line the Waste Rock Dumps (WRDs) as the seepage from the low volume of PAG waste rock that will be deposited, will be effectively neutralised by the underlying calcrete and groundwater.

The high carbonate mineralogy of the marbles (98%) can be used to encapsulate or be mixed with zones of waste rock and the low-grade stockpile if required.

CONCLUSION AND RECOMMENDATION

- The in-situ calcrete geology underlying the TSF, and waste rock dumps will assist in maintaining pH circum neutral to support heavy metals neutralization if any acidic seepage is generated from these waste facilities.
- The confirmation of low concentrations of arsenic released from the tailings material confirms the previous tailings testing results (2022) and that a liner is indicated for the TSF, but that the underlying compacted calcrete is included in the design.
- The PAG material that will be deposited in the waste rock dumps will make up a low percentage of the volume of the WRDS occurring only at the fringes of the orebody due to the below grade mineralisation. Although acidity may be generated from this material, the underlying calcrete with

>50% carbonate mineralogy is considered effective in providing abundant neutralisation capacity to the seepage in the long term. Encapsulation or mixing of marble with the waste rock from mined zones with higher mineralisation is recommended.

- Consideration could be given to adding a layer of crushed marble from the nearby Karibib Marble quarry to provide additional buffering capacity due to the 98% carbonate mineralogy.
- The conclusions are based on the results from testing completed in 2023. However, once mining commences it is recommended to conduct additional static and geochemical testing of waste solids with updates of the geochemical mixing model and possibly reactive transport modelling as part of the routine monitoring of the developing waste facilities.

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APPENDICES

Appendix A Laboratory Certificates

ABBREVIATIONS

ABA	Acid-Base Accounting
AP	Acid Potential
ARD	Acid Rock Drainage
Cl	Chloride
CoC	Constituents of Concern
CO ₂	Carbon Dioxide
DFS	Definitive Feasibility Study
EC	Electrical Conductivity
Fe	Iron
GAI	Geochemical Abundance Index
GARD	Global Acid Rock Drainage
HDPE	High-Density Polyethylene
H ₂ SO ₄	Sulfuric Acid
ICP	Inductively Coupled Plasma
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
IFC	International Financial Cooperation
LC	Leachable Concentrations
LoM	Life of Mine
M	Meter
mg/L	Milligrams Per Liter
Na	Sodium
NAG	Net Acid Generating
NNP	Net Neutralising Potential
Non-PAG	Non-Potentially Acid Generating
NP	Neutralizing Potential
NPR	Neutralising Potential Ratio
PAG	Potentially Acid Generating
PFS	Pre Feasibility Study
PHREEQC	pH, Redox, Equilibrium Code
SA	South Africa
SANAS	South African National Accreditation
SI	Saturation Index
SF	Scaling Factor
SO ₄	Sulphate
SPLP	Synthetic Precipitation Leaching Procedure
Sr	Strontium
TSF	Tailings Storage Facility
WHO	World Health Organization
XRD	X-Ray Diffraction
XRF	X-Ray Fluorescence

1.0 INTRODUCTION

The Twin Hills project forms part of the Karibib Gold Project and is located in central Namibia 16 kilometres (km) north of Karibib.

Knight Piésold Consulting (KP) was requested by Osino Resources (Osino) to undertake a geochemical assessment to evaluate the potential for locally sourced materials to be utilised in the construction of the underliner drainage beneath a High-Density Polyethylene (HDPE) geomembrane forming part of a new tailings storage facility (TSF). Geochemical testing was also conducted on potentially acid generating (PAG) waste rock samples with the underlying calcrete to determine the potential in-situ neutralisation/buffering capacity.

1.1 BACKGROUND INFORMATION

In 2022 Prime Resources was appointed by Osino to undertake supplemental studies relating to the process tailings disposal methodology and design. As part of their scope, geochemical characterisation of the tailing material was required. Tailings samples from metallurgical test work were analysed by Waterlab Laboratories for static geochemical testing. The material was found to be highly enriched in arsenic, molybdenum, nickel and selenium. Acid-Base Accounting (ABA) indicated that the material is PAG.

As part of the DFS, RSG were appointed in 2022 to undertake an assessment of the waste rock materials from the different pit areas and concluded that some of the waste rock, particularly near the fringes of the orebody will be PAG. Soluble trace metals in the leachate included cobalt, iron, manganese and zinc with minor arsenic in the ore.

There is no requirement in Namibia for classification of mine residue material as waste but in line with best practice, the samples were classified according to the South African Waste Classification and Management Regulations and associated Norms and Standards (GNR 634 – 636 of 2013) and classified as Type 1 which should be disposed of in a Class A landfill.

1.1.1 TAILINGS

The PFS (2022) report classified both the tailings and slurry samples as **PAG** as can be seen in Figure 1-1 below and the following are summarised here:

- The samples had a low abundance of total carbon and low calcite low calcite in the XRD.
- Although the paste pH of the tailings sample was alkaline, the sulphide bearing minerals in the tailings resulted in an Acid Potential (AP) of 28 and 88 kg/t respectively.
- The neutralizing potential (NP) was low (< 15 kg/t) and the NAG pH was 2.6.
- The Net Neutralising Potential (NNP) in which $NNP = NP - AP$ was in the uncertain range between - 20 kg/tonne and +20kg/tonne at -97 kg/t which is considered PAG.
- The Neutralising Potential Ratio (NPR) $= NP/AP$ is considered a significant risk if the $NPR < 1$ and low risk if the $NPR > 2$ with very low risk if $NPR > 4$. The NPR for both samples was < 0.5 indicating a significant risk for acid generation (Figure 1-2).
- Prime Resources recommended a composite liner system comprising a geosynthetic clay layer overlain by a 1.5 mm HDPE geomembrane and an over liner herringbone drainage system.

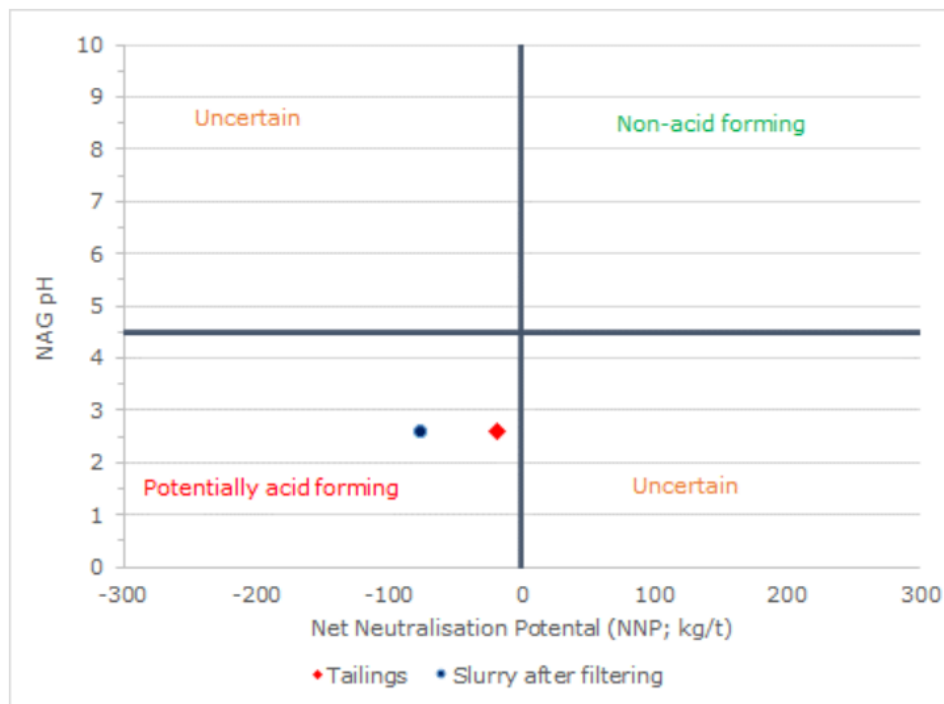


Figure 1-1: NAG pH vs NNP of Twin Hills Samples (PFS 2022)

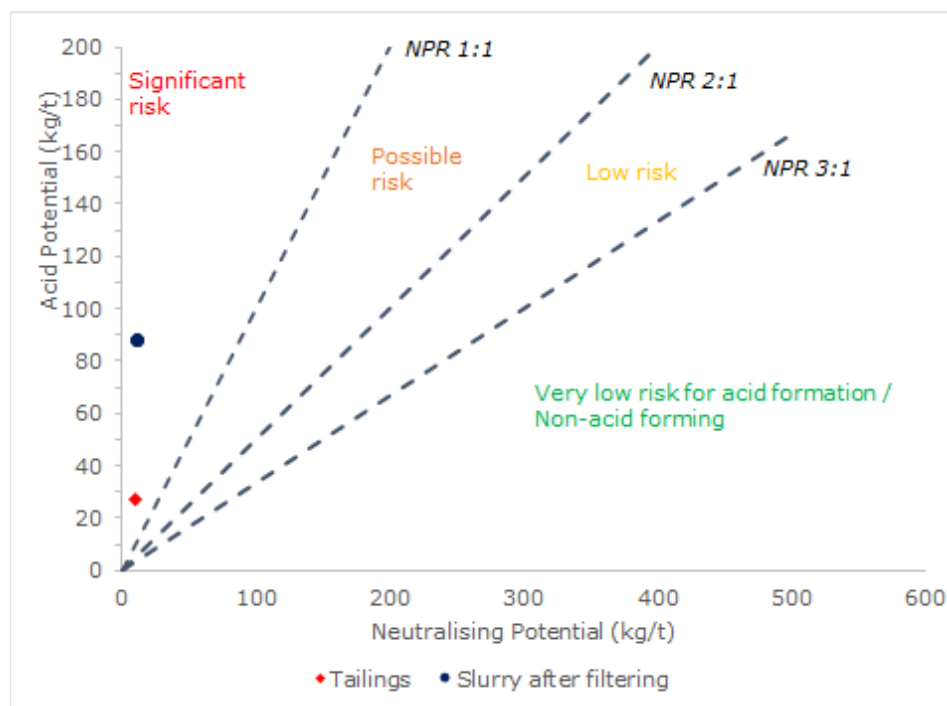


Figure 1-2: Acid Potential vs Neutralising Potential of Twin Hills Tailings Samples (PFS 2022)

The Synthetic Precipitation Leaching Protocol (SPLP) was used by applying a slightly acidic leaching solution in a 1:20 material-to-solution ratio to simulate rainwater. The static leach test of the tailings results was compared to the IFC Effluent Standard for Mining, the Namibian Effluent Guideline and the Namibian Drinking Water Guidelines (Ministry of Agriculture, Water and Land Reform, 2023).

The following were noted with regards to the PFS results:

- Arsenic, aluminium and iron were identified as potential contaminants of concern exceeding the Class A Namibian drinking water guidelines.
- High concentrations of arsenic were released in the short-term leach tests (2.5 and 1.5 mg/L), exceeding the Class D Namibian drinking water guideline.

The dry tailings and slurry results following 20 weeks of humidity cell testing to simulate weathering of the tailings (Prime Resources 2022) concluded that:

- The pH values of the leach tests remained circum-neutral.
- Based on the neutralisation potential consumption, the tailings slurry would generate acidity within 4-7 years, or sooner due to bacterial influence.
- The total dissolved salts will increase due to the release of higher concentrations of sulfate.
- High arsenic concentrations in the leachate during the test, and the fact that 98% of the original arsenic abundance remained within the tailings material, indicated that the concentration of arsenic released would be higher than observed during neutral pH conditions.

The Definitive Feasibility Study (DFS), KP (2022) proposed an alternative composite liner system which comprised a 150 mm crushed calcrete layer (ripped and recompacted in-situ calcrete or imported where required), overlain by an A6 bidim geotextile and a 1.5mm mono-textured HDPE geomembrane and an over liner drainage system. Furthermore, KP proposed that additional kinetic testing be conducted, specifically column leach tests, on samples of calcrete to indicate the buffering capacity if leachate from the underliner drainage tailings seeps into the subsurface environment.

1.1.2 PAG WASTE ROCK

RGS undertook geochemical testing of a total of 131 drill core samples representing waste rock and ore materials likely to be generated from the Twin Hills Central, Bulge and Clouds deposits were geochemically characterised. The results of the static geochemical characterisation program found that:

- Waste rock and ore materials that have not been altered and are not mineralised generally have low sulfur content, excess Acid Neutralisation Capacity (ANC) and are classified as non-acid forming (NAF).
- Altered and mineralised waste rock and ore materials generally have elevated sulfur content, low to moderate ANC and are generally classified as potentially acid forming (PAF).
- NAF waste rock materials are unlikely to pose a significant risk to contact water with respect to their geochemical characteristics.
- PAF waste rock materials will require careful management (potentially encapsulation in NAF waste rock materials) to avoid long term risks to the environment from acid mine drainage (AMD).

2.0 FEED GEOCHEMICAL TESTING PROGRAM (2023)

Static testing was done on a 2-3 kg sample of the local calcrete and on a more recent metallurgical test work tailings slurry sample as provided to KP in 2023. In addition, a sample of composited waste rock material from core hole intervals confirmed to be PAG, was included in the geochemical testing.

Thereafter a **column leach test** was undertaken of the calcrete overlain by tailings material to assess the neutralisation potential of the calcrete as shown in Figure 2-1. The calcrete sample was crushed finely and re-compacted to represent the low permeability of the in-situ calcrete geology below the TSF footprint.

To scale up the laboratory trial to field scale, the tailings height will be approximately 35 m and the thickness of the calcrete in this area is 30-40 m so the ratio adopted was 1:1. The amount of material added to the column is shown in Figure 2-1 below. The picture depicts column 3 material prior to column set up.

The column was flushed with a 1:20 distilled water solution, with pH of 5.5 to simulate slightly acidic rain filtering through the tailings material. The leachate samples were collected and analysed weekly for a period of 6 weeks and the results of the tests are provided in Appendix A.

Table 2-1: Volume of Material Added to the Columns.

Sample	Tailings (T)	Calcrete (Cal)
	Dry Mass (g)	Dry Mass (g)
Column (Calcrete and Tailings)	1963,2	823,3

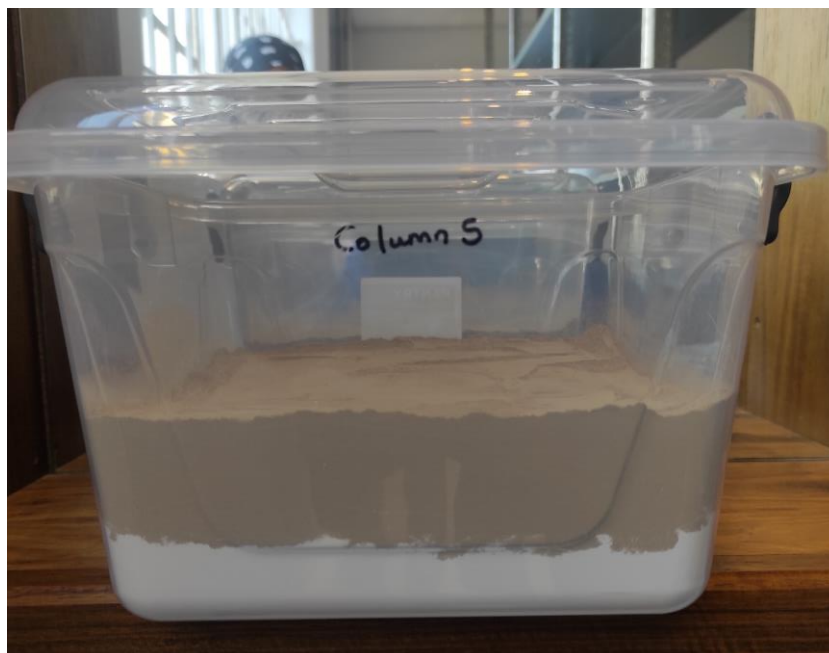


Figure 2-1: Column Test Preparation of Tailings and Calcrete

Two column leach tests of the PAG waste rock were constructed: the first column comprised of waste rock, calcrete with a thin intermediate layer of marble. The second column contained waste rock and calcrete only as shown in the Table below. A ratio of 2:1 was used for both columns with a sprinkling of marble in the first Column. Trickle down leach column testing was conducted over a period of six weeks, then crushed finer and analysed for an additional six weeks.

Table 2-2: Volume of PAG Waste Rock and other Material added to the Columns

Sample	Waste Rock Dry Mass g	Calcrete Dry Mass g	Marble Dry Mass g
Column 1	3511.6	637.1	44.1
Column 2	4122.7	823.3	0

The leaching solution was deionised water (ASTM type I) and the leachate was applied manually with gravity as the only force for flow.

2.1 GEOCHEMICAL TESTING METHODOLOGY

Static testing allows the samples to be classified as Potentially Acid Generating (PAG), Non-Potentially Acid Generating (Non-PAG), or Uncertain. The following static testing was completed on the calcrete sample which was locally sourced and the 2023 tailings material from the metallurgical testing being carried out:

- Mineralogy based on XRD
- Acid-Base Accounting (ABA)
- Net Acid Generation (NAG) pH

The geochemical characterization evaluation is divided into two categories:

- Acid-generating potential (AP)
- Neutralizing potential (NP)

The following assumptions and criteria were used to classify the acid-generating potential of the tested samples.

Samples are assessed in the following order:

- **Criterion 1:** If the sulphide concentration is greater than 0.3% by weight, the suggested classification is PAG.
- **Criterion 2:** If the neutralizing potential/acid potential (NP/AP) ratio is less than 1, the suggested classification is PAG. The NP and AP values are usually reported in units of kg CaCO₃ equivalent/tonne.
- **Criterion 3:** If the NP/AP ratio is greater than 2, the suggested classification is Non-PAG. If the NP/AP ratio is between 1 and 2, the suggested classification is Uncertain.
- **Criterion 4:** If the sulphide concentration is less than 0.3% by weight, the suggested classification is Non-PAG. However, samples with a sulphide concentration between 0.01 and 0.3% by weight and an NP/AP ratio between 1 and 2 are characterized as Uncertain (due to the material being primarily composed of minerals that have poor NP values; Price, 2009).

- **Criterion 5:** If the NP/AP ratio is less than 1 and the NAG pH is less than 4.5, the suggested classification is PAG. If the NP/AP ratio is less than 1, but the NAG pH is greater than 4.5, the suggested classification is Uncertain. The same is true if the NAG pH is less than 4.5, but the NP/AP ratio is greater than 1 (GARD Guide, 2009).

Neutralizing potential can be assessed by reviewing the Net Neutralizing Potential (NNP) values. A sample with an NNP less than 20 kg CaCO₃ equivalent/tonne, is considered to have little to no buffering (neutralizing) capacity.

These criteria are typically used as guidelines when assessing the geochemical characterization of samples and are not necessarily applicable to on-site conditions.

2.2 COLUMN LEACH TESTING

The results from the trickle-down column test were used to evaluate the acid-base balance of the leachate samples to determine the long-term acid neutralisation of any seepage from the TSF/PAG waste rock taking into consideration the underlying calcrete geology.

The parameters including pH, sulfate concentration, alkalinity, and calcium/magnesium concentration are used to assess the long-term neutralisation capacity as seepage from the tailings infiltrates through the calcrete layer.

The leachate was analysed weekly for pH, major ions and metals and plotted against time. Proof of concept that the calcrete will buffer acidic leachate over LOM through the tailings are:

- NPR increases from < 2 (Prime Resources results) to > 2 due to the higher NP in the calcrete.
- pH remains circum neutral.
- Arsenic and other metals are not mobilised from the final leachate through the calcrete due to immobilisation at circum neutral pH.
- The leach testing coupled with the ABA results is used to provide a rough indication of time until neutralisation potential is fully depleted (or not at all due to the calcrete subsurface).

2.3 ASSUMPTIONS AND LIMITATIONS

- The results discussed in this report are based on three columns composed of calcrete and tailings and waste rock material collected in 2023.
- Tailings material composition can be variable over the LOM as well as deposition on the tailings facility depending on the pit geology and mineralisation.
- Waste rock material can be heterogeneous, but the samples collected had visually elevated sulphides to represent worst case scenario of PAG material.
- The calcrete deposits at the Twin Hills site can be spatially variable in terms of composition and thickness. Therefore, a composite sample was taken from more than one location to obtain a more representative composition.

3.0 MINERALOGY

X-ray Diffraction (XRD) were undertaken on the 2023 tailings, waste rock, marble and calcrete samples to quantify the mineralogy as shown in Table 3-1 and Figure 3-1:

- The calcrete and marble samples confirm high composition of carbonate minerals (dolomite plus calcite) of 57% and 98% respectively. These minerals provide the most rapid and effective neutralising minerals to acid generation.
- The waste rock and tailings samples have similar mineralogy with no carbonate minerals and comprise mainly of quartz and other silicates minerals.

Table 3-1: Results of XRD Analysis Mineral Composition (%)

Minerals	Calcrete	Marble	Tailings	Waste Rock
Quartz (SiO ₂)	17.9	0.9	47.8	43.2
Calcite (CaSO ₄ ·2H ₂ O)	14.3	48.0	0	0
Dolomite CaMg(CO ₃) ₂	43.3	49.9	0	0
Microcline (KF) ₂ (Al ₂ O ₃) ₃ (SiO ₂) ₆ (H ₂ O)	9.0	0	10.3	7.8
Plagioclase Mg ₃ (SiO ₅) ₂ (OH) ₂	7.5	0	16.6	20.5
Muscovite FeO ₂ H	5.0	0	25.3	28.5
Palygorskite CaMg (CO ₃) ₂	2.4	0	0	0
Tremolite KFe ₂ +2Al (Al ₂ Si ₂)O ₁₀ (F,OH) ₂	0.7	1.3	0	0

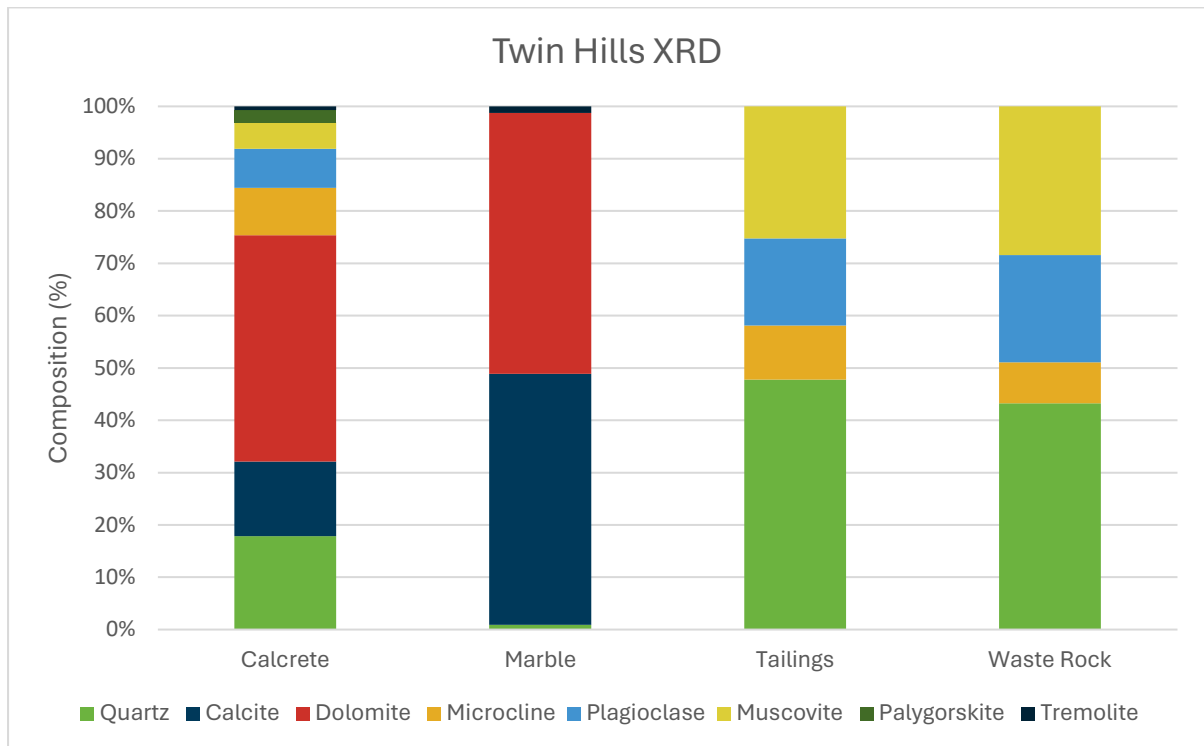


Figure 3-1: Mineral Composition of Twin Hills Samples

4.0 TSF TESTING RESULTS

The results of the static testing for the tailings and calcrete samples are summarized below. For comparative purposes, the 2022 PFS results are included in the diagnostic figures.

4.1 ABA OF TAILINGS AND CALCRETE

The Modified ABA and NAG pH test results are summarised in Table 4-1 and discussed below:

- The total sulphur content of the samples ranges from 0.02% to 0.44% as can be seen in Table 4-1. Both samples plot below the regression line which indicates that the sulphur is present mostly as sulfate (Figure 4-1). The tailings sample had a sulphide concentration between 0.01% and 0.3% by weight and therefore characterized as Uncertain (Criterion 4).
- The calcrete sample has an NPR>2 and is considered Non-PAG (Criterion 2) as shown in Figure 4-2.
- The tailings sample has an NPR of 2.6 and is considered Uncertain. It is unclear why this more recent tailings sample had a higher NPR compared to the 2022 tailings sample which had an NPR of 0.14 classifying it as PAG. Change in laboratory may play a role as well as change in handling or processing of the tailings sample.
- Although the Neutralisation potential of the tailings is similar (around 10 kg H₂SO₄/t), the Acid potential of the 2022 tailings samples was 88 Kg H₂SO₄/t compared with lower 4 Kg H₂SO₄/t for the 2023 sample and may indicate that different processing or ore materials processed.

Table 4-1: ABA and NAG pH Results for the Twin Hills Samples

Sample		Tailings	Calcrete
Paste pH		8.2	9.1
ABA	Total Sulphur (%)	0.44	0.02
	Sulphide Sulphur	0.13	0.001
	Acid Potential (AP; kg H ₂ SO ₄ /t)	4	0.155
	Neutralisation potential (NP; kg H ₂ SO ₄ /t)	10	522
	Net Neutralization Potential (NNP)	6	522
	Neutralising Potential Ratio (NPR)	2.6	8790
NAG	NAG pH	5.9	9.2
	NAG. pH 4.5 (kg H ₂ SO ₄ /t)	<0.5	<0.5
	NAG. pH 7 (kg H ₂ SO ₄ /t)	1.6	<0.5
Rock Type		Uncertain	Non-PAG

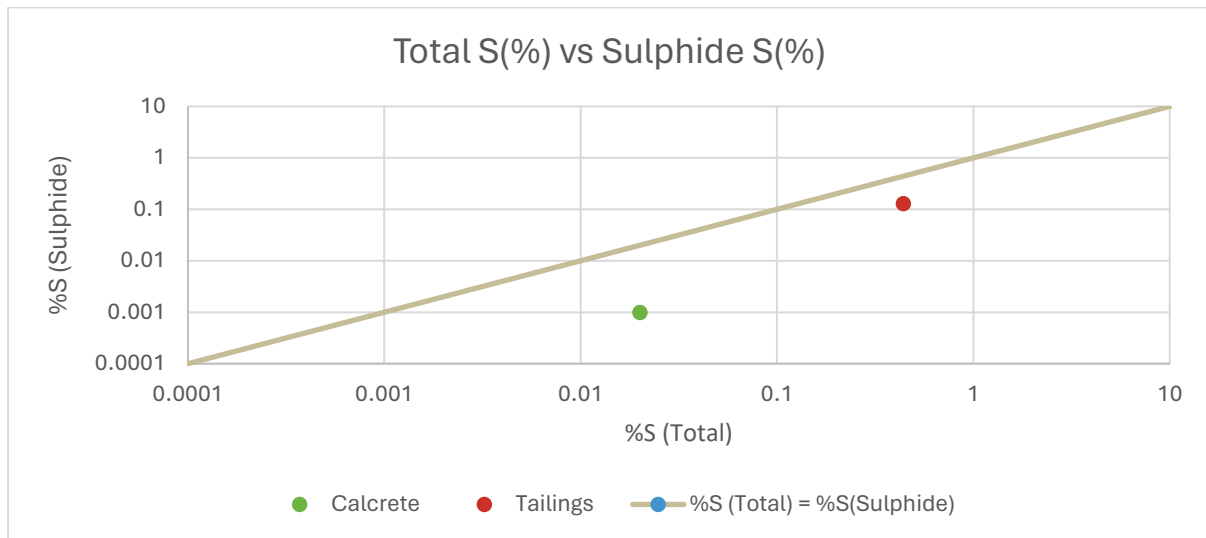


Figure 4-1: Total Sulphur (%S) vs Sulphur-Sulphide (%S) for 2023

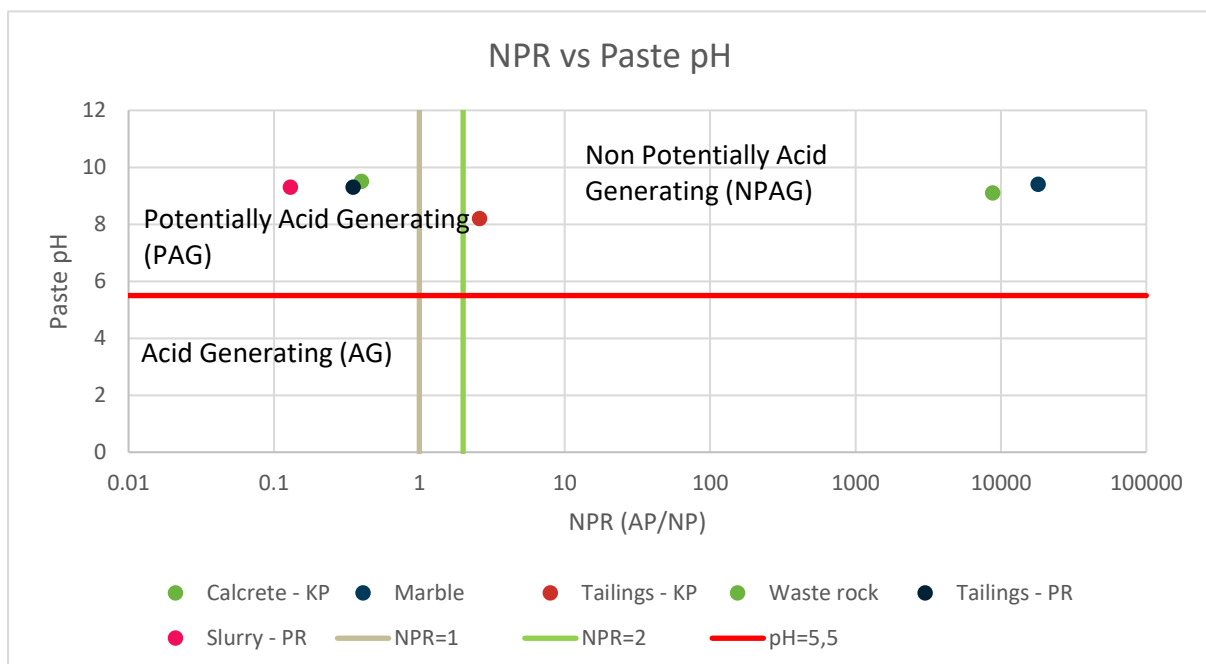


Figure 4-2: NPR versus Paste pH for Tailings and Calccrete

4.2 NAG PH RESULTS

NAG pH test results for the samples are presented below. Samples with a NAG pH of less than 4.5 and an NP/AP ratio of less than 1.0 are considered PAG (Criterion 4). The acid-generating potential of a sample with an NP/AP ratio of less than 1.0 and a NAG pH greater than 4.5 is considered to be Uncertain (Criterion 5).

- Based on Table 4-1 and Figure 4-3, calcrete had a pH greater than 4.5 and an NP/AP ratio greater than 2 (Figure 4-3), which indicates that the sample is considered Non-PAG (Criterion 3).
- The tailings sample had a pH greater than 4.5 and an NP/AP of greater than 1 but according to criterion 4 samples with a sulphide concentration between 0.01 and 0.3% by weight are characterized as Uncertain (due to the material being primarily composed of minerals that have poor NP values; Price, 2009).
- The Prime Resources (2022) report classified the tailings and slurry as PAG.

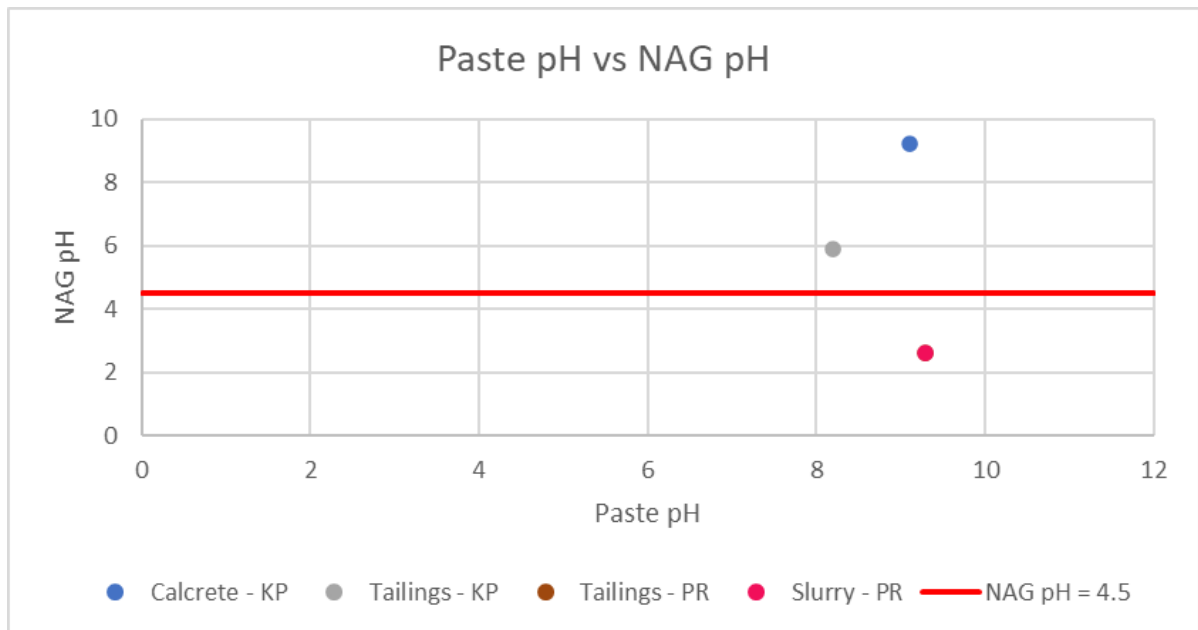


Figure 4-3: Paste pH versus NAG pH

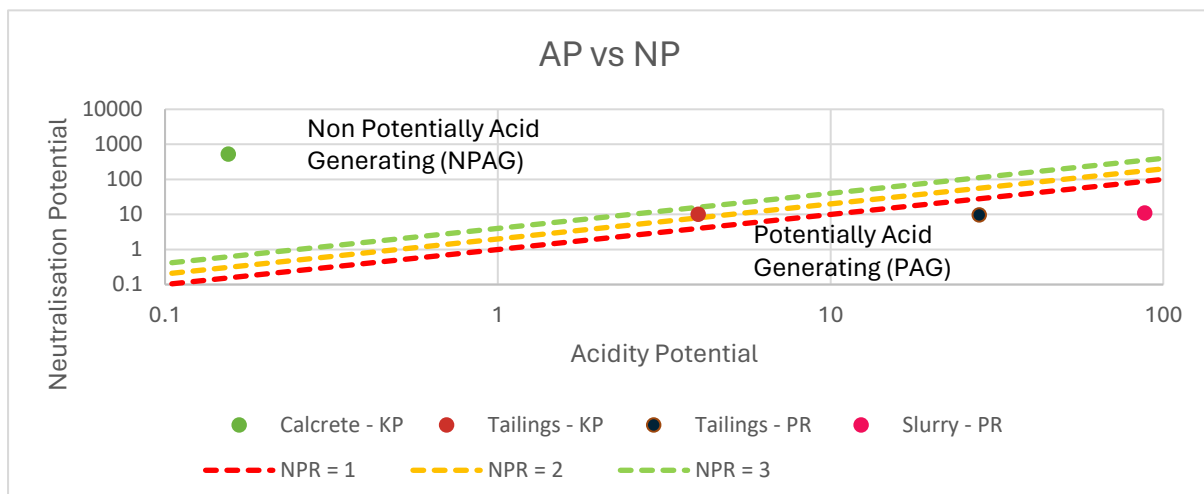


Figure 4-4: Acid Potential vs Neutralisation Potential of Twin Hills Samples

4.3 COLUMN LEACH TESTING OF TAILINGS

The results of the column leachate have been compared to the International Finance Corporation (IFC) mining effluent standards and the Namibian discharge limits and are discussed below:

4.3.1 MAJOR IONS (TABLE 4-2)

- The pH of the column leachate was neutral for the entire duration of the test program and ranged between 8.2 and 8.5.
- Initially sulfate was high at 3270 mg/L but after the initial flush concentrations decreased to 1240 mg/L.
- The alkalinity stabilised at 60 mg/L due to the reaction with the calcrete minerals.
- During the initial flush, total dissolved solids (TDS) concentrations were elevated and exceeded the Namibian discharge limits of 500 mg/L. During the final week, it had decreased below the limit.
- The sodium (Na) concentrations exceed the Namibian discharge limit of 90 mg/L during the first 2 weeks (Initial flush) only.
- Figure 4-5 and Figure 4-6 shows concentrations trend of major ions with time.

4.3.2 HEAVY METALS (TABLE 4-3)

- Most heavy metals analysed were below the Namibian discharge limits and IFC mining release standards for the duration of the column leach test program.
- Arsenic (Figure 4-7) was noted to be increasing from weeks 4 and 5 which indicates a possible trend of mobile arsenic being released. During week six, the arsenic concentration dropped below detection limit.
- Aluminium and Iron were below the IFC and Namibian effluent limits confirming the buffering potential of the calcrete compared to the 2022 results.
- The confirmation of low concentrations of arsenic released from the tailings material confirms the previous tailings testing results (2022) and confirms that a liner is indicated for the TSF.

Table 4-2: Major Ions of Tailings Column Leachate

Parameter		pH	Electrical Conductivity (EC)	Total Dissolved Solids (TDS)	Total Alkalinity	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Chloride (Cl)	Fluoride (F)	Sulphate (SO ₄)	Nitrate (NO ₃)
Units			mS/m	mg/L	mg/L CaCO ₃	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Namibian Effluent Limits		5.5-9.5	75	500				90		70	2	40	20
IFC Limits		6 -- 9											
Column 3 (calcrete and tailings)	Week 1	8.4	738	4900	130	146	365	1010	95	185	1.4	3270	35
	Week 2	8.5	260	2700	75	95	180	252	46	9.4	0.31	1240	0.1
	Week 3	8.2	114	810	70	42	69	59	17	2.4	0.6	432	0.1
	Week 4	8.3	69.3	510	80	22	30	29	12	1.0	0.78	258	<0.1
	Week 5	8.3	50.4	420	80	20	25		11	0.92	1.4	160	0.4
	Week 6	8.4	44.3	330	60	18	17	17	11	0.22	1.1	131	0.1

Table 4-3: Metals Concentrations of Tailings Column Leachate

Parameter		Aluminium (Al)	Arsenic (As)	Boron (B)	Barium (Ba)	Cadmium (Cd)	Cobalt (Co)	Chromium (Cr)	Copper (Cu)	Iron (Fe)	Mercury (Hg)	Lithium (Li)	Manganese (Mn)
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
Namibian Effluent Limits		0.2	0.15	1	2	0.05		1	2	1	0.002		
IFC Limits			1			0.05		1	0.3	2	0.002		
Column 3 (calcrete and tailings)	Week 1	<0.02	<0.01	0.044	0.046	<0.001	0.35	<0.002	<0.02	0.29	0.002	0.26	0.01
	Week 2	<0.02	<0.01	0.058	0.022	<0.001	0.12	<0.002	<0.02	0.20	0.00035	0.13	<0.01
	Week 3	<0.02	<0.01	0.068	0.017	<0.001	0.052	<0.002	<0.02	<0.05	0.000017	0.15	<0.01
	Week 4	<0.02	0.01	0.061	0.014	<0.001	<0.005	<0.002	<0.02	0.11	<0.001	0.055	<0.01
	Week 5	<0.02	0.02	0.060	<0.002	<0.001	<0.005	<0.002	<0.02	0.11	<0.001	0.022	<0.01
	Week 6	<0.02	<0.01	0.041	0.011	<0.001	<0.005	<0.002	<0.02	0.12	<0.001	0.034	<0.01
Parameter		Molybdenum (Mo)	Nickel (Ni)	Phosphorous (P)	Lead (Pb)	Sulphur (S)	Antimony (Sb)	Selenium (Se)	Strontium (Sr)	Titanium (Ti)	Uranium (U)	Vanadium (V)	Zinc (Zn)
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
Namibian Effluent Limits			0.3		1			0.05	0.1		0.5		5
IFC Limits			0.5		0.2								1
Column 3	Week 1	0.047	<0.005	0.13	<0.01	3100	<0.01	<0.01	0.74	<0.005	<0.01	0.072	<0.01
	Week 2	0.044	<0.005	<0.03	<0.01	601	<0.01	<0.01	0.52	<0.005	<0.01	0.10	<0.01
	Week 3	<0.005	<0.005	<0.03	<0.01	228	<0.01	<0.01	0.25	<0.005	<0.01	0.14	<0.01
	Week 4	<0.005	<0.005	<0.03	<0.01	87	<0.01	<0.01	0.15	<0.005	<0.01	0.11	<0.01
	Week 5	<0.005	<0.005	<0.03	<0.01	63	<0.01	<0.01	0.12	<0.005	<0.01	0.11	<0.01
	Week 6	<0.005	<0.005	<0.03	<0.01	42	<0.01	<0.01	0.13	<0.005	<0.01	0.13	<0.01

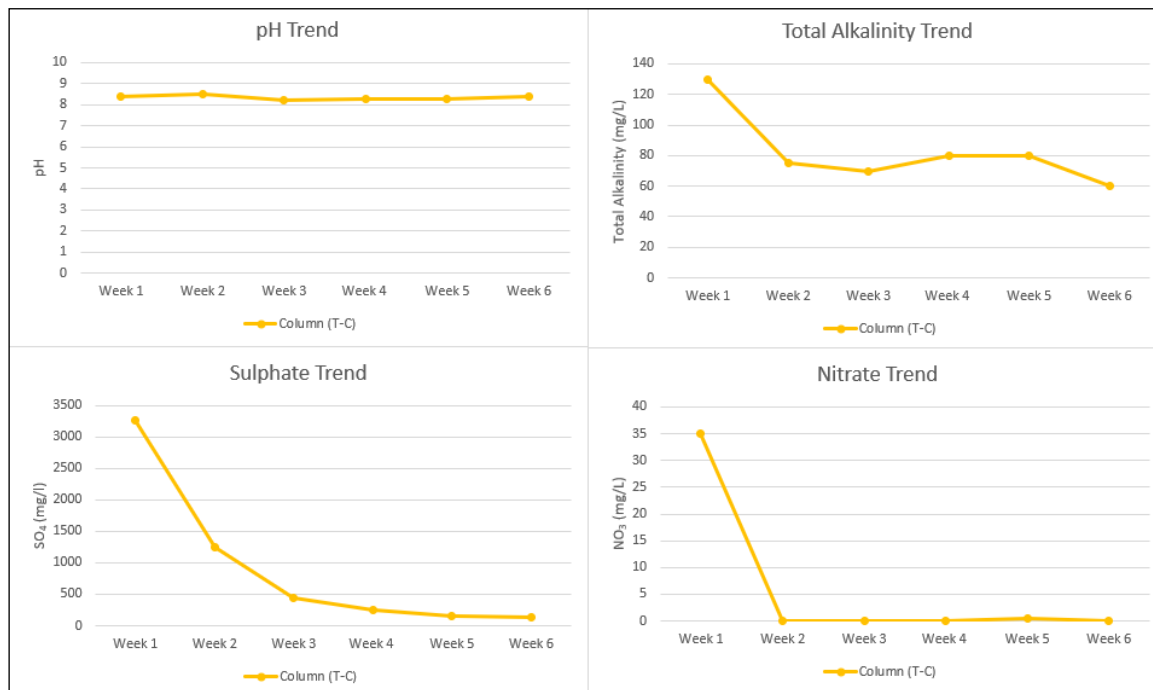


Figure 4-5: Major Ions Concentrations Trend

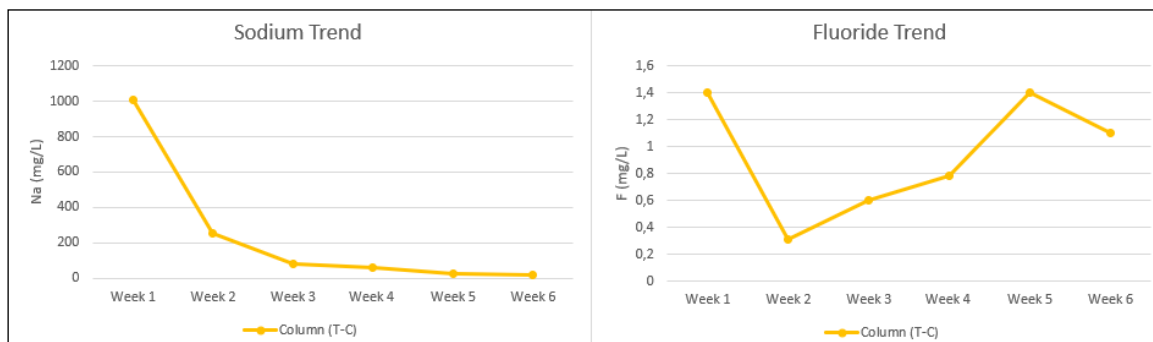


Figure 4-6: Major Ions Concentration Trend Cont.

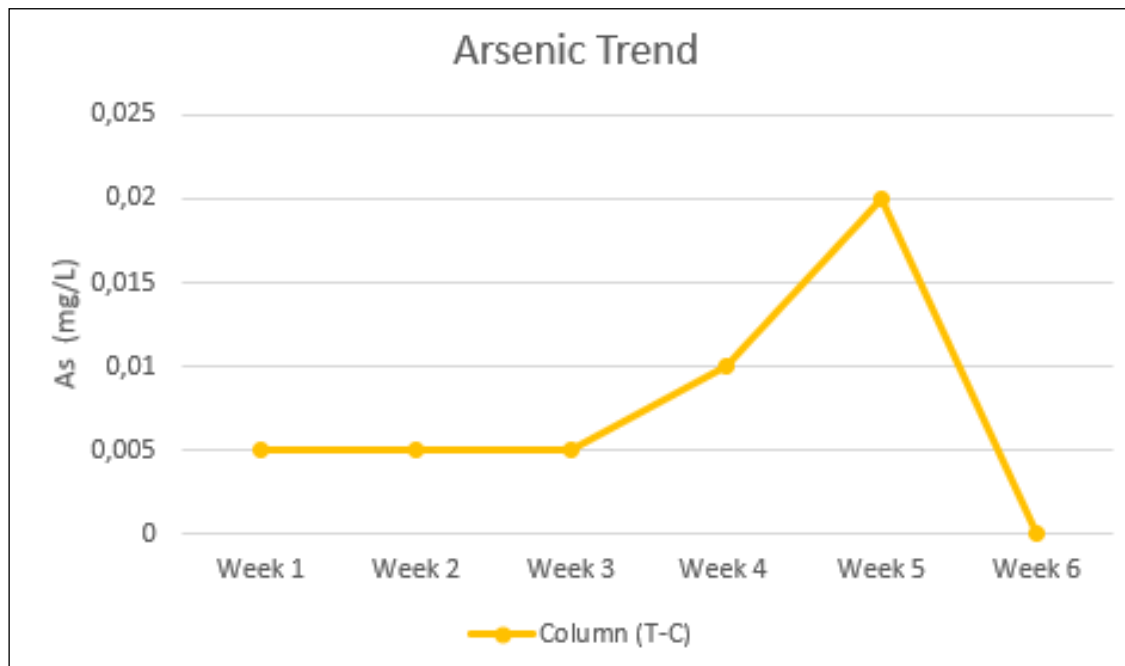


Figure 4-7: Arsenic Concentration Trend

4.4 EQUILIBRIUM MIXING MODEL FOR TSF

In the event that the liner is compromised, the risk of high sulfate levels and heavy metals reaching the groundwater table was evaluated in an equilibrium mixing model.

The column leachate results and groundwater quality data together with the dissolution of calcrete minerals were used as input concentrations for the equilibrium mixing model. PHREEQC (version 3.4.0.12927) geochemical software was used to perform geochemical calculations. The generated geochemical analyte concentrations were evaluated to support the trickle-down column test.

4.4.1 BOUNDARY CONDITIONS

The model boundary conditions are summarised in Table 4-4.

Table 4-4: Model Boundary Conditions

Boundary Conditions	Description
Gas phase	It is assumed that there is little biological activity in the material and the $\text{CO}_2(\text{g})$ pressure was set to $10^{-3.5}$ atm.
Minerals	Based on the mineralogical analysis the pure phase that can react reversibly with the aqueous phase is Calcite, Magnesite, Malachite, Manganite or Cerussite. Mineral phases to simulate only precipitation reactions were added for each sample modelled if they were over saturated in the solution.
Adsorption surface	Metal cations can sorb to charged surfaces. In this simulation no such sorption was simulated.

4.4.2 MODEL LIMITATIONS

Predicting the water qualities of complex systems demands assumptions. Even a rigorous sampling and analysis programme cannot precisely determine the physical and geochemical characteristics of the system, nor can they precisely indicate how these characteristics may change over time. This model assumes only mixing of components with no reactive kinetic reactions. Evaporation was not modelled due to the limits of PHREEQC to concentrating mixtures over time steps.

Table 4-5 summarises the key limitations of the input data and the hydrogeochemical model used for this assessment.

Table 4-5: Model Limitations

No	Limitations	Description
1	Predicting field scale water quality from lab scale test results is an approximation	Leaching of salts and metals at the field scale is variable in time and controlled by factors not fully applied at the lab scale. Amongst others, these factors include temperature, evaporation, nature of the leaching solution, the solution to solid ratio, solution-solid contact time and particle size of the solid. The modelled quality of water due to interaction with tailings or waste is an informed estimate.
2	The geochemical database is relevant to the system being modelled	Hydrogeochemical modelling uses the inherently uncertain laboratory results and water qualities as inputs. These are processed using thermodynamic data determined in the laboratory on ideal materials and solutions. The laboratory determined constants may not be directly applicable to the materials, solutions, and chemical context of the waste material. The minteq.v4.dat database was used for the model.
3	The modelling assumes thermodynamic equilibrium in the model system	In the field, all chemical components are subject to kinetic variation and the system might, at best be in a state of quasi equilibrium. This may suggest that attempts to simulate or predict the state of these complex systems have questionable value. However, geochemical evaluations of natural and mine waters over the last few decades have shown that the equilibrium assumption is a powerful tool that in many circumstances produces results that accurately describe the general chemistry of such waters.
4	Adsorption surface	Metal cations can sorb to charged surfaces. There is no data to quantify either these surfaces, or their effect on water quality.

4.4.3 GEOCHEMICAL MODELING SOURCE TERMS AND RESULTS FOR TSF

To assess or predict impacts to groundwater and surface water resources from any facility that may be a significant source of water contamination, a source term model must be developed. The source term results are summarised in Table 4-6. The background groundwater quality data was adopted from the hydrogeological study for the DFS (KP, 2022).

Half detection limits were used for those common major and trace elements that reported below detection limits. The results were screened against the Namibian discharge limits as well as the IFC effluent limits. The modelled source terms did not predict any exceedances with the exception of chloride (Cl), sodium (Na) and sulphate (SO_4) which were already elevated in the background groundwater chemistry.

Iron (Fe) and Strontium (Sr) from the measured leachate and modelled results were initially above the Namibian discharge limits but the mix model results show that the heavy metals were neutralised by groundwater and are below limits. The mix model also shows that the pH will remain neutral.

The modelling results proves the effectiveness of the calcrete in buffering the leachate. The Cl, Na and SO_4 increased marginally but these were already elevated in the brackish groundwater.

Table 4-6: Source Terms and Results Generated by PHREEQC

Element	Units	Namibian Effluent Limits	IFC Limits	Source Terms			Results
				Measured Concentrations Column (Tal. Cal)	Modelled Concentrations Column (Tal. Cal)	Groundwater Chemistry	Mix Model (source terms) concentrations
pH	mg/L	5.5 – 9.5	6 - 9	8.3	8.4	7.4	7.4
Alkalinity	mg/L			73	120	470	580
Cl	mg/L	70		1.1	186	347	532
SO ₄	mg/L	40		245.3	536	426	436
Al	mg/L	0.2		0.01	0.02	0.0	0.0
As	mg/L	0.15	1	0.02	0.01	0.01	0.01
B	mg/L	1		0.06	0.04	0.0	0.0
Ba	mg/L	2		0.02	0.05	0.0	0.001
Be	mg/L			0.0	0.0001	0.0	0.0
Ca	mg/L			28	146	194	197
Cd	mg/L	0.05	0.05	0.0005	0.001	0.01	0.01
Co	mg/L			0.05	0.35	0.0	0.004
Cu	mg/L			0.01	0.02	0.02	0.02
Cr	mg/L	1	1	0.001	0.002	0.01	0.005
F	mg/L	2		1.0	1.40	1.0	1.02
Fe	mg/L	1	2	0.11	0.29	0.04	0.04
Hg	mg/L	0.002	0.002	0.02	0.00	0.0	0.0
K	mg/L			13.3	95	15	16
Li	mg/L			0.08	0.26	0.0	0.003
Mg	mg/L			41.3	365	153	158
Mn	mg/L			0.005	0.01	0.17	0.17
Mo	mg/L			0.04	0.047	0.07	0.07
NO ₃	mg/L	20		0.2	0.00	0.0	13.4
Na	mg/L	90		56.7	178	103	106
Ni	mg/L	0.3	0.5	0.025	0.005	0.0	0.0
P	mg/L			0.13	0.00	0.0	0.0
Pb	mg/L	1	0.2	0.005	0.01	0.1	0.18
Sb	mg/L			0.005	0.01	0.0	0.0
Se	mg/L	0.05		0.005	0.01	0.02	0.02
Si	mg/L			0.00	0.00	0.0	0.36
Sr	mg/L	0.1		0.17	0.74	0.0	0.008
Ti	mg/L			0.0025	0.005	0.0	0.0
U	mg/L	0.5		0.00	0.01	0.0	0.0
V	mg/L			0.12	0.0072	0.0	0.0
Zn	mg/L	5	1	0.005	0.01	0.05	0.0
TDS	mg/L	500		518	794	-	-

5.0 PAG WASTE ROCK TESTING RESULTS

5.1 ABA OF PAG WASTE ROCK

Acid base accounting (ABA) results as shown in Table 5-1, Figure 5-1 and Figure 5-2 which indicate that the waste rock has an alkaline paste pH but with a total sulphur content of 1.35 wt%, of which 1.05 wt% is present in sulphide form and 0.89 wt% as sulphate. This results in an acid potential (AP) which exceeds the low neutralising potential (NP) of the material. The waste rock sample is therefore classified as potentially acid generating. The NAG pH is less than 4.5 indicating potential for acid generation.

Table 5-1: Acid - Base Accounting Results for Waste Rock

Acid – Base Accounting	Sample Identification
Modified Sobek (EPA-600)	Waste Rock Sample
Paste pH	9.5
Total Sulphur as S (%) (LECO)	1.35
Sulphate Sulphur as S (%)	0.89
Sulphide Sulphur as S (%)	1.05
Acid Potential (AP) (kg/t)	33
Neutralization Potential (NP)	13.2
Nett Neutralization Potential (NNP)	-19
Neutralising Potential Ratio (NPR) (NP : AP)	0.4
NAG pH	2.6
NAG pH 4.5 (kg H ₂ SO ₄ /t)	21
NAG pH 7.0 (kg H ₂ SO ₄ /t)	11
Rock Type	PAG

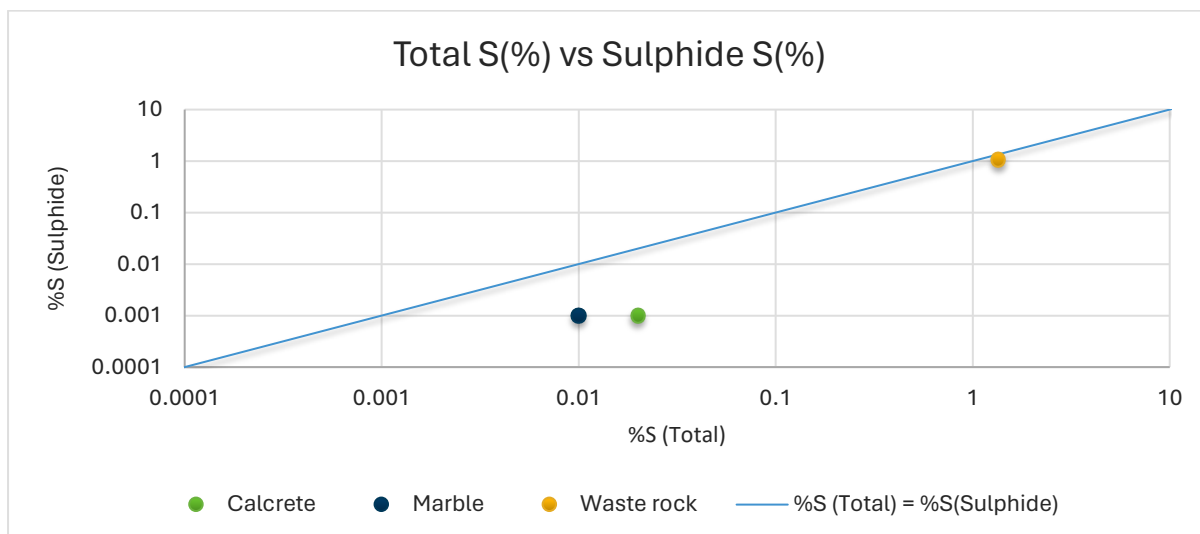


Figure 5-1: Total Sulphur (%S) vs Sulphide (%S) for PAG Waste Rock, Calcrete and Marble

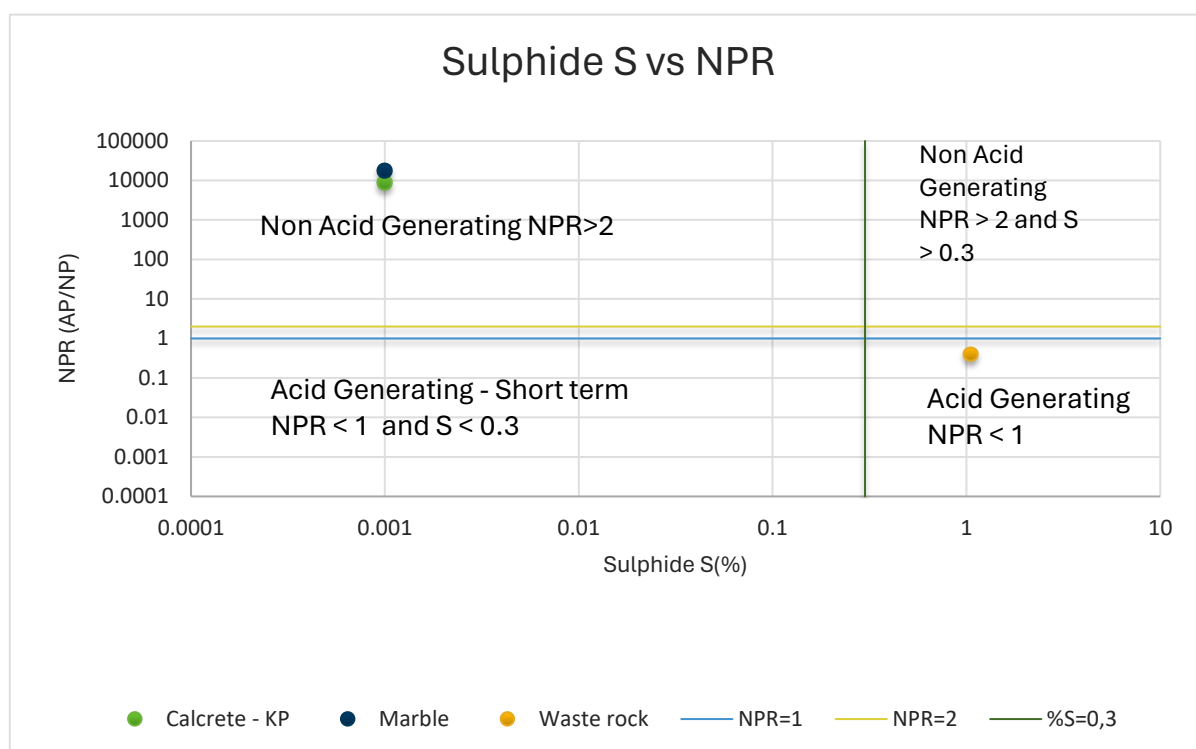


Figure 5-2: NPR versus Paste pH for PAG Waste rock, Calcrete and Marble

5.2 NAG PH RESULTS

NAG pH test results for the samples are presented below in Figure 5-1 and Figure 5-2.

- The PAG waste rock sample has a NAG pH of 2.6 as compared to the marble and calcrete with NAG pH values of 9 and 10 respectively.

- The NP/AP ratio of PAG waste rock is 0.4 and is classified as PAG. The marble and calcrete are Non-PAG with an NPR of >8000.
- The PAG waste rock results are similar to the RGS 2022 results.

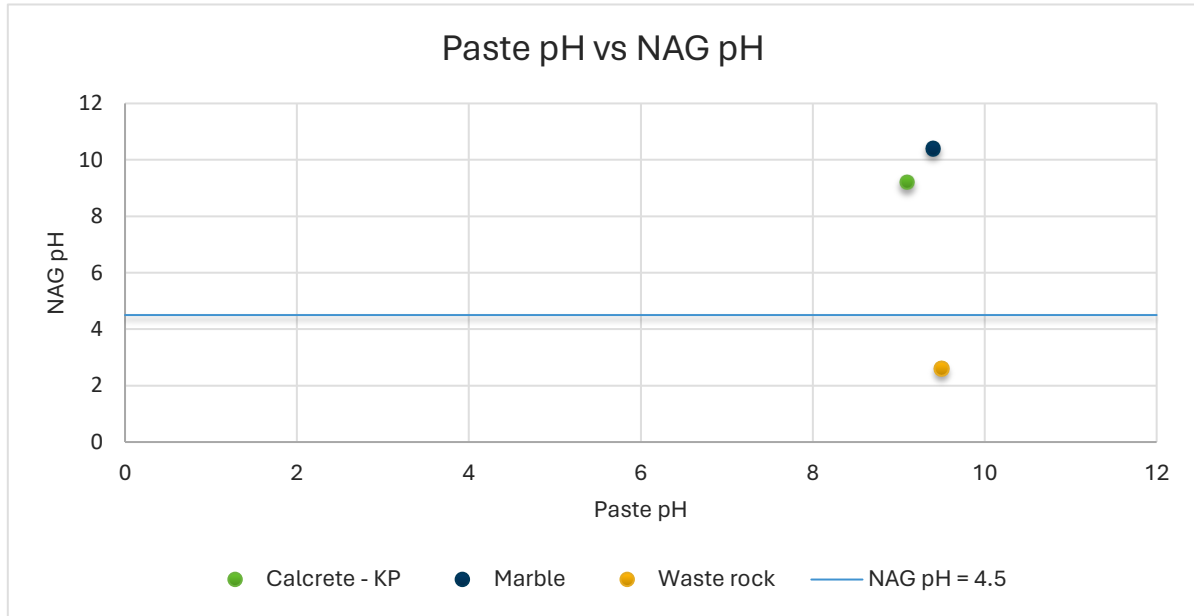


Figure 5-3: Paste pH versus NAG pH

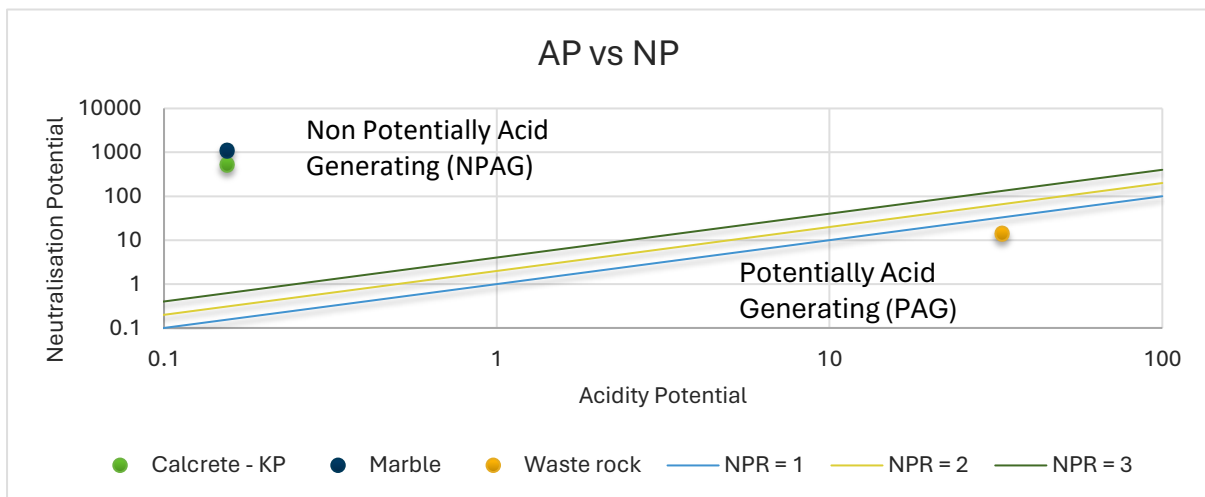


Figure 5-4: Acid Potential vs Neutralisation Potential of PAG Waste Rock, Calcrete and Marble

5.3 COLUMN LEACH TESTING OF WASTE ROCK

The results of the waste rock column leachate have been compared to the International Finance Corporation (IFC) mining effluent standards and the Namibian discharge limits and are discussed below:

MAJOR IONS (TABLE 5-2)

- The pH remains alkaline for both columns (first column contains waste, calcrete, and marble while the second column contains waste rock and calcrete).
- Initially sulfate was 129 mg/L 143 mg/L but after the initial flush concentrations decreased to 57 mg/L and 71 mg/L.
- The alkalinity remained stabilised at 130 mg/L.
- Figure 5-5 and Figure 5-6 shows concentrations trend of major ions with time.
- The results show that there was insufficient time and reactive surfaces for the sulphide minerals in the PAG rock to react with the solution.
- The waste rock and calcrete column test continued for another six weeks and pH remained alkaline.
- Since the test was stopped and restarted, initial flush concentrations are observed in week 7 and week 8.
- Sulfate concentrations are high during the initial flush but are decreasing which shows the effectiveness of calcrete to buffer acid formed by the waste rock.

5.3.1 HEAVY METALS (TABLE 5-3)

- The results show that none of the heavy metals analysed were mobilised into the solution and confirm that there was insufficient time and exposed surfaces for the mobilisation of metals.
- Following the crushing of the PAG waste rock to finer size, the leach testing over an additional six weeks, showed that, with the exception of strontium, most of the heavy metals are below Namibian effluent limits and IFC limits.
- This shows the effectiveness of the underlying calcrete geology to neutralise the leachate from the PAG waste rock.

Table 5-2: Major Ions of PAG Waste Rock Leachate

Parameter		pH	Electrical Conductivity (EC)	Total Dissolved Solids (TDS)	Total Alkalinity	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Chloride (Cl)	Fluoride (F)	Sulphate (SO ₄)	Nitrate (NO ₃)
Units			mS/m	mg/L	mg/L CaCO ₃	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Namibian Effluent Limits		5.5-9.5	75	500				90		70	2	40	20
IFC Limits		6 - 9											
Column 1 WR-Cal-Mar	Week 1	8.6	91.6	810	150	20	57	40	17	106	0.91	143	20
	Week 2	8.7	43.8	310	130	9.8	33	25	12	22	0.65	57	0.9
	Week 3	8.4	32.0	160	140	9.2	28	17	7.6	3.6	0.85	28	0.3
	Week 4	8.5	28.9	270	130	8.1	20	13	6.3	1.5	0.83	22	<0.1
	Week 5	8.5	27.0	220	130	9.5	20	6.9	6.1	0.57	1.2	19	0.2
	Week 6	8.4	30.5	200	110	9.2	15	4.4	6.3	0.41	0.86	16	0.2
Column 2 WR-Cal	Week 1	8.6	82.4	530	140	19	51	35	16	87	1.1	129	17
	Week 2	8.7	46.9	340	135	11	36	26	12	28	0.64	71	1.1
	Week 3	8.5	33.5	220	120	9.5	28	17	7.3	5.2	0.84	38	0.1
	Week 4	8.5	28.1	230	120	8.1	18	13	6.0	1.7	0.74	29	<0.1
	Week 5	8.5	25.9	210	110	9.3	19	7.0	5.4	0.57	1.1	23	0.1
	Week 6	8.5	25.5	180	100	9.4	14	4.2	6.3	0.50	0.82	18	0.1
	Week 7	8.3	36.2	260	80	17	26	8.1	7.4	0.95	0.52	85	0.2
	Week 8	8.4	33.2	264	90	15	24	7.6	7.2	0.40	0.65	79	<0.1
	Week 9	8.2	26.2	170	70	14	20	5.1	6.2	0.49	0.69	55	0.2
	Week 10	8.4	23.9	190	70	12	16	3.5	5.4	0.09	0.39	45	<0.1
	Week 11	8.4	22.2	170	70	14	17	3.2	5.1	0.10	0.77	42	<0.1
	Week 12	8.2	21.9	150	50	13	15	2.4	4.6	0.08	0.68	42	0.1

Table 5-3: Metals Concentrations of PAG Waste Rock Column Leachate

Parameter		Aluminium (Al)	Arsenic (As)	Boron (B)	Barium (Ba)	Cadmium (Cd)	Cobalt (Co)	Chromium (Cr)	Copper (Cu)	Iron (Fe)	Mercury (Hg)	Lithium (Li)	Manganese (Mn)
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
Namibian Effluent Limits		0.2	0.15	1	2	0.05		1	2	1	0.002		
IFC Limits			1			0.05		1	0.3	2	0.002		
Column 1 WR-Cal-Mar	Week 1	<0.02	<0.01	0.050	0.017	<0.001	<0.005	<0.002	<0.02	<0.05	<0.001	0.077	<0.01
	Week 2	<0.02	<0.01	0.067	0.008	<0.001	<0.005	<0.002	<0.02	<0.05	<0.001	0.057	<0.01
	Week 3	<0.02	<0.01	0.059	<0.002	<0.001	<0.005	<0.002	<0.02	<0.05	<0.001	0.10	<0.01
	Week 4	<0.02	0.02	0.052	<0.002	<0.001	<0.005	<0.002	<0.02	<0.05	<0.001	0.050	<0.01
	Week 5	<0.02	0.02	0.049	<0.002	<0.001	<0.005	<0.002	<0.02	<0.05	<0.001	0.021	<0.01
	Week 6	<0.02	<0.01	0.33	0.005	<0.001	<0.005	<0.002	<0.02	<0.05	<0.001	0.033	<0.01
Column 2 WR-Cal	Week 1	<0.02	<0.01	0.044	0.016	<0.001	<0.005	<0.002	<0.02	<0.05	<0.001	0.069	<0.01
	Week 2	<0.02	<0.01	0.061	0.009	<0.001	<0.005	<0.002	<0.02	<0.05	<0.001	0.057	<0.01
	Week 3	<0.02	<0.01	0.056	<0.002	<0.001	<0.005	<0.002	<0.02	<0.05	<0.001	0.10	<0.01
	Week 4	<0.02	0.02	0.049	0.005	<0.001	<0.005	<0.002	<0.02	<0.05	<0.001	0.045	<0.01
	Week 5	<0.02	0.02	0.045	<0.002	<0.001	<0.005	<0.002	<0.02	<0.05	<0.001	0.020	<0.01
	Week 6	<0.02	<0.01	0.028	0.004	<0.001	<0.005	<0.002	<0.02	<0.05	<0.001	0.030	<0.01
	Week 7	<0.02	<0.003	0.028	0.009	<0.001	<0.005	<0.002	<0.02	<0.05	<0.001	0.046	<0.01
	Week 8	<0.02	<0.003	0.024	0.008	<0.001	<0.005	<0.002	<0.02	0.11	<0.001	0.044	<0.01
	Week 9	<0.02	<0.003	0.019	0.006	<0.001	<0.005	<0.002	<0.02	<0.05	<0.001	0.031	<0.01
	Week 10	<0.02	<0.003	0.011	0.006	<0.001	<0.005	<0.002	<0.02	<0.05	<0.001	0.026	<0.01
	Week 11	<0.02	<0.003	0.015	0.005	<0.001	<0.005	<0.002	<0.02	<0.05	<0.001	0.023	<0.01
	Week 12	<0.02	<0.003	0.013	0.005	<0.001	<0.005	<0.002	<0.02	<0.05	<0.001	0.021	<0.01

Parameter		Molybdenum (Mo)	Nickel (Ni)	Phosphorous (P)	Lead (Pb)	Sulphur (S)	Antimony (Sb)	Selenium (Se)	Strontium (Sr)	Titanium (Ti)	Uranium (U)	Vanadium (V)	Zinc (Zn)
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
Namibian Effluent Limits			0.3		1			0.05	0.1		0.5		5
IFC Limits			0.5		0.2								1
Column 1 WR-Cal-Mar	Week 1	0.008	<0.005	0.09	<0.01	48	<0.01	<0.01	0.13	<0.005	<0.01	0.088	<0.01
	Week 2	0.006	<0.005	<0.03	<0.01	21	<0.01	<0.01	0.068	<0.005	<0.01	0.20	<0.01
	Week 3	<0.005	<0.005	<0.03	<0.01	8.4	<0.01	<0.01	0.054	<0.005	<0.01	0.21	<0.01
	Week 4	<0.005	<0.005	<0.03	<0.01	7.7	<0.01	<0.01	0.051	<0.005	<0.01	0.14	<0.01
	Week 5	<0.005	<0.005	<0.03	<0.01	6.9	<0.01	<0.01	0.053	<0.005	<0.01	0.12	0.03
	Week 6	<0.005	<0.005	<0.03	<0.01	5.5	<0.01	<0.01	0.059	<0.005	<0.01	0.15	<0.01
Column 2 WR-Cal	Week 1	0.007	0.006	0.07	<0.01	41	<0.01	<0.01	0.12	<0.005	<0.01	0.078	<0.01
	Week 2	0.006	<0.005	<0.03	<0.01	26	<0.01	<0.01	0.075	<0.005	<0.01	0.19	<0.01
	Week 3	<0.005	<0.005	<0.03	<0.01	13	<0.01	<0.01	0.056	<0.005	<0.01	0.19	<0.01
	Week 4	<0.005	<0.005	<0.03	<0.01	9.8	<0.01	<0.01	0.049	<0.005	<0.01	0.13	<0.01
	Week 5	<0.005	<0.005	<0.03	<0.01	8.5	<0.01	<0.01	0.053	<0.005	<0.01	0.11	0.01
	Week 6	<0.005	<0.005	<0.03	<0.01	6.2	<0.01	<0.01	0.057	<0.005	<0.01	0.14	<0.01
	Week 7	<0.005	<0.005	<0.03	<0.003	31	<0.003	<0.01	0.12	<0.005	<0.003	0.061	<0.01
	Week 8	<0.005	<0.005	<0.03	<0.003	30	<0.003	<0.01	0.11	<0.005	<0.003	<0.001	<0.01
	Week 9	<0.005	<0.005	<0.03	<0.003	20	<0.003	<0.01	0.083	<0.005	<0.003	<0.001	<0.01
	Week 10	<0.005	<0.005	<0.03	<0.003	16	<0.003	<0.01	0.086	<0.005	<0.003	0.049	<0.01
	Week 11	<0.005	<0.005	<0.03	<0.003	15	<0.003	<0.01	0.076	<0.005	<0.003	0.076	<0.01
	Week 12	<0.005	<0.005	<0.03	<0.003	14	<0.003	<0.01	0.078	<0.005	<0.003	0.062	<0.01

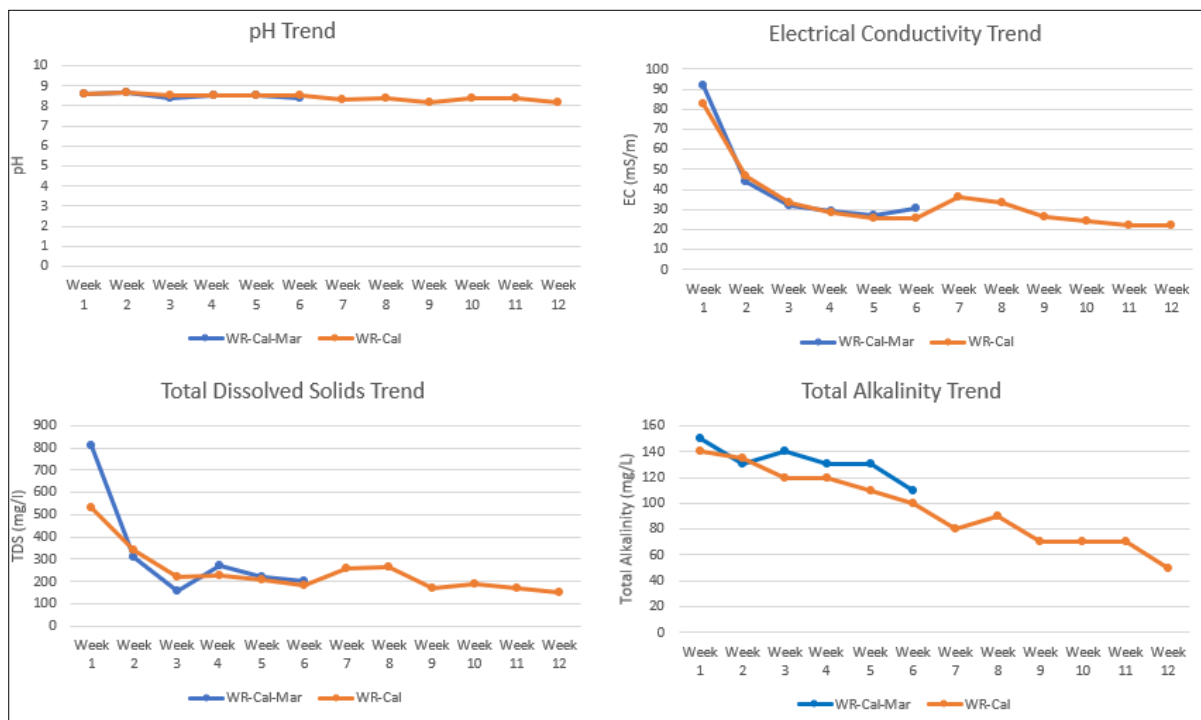


Figure 5-5: Change of pH, EC, TDS and Alkalinity in Test Columns Leachate

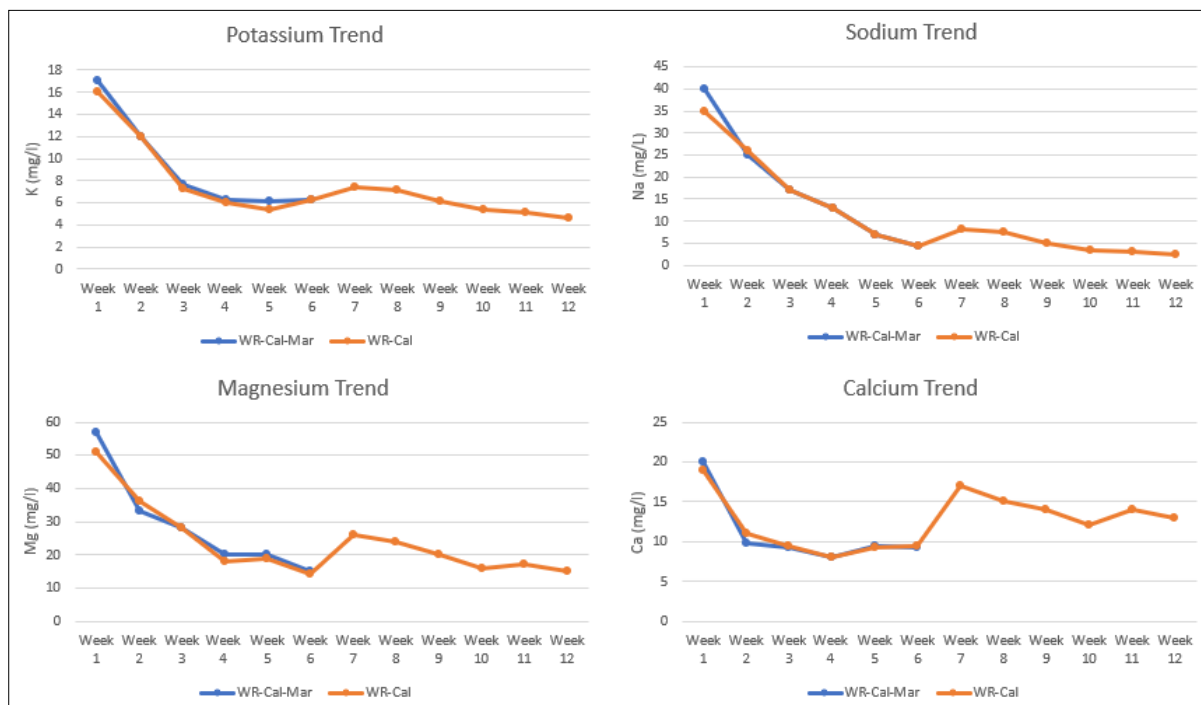


Figure 5-6: Change of Major Cations Distribution with Time in Test Column Leachate

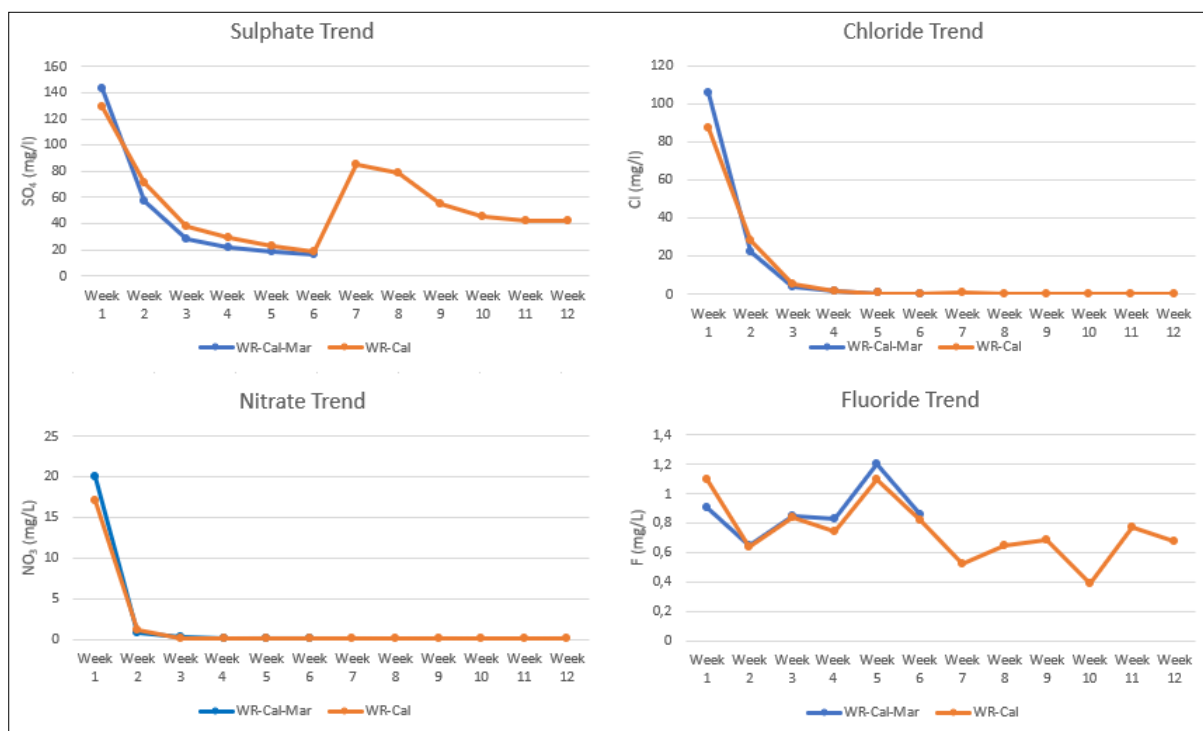


Figure 5-7: Change of major Anions Distribution with Time in Test Column Leachate

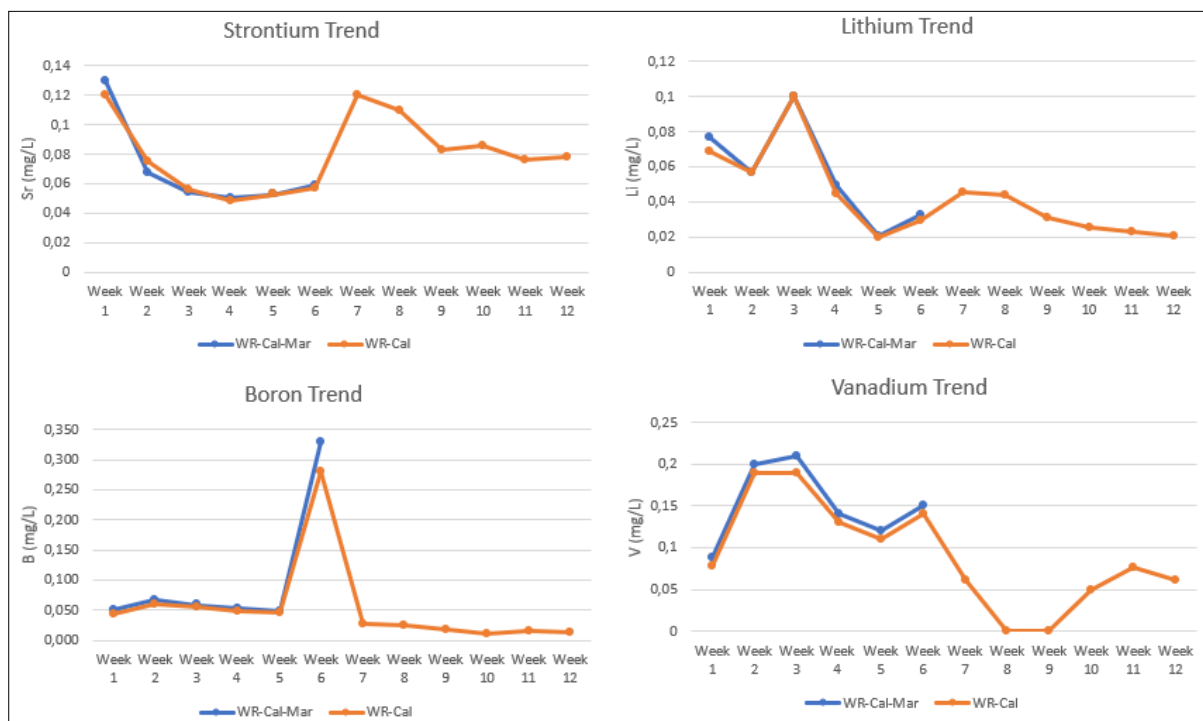


Figure 5-8: Change of Sr, Li, B and V Distribution with Time in Test Column Leachate

5.4 EQUILIBRIUM MIXING MODEL FOR PAG WASTE ROCK

Due to the low concentrations released from the PAG waste rock columns over 12 weeks, the kinetic leachate result from RGS PAG waste rock (2022) were used in the equilibrium mixing model to simulate the worst-case scenario.

The RGS PAG waste rock leachate and groundwater quality data together with the dissolution of calcrete minerals were used as input concentrations for the equilibrium mixing model.

5.5 MODELLING RESULTS

The Source Term results using four samples representative of PAG waste rock (KLC2, KLC5, KLC11 and KLC12) from the RGS mixed with brackish groundwater and allowing the dissolution of calcrete are shown in Table 5-4. The results indicate that Na, SO₄ and Cl are elevated due to the background groundwater. No elevated metals are noted in the final solution confirming the neutralisation capacity from the calcrete and groundwater.

The model will be updated once the results from the extended column testing with smaller sizes of crushed PAG waste rock are received. Based on the results to date, the calcrete appears to be sufficient in buffering the acidity generated from the PAG waste rock, but the addition of a thin marble layer would provide additional buffering capacity if required.

The model could not be re-run as most analytes were below detection and concentrations detected were below the applicable limits.

Table 5-4: Results for PAG Waste Rock Leachate, Groundwater and Calcrete

Element	Units	Namibian Effluent Limits	IFC Limits	SOURCE TERMS					RESULTS
				Bulge PAF Waste Rock (KLC2)	Twin Hills Central Waste Rock (KLC5)	Clouds Waste Rock (KLC11)	Twin Hills Central Ore (KLC12)	Groundwater Chemistry	
pH	mg/L	5.5 – 9.5	6 - 9	6.5	5.5	6.5	6.5	7.4	7.39
Alkalinity	mg/L			41	45	33	45	470	561
Cl	mg/L	70		1.52	1.23	63.81	1.35	347	341
S(6)	mg/L	40		38.71	36.86	283	9	426	421
Al	mg/L	0.2		2.36	2.69	5.83	0.38	0.0	0.11
As	mg/L	0.15	1	0.07	0.09	0.13	0.06	0.01	0.01
B	mg/L	1		0.04	0.04	0.05	0.01	0.0	0.0
Ba	mg/L	2		0.0	0.0	0.0	0.0	0.0	0.0
Be	mg/L			0.0	0.0	0.0	0.0	0.0	0.0
Ca	mg/L			9.3	10.4	33.67	3.13	194	191
Cd	mg/L	0.05	0.05	0.00	0.00	0.01	0.00	0.01	0.01
Co	mg/L			0.01	0.01	0.36	0.00	0.0	0.0
Cu	mg/L			0.01	0.01	0.03	0.00	0.02	0.02

				SOURCE TERMS					RESULTS
Element	Units	Namibian Effluent Limits	IFC Limits	Bulge PAF Waste Rock (KLC2)	Twin Hills Central Waste Rock (KLC5)	Clouds Waste Rock (KLC11)	Twin Hills Central Ore (KLC12)	Groundwater Chemistry	Mix Model (source terms) concentrations
Cr	mg/L	1	1	0.01	0.00	0.01	0.00	0.01	0.0
F	mg/L	2		0.33	0.67	0.74	0.2	1.0	1.0
Fe	mg/L	1	2	3.83	2.34	82.54	0.25	0.04	0.95
Hg	mg/L	0.002	0.002	0.00	0.00	0.00	0.00	0.0	0.0
K	mg/L			4.5	1.86	1.87	0.59	15	14.78
Li	mg/L			0.0	0.0	0.0	0.0	0.0	0.0
Mg	mg/L			5.5	1.33	10.1	0.4	153	150
Mn	mg/L			0.23	2.03	1.21	0.71	0.17	0.21
Mo	mg/L			0.01	0.01	0.03	0.00	0.07	0.0
N(5)	mg/L	20		0.0	0.0	0.0	0.0	0.0	13
Na	mg/L	90		2.84	3.06	4.06	2.23	103	101
Ni	mg/L	0.3	0.5	0.03	0.02	0.87	0.00	0.0	0.01
P	mg/L			0.24	0.31	0.22	0.05	0.0	0.01
Pb	mg/L	1	0.2	0.01	0.01	0.02	0.01	0.1	0.1
Sb	mg/L			0.00	0.00	0.00	0.01	0.0	0.0
Se	mg/L	0.05		0.00	0.00	0.00	0.00	0.02	0.001
Si	mg/L			0.0	0.0	0.0	0.0	0.0	0.0
Sr	mg/L	0.1		0.0	0.0	0.0	0.0	0.0	0.0
Ti	mg/L			0.0	0.0	0.0	0.0	0.0	0.0
U	mg/L	0.5		0.01	0.01	0.01	0.01	0.0	0.0
V	mg/L			0.01	0.00	0.00	0.00	0.0	0.0
Zn	mg/L	5	1	0.02	0.03	0.57	0.00	0.05	0.00

6.0 DISCUSSION AND RECOMMENDATIONS

6.1 KEY FINDINGS OF 2023 GEOCHEMICAL TESTING

6.1.1 STATIC RESULTS

The static testing of the tailings in this study were uncertain (NPR of 2.6) with regards to acid generation, which is different from the results obtained in the PFS level testing program which indicated that the tailings were PAG. This is due either to different processing in the metallurgical testing or variability in the ore and tailings material.

The static results indicate that the composited waste rock sample is classified as potentially acid generating. These results are similar to the geochemical assessment conducted by RGS dated 2022.

The calcrete samples are composed mostly of dolomite, calcite (57%) and the Karibib Marble (sourced locally) is composed of 98% of calcite and dolomite. This provides confirmation that in the event of leakage through the TSF liner, and as the subsurface to the waste rock dumps, the underlying calcrete layer will provide buffering capacity to the leachate if it seeps through.

6.1.2 COLUMN LEACH TEST RESULTS

The column testing results for the tailings overlying the calcrete confirms that the pH will remain circum neutral and with low metals that can be leached in the short term (arsenic). This supports the findings that a liner is required for the TSF. In the event that there is a deterioration or tears in the liner, the underlying calcrete layer and groundwater will provide neutralisation of any potential acidic seepage from the TSF as confirmed from the mixing model.

The column leach testing for the PAG waste rock was inconclusive due to the large rock sample size preventing sufficient reactive surfaces with the distilled water solution in the short time. Consequently, the tests duration was extended for a further six weeks with crushed PAG waste rock. The pH remained neutral for the 12 weeks of testing and most metals were within the limits indicating the effectiveness of the calcrete to neutralise any seepage generated from the PAG waste rock. The leachate results from the RGS PAG waste rock kinetic testing conducted in 2022 were used as input concentrations to the mixing model to represent the worst-case scenario of PAG waste rock leachate seeping from the WRD. The results confirmed that the calcrete layer and groundwater will be effective in neutralising the acidity. No heavy metals exceeding the Namibian and IFC limits were evident in the final mix results.

6.2 CONSIDERATIONS LINER DESIGN

- The calcrete foundation below the TSF will assist in maintaining pH circum neutral to support heavy metals neutralization as part of the combined liner system.
- The mobility of the arsenic at high and low pH confirms that a liner system is required to limit contamination of the downstream environment and in compliance with regulations.
- No liner is required for the waste rock dump at this stage.

7.0 CONCLUSION AND RECOMMENDATION

- The in-situ calcrete geology underlying the TSF, and waste rock dumps will assist in maintaining pH circum neutral to support heavy metals neutralization if any acidic seepage is generated from these waste facilities.
- The confirmation of low concentrations of arsenic released from the tailings material confirms the previous tailings testing results (2022) and confirms that a liner is indicated for the TSF.
- The PAG material that will be deposited in the waste rock dumps will make up a low percentage of the volume of the WRDS occurring only at the fringes of the orebody due to the below grade mineralisation. Although acidity may be generated from this material, the underlying calcrete with >50% carbonate mineralogy is considered effective in providing abundant neutralisation capacity to the seepage in the long term. Encapsulation or mixing of marble with the waste rock from mined zones with higher mineralisation is recommended.
- Consideration could be given to adding a layer of crushed marble from the nearby Karibib Marble quarry to provide additional buffering capacity due to the 98% carbonate mineralogy.
- The conclusions are based on the results from testing completed in 2023. However, once mining commences it is recommended to conduct additional static and geochemical testing of waste solids with updates of the geochemical mixing model and possibly reactive transport modelling as part of the routine monitoring of the developing waste facilities.

8.0 REFERENCES

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This report was prepared and reviewed by the undersigned.



Prepared:

Mashudu Mathobo, PhD
Senior Hydrogeologist



Reviewed:

Diana Duthe, Pr. Sci. Nat
Lead Hydrogeologist

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Approval that this document adheres to Knight Piésold Quality Systems:

DD

APPENDIX A

Laboratory Certificates

CLIENT DETAILS

Contact **Diana Duthe**
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Order Number **Twinhills**
Samples **2**
Sample matrix **WATER**

LABORATORY DETAILS

Laboratory **X-Lab Earth Science**
Address **2 Samantha Street, Strydompark, Randburg, 2169**
Telephone **+27 (0)11 590 3000**

Laboratory Manager **Mrs Tasneem Tagari**
Lab Reference **JBX24-18379**
Report Number **0000078297**
Date Received **03/04/2024 14:21**
Date Started **4/04/2024 11:25**
Date Reported **22/04/2024 08:48**

The document is issued in accordance with SANAS's accreditation requirements.
Accredited for compliance with ISO/IEC 17025. SANAS accredited laboratory T0775.



Samples received at ambient temp good condition.

SIGNATORIES

Sarah Newton

Technical Specialist/Technical Signatory

TEST REPORT

Sample Number
Sample Name

JBX24-18379.001 Column 4 (CW) 6mm - W5	JBX24-18379.002 Blank - W5
--	-------------------------------

Parameter Units LOR

Alkalinity on waters by titration Method: ME-AN-001

Total Alkalinity as CaCO ₃	mg/l	12	70	<12
Methyl Orange (M) Alkalinity as CaCO ₃	mg/l	12	70	<12
Phenolphthalein (P) Alkalinity as CaCO ₃	mg/l	12	<12	<12

Conductivity on waters Method: ME-AN-007

Conductivity in mS/m @ 25°C	mS/m	2	22	<2.0
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Total Dissolved Solids (TDS) in water at 105 deg Method: ME-AN-011

TDS (0.7µm) @ 105°C	mg/l	21	170	<20
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ICP-OES Metals on waters (Dissolved) Method: ME-AN-027

Aluminium	mg/l	0.02	<0.02	<0.02
Antimony	mg/l	0.003	<0.003	<0.003
Arsenic	mg/l	0.003	<0.003	<0.003
Barium	mg/l	0.002	0.005	<0.002
Beryllium	mg/l	0.0001	<0.0001	<0.0001
Bismuth *	mg/l	0.03	<0.03	<0.03
Boron	mg/l	0.005	0.015	<0.005
Cadmium	mg/l	0.001	<0.001	<0.001

TEST REPORT

Sample Number
Sample Name

JBX24-18379.001 Column 4 (CW) 6mm - W5	JBX24-18379.002 Blank - W5
--	-------------------------------

Parameter

Units

LOR

ICP-OES Metals on waters (Dissolved) Method: ME-AN-027 (continued)

Calcium	mg/l	0.5	14	<0.5
Chromium	mg/l	0.002	<0.002	<0.002
Cobalt	mg/l	0.005	<0.005	<0.005
Copper	mg/l	0.02	<0.02	<0.02
Iron	mg/l	0.05	<0.05	<0.05
Lead	mg/l	0.003	<0.003	<0.003
Lithium *	mg/l	0.005	0.023	<0.005
Magnesium	mg/l	0.01	17	<0.01
Manganese	mg/l	0.01	<0.01	<0.01
Molybdenum	mg/l	0.005	<0.005	<0.005
Nickel	mg/l	0.005	<0.005	<0.005
Phosphorus	mg/l	0.03	<0.03	<0.03
Potassium	mg/l	0.2	5.1	<0.2
Selenium	mg/l	0.01	<0.01	<0.01
Sodium	mg/l	0.5	3.2	<0.5
Strontium	mg/l	0.001	0.076	<0.001
Sulphur	mg/l	0.07	15	<0.07
Tellurium *	mg/l	0.17	<0.17	<0.17
Thallium *	mg/l	0.01	<0.01	<0.01
Thorium *	mg/l	0.04	<0.04	<0.04
Tin	mg/l	0.01	<0.01	<0.01
Titanium	mg/l	0.005	<0.005	<0.005
Uranium *	mg/l	0.003	<0.003	<0.003
Vanadium	mg/l	0.001	0.044	<0.001
Zinc	mg/l	0.01	<0.01	<0.01

Anions on Waters by Ion Chromatography Method: ME-AN-014

TEST REPORT

Sample Number	JBX24-18379.001	JBX24-18379.002
Sample Name	Column 4 (CW) 6mm - W5	Blank - W5

Parameter Units LOR

Anions on Waters by Ion Chromatography Method: ME-AN-014 (continued)

Chloride	mg/l	0.05	0.10	<0.05
Fluoride	mg/l	0.05	0.77	<0.05
Nitrate	mg/l	0.1	<0.1	<0.1
Sulphate	mg/l	0.05	42	<0.05

pH in water Method: ME-AN-016

pH in water at 25°C	-	1	8.4	5.4
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Dissolved Hg on waters by ICP-MS Method: ME-AN-026

Mercury	µg/l	0.001	<0.001	<0.001
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METHOD SUMMARY

METHOD

METHOD SUMMARY

ME-AN-016	The pH of an aliquot of aqueous sample is measured electrometrically using an electrode connected to a calibrated meter with automated temperature correction. This method is based on APHA 4500-H B.
ME-AN-001	An aliquot of aqueous sample is titrated first to pH 8.3 and then to 4.3 using standardised acid. The volumes of acid titrated are used to calculate total alkalinity and/or alkaline species. The method is based on EPA 310.2 and APHA 2320 B.
ME-AN-011	Total dissolved solids (TDS) is determined gravimetrically on a filtered aliquot of aqueous sample by evaporating the sample to dryness in a pre-weighed container at 105 deg C. The method is based on APHA 2540 C.
ME-AN-014	Inorganic anions (Br, Cl, F, NO3, NO2, SO4) are determined on aqueous samples by ion chromatography. The method is based on EPA 300.1 and APHA 4110 B.
ME-AN-026	Dissolved Hg on waters by ICP-MS
ME-AN-007	The conductivity of an aliquot of aqueous sample is measured electrometrically using a standard cell connected to a calibrated meter with automated temperature correction. This method is based on APHA 2510.
Calculation of Anion-Cation	Calculation of the cation/anion balance
ME-AN-027	Dissolved metals are determined on a filtered and acidified (to 1% HNO3) portion of aqueous sample by inductively coupled plasma optical emission spectrometry (ICP-OES). The method is based on EPA 200.7 and APHA 3120.

FOOTNOTES

IS	Insufficient sample for analysis.	-	The sample was not analysed for this analyte
LNR	Sample listed, but not received.	*	Results marked "Not SANAS Accredited" in this report are not included in the SANAS Schedule of Accreditation for this laboratory / certification body / inspection body".
^	Performed by outside laboratory.		
LOR	Limit of Reporting		

Samples analysed as received.
Solid samples expressed on a dry weight basis.

Unless otherwise indicated, samples were received in containers fit for purpose.

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EARTH

PRELIMINARY REPORT

CLIENT DETAILS

Contact **Diana Duthe**
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Email **dduthe@knightpiesold.com**

Order Number **Twinhills**
Samples **2**
Sample matrix **WATER**

LABORATORY DETAILS

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Laboratory Manager **Mrs Tasneem Tagari**
Lab Reference **JBX24-18440**
Report Number **0000078348**
Date Received **10/04/2024 15:14**
Date Started **11/04/2024 10:56**
Date Reported **22/04/2024 08:45**

This is an interim report. Final QC checks are yet to be completed.

Samples received at ambient temp good condition.

SIGNATORIES

Sarah Newton

Technical Specialist/Technical Signatory

PRELIMINARY REPORT

Sample Number
Sample Name

JBX24-18440.001 Column 4 (CW) 6mm - W6	JBX24-18440.002 Blank - W6
--	-------------------------------

Parameter Units LOR

Alkalinity on waters by titration Method: ME-AN-001

Total Alkalinity as CaCO ₃	mg/l	12	50	<12
Methyl Orange (M) Alkalinity as CaCO ₃	mg/l	12	50	<12
Phenolphthalein (P) Alkalinity as CaCO ₃	mg/l	12	<12	<12

Conductivity on waters Method: ME-AN-007

Conductivity in mS/m @ 25°C	mS/m	2	22	<2.0
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Total Dissolved Solids (TDS) in water at 105 deg Method: ME-AN-011

TDS (0.7µm) @ 105°C	mg/l	21	150	<20
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ICP-OES Metals on waters (Dissolved) Method: ME-AN-027

Aluminium	mg/l	0.02	<0.02	<0.02
Antimony	mg/l	0.003	<0.003	<0.003
Arsenic	mg/l	0.003	<0.003	<0.003
Barium	mg/l	0.002	0.005	<0.002
Beryllium	mg/l	0.0001	<0.0001	<0.0001
Bismuth *	mg/l	0.03	<0.03	<0.03
Boron	mg/l	0.005	0.013	<0.005
Cadmium	mg/l	0.001	<0.001	<0.001

PRELIMINARY REPORT

Sample Number
Sample Name

JBX24-18440.001 Column 4 (CW) 6mm - W6	JBX24-18440.002 Blank - W6
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Parameter

Units

LOR

ICP-OES Metals on waters (Dissolved) Method: ME-AN-027 (continued)

Calcium	mg/l	0.5	13	<0.5
Chromium	mg/l	0.002	<0.002	<0.002
Cobalt	mg/l	0.005	<0.005	<0.005
Copper	mg/l	0.02	<0.02	<0.02
Iron	mg/l	0.05	<0.05	<0.05
Lead	mg/l	0.003	<0.003	<0.003
Lithium *	mg/l	0.005	0.021	<0.005
Magnesium	mg/l	0.01	15	<0.01
Manganese	mg/l	0.01	<0.01	<0.01
Molybdenum	mg/l	0.005	<0.005	<0.005
Nickel	mg/l	0.005	<0.005	<0.005
Phosphorus	mg/l	0.03	<0.03	<0.03
Potassium	mg/l	0.2	4.6	<0.2
Selenium	mg/l	0.01	<0.01	<0.01
Sodium	mg/l	0.5	2.4	<0.5
Strontium	mg/l	0.001	0.078	<0.001
Sulphur	mg/l	0.07	14	<0.07
Tellurium *	mg/l	0.17	<0.17	<0.17
Thallium *	mg/l	0.01	<0.01	<0.01
Thorium *	mg/l	0.04	<0.04	<0.04
Tin	mg/l	0.01	<0.01	<0.01
Titanium	mg/l	0.005	<0.005	<0.005
Uranium *	mg/l	0.003	<0.003	<0.003
Vanadium	mg/l	0.001	0.062	<0.001
Zinc	mg/l	0.01	<0.01	<0.01

Anions on Waters by Ion Chromatography Method: ME-AN-014

PRELIMINARY REPORT

Sample Number	JBX24-18440.001	JBX24-18440.002
Sample Name	Column 4 (CW) 6mm - W6	Blank - W6

Parameter Units LOR

Anions on Waters by Ion Chromatography Method: ME-AN-014 (continued)

Chloride	mg/l	0.05	0.08	<0.05
Fluoride	mg/l	0.05	0.68	<0.05
Nitrate	mg/l	0.1	0.1	<0.1
Sulphate	mg/l	0.05	42	<0.05

pH in water Method: ME-AN-016

pH in water at 25°C	-	1	8.2	5.7
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METHOD SUMMARY

METHOD

METHOD SUMMARY

ME-AN-027	Dissolved metals are determined on a filtered and acidified (to 1% HNO ₃) portion of aqueous sample by inductively coupled plasma optical emission spectrometry (ICP-OES). The method is based on EPA 200.7 and APHA 3120.
ME-AN-007	The conductivity of an aliquot of aqueous sample is measured electrometrically using a standard cell connected to a calibrated meter with automated temperature correction. This method is based on APHA 2510.
ME-AN-014	Inorganic anions (Br, Cl, F, NO ₃ , NO ₂ , SO ₄) are determined on aqueous samples by ion chromatography. The method is based on EPA 300.1 and APHA 4110 B.
Calculation of Anion-Cation	Calculation of the cation/anion balance
ME-AN-011	Total dissolved solids (TDS) is determined gravimetrically on a filtered aliquot of aqueous sample by evaporating the sample to dryness in a pre-weighed container at 105 deg C. The method is based on APHA 2540 C.
ME-AN-016	The pH of an aliquot of aqueous sample is measured electrometrically using an electrode connected to a calibrated meter with automated temperature correction. This method is based on APHA 4500-H B.
ME-AN-026	Dissolved Hg on waters by ICP-MS
ME-AN-001	An aliquot of aqueous sample is titrated first to pH 8.3 and then to 4.3 using standardised acid. The volumes of acid titrated are used to calculate total alkalinity and/or alkaline species. The method is based on EPA 310.2 and APHA 2320 B.

FOOTNOTES

IS	Insufficient sample for analysis.	-	The sample was not analysed for this analyte
LNR	Sample listed, but not received.	*	Results marked "Not SANAS Accredited" in this report are not included in the SANAS Schedule of Accreditation for this laboratory / certification body / inspection body".
^	Performed by outside laboratory.		
LOR	Limit of Reporting		

Samples analysed as received.
Solid samples expressed on a dry weight basis.

Unless otherwise indicated, samples were received in containers fit for purpose.

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