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Pan African Resources PLC (PAR) Environmental Application Process`

Geochemistry and Waste Classification Assessment

Prepared for:
Pan African Resources PLC

Project Number:
PAR7273

July 2022

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EXECUTIVE SUMMARY

Digby Wells Environmental (hereafter Digby Wells) has been appointed to undertake an Environmental Application Process and associated specialist studies for the Mogale Cluster - Mining Right (GP) 30/5/1/2/2 (206) Mining Right (MR) and, more specifically for the proposed construction of a large-scale gold tailings retreatment operation. Pan African Resources PLC (PAR) has entered into a Sale and Purchase Agreement for the acquisition of the shares in and claims against Mogale Gold (Pty) Ltd (Mogale Gold). The agreement was entered into between PAR and the liquidators of Mintails Mining SA (Pty) Ltd (in liquidation) (MMSA). MMSA is the holding company of Mogale Gold. The intended transaction is subject to a due diligence investigation which is in the process of being concluded.

The project entails the reclamation of historical unlined Tailings Storage Facilities (TSFs). The reprocessed tailings will be first discarded into West Wit Pit and possibly other nearby small pits. Any extra processed tailings will be stored on a ground TSF. The new TSF will also be unlined.

This report constitutes the **Environmental Geochemistry Assessment** to describe the high degree of baseline environmental conditions and assess the potential geochemical impacts of the Project.

Three seepage water samples were collected from the existing Tailings Storage Facilities, South Sand, 1L23-1L25 and 1L13. One reprocessed tailings was obtained from the metallurgical test work of a tailings sample from 1L13 1L15 TSF.

Waterlab (Pty) Ltd, a South African National Accreditation System laboratory analysed the samples. The analytical suite included the following:

- Sample preparation – crushing, grinding, and compositing of the tailings;
- Mineralogical analysis – X-ray diffraction (XRD) analysis to -determine the mineral constituents of the samples;
- Acid digestion (aqua regia) followed by semi-quantitative 29 elements Inductively Coupled Plasma (ICP) scan;
- Deionised (DI) leachate test with a 4:1 liquid:solid ration
- Synthetic Precipitation Leaching Procedure (SPLP) leach testing 20:1 liquid: solid ratio;
- Acid-Base Accounting (ABA) tests including sulphur speciation (total sulphur, sulphate sulphur, and sulphide sulphur); and
- NAG test – where an oxidising agent (hydrogen peroxide) is used to assess whether a sample can neutralise the potential acidity on complete oxidation of sulphide.

Table 1-1 presents a summary of the geochemical characteristics of the reprocessed tailings.

No acid-forming minerals were detected in the reprocessed tailings. The tailings are currently neutral in pH but classified as uncertain/inconclusive under ABA and NAG tests in the long term. The leachate from the reprocessed tailings is not acidic but neutral to alkaline.

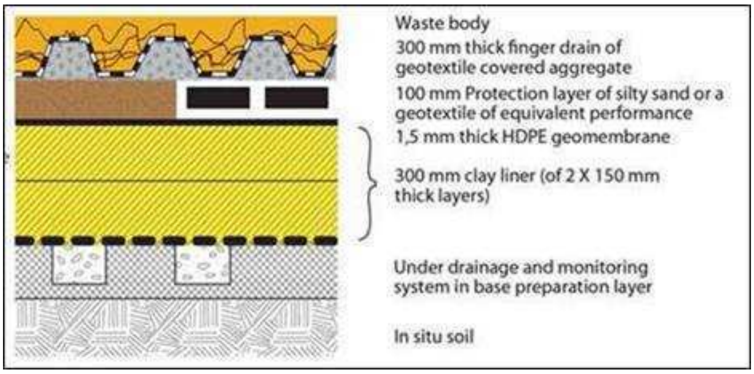
Although the reprocessed tailings classify as Type 3 waste requiring deposition in a liner consistent with a Class C liner requirements, Digby Wells notes that the barrier systems are not necessarily the default barrier systems if Pan African Resources can demonstrate that the risks associated with the reprocessed tailings can be adequately managed without the default barrier systems. An alternative barrier with the same or lower performance criteria as a Class C liner may also be considered. While the regulation makes provision for a risk-based approach, there is no guidance provided by the legislation as to what information the authorities require in a risk-based approach.

Motivation for an alternative liner may be made on the following basis:

- The leachate from the reprocessed tailings are not acidic but neutral to alkaline. No acid-forming minerals were detected in the reprocessed tailings.
- The metals/metalloids are relatively immobile under the neutral conditions of the reprocessed tailings and are not mobilised into the leach solution with all their LC below the LCT0 limit except sulphate and arsenic which marginally exceed the LCT0 limits but can be managed.
- All the metals/metalloids in the leachate from the reprocessed tailings will be within the IFC limits except manganese (0.62-0.76 mg/L) which marginally exceeded the IFC limit (0.5 mg/L) but can be managed.
- The leachate from the reprocessed tailings will be substantially better than the current seepage from the existing TSFs. The seepage quality will change from acidic (pH 2.4-2.8) to neutral (pH 7.5-7.6) resulting in a significant reduction in total dissolved solids. The total dissolved solids in the seepage will change from 4166-14094 mg/L in the current seepage to 1554-1893 mg/L in the reprocessed tailings.

Overall, reprocessing the existing tailings is supported as a measure to remove the existing TSFs that are acidic and contaminant sources at the site. The reprocessed tailings will be neutral with a low risk of leaching metal/metalloids. The seepage from the reprocessed tailings will be substantially better than the current seepage water.

Table 1-1: Geochemical Characteristics of Reprocessed Tailings

<table>
<tr><th>Material</th><th colspan="2">Tailings (n=2)</th></tr>
<tr><td rowspan="10">Geochemical Characteristics</td><td>Current pH</td><td>Neutral paste pH (pH of 7.62 - 7.67)</td></tr>
<tr><td rowspan="2">Future pH</td><td>Non acidic (pH of 4.50 - 4.53) (> 4.5) - neutral</td></tr>
<tr><td>The two samples were classified as uncertain under the ABA and NAG tests.</td></tr>
<tr><td rowspan="3">Mineralogy</td><td>• No acid-forming minerals</td></tr>
<tr><td>• No fast-dissolving carbonates acid neutralising minerals detected</td></tr>
<tr><td>• Aluminosilicates – pyrophyllite, chlorite, biotite, muscovite, smectite, kaolinite, and orthoclase.</td></tr>
<tr><td rowspan="2">Supernatant Water Quality</td><td>Alkaline pH (pH of 9.0)</td></tr>
<tr><td>Potential constituents of concern - conductivity, arsenic, copper, cadmium, iron, manganese, mercury, nickel and zinc</td></tr>
<tr><td rowspan="2">Leachate quality</td><td>Neutral leachate pH (average pH 7.50 - 7.60)</td></tr>
<tr><td>Potential constituents of concern – electrical conductivity, arsenic and manganese.</td></tr>
<tr><td colspan="2">Waste Classification</td><td>Reprocessed tailings from 1L13-1L15 TSF are classified as Type 3 waste and require a Class C liner as depicted below.

</td></tr>
<tr><td>Geochemical Risks</td><td colspan="2">Seepage and runoff from the tailings containing arsenic, copper, fluoride, iron, manganese, mercury and zinc may be of risk to surface and groundwater quality.</td></tr>
<tr><td rowspan="2">Management (Operations to closure and aftercare)</td><td colspan="2">The reprocessed tailings are classified as Type 3 waste and would potentially require a Class C liner underneath the new TSF, with further engagement to be undertaken with DWS with respect to the liner requirements.</td></tr>
<tr><td colspan="2">Reprocessing the existing tailings is supported as a measure to remove the existing TSFs that are acidic and contaminant sources at the site. The reprocessed tailings will be neutral with a low risk of leaching metal/metalloids.</td></tr>
</table>

Material	Tailings (n=2)
	The reprocessing of the tailings should be handled expeditiously to minimise exposure to oxidation, weathering and leaching during reclamation and processing.
	Clean surface water should be diverted away from the operation using runoff control diversions.
	Dirty water from percolation and runoff from the reprocessing operations and the new reprocessed tailings TSF should be collected in toe paddocks and channelled to the return water dam for management (recycled for use in the plant, dust suppression, treatment before discharge, and establishing vegetation).
	The reprocessing operations would require monitoring the quality of toe seepage collecting in toe paddocks, return water dam, surface water, and groundwater for potential constituents of concern including pH, electrical conductivity, copper, cadmium, manganese, nickel and zinc.

Based on the above understanding, Digby Wells recommends the following:

- Further characterisation of the reprocessed tailings by kinetic tests is required to determine the long-term ARD/ML potential of the tailings;
- The existing tailings should be handled expeditiously to minimise exposure to oxidation, weathering and leaching during reclamation and reprocessing that may exacerbate the formation of acidic mine drainage and metal leaching;
- Clean surface water should be diverted away from the operation using runoff control diversions; and
- The reprocessing operations would require monitoring the quality of water for potential constituents of concern including pH, electrical conductivity, arsenic, cadmium, copper, total cyanide, iron, manganese, nickel, lead, selenium and zinc.

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LIST OF ABBREVIATION

Abbreviation	Description
ABA	Acid-Base Accounting
AMD	Acid Mine Drainage
AP	Acid Potential
ARD	Acid Rock Drainage
ASLP	Australian Standard Leaching Procedure
CMA	Catchment Management Agency
DEA	Department of Environmental Affairs
DFFE	Department of Forestry, Fisheries and Environment
DFS	Definitive Feasibility Study
DI	Deionised
DWS	Department of Water and Sanitation
EC	Electrical Conductivity
EHSEBS	Environmental, Health, and Social-Economic Baseline Studies
GAI	Geochemical Abundance Index
GIIP	Good International Industry Practice
GN	Government Notice
ICP	Inductively Coupled Plasma
LC	Leachable Concentration
LCT	Leachable Concentrations Threshold
mg/kg	milligram per kilogram
mg/L	milligram per litre
NEM: WAA	National Environmental Management: Waste Amendment Act, 2014
µS/cm	microSimens/centimeter
ML	Metal Leaching
MCLM	Mogale City Local Municipality
Mt	Megatonne
NAF	Non-Acid Forming
NAG	Nett Acid Generation
NNP	Nett Neutralising Potential
NP	Neutralising Potential
NPR	Neutralising Potential Ratio
PAF	Potential Acid Forming

Abbreviation	Description
PAR	Pan African Resources PLC
PAF	Potentially Acid Forming
NEM: WAA	National Environmental Management: Waste Amendment Act 26 of 2014
SANAS	South Africa National Accreditation System
SPLP	Synthetic Precipitation Leaching Procedure
s.u	Standard Unit
TC	Total Concentration
TCT	Total Concentrations Threshold
TDS	Total Dissolved Solids
TSF	Tailings Storage Facility
USEPA	US Environmental Protection Agency
WHO	World Health Organization
WMA	Water Management Area
WRDM	West Rand District Municipality
WUL	Water Use License
wt.%)	wt.%)
XRD	X-Ray Diffraction

1. Introduction

Digby Wells Environmental (hereafter Digby Wells) has been appointed to undertake an Environmental Application Process and associated specialist studies for the Mogale Cluster - Mining Right (GP) 30/5/1/2/2 (206) Mining Right (MR) and, more specifically for the proposed construction of a large-scale gold tailings retreatment operation. Pan African Resources PLC (PAR) has entered into a Sale and Purchase Agreement for the acquisition of the shares in and claims against Mogale Gold (Pty) Ltd (Mogale Gold). The agreement was entered into between PAR and the liquidators of Mintails Mining SA (Pty) Ltd (in liquidation) (MMSA). MMSA is the holding company of Mogale Gold. The intended transaction is subject to a due diligence investigation which is in the process of being concluded.

The project entails the reclamation of historical unlined Tailings Storage Facilities (TSFs). The reprocessed tailings will be first discarded into West Wit Pit and possibly other nearby small pits. Any extra processed tailings will be stored on a ground TSF. The new TSF will also be unlined.

The project consists of 120 Mt of tailings to be reprocessed and deposited, firstly within the West Wits Pit and then on the reclaimed footprint of 1L23-1L25. Six dumps are being considered to be reprocessed, the largest of which amounts to 57.9 Mt, while the smallest contains 0.57 Mt. The primary location of processed tailings storage has been earmarked for deposition in the 1L4-1L6. This report constitutes the **Environmental Geochemistry Assessment** to describe the high degree of baseline environmental conditions and assess the potential geochemical impacts of the Project.

1.2. Project Location

The Mining Right Area of the Mintails Mogale Cluster includes GI, G2 plant; Cams North Sand; South Sand; 1L23; 1L28; 1L13; 1L8; 1LI0; West Wits Pit and Lancaster Dam. An existing Water Use License (WUL) No. 27/2/2/C423/1/1 was issued on 22 November 2013 to Mintails Mining SA (Pty) Ltd: Mogale Gold. The mining right is located on Portions 66 and 99 of the farm Waterval 174 IQ and portions 136 and 209 of the farm Luipaardsvlei 246 IQ.

The project is within the Mogale City Local Municipality (MCLM), which is located within the West Rand District Municipality (WRDM). MCLM is the regional services authority and the area falls under the jurisdiction of the Krugersdorp Magisterial District.

The site is located in the catchment of the Upper Wonderfonteinspruit, quaternary catchment C23D, which forms part of the Vaal River Water Management Area (WMA) within the Vaal Catchment Management Agency (CMA). The project is about 4 km south of Krugersdorp and northeast of Randfontein, approximately 10 km off the N14 National Road in the Gauteng Province, in an area that has been transformed by past gold mining activities.

The regional setting and location of the site are illustrated in Figure 1-1 and Figure 1-2.

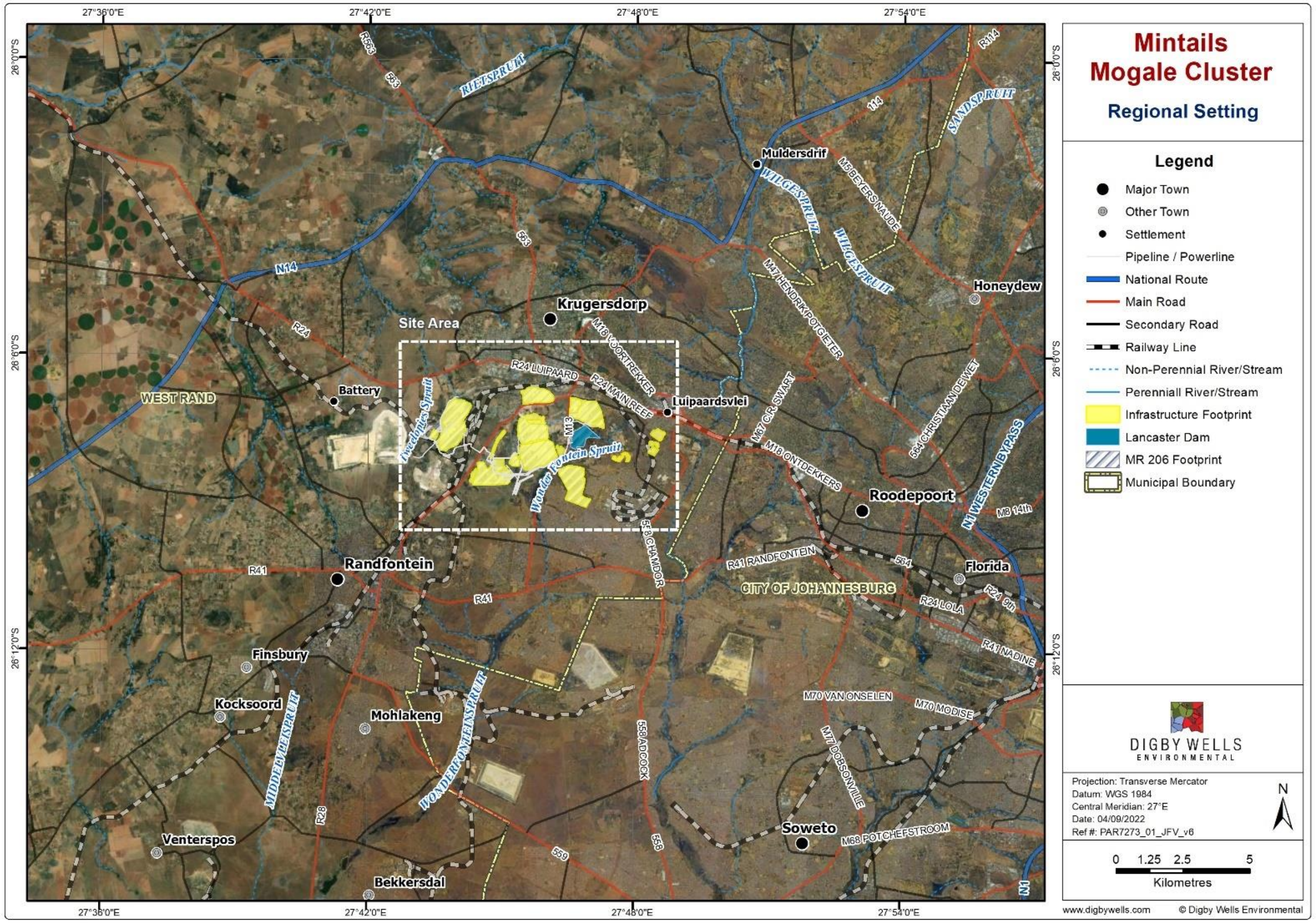


Figure 1-1: Regional Setting Location

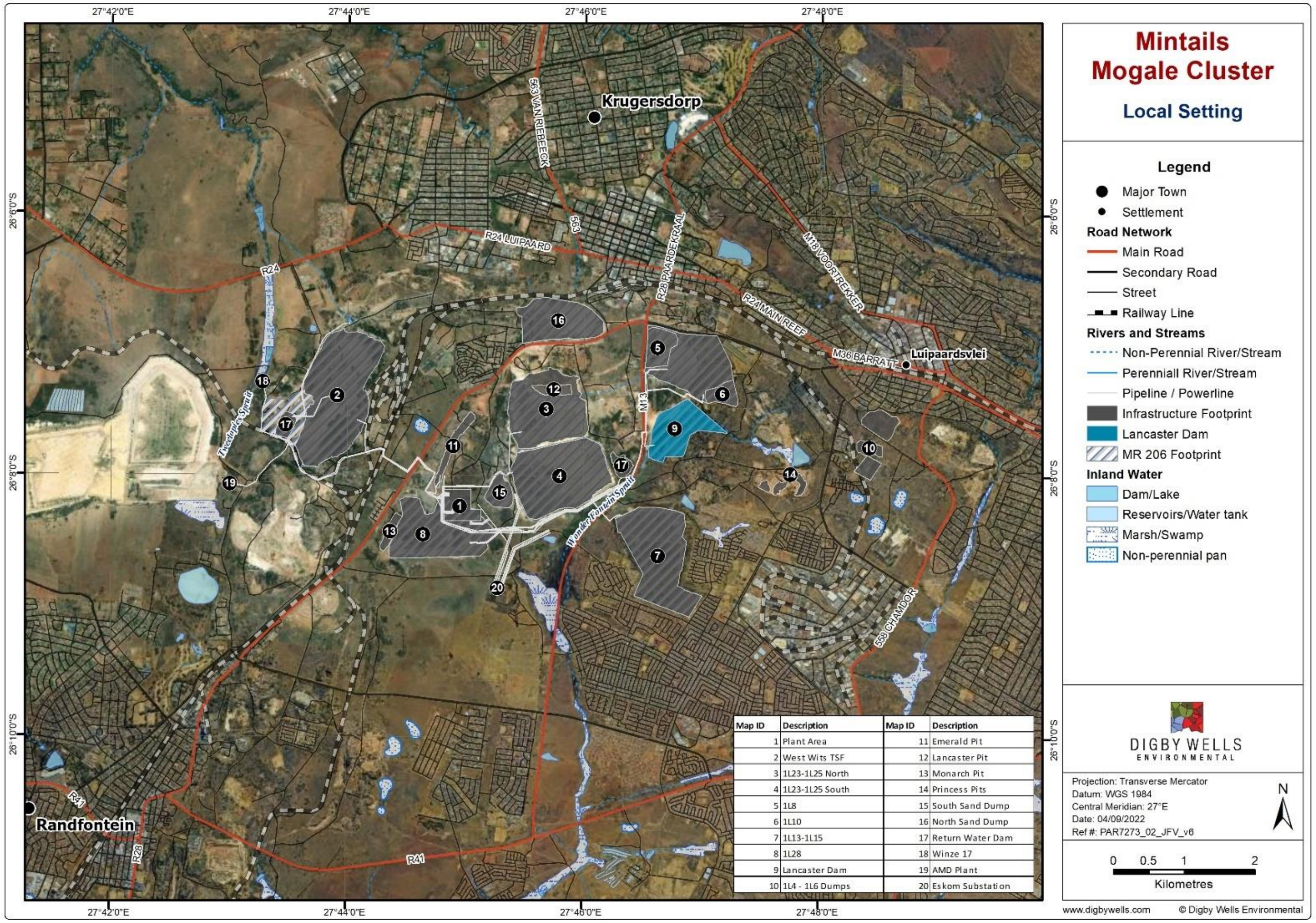


Figure 1-2: Local Setting

1.3. Geology

1.3.1. Regional Geology

The regional geology comprises of four main supergroups, namely: Witwatersrand, Ventersdorp, Transvaal and Karoo. The characteristics of these geological groups are discussed, in their chronological order (oldest first), in the subsections below. The regional geology of the area is indicated in Figure 1-4.

1.3.1.1. Witwatersrand Supergroup

The Witwatersrand Basin is a thick sequence of shale, quartzite and conglomerate. The average dip of the strata varies between 10º and 30° south, although localised dips of up to 80° have been encountered in mine workings closer to the reef outcrop. There are two main divisions, a lower predominantly argillaceous unit, known as the West Rand Group and an upper unit, composed almost entirely of quartzite and conglomerates, known as the Central Rand Group. The West Rand Group is divided into three subgroups namely the Hospital Hill, Government Reef and Jeppestown. These rocks comprise mainly shale, but quartzite, banded ironstones, tillite and intercalated lava flows are also present. The rocks were subjected to low-grade metamorphism causing the shale to become more indurated and slatey, and the original sandstone was re-crystallised to form quartzite.

1.3.1.2. Ventersdorp Supergroup

The younger Ventersdorp Supergroup overlies the Witwatersrand rocks. Although acid lavas and sedimentary intercalations occur, the Ventersdorp is composed largely of andesitic lavas and related pyroclastics. The Ventersdorp Supergroup consists of the Platberg Group and the Klipriviersberg Group.

The Alberton Formation is composed of green – grey amygdaloidal andesitic lavas, agglomerates and tuffs with a total thickness of 1 500 m. The lack of sediments in this sequence indicates a rapid succession of lava flows, which probably came from fissure eruptions. Material of similar composition forms the oldest dykes that have intruded the Witwatersrand rocks. The abundant agglomerates provide indications of periodic explosive activity. The removal of huge volumes of volcanic material from an underlying magma chamber gave rise to tensional conditions and as a result a number of faulted structures, such as, horst and grabens formed.

1.3.1.3. Transvaal Supergroup

Overlying the Ventersdorp Lavas are the Black Reef Quartzite and dolomites of the Transvaal Supergroup. The Black Reef quartzite comprises coarse to gritty quartzite with occasional economically exploitable conglomerates (reefs). The entire area was peneplane in post-Ventersdorp time and it was on this surface that the Transvaal Supergroup was deposited, some 2 200 million years ago. The deposition commenced with the Kromdraai Member with the Black Reef at its base. The Black Reef is formed from material that has been eroded from the Witwatersrand outcrop areas. As a result, the Black Reef contains zones (reefs) in which gold is present. The occurrence of the gold is not as widespread as in the Witwatersrand and is mainly restricted to north-south trending channels. The Black Reef is overlain by a dark, siliceous quartzite with occasional grits or small pebble bands. The quartzite grades into black carbonaceous shale. The shale then grades into the overlying dolomite through a transition zone approximately 10 m thick.

Overlying the Kromdraai Member is the dolomite of the Malmani Subgroup of the Chuniespoort Group. The dolomites that are 1,500 m thick are known for their huge water storage potential.

The dolomite also contains lenses and layers of chert. The dense, hard and fine-grained chert tends to stand out in relief. Chert (silica) replaces carbonate material.

The dolomites are overlain in the south by the Pretoria Group rocks. The Rooihoogte Formation forms the basal member of the Pretoria Group, consisting predominantly of shale and quartzite.

1.3.1.4. Karoo Supergroup

The Karoo Supergroup was deposited approximately 345 million years ago. It commenced with a glacial period during which most of South Africa was covered by a thick sheet of ice. This ice cap slowly moved towards the south, causing extensive erosion of the underlying rocks. The erosion debris was eventually deposited and formed the Dwyka tillite. The latter is only partially preserved in the study area, as are the younger sedimentary deposits the Karoo Supergroup, including mudstone, shale and sandstone.

1.3.2. Local Geology

The Project area lies along the Witwatersrand on the Witwatersrand Supergroup Formations. The area is, however, highly faulted, folded and eroded, leading to complex and varied geology and rock formations. However, being a surface dump mining operation, the geology has little influence or impact on the project.

The project is situated within the Archaean-aged (i.e., approximately 2970 million years) Witwatersrand Basin - the world's largest natural repository of gold mineralisation, i.e. more than 1,600 million gold ounces have been exploited since 1886. The reefs mined to depths exceeding 3 km are generally considered ancient river placers. These reefs are frequently less than a metre thick and characterised by abundant pyrite, which may comprise up to 5% of the reef, as well as flyspeck and/or seam carbon/kerogen. These three components display a strong spatial correlation with the gold mineralisation, which is rarely visible, in the 10–20-micron range.

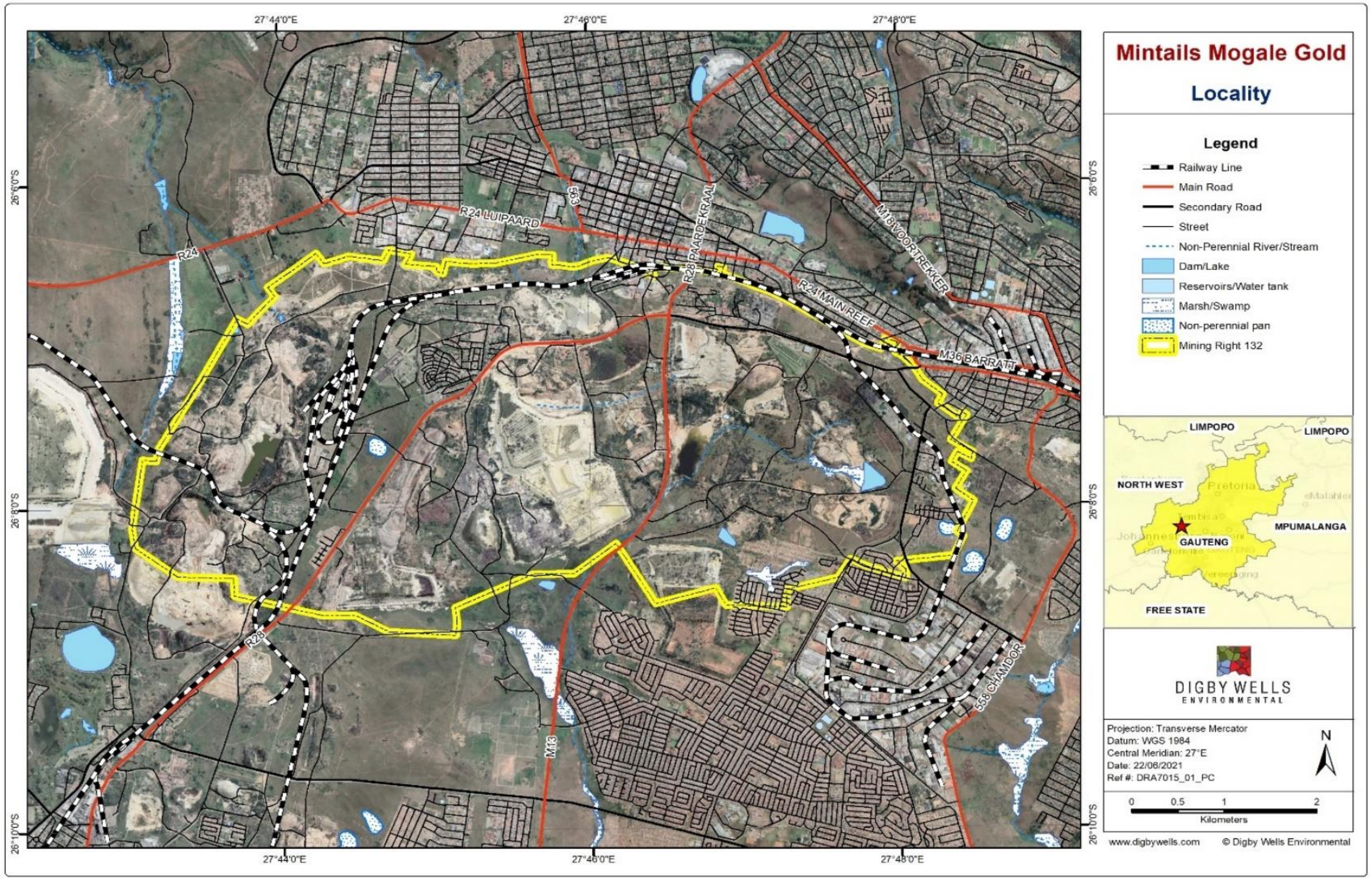


Figure 1-3: Locality Map

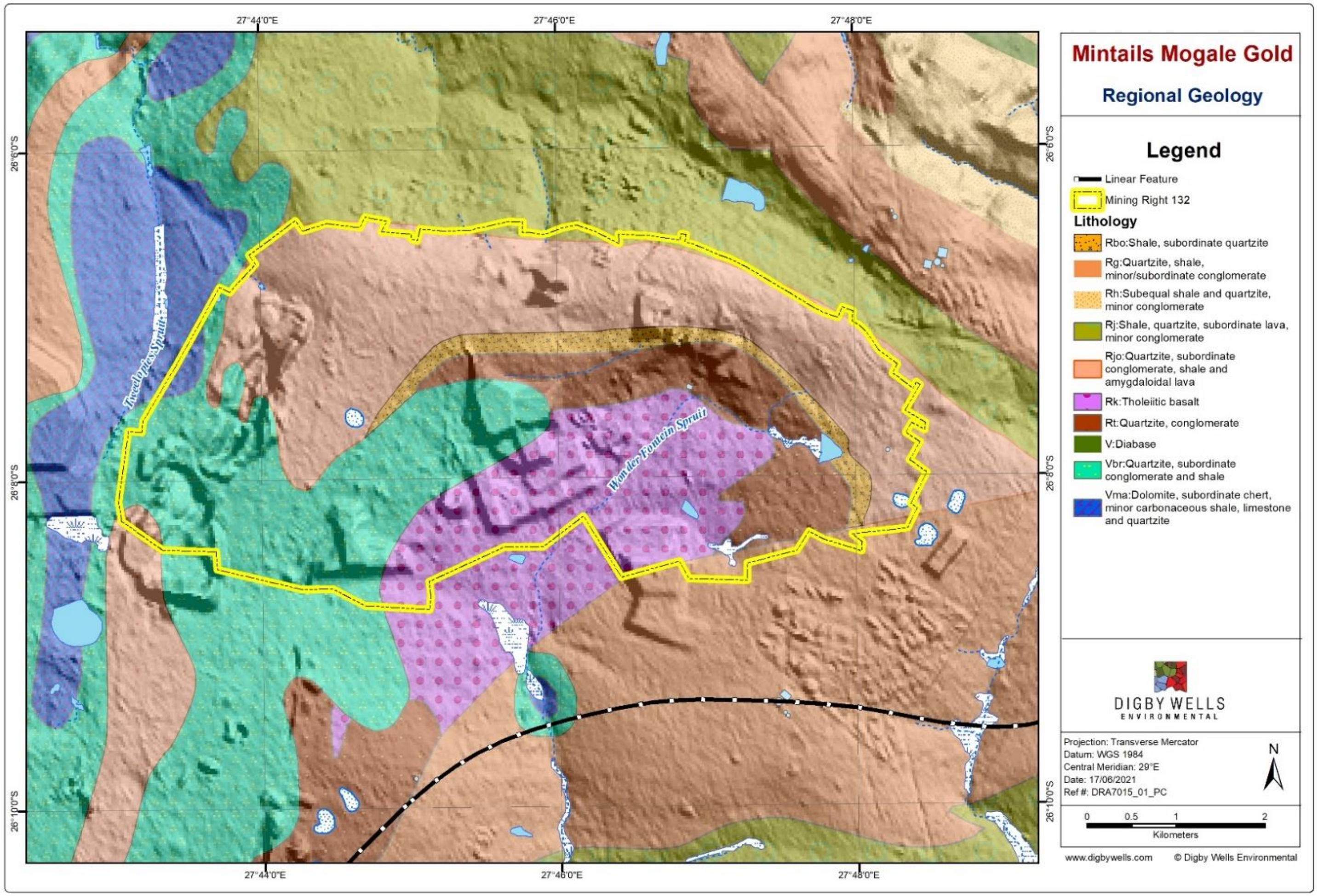


Figure 1-4 Regional Geology

2. Pre-feasibility Study Results

Digby Wells conducted an Environmental and Social Pre-Feasibility Study (PFS) and associated specialist studies for the Mintails Mogale Cluster for Pan African Resources in 2021. The purpose of the study was to describe the current state of the tailings material, identify the potential geochemical impacts, and recommend mitigation and management measures for the project.

The study analysed 32 tailing samples across seven TSFs and a Manganese Slag sample. The geochemical analysis included the following:

- Sample preparation – grinding, and compositing of the tailings;
- Mineralogical analysis – X-ray diffraction (XRD) analysis to determine the mineral constituents of the samples;
- Total metal analysis – acid digestion (aqua regia) followed by semi-quantitative 29 elements Inductively Coupled Plasma (ICP) scan;
- Deionised water leaching test at 1:4 solid to liquid ratio;
- Australian Standard Leach Procedure (ASLP) including Borax and deionised water leaching test at 1:20 solid to liquid ratios;
- Acid-Base Accounting (ABA) tests including sulphur speciation (total sulphur, sulphate sulphur, and sulphide sulphur); and
- Net Acid Generation (NAG) test – where an oxidising agent (hydrogen peroxide) is used to assess whether a sample can neutralise the potential acidity on complete oxidation of sulphides.

Table 2-1 presents a summary of the results of the study. The full report is presented in Appendix A.

Table 2-1: Summary of the results of the pre-feasibility study

Material		Tailings (n=32)	Manganese Slag (n=2)
Geochemical Characteristics	Current pH	Acidic to slightly alkaline (paste pH 2.4-7.8)	Acidic (Paste pH 4.9-5,0)
	Future pH	97% Potentially Acid Forming (PAF) and 3% Inconclusive	100% PAF
		NAG-pH is acidic (pH 4.5 - 6.5)	NAG-pH is 6.4-6.5
	Mineralogy	Acid Forming - pyrite (0.2 -1.2 wt.%)	Gypsum (48-64%), magnetite (34-36%), and chlorite (18%)
		• Acid Neutralising: ○ Carbonates - calcite (0.1 - 3.9 wt.%);	

Material		Tailings (n=32)	Manganese Slag (n=2)
		• Aluminosilicates - chlorite, muscovite, pyrophyllite and kaolinite	
	Leachate quality	Acidic to alkaline (pH 3.9 - 12)	Acidic (Paste pH 4.6)
		Potential constituents of concern - pH, electrical conductivity, calcium, iron, mercury, lead, sulphate, and zinc	Potential constituents of concern - pH, electrical conductivity, boron, calcium, manganese, and sulphate
Geochemical Risks		Acidic seepage and runoff from the tailings and manganese slag containing boron, calcium, iron, manganese, mercury, lead, sulphate, and zinc pose a risk to surface and groundwater quality. Other parameters of concern are pH, electrical conductivity, and TDS.	
Management measures for the proposed reprocessing and the new TSF (Operations to closure)		• Reprocessing the tailings is supported as a measure to remove the existing ARD/ML TSFs and manganese slag as potential contaminant source footprints at the site; • The tailings and manganese slag should be handled expeditiously to minimise exposure to oxidation, weathering and leaching during reclamation and processing; Clean surface water should be diverted away from the operation using runoff control diversions; • Dirty water from percolation and runoff from the TSFs and manganese slag should be collected in toe paddocks and channelled to the return water dam for management (recycled for use in the plant, dust suppression, treatment before discharge, and establishing vegetation); • The reprocessing operations would require monitoring the quality of toe seepage collecting in toe paddocks, return water dam, surface water, and groundwater for potential constituents of concern including pH, electrical conductivity, total dissolved solids, boron, calcium, iron, manganese, mercury, lead, sulphate, and zinc; and • The results imply that a liner consistent with design requirements for the disposal of Type 3 waste at a minimum would theoretically be required to be placed underneath the new TSF for the reprocessed tailings.	

The geochemical risk was identified as acidic to neutral (pH 2.6-7.7) seepage and runoff containing boron, calcium, iron, manganese, mercury, lead, sulphate, and zinc from the tailings and manganese slag that may impact the quality of the surface and groundwater depending on site conditions if not managed appropriately.

Digby wells recommended the following measures to manage the tailings and manganese slag during operations to closure:

- Reprocessing the tailings is supported as a measure to remove the existing ARD/ML TSFs and manganese slag as potential contaminant source footprints at the site;
- The tailings and manganese slag should be handled expeditiously to minimise exposure to oxidation, weathering and leaching during reclamation and processing;

- Clean surface water should be diverted away from the operation using runoff control diversions;
- Dirty water from percolation and runoff from the TSFs and manganese slag should be collected in toe paddocks and channelled to the return water dam for management (recycled for use in the plant, dust suppression, treatment before discharge, and establishing vegetation);
- The reprocessing operations would require monitoring the quality of toe seepage collecting in toe paddocks, return water dam, surface water, and groundwater for potential constituents of concern to include pH, electrical conductivity, total dissolved solids, boron, calcium, iron, manganese, mercury, lead, sulphate, and zinc; and
- The results imply that a liner consistent with design requirements for the disposal of Type 3 waste at a minimum would theoretically be required to be placed underneath the new TSF for the reprocessed tailings. However, this requirement was being evaluated and discussed further with the respective authorities to determine the liner requirements as the site proposed for the tailings facility is a footprint that was previously disturbed.

The tailings characterised in the PFS were from the existing TSFs before reprocessing and therefore represented the baseline geochemistry before reprocessing of the tailings project. The reprocessed tailings samples were not available for characterisation at the time of the PFS and are now presented in this report.

3. Assumptions, Limitations and Exclusions

The following limitations are noted:

- There is a total of six TSFs that will be reclaimed and for this study, only one TSF was analysed and assumed to be representative of all the TSFs;
- Tailings materials in this study are from the reprocessing of the existing tailings, it is assumed that the same reprocessing method will be applied to reprocess all the other TSFs; and
- Two samples were analysed and assumed to be representative of the tailings in the 1L13-1L15 TSF.

4. Reporting Standards

4.2. Elemental Enrichment

One measure of enrichment of elements in samples is the Geochemical Abundance Index (GAI). The GAI compares the actual concentration of an element in a sample with the median abundance for that element in the most relevant media (such as crustal abundance, soils, or a rock type). The main purpose of the GAI is to indicate any elemental enrichments that may be of environmental importance.

The GAI for an element is calculated as follows:

Equation 1: $$\mathrm{GAI} = \mathrm{Log2}\ [\mathrm{Cn}\ /\ (1.5 \times \mathrm{Bn})$$

Where Cn is the concentration of the element in the sample and Bn is the median or average content for that element in the reference material (mean world soil, crustal abundance, etc.).

GAI values are truncated to integer increments (0 through to 6, respectively), where a GAI of 0 indicates the element is present at a concentration equal to, or less than, median abundance, and a GAI of 6 indicates approximately a 100-fold, or greater, enrichment above-median abundance. The actual enrichment ranges for the GAI values are as follows:

- GAI=0 represents <3 times median abundance,
- GAI=1 represents 3 to 6 times median abundance,
- GAI=2 represents 6 to 12 times median abundance,
- GAI=3 represents 12 to 24 times median abundance,
- GAI=4 represents 24 to 48 times median abundance,
- GAI=5 represents 48 to 96 times median abundance, and
- GAI=6 represents more than 96 times the median abundance.

As a general guide, a GAI of 3 or above is considered significant and such enrichment may warrant further examination (INAP, 2009).

4.3. Acid-Base Accounting and Net Acid Generation

In the absence of Senegalese guidelines, Digby Wells assessment adopted the following ARD/ML assessment guidelines that have gained regulatory acceptance in various jurisdictions around the world:

- Guidelines and Recommended Methods for the Prediction of Metal Leaching and Acid Rock Drainage at Mine Sites in British Columbia (Price & Errington, 1995);
- Prediction Manual for Drainage Chemistry from Sulfidic Geologic Materials (MEND, 2009); and
- Global Acid Rock Drainage Guide (GARD) (INAP, 2009).

The international guidelines emphasise that there is no minimum concentration of sulphide responsible for generating acidity. The MEND, 2009 guideline was used. The guideline bases the assessment of ARD/ML on Neutralisation Potential Ratio (NPR) and Net Neutralisation Potential (NNP) criteria as detailed below:

- NPR < 1: Potentially Acid Forming (PAF), unless sulphide minerals are non-reactive;
- 1 < NPR < 2: Possibly acid-generating if Neutralisation Potential (NP) is insufficiently reactive or is depleted at a rate faster than sulphide;

- NPR > 2: Non-Acid Forming (NAF) unless significant preferential exposure of sulphide along fractures planes or extremely reactive sulphide in combination with insufficiently reactive NP;
- NNP less than -20 kg $CaCO_3$/tonne is PAF; and
- A sample is PAF if the NAG pH is <4.5 and NAF if pH is >4.5.

4.4. Metal leaching potential

The guidelines used in the study are the following:

4.4.1. National Environmental Management Act

Digby Wells assessed the tailings against the South African National N&S for the Assessment of Waste for Landfill Disposal (Government Notice R635 of 23 August 2014) and the National N&S for Disposal of Waste to Landfill (GN R636 of 23 August 2014) to determine the type of waste and the barrier/liner requirements

4.4.1.1. Waste Act 2014

On 2 June 2014, the National Environmental Management: Waste Amendment Act, 2014 (Act No. 26 of 2014) (NEM: WAA) was published, which for the first time included "residue deposits" and "residue stockpiles" under the environmental waste legislation (previously mining residue was covered under the Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002). Mine wastes are listed under Schedule 3, under the category "Hazardous Waste", therefore the understanding is that mine wastes are hazardous unless the applicant can prove that the waste is non-hazardous.

As residue deposits and residue stockpiles are considered to be waste, they are regulated by the following regulations, both promulgated on 23 August 2013 under NEM: WAA:

- Norms and Standards for the Assessment of Waste for Landfill Disposal (GN R635 of 23 August 2013), and
- National Norms and Standards for Disposal of Waste to Landfill (GN R636 of 23 August 2013).

According to these regulations, waste that is generated must be classified following SANS 10234 "Globally Harmonised System" within 180 days of generation. Waste that has already been generated, but not previously classified must be classified within 18 months of the date of commencement of the regulations. The Norms and Standards (N&S) specify the waste classification methodologies for determining the waste category, and the specifications for pollution control barrier systems (liners) for each of the waste categories.

The Department of Forestry, Fisheries and Environment (DFFE) has further published the Regulations Regarding the Planning and Management of Residue Stockpiles and Residue Deposits (GN R632 of 24 July 2015, as amended) and in terms of waste classification, these regulations state that residue stockpiles and residue deposits must be characterised to identify any potential risk to health or safety and environmental impact in terms of physical characteristics, chemical characteristics (i.e. toxicity, propensity to oxidise and decompose, propensity to undergo spontaneous combustion, pH and chemical composition of the water separated from the solids, stability, and reactivity and the rate thereof, neutralising potential and concentration of volatile organic compounds), and mineral content.

4.4.1.2. Waste Type

Digby Wells followed the approach outlined below and presented in Figure 4-1, as per the South African regulations.

- The chemical substances present in the tailings were identified,
- Sampling and analysis were undertaken to determine the Total Concentration (TC) and Leachable Concentration (LC) of the elements and chemical substances identified in the tailings and that are specified in Section 6 of the N&S,
- All analyses of the TC and LC of the elements and the chemical substances in the tailings were conducted by a South Africa National Accreditation System (SANAS) accredited laboratory,
- The TC and LC of the elements and the chemical substances in the tailings were compared to threshold limits specified in Section 6 of the N&S, and
- Based on the comparison with the threshold limits, the specific type of waste was determined according to Section 7 of the N&S.

Total Concentration Threshold (TCT) limits are subdivided into three categories as indicated in Table 4-1 and are summarised as follows:

- TCT0 limits are based on screening values for the protection of water resources, as contained in the Framework for the Management of Contaminated Land (DEA, March 2010),
- TCT1 limits derived from land remediation values for commercial/industrial land (DEA, March 2010), and
- TCT2 limits were derived by multiplying the TCT1 values by a factor of 4, as used by the Environmental Protection Agency, Australian State of Victoria.

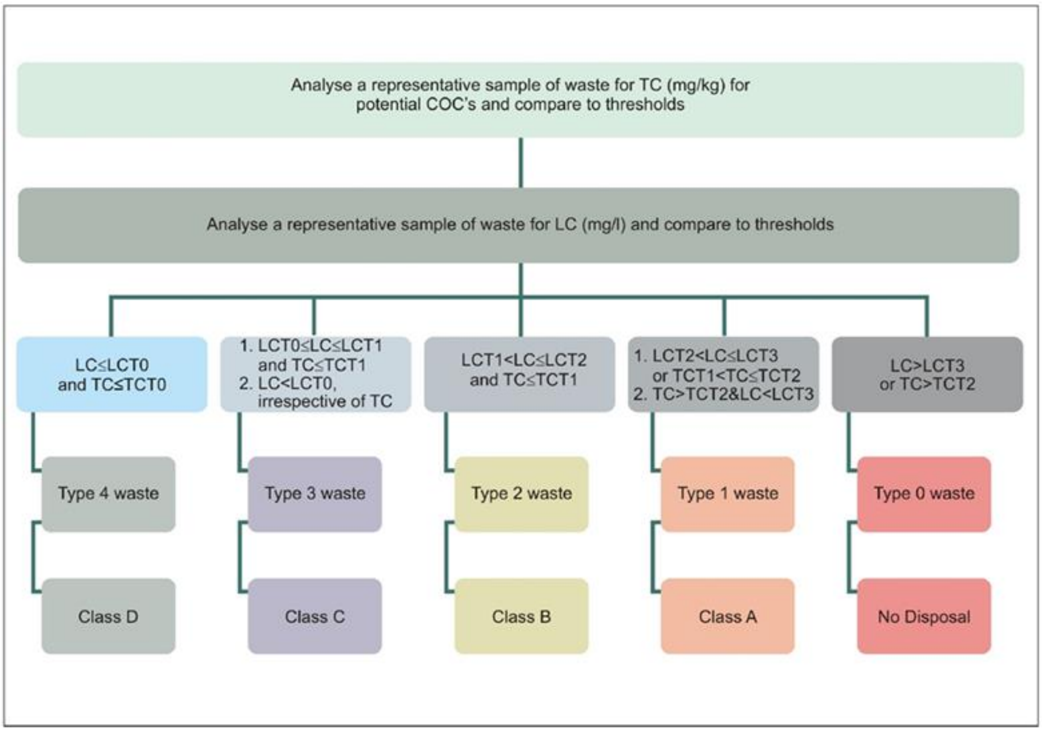


Figure 4-1: Flow Diagram For Waste Assessment (GN R635 of 23 August 2013)

Leachable concentration was determined by following the Australian Standard Leaching Procedure for Wastes, Sediments, and Contaminated Soils (AS 4439.3-1997), as specified in the N&S (2013). The procedure recommends the use of Deionised (DI) Water to detect the metals that are present on the surface exterior. The procedure can also be done under the Borax leaching procedure which consists of two types of pH 9 for co-disposal. Leachate of 1:20 solids per reagent water was advised for the NEM: WA guidelines, but for this study, a 1:20 and 1:4 tailings and water ratio was prepared and analysed by Waterlab Laboratory same as indicated in the NEMWA guidelines.

Leachable Concentration Threshold (LCT) limits are subdivided into four categories as follows:

- LCT0 limits derived from human health effect values for drinking water, as published by the Department of Water and Sanitation (DWS), SANAS, World Health Organization (WHO) or the United States Environmental Protection Agency (USEPA),
- LCT1 limits are derived by multiplying LCT0 values by a Dilution Attenuation Factor (DAF) of 50, as proposed by the Australian State of Victoria,
- LCT2 limits are derived by multiplying LCT1 values by a factor of 2, and LCT3 limits are derived by multiplying the LCT2 values by a factor of 4.

Table 4-1: Summary of guidelines used in the study

Parameter	Unit	TCT0	TCT1	TCT2	Unit	LCT0	LCT1	LCT2	LCT3
Al, Aluminium	mg/kg				mg/L				
As, Arsenic	mg/kg	5.8	500	2000	mg/L	0.01	0.5	1	4
B, Boron	mg/kg	150	15000	60000	mg/L	0.5	25	50	200
Ba, Barium	mg/kg	62.5	6250	25000	mg/L	0.7	35	70	280
Ca, Calcium	mg/kg				mg/L				
Cd, Cadmium	mg/kg	7.5	260	1040	mg/L	0.003	0.15	0.3	1.2
Co, Cobalt	mg/kg	50	5000	20000	mg/L	0.5	25	50	200
Cr total	mg/kg	46000	800000	N/A	mg/L	0.1	5	10	40
Cr (IV), Chromium (IV)	mg/kg	6.5	500	2000	mg/L	0.05	2.5	5	20
Cu, Copper	mg/kg	16	19500	78000	mg/L	2	100	200	800
Fe, Iron	mg/kg				mg/L				
Hg, Mercury	mg/kg	0.93	160	640	mg/L	0.006	0.3	0.6	2.4
Mg, Magnesium	mg/kg				mg/L				
Mn, Manganese	mg/kg	1000	25000	100000	mg/L	0.5	25	50	200
Mo, Molybdenum	mg/kg	40	1000	4000	mg/L	0.07	3.5	7	28
Na, Sodium	mg/kg				mg/L				
Ni, Nickel	mg/kg	91	10600	42400	mg/L	0.07	3.5	7	28
Pb, Lead	mg/kg	20	1900	7600	mg/L	0.01	0.5	1	4
Sb, Antimony	mg/kg	10	75	300	mg/L	0.02	1	2	8
Se, Selenium	mg/kg	10	50	200	mg/L	0.01	0.5	1	4
U, Uranium	mg/kg				mg/L				
V, Vanadium	mg/kg	150	2680	10720	mg/L	0.2	10	20	80
Zn, Zinc	mg/kg	240	160000	640000	mg/L	5	250	500	2000
Chloride as Cl	mg/kg	n/a	n/a	n/a	mg/L	300	15000	30000	120000
Sulphate as SO_4	mg/kg	n/a	n/a	n/a	mg/L	250	12500	25000	100000
Nitrate as N	mg/kg	n/a	n/a	n/a	mg/L	11	550	1100	4400
F, Fluoride	mg/kg	100	10000	40000	mg/L	1.5	75	150	600
CN total, Cyanide total	mg/kg	14	10500	42000	mg/L	0.07	3.5	7	28

Waste is classified by comparison of the total and leachable concentration of elements and chemical substances in the waste material to TCT and LCT limits as specified in the N&S for Waste Classification and the N&S for Disposal to Landfill.

4.4.2. Water Quality Guidelines

The leachate water quality has been assessed against the following guidelines:

- The International Finance Corporation (IFC, 2007) Environmental Health and Safety effluent guidelines for site runoff and treated effluents to surface water for general use; and
- The 2013 South African General Discharge Limits for discharging wastewater into a water source.

4.4.2.1. International Finance Corporation Effluent Guidelines

Table 4-2 presents the 2007 IFC Environment Health and Safety effluent guideline values for the mining sector. The guidelines are indicative of Good International Industry Practice (GIIP) and are considered achievable under normal operating conditions in appropriately designed and operated facilities through the application of pollution prevention and control techniques. The effluent guidelines are applicable for site runoff and treated effluents to surface waters for general use.

4.4.2.2. South African General Discharge Limits

The General/Special limits (General Authorisation, GN665 of September 2013) and standard (GN 991 of May 1984 as amended by GN 1930 of August 1984 and GN 1864 of November 1996) for discharge of wastewater into a water source are also used to assess the water quality in this report (Table 4-2). The General/Special Limits have been adopted because the available WUL was obtained in 2013 and is therefore invalid. There is no background groundwater to be used. The hydrocensus study groundwater appears to be contaminated by mining activities.

Table 4-2: Water Quality Guidelines

Parameter	General Limit (2013)	IFC Discharge Limits (2007)
Faecal Coliforms (per 100 ml)	1000	
Chemical Oxygen Demand (mg/l)	75	
pH (s.u)	5.5-9.5	6.0-9.0
Ammonia (ionized and unionized) as Nitrogen (mg/l)	6.0	
Nitrate/Nitrite as Nitrogen (mg/l)	15.00	
Chlorine as Free Chlorine (mg/l)	0.25	
Suspended Solids (mg/l)	25.00	
Electrical Conductivity (mS/m)	70 mS/m above intake to a maximum of 150 mS/m	
Sodium (mg/l)	Ns	

Parameter	General Limit (2013)	IFC Discharge Limits (2007)
Orthophosphate as phosphorus (mg/l)	10.00	
Fluoride (mg/l)	1.00	
Soap, oil, or grease (mg/l)	2.50	
Dissolved Arsenic (mg/l)	0.02	0.10
Dissolved Cadmium (mg/l)	0.005	0.05
Dissolved Chromium		0.10
Dissolved Chromium (VI) (mg/l)	0.05	
Dissolved Copper (mg/l)	0.01	0.30
Dissolved Cyanide (mg/l)	0.02	
Dissolved Iron (mg/l)	0.30	2.00
Dissolved Lead (mg/l)	0.01	
Dissolved Manganese (mg/l)	0.10	0.50
Dissolved Mercury and its compounds (mg/l)	0.005	
Dissolved Nickel (mg/L)		0.50
Dissolved Selenium (mg/l)	0.02	
Dissolved Zinc (mg/l)	0.10	0.50
Boron (mg/l)	1.00	

5. Geochemical Test Work

This section describes the sampling and laboratory analysis used for the study.

5.2. Sampling

Digby Wells collected three seepage water samples from the exixting tailings, South Sand, 1L23-1L25 and 1L13-1L15, on the 4th of October 2021.

Reprocessed tailings from metallurgical test work undertaken on a sample of 1L13 1L15 TSF were delivered to Digby Wells on the 24th of March 2022 for laboratory test work. The reprocessed tailings were generated in the laboratory by Maelgwyn South Africa. It is assumed that the same metallurgical process will be used during operations for all the other TSFs.

Table 5-1: Sampling Details

Sample ID	Sample Type	Collected From
Seepage Water from Existing TSFs		
South Sand	Seepage Water	Field
1L23-1L25	Seepage Water	Field
1L13-1L15	Seepage Water	Field
Reprocessed Tailings		
1L13-1L15-1	Tailings	Metallurgical Test Work
1L13-1L15-2	Tailings	Metallurgical Test Work
1L13-1L15-1	Supernatant Water	Metallurgical Test Work

5.3. Laboratory Analysis

Waterlab (Pty) Ltd, a SANAS laboratory, analysed the samples. The analytical suite included the following:

- Sample preparation – crushing, grinding, and compositing of the tailing;
- Mineralogical analysis – X-ray diffraction (XRD) analysis to -determine the mineral constituents of the samples;
- Acid digestion (aqua regia) followed by semi-quantitative 29 elements Inductively Coupled Plasma (ICP) scan;
- Deionised (DI) leachate test with a 4:1 liquid:solid ration;
- Synthetic Precipitation Leaching Procedure (SPLP) leach testing 20:1 liquid: solid ratio;
- Acid-Base Accounting (ABA) tests including sulphur speciation (total sulphur, sulphate sulphur, and sulphide sulphur); and
- NAG test – where an oxidising agent (hydrogen peroxide) is used to assess whether a sample can neutralise the potential acidity on complete oxidation of sulphide.

6. Geochemical characteristics

This section discusses the geochemical characteristics of the tailings. The laboratory certificates of analysis are presented in Appendix A.

6.2. Processed Tailings

6.2.1. Mineralogy

The mineral composition indicates the long-term geochemical behaviour of the material. The purpose of the analysis was to identify the mineral phases present in the tailing that could be a source of acidity, neutralisation capacity, or metals.

The laboratory prepared the samples for XRD analysis using a zero-background holder. The diffractograms were generated using a Malvern PANalytical Aeris diffractometer. The instrument used a PIXcel detector with variable divergence and receiving slits with Fe-filtered Co-Kα radiation (λ = 1.789À). X'Pert Highscore Plus software was used to identify the mineral phases. The Rietveld method (Autoquan Program) was used to estimate the relative phase amounts in percentage weight, normalising them to 100%.

Digby Wells evaluated the mineralogical analysis results on the following basis:

- Occurrence - relative quantities described as predominant to trace (normalised to 100%);
- Weathering rates – dissolving, fast weathering to inert; and
- The presence and quantities of acid-forming/neutralising minerals

Table 6-1 presents a summary of the mineralogy results.. The mineralogy of the reprocessed tailing is as follows:

- No acid-forming minerals have been detected;
- No fast-dissolving acid neutralising minerals were detected; and
- Aluminosilicates occur in the tailing and include pyrophyllite (7.79%), chlorite (1.42%) and biotite (0.44%). The weathering rates of these minerals are intermediate and can react with acid and consume acidity to contribute to the overall NP of the tailings.

In summary, no acid-forming and fast acid neutralising minerals were detected in the reprocessed tailing samples. The aluminosilicates detected have an intermediate weathering rate and include pyrophyllite, chlorite and biotite. The aluminosilicates will contribute to the overall netralisation potential (NP) of the tailings in the long term.

Table 6-1: Mineralogy of the 1L13-1L15 TSF the reprocessed tailings

		Mineral (%)	Molecular Formula	1L13-1L15-1	1L13-1L15-2
				157163	157164
Acid neutralising minerals	Intermediate Weathering Rate	Pyrophyllite	$Al(Si2O_5)(OH)$	10.05	5.53
		Chlorite	$(Mg,Fe)_5Al(AlSi_3O_{10})(OH)_8$	1.35	1.49
		Biotite	$K(Mg,Fe)_3 ((OH)_2 AlSi_3 O_{10})$	0.29	0.59
Secondary Mineral		Gypsum	$Ca(SO_4)(H_2O)_2$	0.56	0.43
Resistant/Inert		Quartz	SiO_2	87.8	92.0
Total				**100**	**100**

Predominant	>50%	
Abundant	20-50%	
Less abundant	10-20%	
Minor	3-10%	
Trace	<3%	

6.2.2. Acid Rock Drainage Potential

Acid-base accounting (ABA) testing was used to assess the acid generating and neutralising potential of the tailings. The ABA is a series of compositional analyses and calculations that include the following:

- The measurement of paste pH;
- Determination of sulphur species;
- Calculation of the Sulphide Acid Potential (SAP) from sulphide;
- Determination of NP;
- Calculation of Neutralisation Potential Ratio (NPR = NP/AP);
- Calculation of Nett Neutralisation Potential (NNP = NP AP); and
- Determination of NAG pH. The NAG pH indicates the resultant pH on the complete oxidation of sulphides in the tailing using hydrogen peroxide.

Digby Wells followed the Prediction Manual for Drainage Chemistry from sulfidic geological materials criteria (MEND, 2009) in assessing the ARD potential of the tailings. The generation of acidic drainage requires AP to exceed NP. Acidic drainage will only result when the rate of acid generation exceeds that of acid neutralisation.

Assuming accurate AP and NP measurement, future drainage pH is:

- PAF if NP/AP < 1;
- Not Acid Forming (NAF) if NP/AP > 2;

- Uncertain if NP/AP is between 1 and 2; and
- PAF if NNP is less than -20 kg $CaCO_3$/tonne.
- A NAG pH < 4.5 indicates acid generation, and a NAG pH > 4.5 indicates NAF.

Table 6-2 presents a summary of the ABA and sulphur speciation results for the tailings samples. The acid-generating and neutralising characteristics of the tailings are as follows:

- The paste pH is neutral (pH 7.62-7.67);
- Sulphur species are the primary source of acid, acidity, and potentially deleterious elemental species in the drainage from the tailings. Total sulphur in the reprocessed tailings ranges from 0.67-0.79% and occurs predominantly (68%) as sulphides (0.4-0.6%);
- The sulphide acid potential (SAP) ranges from 12-19 kg $CaCO_3$/t;and
- Consistent with the mineralogy, the tailings classify as uncertain/inconclusive (neither PAF nor NAF) based on ABA and NAG tests. The samples require kinetic tests to determine their long-term ARD/ML potential.

In summary, the tailings are neutral (paste pH 7.62-7.67), with 68% of the total sulphur detected occurring as sulphide-sulphur (0.4-0.6%). The tailings samples are classified as Uncertain/Inconclusive (neither PAF nor NAF). The samples require kinetic tests to determine their long-term ARD/ML potential.

Table 6-2: Acid-base accounting and sulphur speciation for the 1L13-1L15 TSF reprocessed tailings

	Units	1L13-1L15-1	1L13-1L15-2
Paste pH	s.u	7.62	7.67
Total sulphur as S	%	0.67	0.79
Sulphide as S (Pyritic sulphur)	%	0.40	0.60
Sulphate as SO_4	%	0.27	0.19
Sulphide Acid potential (SAP)	kg $CaCO_3$/t	12.39	18.74
Total Acid potential (TAP)	kg $CaCO_3$/t	20.8	24.6
Neutralisation potential (NP)	kg $CaCO_3$/t	2.0	0.8
NP:AP ratio (SNPR)	No unit	0.16	0.04
NP:AP ratio (TNPR)	No unit	0.10	0.03
Net neutralising potential (SNNP)	kg $CaCO_3$/t	-10.4	-18.0
Net neutralising potential (TNNP)	kg $CaCO_3$/t	-18.8	-23.9

	Units	1L13-1L15-1	1L13-1L15-2
NAG	kg H_2SO_4/t	7.64	10.19
NAG pH (pH 4.5)	s.u.	2.70	2.69
NAG	kg H_2SO_4/t	3.72	2.94
NAG pH (pH 7)	s.u.	4.53	4.50
Classification (paste pH/NPR)	**-**	**Uncertain**	**Uncertain**
Classification (NAG pH/NNP)		**Uncertain**	**Uncertain**

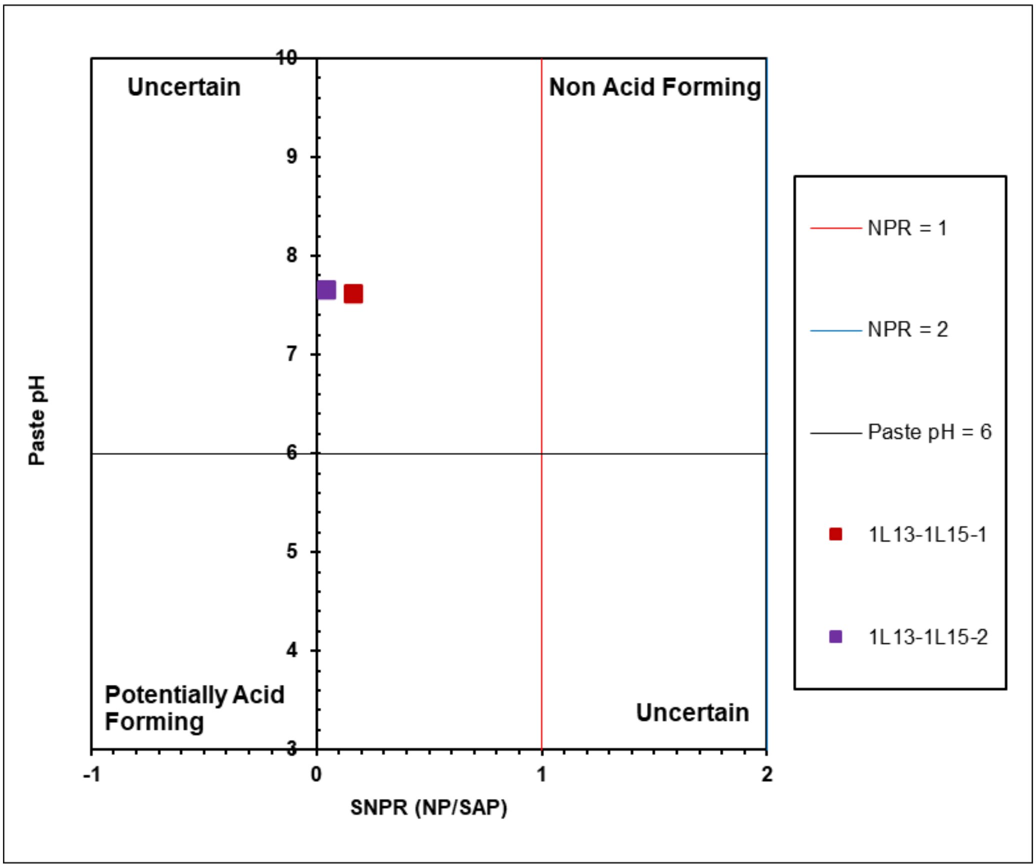


Figure 6-1: Paste pH versus SNPR for the reprocessed tailings from 1L13-1L15 TSF

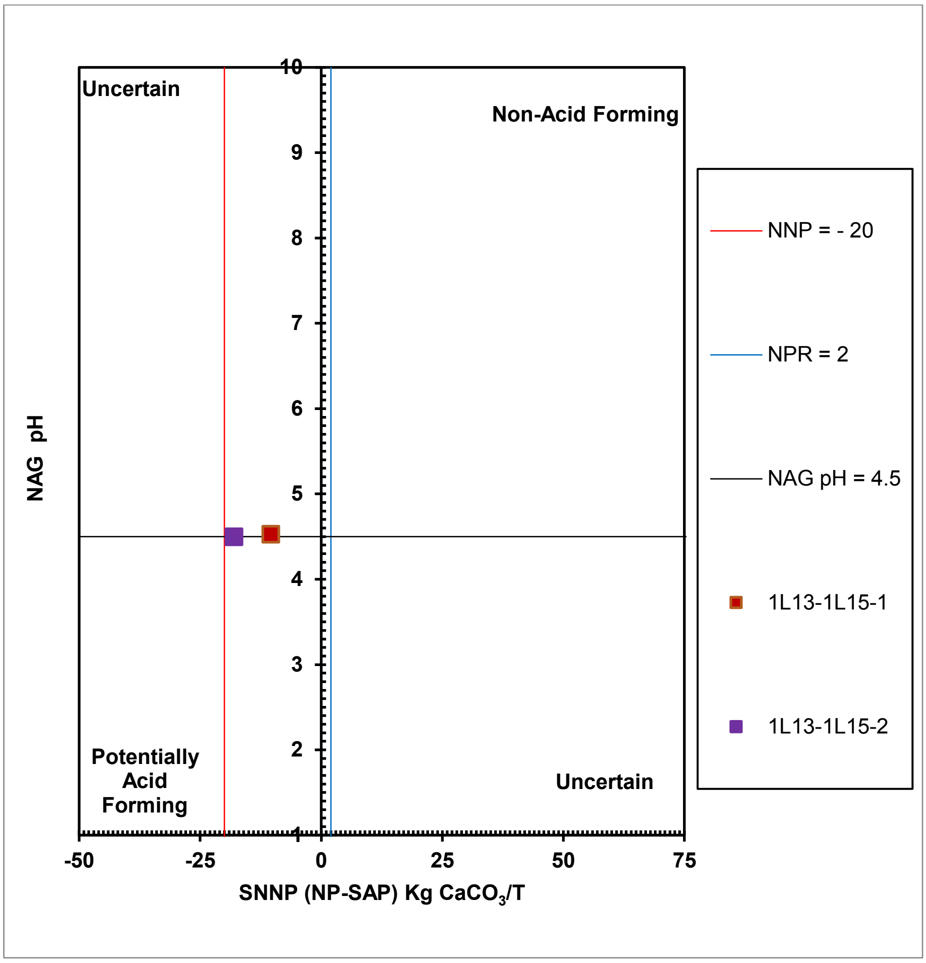


Figure 6-2: NAG pH versus SNNP for the reprocessed tailings from 1L13-1L15 TSF

6.2.3. Elemental Enrichment

The total metal analysis was undertaken to identify elements enriched in the materials that may be of environmental concern relative to the average elemental concentration for the unprocessed tailings..

Table 6-3 presents the elemental concentrations and GAI values for the reprocessed tailings. A GAI value of 0 indicates that the element is present at a concentration equal to or less than the crustal abundance. A GAI of six indicates approximately a 100-fold, or more, enrichment above average elemental concentration for the unprocessed tailings. As a general guide, a GAI of three or above is significant in triggering environmental concerns. All elements are below the GAI.

Table 6-3: Elemental concentrations and GAI values for the 1L13-1L15 TSF reprocessed tailings

Sample ID	IL13-L15-1	IL13-L15-2	Average Elemental Composition of Existing Tailings (Ore) n=6	IL13-L15-1	IL13-L15-2
Ag	<10	<10	**8.33**	-	-
Al	11600	12800	**7326**	0	0
As	111	107	**78.7**	0	0
Ba	34	39	**90.07**	0	0
Be	<10	<10	**8.33**	-	-
Bi	<10	<10	**8.33**	-	-
Cd	0.4	0.4	**0.33**	0	0
Co	29	29	**124**	0	0
Cr	390	446	**509**	0	0
Cu	30	27	**23.81**	0	0
Fe	15600	16400	**17649**	0	0
K	2405	2052	**1604**	0	0
Mg	800	1,200	**999**	0	0
Mn	631	598	**1333**	0	0
Mo	<10	<10	**8.33**	-	-
Ni	112	107	**90.07**	0	0
Pb	183	154	**149**	0	0
Sb	<0.400	<0.400	**0.33**	0	0
Se	<0.400	<0.400	**0.33**	0	0
Sr	<10	12	**20.03**	-	0
Ti	1296	1282	**1318**	0	0
U	40	40	**43.79**	0	0
V	<10	<10	**25.64**	-	-
Zn	168	118	**143**	0	0

The results indicate no enrichment of any of the elements in the reprocessed tailings relative to the average total elemental concentrations of the existing tailings (ore).

6.3. Existing Seepage versus Reprocessed Tailings Supernatant Water Quality

The seepage water collected from the toes of three TSFs (South Sand, 1L23-1L25 and 1L13) indicates the base case seepage quality at the site from the existing tailings.

The supernatant water indicates the potential seepage water quality after the reprocessing of tailings. Supernatant water is from metallurgical test work undertaken on a tailings sample from 1L13-1L15 TSF.

Table 6-4 presents the results of the assessment of the seepage and supernatant water quality against the Water Quality Guidelines. The results of the assessment are presented below.

6.3.1. Seepage Water

The assessment of the seepage water indicates the following:

- The seepage water is acidic, pH ranging between 2.4 and 2.8, and below the General Limits and the IFC guidelines;
- The electrical conductivity ranges between 435 mS/m and 960 mS/m with all samples being above the General Limits of 150 mS/m;
- Arsenic concentration exceeds the General Limits (0.02 mg/L) and IFC guidelines (0.1 mg/L) ranging from 0.013 mg/L to 0.79 mg/L;
- Copper, iron, manganese and zinc are all above the General and IFC guideline limits for all samples ranging between 0.36 – 25.00 mg/L, 44.00 – 931 mg/L, 26.00 – 258 mg/L and 3.52 – 18.00 mg/L respectively; and
- Nickel exceeds the IFC limits for all samples ranging between 2.6 – 27 mg/L;
- Lead exceeds the General Limits for South Sand (0.07 mg/L) and 1L23-1L25 (0.02 mg/L);
- Cadmium marginally (0.06 mg/L) exceeds the IFC limit for South Sand TSF at 0.6 mg/L; and
- Selenium exceeds the General Limits (0.02 mg/L) for South Sand TSF seepage water at 0.05 mg/L.

6.3.2. Supernatant Water

The assessment of the supernatant water indicates the following:

- The pH of supernatant water is alkaline (pH 9.0) and within the General Limits and IFC limit;
- The electrical conductivity is above the General Limit at 456 mS/m;
- Fluoride marginally (1.1 mg/l) exceeds the General Limits (1.0 mg/L); and

- Arsenic, cadmium, iron, and mercury are all above the General Limits at 0.06 mg/L, 0.03 mg/L, 0.61 mg/L, and 0.005 mg/L respectively;
- Copper, manganese, nickel and zinc are all above the IFC limit at 3.9 mg/L, 2.4 mg/L, 1.7 mg/L and 13 mg/L respectively; and
- Cyanide concentration is 134 mg/L, which is relatively high. However, this is not a concern because the metallurgical test work method used to generate the tailings included cyanide in the process at levels way higher than the levels that will be used in the actual reprocessing process.

In summary, the current seepage from the existing TSF is acidic (pH 2.4-2.8). The constituents of concern in the seepage include arsenic, cadmium, copper, electrical conductivity, iron, lead, manganese, nickel, selenium and zinc.

On the contrary, the reprocessed tailings will be alkaline (pH 9.0). The potential contaminants of concern that exceed the IFC limits are copper, manganese, nickel and zinc. Electrical conductivity, arsenic, iron and total cyanide also exceed the General Limits.

The assessment indicates that the supernatant water quality will be substantially better than the seepage from the current TSF. The supernatant water quality will be alkaline (pH 9.0) relative to the current acidic seepage (pH 2.4-2.8). The alkaline pH reduces the mobilisation of metals/metalloids from the reprocessed tailings resulting in a reduced total dissolved solids to 4116 mg/L from 4166-14094 mg/L.

Table 6-4: Summary of seepage and supernatant quality from the 1L13-1L15 TSF and reprocessed tailings

Analytes	Units	South Sand	1L23-1L25	1L13	IL13-L15-2	General Discharge Limits (2013)	IFC (2007)
		Seepage Water			Supernatant Water		
Physicochemical Parameters							
pH at 25ºC	s.u	2.4	2.8	2.5	9.0	5.5-9.5	6.0-9.0
Conductivity	mS/m	960	435	839	456	150	
TDS Measured	mg/L	14094	4166	11544	4116		
Acidity as $CaCO_3$	mg/L	6280	760	3480	<5.0		
Inorganic Anions							
Chloride	mg/L	24	37	227	174		
Sulfate	mg/L	8606	2475	5448	2267		
Fluoride	mg/L	0.40	0.30	0.30	1.1	1.0	
Nitrate as N	mg/L	<0.1	0.10	<0.1	<0.1	15	
Total Cyanide	mg/L	<0.07	<0.07	<0.07	134		
Free and Saline Ammonia	mg/L	5	41	58	8.3		
Sodium as Na	mg/L	382	67	335	476		
Potassium as K	mg/L	52	25	11.5	219		
Calcium as Ca	mg/L	474	512	475	554		
Magnesium as Mg	mg/L	455	164	625	44		
Metals and metalloids							

Analytes	Units	South Sand	1L23-1L25	1L13	IL13-L15-2	General Discharge Limits (2013)	IFC (2007)
		Seepage Water			Supernatant Water		
Aluminium as Al	mg/L	674	52	84	0.46		
Antimony as Sb	mg/L	<0.001	<0.001	<0.001	0.003		
Arsenic as As	mg/L	0.79	0.013	0.45	0.06	0.02	0.1
Barium as Ba	mg/L	0.067	0.066	0.052	<0.025		
Beryllium as Be	mg/L	<0.025	<0.025	<0.025	<0.025		
Bismuth as Bi	mg/L	<0.025	<0.025	<0.025	<0.025		
Boron as B	mg/L	<0.025	1.0	<0.025	0.11	1.0	
Cadmium as Cd	mg/L	0.06	0.005	0.003	0.033	0.005	0.05
Chromium as Cr	mg/L	5.6	1.0	1.0	<0.025		0.1
Chromium VI	mg/L	<0.010	0.059	<0.010	0.013	0.05	
Cobalt as Co	mg/L	13	2.3	1.3	3.5		
Copper as Cu	mg/L	25	0.36	0.82	3.9	0.01	0.3
Iron as Fe	mg/L	628	44	931	0.61	0.3	2.0
Lead as Pb	mg/L	0.07	0.02	0.009	<0.001	0.01	0.2
Manganese as Mn	mg/L	26	110	258	2.4	0.1	0.5
Mercury as Hg	mg/L	<0.001	<0.001	0.001	0.005	0.005	
Molybdenum as Mo	mg/L	<0.025	<0.025	<0.025	<0.025		2.0
Nickel as Ni	mg/L	27	3.1	2.6	1.7		0.5
Phosphorus as P	mg/L	3.39	1.4	2.64	0.08		
Selenium as Se	mg/L	0.047	0.004	0.003	0.012	0.02	
Silicon as Si	mg/L	132	48	66	4.0		
Silver as Ag	mg/L	<0.025	<0.025	<0.025	<0.025		
Strontium as Sr	mg/L	0.20	1.2	1.6	0.54		
Thallium as Tl	mg/L	<0.025	<0.025	<0.025	<0.025		
Thorium as Th	mg/L	1.5	0.023	0.18	0.001		
Tin as Sn	mg/L	<0.001	<0.001	<0.001	<0.001		
Titanium as Ti	mg/L	0.51	0.46	0.43	<0.025		
Uranium as U	mg/L	0.027	0.78	0.95	0.31		
Vanadium as V	mg/L	0.055	0.026	0.132	<0.025		
Zinc as Zn	mg/L	18	3.5	2.6	13	0.1	0.5

6.4. Leaching Potential

The mobility of the metals and salts from materials is typically assessed using the leach test for solid samples. The reprocessed tailings from 1L13-1L15 TSF were subjected to deionised (DI) leachate test at a 1:4 water-rock ratio. It is noted that laboratory leachate tests do not directly replicate metal release under field conditions and apply only as a guide.

To assess the metal leaching potential of the reprocessed tailings from 1L13-1L15 TSF, the leachate results were assessed against the General and IFC Limits. The results of the assessment are presented in Table 6-5.

Table 6-5: Summary of potential constituents of concern for 1L13-1L15 TSF

	Units	Reporting Limit	1L13-1L15-1	1L13-1L15-2	General Limit (2013)	IFC Guidelines
Physicochemical Parameters						
pH at 25ºC	s.u		7.5	7.6	5.5-9.5	6.0-9.0
Conductivity	mS/m		225	190	150	
TDS at 180ºC (measured)	mg/L	<5	1893	1554		
TDS Calculated	mg/L	<5	24	40		
Total Alkalinity as $CaCO_3$	mg/L	<5	6.0	4.0		
Inorganic Anions						
Chloride	mg/L	<2	6.0	4.0		
Fluoride	mg/L	<0.10	0.2	0.2	1	
Nitrate as N	mg/L	<0.10	0.1	0.1	15	
Sulfate	mg/L	<5	1282	1032		
Calcium as Ca	mg/L	<1	500	425		
Magnesium as Mg	mg/L	<1	36	32		
Sodium as Na	mg/L	<1	37	32		
Potassium as K	mg/L	<0.5	31	26		
Metals and metalloids						
Aluminium as Al	mg/L	<0.100	<0.100	<0.100		
Antimony as Sb	mg/L	<0.001	0.002	0.002		
Arsenic as As	mg/L	<0.001	0.03	0.03	0.02	0.1
Barium as Ba	mg/L	<0.025	<0.025	<0.025		
Beryllium as Be	mg/L	<0.025	<0.025	<0.025		
Bismuth as Bi	mg/L	<0.100	<0.025	<0.025		
Boron as B	mg/L	<0.025	0.08	0.07	1	
Cadmium as Cd	mg/L	<0.001	<0.001	<0.001	0.005	0.05
Chromium as Cr	mg/L	<0.025	<0.025	<0.025		0.1
Chromium VI	mg/L	<0.010	<0.010	<0.010	0.05	
Cobalt as Co	mg/L	<0.100	0.42	0.31		
Copper as Cu	mg/L	<0.010	<0.010	<0.010	0.01	0.3
Iron as Fe	mg/L	<0.025	0.29	0.25	0.3	2
Lead as Pb	mg/L	<0.001	<0.001	<0.001	0.01	0.2
Lithium as Li	mg/L	<0.025	<0.025	<0.025		
Manganese as Mn	mg/L	<0.025	0.76	0.62	0.1	0.5
Mercury as Hg	mg/L	<0.001	0.001	<0.001	0.005	
Molybdenum as Mo	mg/L	<0.025	<0.025	<0.025		2
Nickel as Ni	mg/L	<0.025	0.1	0.05		0.5
Phosphorus as P	mg/L	<0.025	<0.025	<0.025		
Selenium as Se	mg/L	<0.001	0.004	<0.001	0.02	
Silicon as Si	mg/L	<0.2	4.74	5.07		
Silver as Ag	mg/L	<0.025	<0.025	<0.025		
Thorium as Th	mg/L	<0.001	<0.001	<0.001		
Titanium as Ti	mg/L	<0.025	<0.025	<0.025		

	Units	Reporting Limit	1L13-1L15-1	1L13-1L15-2	General Limit (2013)	IFC Guidelines
Uranium as U	mg/L	<0.001	0.24	0.22		
Vanadium as V	mg/L	<0.025	<0.025	<0.025	0.1	
Zinc as Zn	mg/L	<0.025	<0.025	<0.025	0.1	0.5

The assessment evaluated the data quality of the leachate solutions by balancing the reported cation and anion concentrations. The ion imbalances (5.1 – 8.8%) for the DI leachate results were within the error margin of +/-10% taken to represent an acceptable level of analytical accuracy. The assessment of the reprocessed tailings leachate indicates the following:

- The leachate pH is neutral, 7.5 and 7.6, and within the General Limits and IFC limits;
- The electrical conductivity (190 - 225 mS/m) exceeds the General Limits of 150 mS/m; and
- Arsenic (0.03 mg/L) exceeds the General Limit (0.02 mg/L) but is within the IFC limits (1.0 mg/L); and
- Manganese (0.62-0.76 mg/l) exceeds the General Limit (0.1 mg/l) but marginally exceeds the the IFC limit (0.5 mg/L).

In summary, the assessment indicates that the leachate from the reprocessed tailings will be substantially better than the current seepage from the existing TSFs. The seepage quality will change from acidic (pH 2.4-2.8) to neutral (pH 7.5-7.6) resulting in a significant reduction in total dissolved solids from 4166-14094 mg/L in the current seepage to 1554-1893 mg/L in the reprocessed tailings leachate. The metals/metalloids will not be mobilised under the neutral pH of the reprocessed tailings. All the metals/metalloids will be within the IFC limits except manganese (0.62-0.76 mg/L) which marginally exceeded the IFC limit (0.5 mg/L).

6.5. Tailings Classification

The study assessed the liner requirements for the material against the Norms and Standards for the Assessment of Waste for Landfill Disposal, 2013 (GN R635 of 24 August 2013) and the Norms and Standards for Disposal of Waste to Landfill, 2013 (GN R636 of 24 August 2013).

The type of waste was determined by comparing the TC and LC of the elements and chemical substances in the waste with the TCT and LCT limits. Based on the TC and LC limits of the elements and chemical substances in the materials exceeding the corresponding TCT and LCT limits respectively, the waste type and the landfill disposal requirements were determined.

6.5.1. Total Concentration Threshold

Table 6-6 presents a summary of the assessment of total concentrations against the TCT. The constituents that exceed the threshold limits include the following:

- Arsenic (average 109 mg/kg);
- Copper (average 28.28 mg/kg);

- Nickel (average 109.58 mg/kg); and
- Lead (average 168.60 mg/kg).

Table 6-6: Total concentrations in mg/kg for the tailings material against the TCT

Elements	Units	Reporting Limits	1L13-1L15-1	1L13-1L15-2	Total Concentrations Threshold (mg/l)		
			157163	157164	TCT0	TCT1	TCT2
Inorganic Ions							
Fluoride	mg/kg	<0.5	<0.5	<0.5	100	10000	40000
Metal Ions							
As	mg/kg	<0.400	111	106.80	5.8	500	2000
B	mg/kg	<10	<10	<10	150	15000	6000
Ba	mg/kg	<10	33.73	38.70	62.5	6250	25000
Cd	mg/kg	<0.400	0.40	0.40	7.5	260	1040
Co	mg/kg	<10	28.76	28.57	50	5000	20000
Cr total	mg/kg	<10	390	446	46000	800000	N/A
Cr (VI)	mg/kg	<2	<2	<2	6.5	500	2000
Cu	mg/kg	<0.010	30	27.05	16	19500	78000
Hg	mg/kg	<0.400	<0.400	<0.400	0.93	160	640
Mn	mg/kg	<10	631	598	1000	25000	100000
Mo	mg/kg	<10	<10	<10	40	1000	4000
Ni	mg/kg	<10	112	107	91	10600	42400
Pb	mg/kg	<0.400	183	154	20	1900	7600
Sb	mg/kg	<0.400	<0.400	<0.400	10	75	300
Se	mg/kg	<0.400	<0.400	<0.400	10	50	200
V	mg/kg	<10	<10	<10	150	2680	10720
Zn	mg/kg	<10	168	118	240	160000	640000

6.5.2. Leachate Concentration Threshold

Table 6-7 presents a summary of the assessment of leachable concentrations. The leachable concentrations of sulphate and arsenic marginally exceed the LCT0 limits.

In summary, the total metal concentrations of arsenic, copper, nickel and lead exceeded the TCT0 limit but did not exceed the TCT1 limit. These metals are relatively immobile under the neutral conditions of the reprocessed tailings and are not mobilised into the leach solution with all their LC below the LCT0 limit. The leachable concentrations of sulphate and arsenic marginally exceed the LCT0 limits.

Overall, the tailings are assessed to be Type 3 waste; TC ≤ TCT1 and LCT0 < LC ≤ LCT1. Applying the N&S for Disposal of Waste to Landfill, the disposal of the tailings would require a liner consistent with a Class C barrier system illustrated in Figure 6-3.

Table 6-7: SPLP concentration results for the waste materials against the LCT

Sample ID	Units	Reporting Limit	1L13-1L15-1	1L13-1L15-2	Leachable Concentrations Threshold		
			157163	157164	LCT0	LCT1	LCT2
Inorganic Anions							
pH	s.u		7.20	7.40			
EC	mS/m		65	55			
Alkalinity	mg/L as $CaCO_3$		16	16			
TDS calculated	mg/L		414	339	1000	12500	25000
Cl	mg/L	<2	<2	<2	300	15000	30000
SO_4	mg/L		270	222	250	12500	25000
F	mg/L	<0.2	<0.2	<0.2	1.5	75	150
NO_3-N	as N mg/L	<0.1	<0.1	<0.1	11	550	1100
Metal Ions							
As	mg/L	<0.001	0.02	0.02	0.01	0.5	1
B	mg/L	<0.025	0.03	<0.025	0.5	25	50
Ba	mg/L	<0.025	0.03	0.03	0.7	35	70
Cd	mg/L	<0.001	<0.001	<0.001	0.003	0.15	0.3
Co	mg/L	<0.025	0.08	0.09	0.5	25	50
Cr tot	mg/L	<0.025	<0.025	<0.025	0.1	5	10
Cu	mg/L	<0.010	<0.010	<0.010	2	100	200
Hg	mg/L	<0.001	0.002	<0.001	0.006	0.3	0.6
Mn	mg/L	<0.025	0.17	0.13	0.5	25	50
Mo	mg/L	<0.025	<0.025	<0.025	0.07	3.5	7
Ni	mg/L	<0.025	<0.025	<0.025	0.07	3.5	7
Pb	mg/L	<0.001	<0.001	<0.001	0.01	0.5	1
Sb	mg/L	<0.001	<0.001	<0.001	0.02	1	2
Se	mg/L	<0.001	<0.001	<0.001	0.01	0.5	1
V	mg/L	<0.025	<0.025	<0.025	0.2	10	20
Zn	mg/L	<0.025	<0.025	<0.025	5	250	500

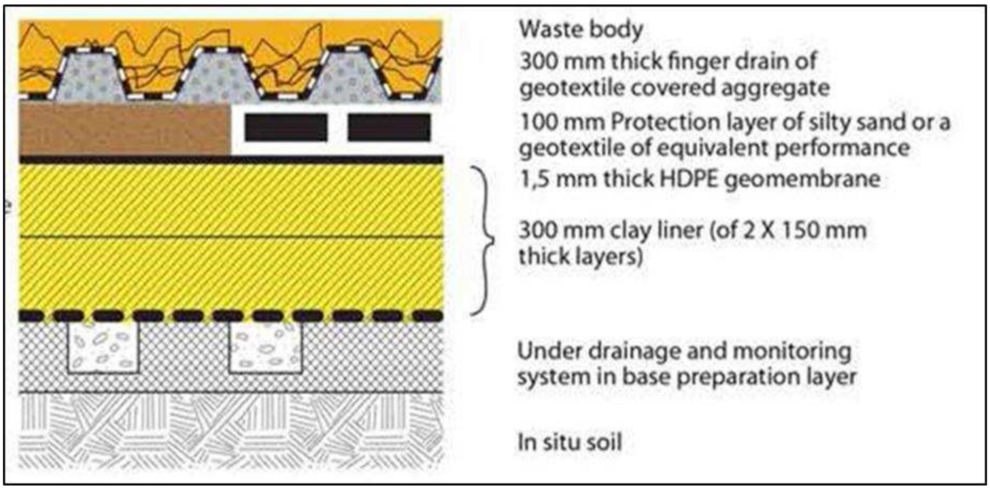


Figure 6-3: Illustration of a Class C barrier requirements for waste material (GN R636 of 23 August 2013)

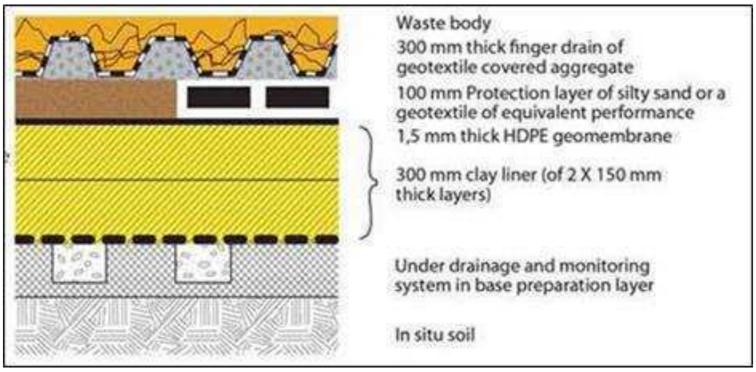
Digby Wells notes that the barrier systems are not necessarily the default barrier systems if Pan African Resources can demonstrate that the risks associated with the reprocessed tailings can be adequately managed without the default barrier systems. An alternative barrier with the same or lower performance criteria as Class C liner may also be considered. While the regulation makes provision for a risk-based approach, there is no guidance provided by the legislation as to what information the authorities require in a risk-based approach.

7. Geochemical Implications

This section discusses the geochemical implications of the results. Table 7-1 presents a summary of the geochemical characteristics of reprocessed tailings from 1L13-1L15 TSF, the risks, and management options.

Table 7-1: Geochemical characteristics of the tailings, risks, and mitigation measures

Material	Tailings (n=2)	
Geochemical Characteristics	**Current pH**	Neutral paste pH (pH of 7.62 - 7.67)
	Future pH	Non acidic (pH of 4.50 - 4.53) (> 4.5) - neutral
		The two samples classified as uncertain under the ABA and NAG tests.
	Mineralogy	• No acid-forming minerals
		• No fast-dissolving carbonates acid neutralising minerals detected
		• Aluminosilicates – pyrophyllite, chlorite, biotite, muscovite, smectite, kaolinite, and orthoclase.
		Alkaline pH (pH of 9.0)

<table>
<tr><th>Material</th><th colspan="2">Tailings (n=2)</th></tr>
<tr><td rowspan="3"></td><td>Supernatant Water Quality</td><td>Potential constituents of concern - conductivity, arsenic, copper, cadmium, iron, manganese, mercury, nickel and zinc</td></tr>
<tr><td rowspan="2">Leachate quality</td><td>Neutral leachate pH (average pH 7.50 - 7.60)</td></tr>
<tr><td>Potential constituents of concern – electrical conductivity, arsenic and manganese.</td></tr>
<tr><td colspan="2">Waste Classification</td><td>Reprocessed tailings from 1L13-1L15 TSF are classified as Type 3 waste and require a Class C liner as depicted below.

</td></tr>
<tr><td>Geochemical Risks</td><td colspan="2">Seepage and runoff from the tailings containing arsenic, copper, fluoride, iron, manganese, mercury and zinc may be of risk to surface and groundwater quality.</td></tr>
<tr><td rowspan="6">Management (Operations to closure and aftercare)</td><td colspan="2">The reprocessed tailings are classified as Type 3 waste and would potentially require a Class C liner underneath the new TSF, with further engagement to be undertaken with DWS with respect to the liner requirements.</td></tr>
<tr><td colspan="2">Reprocessing the existing tailings is supported as a measure to remove the existing TSFs that are acidic and contaminant sources at the site. The reprocessed tailings will be neutral with a low risk of leaching metal/metalloids.</td></tr>
<tr><td colspan="2">The reprocessing of the tailings should be handled expeditiously to minimise exposure to oxidation, weathering and leaching during reclamation and processing.</td></tr>
<tr><td colspan="2">Clean surface water should be diverted away from the operation using runoff control diversions.</td></tr>
<tr><td colspan="2">Dirty water from percolation and runoff from the reprocessing operations and the new reprocessed tailings TSF should be collected in toe paddocks and channelled to the return water dam for management (recycled for use in the plant, dust suppression, treatment before discharge, and establishing vegetation).</td></tr>
<tr><td colspan="2">The reprocessing operations would require monitoring the quality of toe seepage collecting in toe paddocks, return water dam, surface water, and groundwater for potential constituents of concern to include pH, electrical conductivity, copper, cadmium, manganese, nickel and zinc.</td></tr>
</table>

8. Conclusion and Recommendations

No acid-forming minerals were detected in the reprocessed tailings. The tailings are currently neutral in pH but classified as uncertain/inconclusive under ABA and NAG tests in the long term. The leachate from the reprocessed tailings are not acidic but neutral to alkaline.

Although the reprocessed tailings classify as Type 3 waste requiring deposition in a liner consistent with a Class C liner requirements, Digby Wells notes that the barrier systems are not necessarily the default barrier systems if Pan African Resources can demonstrate that the risks associated with the reprocessed tailings can be adequately managed without the default barrier systems. An alternative barrier with the same or lower performance criteria as a Class C liner may also be considered. While the regulation makes provision for a risk-based approach, there is no guidance provided by the legislation as to what information the authorities require in a risk-based approach.

Motivation for an alternative liner may be made on the following basis:

- The leachate from the reprocessed tailings are not acidic but neutral to alkaline. No acid-forming minerals were detected in the reprocessed tailings.
- The metals/metalloids are relatively immobile under the neutral conditions of the reprocessed tailings and are not mobilised into the leach solution with all their LC below the LCT0 limit except sulphate and arsenic which marginally exceed the LCT0 limits but can be managed.
- All the metals/metalloids in the leachate from the reprocessed tailings will be within the IFC limits except manganese (0.62-0.76 mg/L) which marginally exceeded the IFC limit (0.5 mg/L) but can be managed.
- The leachate from the reprocessed tailings will be substantially better than the current seepage from the existing TSFs. The seepage quality will change from acidic (pH 2.4-2.8) to neutral (pH 7.5-7.6) resulting in a significant reduction in total dissolved solids. The total dissolved solids in the seepage will change from 4166-14094 mg/L in the current seepage to 1554-1893 mg/L in the reprocessed tailings.

Overall, reprocessing the existing tailings is supported as a measure to remove the existing TSFs that are acidic and contaminant sources at the site. The reprocessed tailings will be neutral with a low risk of leaching metal/metalloids. The seepage from the reprocessed tailings will be substantially better than the current seepage water.

Based on the above understanding, Digby Wells recommends the following:

- Further characterisation of the reprocessed tailings by kinetic tests is required to determine the long-term ARD/ML potential of the tailings;
- The existing tailings should be handled expeditiously to minimise exposure to oxidation, weathering and leaching during reclamation and reprocessing that may exacerbate the formation of acidic mine drainage and metal leaching;

- Clean surface water should be diverted away from the operation using runoff control diversions; and
- The reprocessing operations would require monitoring the quality of water for potential constituents of concern including pH, electrical conductivity, arsenic, cadmium, copper, total cyanide, iron, manganese, nickel, lead, selenium and zinc.

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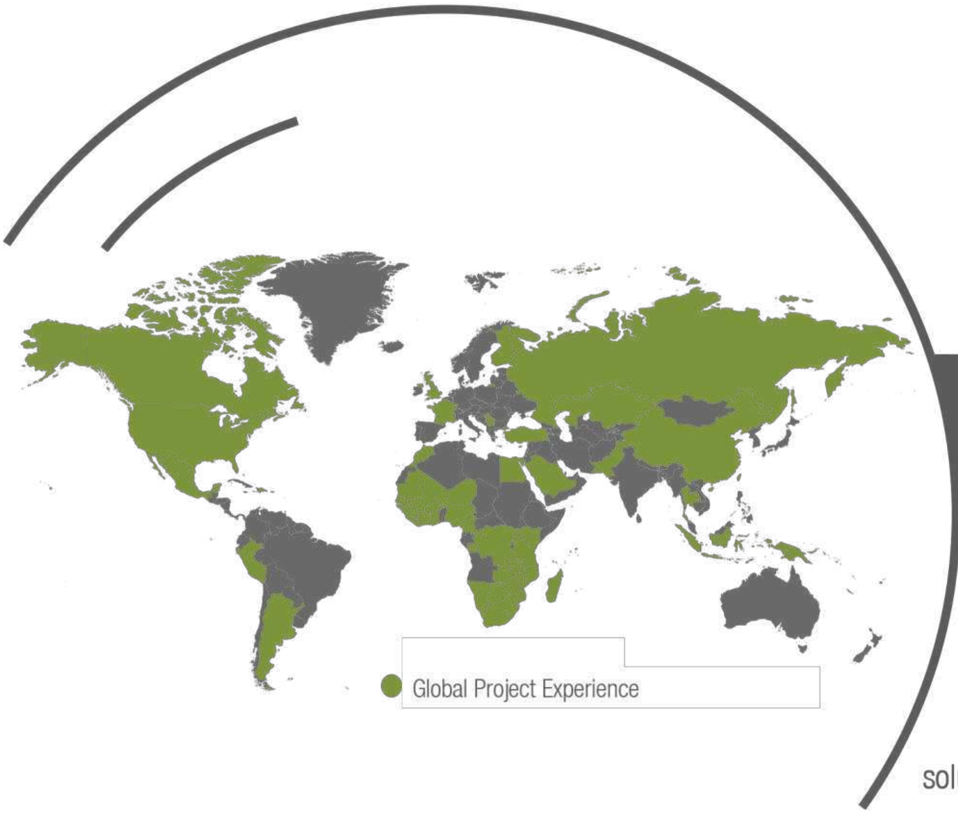
Appendix A: Prefeasibility Study - Geochemistry Report



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Pan African Resources Mogale Gold PFS - Geochemistry and Waste Classification Assessment

Prefeasibility Study

Prepared for:
Pan African Resources

Project Number:
DRA7015

August 2021

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This document has been prepared by Digby Wells Environmental.

Report Type:	Prefeasibility Study
Project Name:	Pan African Resources Mogale Gold PFS - Geochemistry and Waste Classification Assessment
Project Code:	DRA7015

Name	Responsibility	Signature	Date
Kgaugelo Thobejane	Reporter		August 2021
Levi Ochieng'	Reviewer		August 2021

EXECUTIVE SUMMARY

Digby Wells Environmental (hereafter Digby Wells) has been appointed by DRA SA (hereafter DRA), to conduct an Environmental and Social Pre-feasibility Study (PFS) and associated specialist studies for the Mintails Mogale Cluster for Pan African Resources (hereafter the Project). This report constitutes the **Environmental Geochemistry Assessment Pre-Feasibility Report** to describe the baseline environmental conditions and assess the potential geochemical impacts of the Project.

The specific objective of the geochemistry study was to assess the potential impacts of acid rock drainage and metal leaching (ARD/ML) of the tailings. The purpose of the study was to describe the current state of the tailings material, identify potential geochemical impacts, and recommend mitigation and management measures for the project.

The study analysed 32 tailing samples across 7 Tailings Storage Facilities (TSF) and a Manganese Slag sample. The geochemical analysis included the following:

- Sample preparation – grinding, and compositing of the tailings;
- Mineralogical analysis – X-ray diffraction (XRD) analysis to determine the mineral constituents of the samples;
- Total metal analysis – acid digestion (aqua regia) followed by semi-quantitative 29 elements Inductively Coupled Plasma (ICP) scan;
- Deionised water leaching test at 1:4 solid to liquid ratio;
- Australian Standard Leach Procedure (ASLP) including Borax and deionised water leaching test at 1:20 solid to liquid ratios;
- Acid-Base Accounting (ABA) tests including sulphur speciation (total sulphur, sulphate sulphur, and sulphide sulphur); and
- Net Acid Generation (NAG) test – where an oxidising agent (hydrogen peroxide) is used to assess whether a sample can neutralise the potential acidity on complete oxidation of sulphides.

Table 1-1presents a summary of the results of the study

Table 1-1: Summary of the results of the study

Material		Tailings (n=32)	Manganese Slag (n=2)
Geochemical Characteristics	**Current pH**	Acidic to slightly alkaline (paste pH 2.4-7.8)	Acidic (Paste pH 4.9-5,0)
	Future pH	97% Potentially Acid Forming (PAF) and 3% Inconclusive	100% PAF
		NAG-pH is acidic (pH 4.5 - 6.5)	

Material		Tailings (n=32)	Manganese Slag (n=2)
	Mineralogy	Acid Forming - pyrite (0.2 -1.2 wt.%)	Gypsum (48-64%), magnetite (34-36%), and chlorite (18%)
		Acid Neutralising: • Carbonates - calcite (0.1 - 3.9 wt.%); • Aluminosilicates - chlorite, muscovite, pyrophyllite and kaolinite	
	Leachate quality	Acidic to alkaline (pH 3.9 - 12)	Acidic (Paste pH 4.6)
		Potential constituents of concern - pH, electrical conductivity, calcium, iron, mercury, lead, sulphate, and zinc	Potential constituents of concern - pH, EC, B, Ca, Mn, and SO_4
Geochemical Risks		Acidic seepage and runoff from the tailings and manganese slag containing boron, calcium, iron, manganese, mercury, lead, sulphate, and zinc pose a risk to surface and groundwater quality. Other parameters of concern are pH, electrical conductivity, and TDS.	
Management measures for the proposed reprocessing and the new TSF (Operations to closure)		• Reprocessing the tailings is supported as a measure to remove the existing ARD/ML TSFs and manganese slag as potential contaminant source footprints at the site; • The tailings and manganese slag should be handled expeditiously to minimise exposure to oxidation, weathering and leaching during reclamation and processing; Clean surface water should be diverted away from the operation using runoff control diversions; • Dirty water from percolation and runoff from the TSFs and manganese slag should be collected in toe paddocks and channelled to the return water dam for management (recycled for use in the plant, dust suppression, treatment before discharge, and establishing vegetation); • The reprocessing operations would require to monitor the quality of toe seepage collecting in toe paddocks, return water dam, surface water, and groundwater for potential constituents of concern to include pH, electrical conductivity, total dissolved solids, boron, calcium, iron, manganese, mercury, lead, sulphate, and zinc; and • The results imply that a liner consistent with design requirements for the disposal of Type 3 waste at a minimum would theoretically be required to be placed underneath the new TSF for the reprocessed tailings and engagements with DWS are required.	

The tailing characterised in this study are the existing tailings before reprocessing. The geochemistry presented in this report therefore indicates the baseline geochemistry before reprocessing the tailings. The reprocessed tailings were not available for characterisation at the time of the writing of this report. It is recommended that the reprocessed tailings and manganese slag are characterised to update this report when available.

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LIST OF ABBREVIATION

Abbreviation	Description
ABA	Acid-Base Accounting
Alk	Alkalinity
AMD	Acid Mine Drainage
AP	Acid Potential
ARD	Acid Rock Drainage
ASLP	Australian Standard Leaching Procedure
CMA	Catchment Management Agency
DEA	Department of Environmental Affairs
DI	Deionised
DWS	Department of Water and Sanitation
EC	Electrical Conductivity
GAI	Geochemical Abundance Index
GN	Government Notice
LC	Leachable Concentration
LCT	Leachable Concentrations Threshold
mg/kg	milligram per kilogram
mg/L	milligram per litre
µS/cm	microSimens/centimeter
ML	Metal Leaching
NAF	Non-Acid Forming
NAG	Nett Acid Generation
NNP	Nett Neutralising Potential
NP	Neutralising Potential
NPR	Neutralising Potential Ratio
PAF	Potential Acid Forming
PAR	Pan African Resources PLC
NEM: WAA	National Environmental Management: Waste Amendment Act 26 of 2014
SS%	Sulphide-Sulphur percent
s.u	Standard Unit
TCT	Total Concentrations Threshold
TDS	Total Dissolved Solids
TSF	Tailings Storage Facility

Abbreviation	Description
UTD	Undetermined
US EPA	US Environmental Protection Agency
WMA	Water Management Area
wt.%	weight percent
WUL	Water Use License
wt.%)	wt.%)
XRD	X-Ray Diffraction

1 Introduction

Digby Wells Environmental (hereafter Digby Wells) has been appointed by DRA SA (hereafter DRA), to conduct an Environmental and Social Pre-feasibility Study (PFS) and associated specialist studies for the Mogale Cluster (GP) 30/5/1/2/2 (206) Mining Right (MR) and, more specifically for the proposed construction of a large-scale gold tailings retreatment operation for Pan African Resources PLC (hereafter the Project). Pan African Resources PLC (PAR) has entered into a Sale and Purchase Agreement for the acquisition of the shares in and claims against Mogale Gold (Pty) Ltd (Mogale Gold). The agreement was entered into between PAR and the liquidators of Mintails Mining SA (Pty) Ltd (in liquidation) (MMSA). MMSA is the holding company of Mogale Gold. The intended transaction is subject to a due diligence investigation which is in the process of being concluded.

The project consists of 120 Mt of tailings to be reprocessed and deposited at a new TSF. Six dumps are being considered to be reprocessed, the largest of which amounts to 57.9 Mt, while the smallest contains 0.57 Mt. The primary location of processed tailings storage has been earmarked for deposition in the West Wits Pit. This report constitutes the **Environmental Geochemistry Assessment Pre-Feasibility Report** to describe the baseline environmental conditions and assess the potential geochemical impacts of the Project.

The purpose of the Pre-Feasibility Study (PFS) Report is to detail the Environmental and Social baseline for the project, highlighting the environmental and social sensitivities associated with the project.

1.1 Project Location

The Mining Right Area of the Mintails Mogale Cluster includes: GI, G2 plant; Cams North Sand; South Sand; 1L23; 1L28; 1L13; 1L8; 1LI0; West Wits Pit (WWP) and Lancaster Dam. An existing Water Use License (WUL) No. 27/2/2/C423/1/1 was issued on 22 November 2013 to Mintails Mining SA (Pty) Ltd: Mogale Gold. The mining right is located on Portions 66 and 99 of the farm Waterval 174 IQ and portions 136 and 209 of the farm Luipaardsvlei 246 IQ.

The project is within the Mogale City Local Municipality (MCLM), which is located within the West Rand District Municipality (WRDM). MCLM is the regional services authority and the area falls under the jurisdiction of the Krugersdorp Magisterial District.

The site is located in the catchment of the Upper Wonderfonteinspruit, quaternary catchment C23D, which forms part of the Vaal River Water Management Area (WMA) within the Vaal Catchment Management Agency (CMA). The project is about 4 km south of Krugersdorp and north-east of Randfontein, approximately 10 km off the N14 National Road in the Gauteng Province, in an area that has been transformed by past gold mining activities.

The regional setting and location of the site is illustrated in Figure 1-1.

1.2 Geology

1.2.1 Regional Geology

The regional geology comprises of four main supergroups, namely: Witwatersrand, Ventersdorp, Transvaal and Karoo. The characteristics of these geological groups are discussed, in their chronological order (oldest first), in the subsections below. The regional geology of the area is also indicated in Figure 1-2.

1.2.1.1 Witwatersrand Supergroup

The Witwatersrand Basin is a thick sequence of shale, quartzite and conglomerate. The average dip of the strata varies between 10º and 30° south, although localised dips of up to 80° have been encountered in mine workings closer to the reef outcrop. There are two main divisions, a lower predominantly argillaceous unit, known as the West Rand Group and an upper unit, composed almost entirely of quartzite and conglomerates, known as the Central Rand Group. The West Rand Group is divided into three subgroups namely the Hospital Hill, Government Reef and Jeppestown. These rocks comprise mainly shale, but quartzite, banded ironstones, tillite and intercalated lava flows are also present. The rocks were subjected to low-grade metamorphism causing the shale to become more indurated and slatey, and the original sandstone was re-crystallised to form quartzite.

1.2.1.2 Ventersdorp Supergroup

The younger Ventersdorp Supergroup overlies the Witwatersrand rocks. Although acid lavas and sedimentary intercalations occur, the Ventersdorp is composed largely of andesitic lavas and related pyroclastics. The Ventersdorp Supergroup consists of the Platberg Group and the Klipriviersberg Group.

The Alberton Formation is composed of green – grey amygdaloidal andesitic lavas, agglomerates and tuffs with a total thickness of 1 500 m. The lack of sediments in this sequence indicates a rapid succession of lava flows, which probably came from fissure eruptions. Material of similar composition forms the oldest dykes that have intruded the Witwatersrand rocks. The abundant agglomerates provide indications of periodic explosive activity. The removal of huge volumes of volcanic material from an underlying magma chamber gave rise to tensional conditions and as a result a number of faulted structures, such as, horst and grabens formed.

1.2.1.3 Transvaal Supergroup

Overlying the Ventersdorp Lavas are the Black Reef Quartzite and dolomites of the Transvaal Supergroup. The Black Reef quartzite comprises coarse to gritty quartzite with occasional economically exploitable conglomerates (reefs). The entire area was peneplane in post-Ventersdorp time and it was on this surface that the Transvaal Supergroup was deposited, some 2 200 million years ago. The deposition commenced with the Kromdraai Member with the Black Reef at its base. The Black Reef is formed from material that has been eroded from the Witwatersrand outcrop areas. As a result, the Black Reef contains zones (reefs) in which gold is present. The occurrence of the gold is not as widespread as in the Witwatersrand and is mainly restricted to north-south trending channels. The Black Reef is overlain by a dark, siliceous quartzite with occasional grits or small pebble bands. The quartzite grades into black carbonaceous shale. The shale then grades into the overlying dolomite through a transition zone approximately 10 m thick.

Overlying the Kromdraai Member is the dolomite of the Malmani Subgroup of the Chuniespoort Group. The dolomites that are 1,500 m thick are known for their huge water storage potential.

The dolomite also contains lenses and layers of chert. The dense, hard and fine-grained chert tends to stand out in relief. Chert (silica) replaces carbonate material.

The dolomites are overlain in the south by the Pretoria Group rocks. The Rooihoogte Formation forms the basal member of the Pretoria Group, consisting predominantly of shale and quartzite.

1.2.1.4 Karoo Supergroup

The Karoo Supergroup was deposited approximately 345 million years ago. It commenced with a glacial period during which most of South Africa was covered by a thick sheet of ice. This ice cap slowly moved towards the south, causing extensive erosion of the underlying rocks. The erosion debris was eventually deposited and formed the Dwyka tillite. The latter is only partially preserved in the study area, as are the younger sedimentary deposits the Karoo Supergroup, including mudstone, shale and sandstone.

1.2.2 Local Geology

The Project area lies along the Witwatersrand on the Witwatersrand Supergroup Formations. The area is, however, highly faulted, folded and eroded, leading to a complex and varied geology and rock formations. However, being a surface dump mining operation, the geology has little influence or impact on the project.

The project is situated within the Archaean aged (i.e., approximately 2970 million years) Witwatersrand Basin - the world's largest natural repository of gold mineralisation, i.e. more than 1,600 million gold ounces have been exploited since 1886. The reefs mined to depths exceeding 3 km are generally considered ancient river placers. These reefs are frequently less than a metre thick and characterised by abundant pyrite, which may comprise up to 5% of the reef, as well as flyspeck and/or seam carbon/kerogen. These three components display a strong spatial correlation with the gold mineralisation, which is rarely visible, in the 10–20-micron range.

Figure 1-1: Locality Map

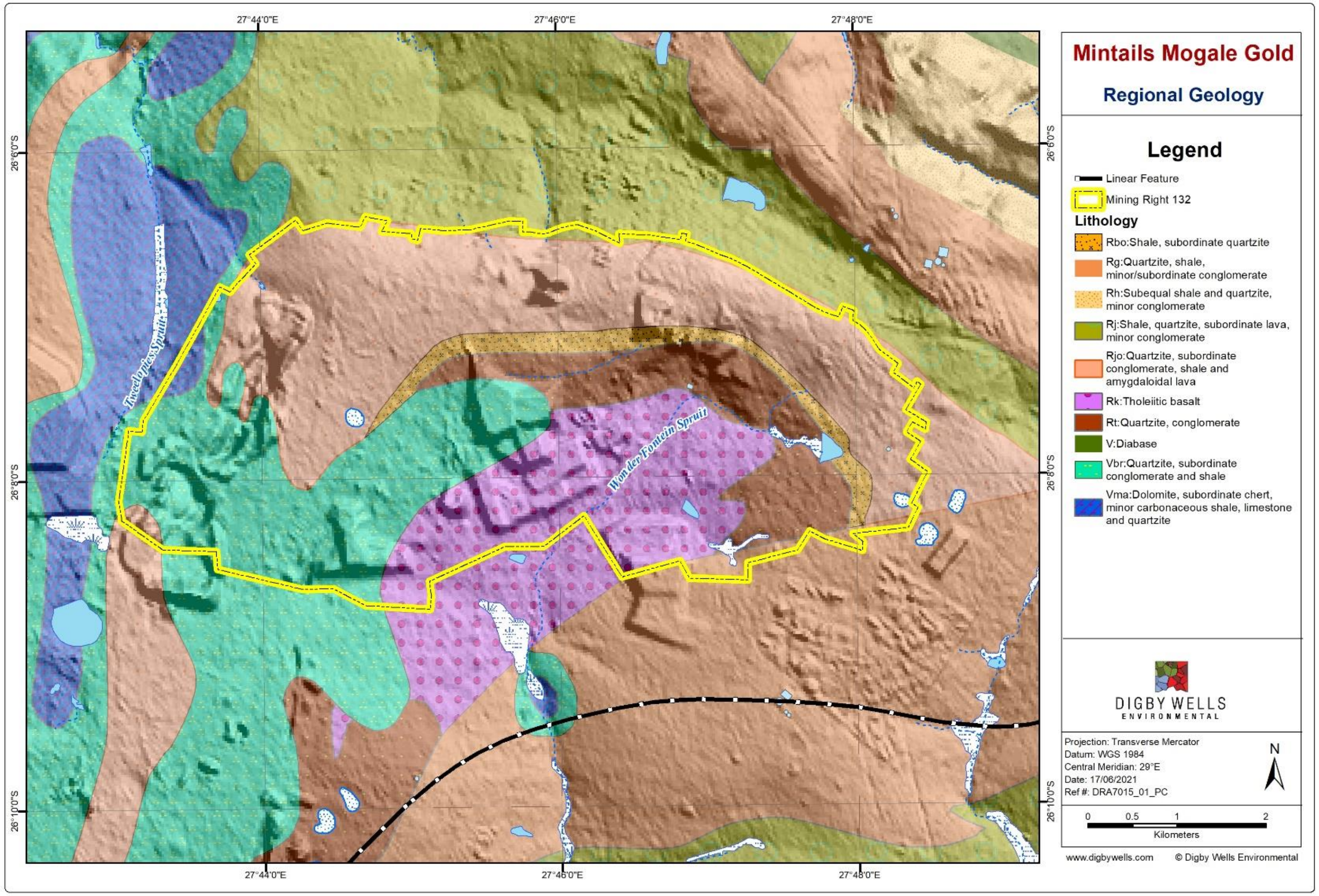

Figure 1-2 Regional Geology

2 Assumptions, Limitations and Exclusions

The following limitation is observed:

- Tailing materials in this study are proposed to be subjected to future reprocessing, thus the tailing materials in this study indicate the background geochemistry of the tailings and not the expected tailings materials after reprocessing.

3 Reporting Standards

3.1 Elemental Enrichment

One measure of enrichment of elements in samples is the Geochemical Abundance Index (GAI). The GAI compares the actual concentration of an element in a sample with the median abundance for that element in the most relevant media (such as crustal abundance, soils, or a rock type). The main purpose of the GAI is to indicate any elemental enrichments that may be of environmental importance.

The GAI for an element is calculated as follows:

Equation 1: $$\mathbf{GAI = Log2\ [Cn\ /\ (1.5 \times Bn)}$$

Where Cn is the concentration of the element in the sample and Bn is the median or average content for that element in the reference material (mean world soil, crustal abundance, etc.).

GAI values are truncated to integer increments (0 through to 6, respectively), where a GAI of 0 indicates the element is present at a concentration equal to, or less than, median abundance, and a GAI of 6 indicates approximately a 100-fold, or greater, enrichment above-median abundance. The actual enrichment ranges for the GAI values are as follows:

- GAI=0 represents <3 times median abundance,
- GAI=1 represents 3 to 6 times median abundance,
- GAI=2 represents 6 to 12 times median abundance,
- GAI=3 represents 12 to 24 times median abundance,
- GAI=4 represents 24 to 48 times median abundance,
- GAI=5 represents 48 to 96 times median abundance, and
- GAI=6 represents more than 96 times the median abundance.

As a general guide, a GAI of 3 or above is considered significant and such enrichment may warrant further examination (INAP, 2009).

3.2 Acid-Base Accounting and Net Acid Generation

Acid-Base Accounting (ABA) is a first-order classification procedure whereby the acid-neutralising potential and acid-generating potential of rock samples are determined and the difference in Net Neutralising Potential (NNP) is calculated. This procedure includes Net Acid Generation (NAG) tests that evaluate the NAG and Neutralising Potential (NP) of the material to evaluate the potential of the material to counter acid production. The NNP and/or the ratio of neutralising potential to acid-generation potential is compared with a predetermined value, or set of values, to divide samples into categories that either require or do not require further determinative acid potential generation test work.

To assess the Acid Rock Drainage/ Metal Leaching (ARD/ML) potential of the materials, Digby Wells used international guidelines provided by the following documents that have gained regulatory acceptance in various jurisdictions around the world, namely:

- Miller, S., Robertson, A. & Donahue, T., 1997. *Advances in acid drainage prediction using the net acid generation (NAG) test.* Vancouver, CANMET, pp. pp. 533-549,
- Price, W. A., 1997. *Draft Guidelines for metal leaching and acid rock drainage at mine sites in British Columbia.* British Columbia: Canada: Ministry of Energy and Mines, and
- Soregaroli, B. A. & Lawrence, R. W., 1998. *Update on waste characterization studies.* Polson, Montana, In Mine Design, Operations, and Closure Conference.

The international guidelines emphasis is that there is no minimum concentration of sulphide responsible for acid generation. The guidelines base the assessment of ARD/ML on Neutralisation Potential Ratio (NPR) and Net Neutralisation Potential (NNP) criteria as detailed in Table 3-1 and Table 3-2.

Table 3-1: Criteria For Interpreting ABA Results Updated From Price (1997) and Soregaroli and Lawrence (1998)

Potential for AMD	Criterion	S^{2-}-S%	Comments
Rock Type I: Likely	NPR<1	>0.3	Potentially acid forming unless sulphide minerals are non-reactive
Rock Type II: Possible	1<NPR<2	0.2-0.3	Possibly acid forming if NP is insufficiently reactive or is depleted at a rate faster than sulphides
Rock Type III: Low	2<NPR<4	0.1-0.2	Not potentially acid forming unless significant preferential exposure of sulphide
Rock Type IV: None	NPR>4	<0.1	Non-acid generating

Table 3-2: A Classification System Based On Paste-pH And NAG-pH Edited From Miller et al. (1997)

Acid Forming Potential	Test Criteria	NAG Value (H_2SO_4 kg/t)	NNP ($CaCO_3$ kg/t)
Rock Type Ia. PAF High Risk	Paste-pH < 4.0 NAG-pH < 4	>10	Negative
Rock Type Ib. PAF Medium Risk	Paste-pH 4.0 – 6 NAG-pH < 4	≤10	-
PAF – Lag to ARD	Paste-pH >6.0 NAG-pH < 4		
Uncertain, possibly Sediment Type Ib	NAG-pH < 4	>10	Positive
Uncertain	NAG-pH ≥4.5	0	Negative (reassess mineralogy)
Rock Type IV: NAF	Paste-pH >6 NAG-pH >4	0	Positive

3.3 Metal leaching potential

The guidelines used in the study are the following:

3.3.1 National Environmental Management Act

Digby Wells assessed the tailings against the South African National N&S for the Assessment of Waste for Landfill Disposal (GN R635 of 23 August 2014) and the National N&S for Disposal of Waste to Landfill (GN R636 of 23 August 2014) to determine the type of waste and the barrier/liner requirements

3.3.1.1 Waste Act 2014

On 2 June 2014, the National Environmental Management: Waste Amendment Act, 2014 (Act No. 26 of 2014) (NEM: WAA) was published, which for the first time included “residue deposits” and “residue stockpiles” under the environmental waste legislation (previously mining residue was covered under the Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002). Mine wastes are listed under Schedule 3, under the category “Hazardous Waste”, therefore the understanding is that mine wastes are hazardous unless the applicant can prove that the waste is non-hazardous.

As residue deposits and residue stockpiles are considered to be waste, they are regulated by the following regulations, both promulgated on 23 August 2013 under NEM: WAA:

- Norms and Standards for the Assessment of Waste for Landfill Disposal (GN R635 of 23 August 2013), and

- National Norms and Standards for Disposal of Waste to Landfill (GN R636 of 23 August 2013).

According to these regulations, waste that is generated must be classified following SANS 10234 “Globally Harmonised System” within 180 days of generation. Waste that has already been generated, but not previously classified must be classified within 18 months of the date of commencement of the regulations. The Norms and Standards (N&S) specify the waste classification methodologies for determining the waste category, and the specifications for pollution control barrier systems (liners) for each of the waste categories.

The Department of Forestry, Fisheries and Environment (DFFE) has further published the Regulations Regarding the Planning and Management of Residue Stockpiles and Residue Deposits (GN R632 of 24 July 2015, as amended) and in terms of waste classification, these regulations state that residue stockpiles and residue deposits must be characterised to identify any potential risk to health or safety and environmental impact in terms of physical characteristics, chemical characteristics (i.e. toxicity, propensity to oxidise and decompose, propensity to undergo spontaneous combustion, pH and chemical composition of the water separated from the solids, stability, and reactivity and the rate thereof, neutralising potential and concentration of volatile organic compounds), and mineral content.

3.3.1.2 Waste Type

Digby Wells followed the approach outlined below and presented in Figure 3-1, as per the South African regulations.

- The chemical substances present in the tailings were identified,
- Sampling and analysis were undertaken to determine the Total Concentration (TC) and Leachable Concentration (LC) of the elements and chemical substances identified in the tailings and that are specified in Section 6 of the N&S,
- All analyses of the TC and LC of the elements and the chemical substances in the tailings were conducted by a South Africa National Accreditation System (SANAS) accredited laboratory,
- The TC and LC of the elements and the chemical substances in the tailings were compared to threshold limits specified in Section 6 of the N&S, and
- Based on the comparison with the threshold limits, the specific type of waste was determined according to Section 7 of the N&S.

Total Concentration Threshold (TCT) limits are subdivided into three categories as indicated in Table 3-3 and are summarised as follows:

- TCT0 limits are based on screening values for the protection of water resources, as contained in the Framework for the Management of Contaminated Land (DEA, March 2010),

- TCT1 limits derived from land remediation values for commercial/industrial land (DEA, March 2010), and

TCT2 limits were derived by multiplying the TCT1 values by a factor of 4, as used by the Environmental Protection Agency, Australian State of Victoria.

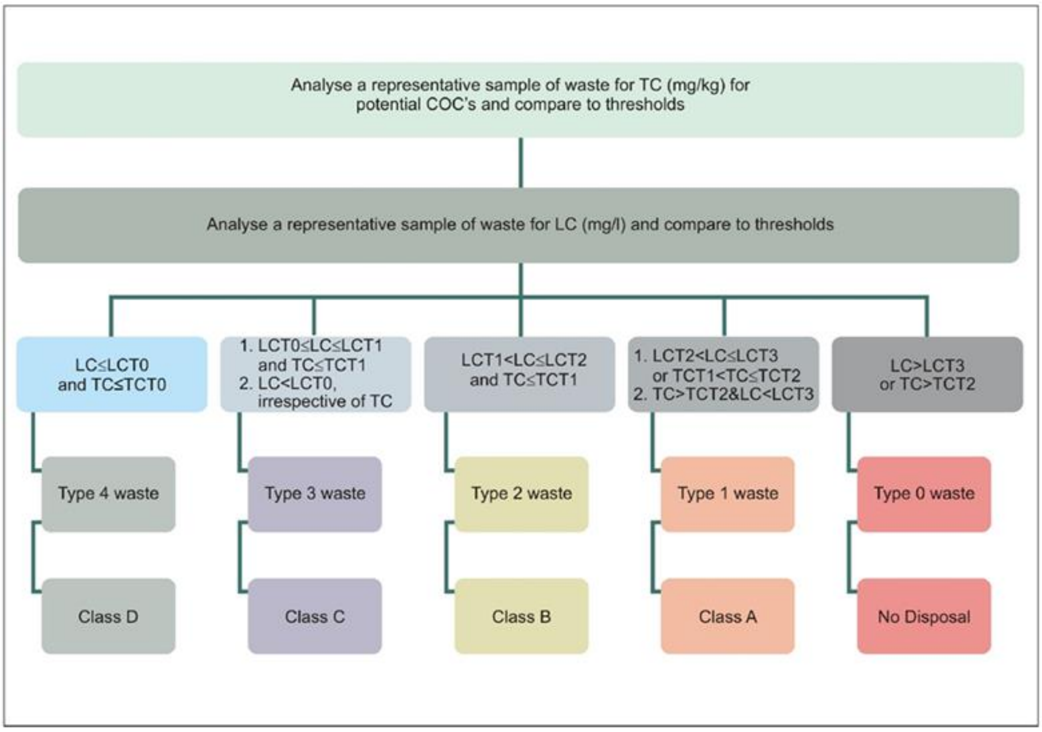

Figure 3-1: Flow Diagram For Waste Assessment (GN R635 of 23 August 2013)

Leachable concentration was determined by following the Australian Standard Leaching Procedure for Wastes, Sediments, and Contaminated Soils (AS 4439.3-1997), as specified in the N&S (2013). The procedure recommends the use of Deionised (DI) Water to detect the metals that are present on the surface exterior. The procedure can also be done under the Borax leaching procedure which consists of two types of pH 9 for co-disposal and. Leachate of 1:20 solids per reagent water was advised for the NEM: WA guidelines, but for this study, a 1:20 and 1:4 tailings and water ratio was prepared and analysed by Waterlab Laboratory same as indicated in the NEMWA guidelines.

Leachable Concentration Threshold (LCT) limits are subdivided into four categories as follows:

- LCT0 limits derived from human health effect values for drinking water, as published by the Department of Water and Sanitation (DWS), SANAS, WHO or the United States Environmental Protection Agency (USEPA),
- LCT1 limits derived by multiplying LCT0 values by a Dilution Attenuation Factor (DAF) of 50, as proposed by the Australian State of Victoria,
- LCT2 limits are derived by multiplying LCT1 values by a factor of 2, and

- LCT3 limits are derived by multiplying the LCT2 values by a factor of 4.Table 3-3: Total and Leachable Concentration Threshold Limits.

Table 3-4: Summary of guidelines used in the study

Parameter	Unit	TCT0	TCT1	TCT2	Unit	LCT0	LCT1	LCT2	LCT3
Al, Aluminium	mg/kg				mg/L				
As, Arsenic	mg/kg	5.8	500	2000	mg/L	0.01	0.5	1	4
B, Boron	mg/kg	150	15000	60000	mg/L	0.5	25	50	200
Ba, Barium	mg/kg	62.5	6250	25000	mg/L	0.7	35	70	280
Ca, Calcium	mg/kg				mg/L				
Cd, Cadmium	mg/kg	7.5	260	1040	mg/L	0.003	0.15	0.3	1.2
Co, Cobalt	mg/kg	50	5000	20000	mg/L	0.5	25	50	200
Cr total	mg/kg	46000	800000	N/A	mg/L	0.1	5	10	40
Cr (IV), Chromium (IV)	mg/kg	6.5	500	2000	mg/L	0.05	2.5	5	20
Cu, Copper	mg/kg	16	19500	78000	mg/L	2	100	200	800
Fe, Iron	mg/kg				mg/L				
Hg, Mercury	mg/kg	0.93	160	640	mg/L	0.006	0.3	0.6	2.4
Mg, Magnesium	mg/kg				mg/L				
Mn, Manganese	mg/kg	1000	25000	100000	mg/L	0.5	25	50	200
Mo, Molybdenum	mg/kg	40	1000	4000	mg/L	0.07	3.5	7	28
Na, Sodium	mg/kg				mg/L				
Ni, Nickel	mg/kg	91	10600	42400	mg/L	0.07	3.5	7	28
Pb, Lead	mg/kg	20	1900	7600	mg/L	0.01	0.5	1	4
Sb, Antimony	mg/kg	10	75	300	mg/L	0.02	1	2	8
Se, Selenium	mg/kg	10	50	200	mg/L	0.01	0.5	1	4
U, Uranium	mg/kg				mg/L				
V, Vanadium	mg/kg	150	2680	10720	mg/L	0.2	10	20	80
Zn, Zinc	mg/kg	240	160000	640000	mg/L	5	250	500	2000
Chloride as Cl	mg/kg	n/a	n/a	n/a	mg/L	300	15000	30000	120000
Sulphate as SO_4	mg/kg	n/a	n/a	n/a	mg/L	250	12500	25000	100000
Nitrate as N	mg/kg	n/a	n/a	n/a	mg/L	11	550	1100	4400
F, Fluoride	mg/kg	100	10000	40000	mg/L	1.5	75	150	600
CN total, Cyanide total	mg/kg	14	10500	42000	mg/L	0.07	3.5	7	28

Waste is classified by comparison of the total and leachable concentration of elements and chemical substances in the waste material to TCT and LCT limits as specified in the N&S for Waste Classification and the N&S for Disposal to Landfill.

3.3.2 Groundwater Quality Guidelines

The direct receptors of the seepage from the tailings will be the surface and groundwater. The Mintails Mining SA (Pty) Ltd: Mogale Gold groundwater quality limits stipulated in the Water Use License (WUL) (Licence No. 27/2/2/C423/1/1) presented in Table 3-5 was used as a qualitative screening tool to identify parameters of potential environmental concern from the leach test results. The WUL groundwater quality limits were supplemented with the General/Special limits (General Authorisation, GN665 of September 2013) and standard (GN 991 of May 1984 as amended by GN 1930 of August 1984 and GN 1864 of November 1996) for discharge of wastewater into a water source (Table 3-6).

Table 3-5: Groundwater quality limits (WUL, 22 November 2013)

Parameters	Groundwater Quality Limits
pH	9,5-10
EC (mS/m)	150
Ca	150
F	1
Mg	100
NO_3	15
Na	200
SO_4	400

Table 3-6: General/Special Limit (General Authorisation, GN665 of 6 September 2013) and Standard (GN 991 of 18 May 1984 as amended by GN 1930 of 31 August 1984 and GN 1864 of 15 November 1996) for discharge of wastewater into a water resource

Parameter	General Limit	General Standard	Special Limit	Special Standard
Faecal Coliforms (per 100 ml)	1 000	0	0	0
Chemical Oxygen Demand (mg/l)	75		30	30
pH (s.u)	5.5-9.5	5.5 – 9.5	5.5-7.5	5.5 – 7.5
Ammonia (ionized and unionized) as Nitrogen (mg/l)	6.0	10	2.0	1.0

Parameter	General Limit	General Standard	Special Limit	Special Standard
Nitrate/Nitrite as Nitrogen (mg/l)	15		1.5	1.5
Chlorine as Free Chlorine (mg/l)	0.25	0.10	0	0
Suspended Solids (mg/l)	25	25	10	10
Electrical Conductivity (mS/m)	70 mS/m above intake to a maximum of 150 mS/m	70 mS/m above intake to a maximum of 250 mS/m	50 mS/m above background receiving water, to a maximum of 100 mS/m	maximum of 15% above intake
Sodium (mg/l)	Ns	maximum of 90 mg/l above intake	Ns	maximum of 50 mg/l above intake
Orthophosphate as phosphorus (mg/l)	10	Ns	1: median; 2,5 : maximum	1.0
Fluoride (mg/l)	1.0	1.0	1.0	1.0
Soap, oil or grease (mg/l)	2.5	2.5	0	0
Dissolved Arsenic (mg/l)	0.02	0.10	0.01	0.10
Dissolved Cadmium (mg/l)	0.005	0.050	0.001	0.050
Dissolved Chromium (VI) (mg/l)	0.050	0.05 for total and Cr (VI)	0.02	0.05 as total Cr
Dissolved Copper (mg/l)	0.010	0.02	0.002	0.02
Dissolved Cyanide (mg/l)	0.020	0.50	0.010	0.50
Dissolved Iron (mg/l)	0.30	0.30	0.30	0.30
Dissolved Lead (mg/l)	0.01	0.10	0.006	0.10
Dissolved Manganese (mg/l)	0.10	0.10	0.1	0.10
Dissolved Mercury and its compounds (mg/l)	0.005	0.020	0.001	0.020
Dissolved Selenium (mg/l)	0.02	0.050	0.020	0.050
Dissolved Zinc (mg/l)	0	0.30	0.040	0.30
Boron (mg/l)	1.0	0.50	0.5	0.50

3.4 Limitations

The tailing and manganese slag assessed in this study are the existing materials before reprocessing. The geochemistry presented in this report therefore indicates the baseline geochemistry before reprocessing the tailings. The reprocessed tailings and manganese slag were not available for characterisation at the time of the writing of this report.

4 Geochemical Test Work

The section below describes the geochemistry assessment and waste classification assessment methodology/techniques.

4.1 Sampling

A total of 24 tailing and two Manganese slag samples were collected by the DRA Global with the guidance of Digby Wells. The samples collected are from pre-existing tailings facilities to understand the geochemistry of the samples. The samples collected are presented in Table 4-1.

Table 4-1 Tailings sample ID and coordinates of locations

	Tailings Facility	Longitude	Latitude
S Sands_Z1	South Sand	27.755333°	-26.135642°
S Sands_Z2			
S Sands_Z3			
N Sands_Z1	North Sand	27.765358°	-26.114347°
N Sands_Z2			
N Sands_Z3			
1L8_Z1	1L8 Dump	27.776422°	-26.117003°
1L8_Z2			
1L8_Z3			
1L10_Z1	1L10 Dump	27.786347°	-26.123144°
1L10_Z2			
1L10_Z3			
1L13_A_Z1	1L13 Dump	27.777148°	-26.139917°
1L13_A_Z2			
1L13_A_Z3			
1L13_B_Z1			
1L13_B_Z2			

	Tailings Facility	Longitude	Latitude
1L13_B_Z3			
1L25_A_Z1	1L25 Dump	27.761622°	-26.126475°
1L25_A_Z2			
1L25_A_Z3			
1L25_B_Z1		27.764964°	-26.130167°
1L25_B_Z2			
1L25_B_Z3			
1L25_C_Z1		27.767281°	-26.134006°
1L25_C_Z2			
1L25_C_Z3			
1L28_Z1	1L28 Dump	27.743469°	-26.140658°
1L28_Z2			
1L28_Z3			
1L 28 M1	Manganese Slag	27.752831°	-26.141915°
1L 28 M2			

4.2 Laboratory Analysis

Water laboratory analysed the tailings samples. The analytical suite included the following:

- Sample preparation – crushing, grinding, and compositing of the waste rock;
- Mineralogical analysis – X-ray diffraction (XRD) analysis to determine the mineral constituents of the samples;
- Acid digestion (aqua regia) followed by semi-quantitative 29 elements Inductively Coupled Plasma (ICP) scan;
- Deionised water leaching test at 1:4;
- ASLP using deionised water at and Borax leaching tests at 1:20 tailings to water ratio;
- Acid-Base Accounting (ABA) tests including sulphur speciation (total sulphur, sulphate sulphur, and sulphide sulphur); and
- NAG test – where an oxidising agent (hydrogen peroxide) is used to assess whether a sample can neutralise the potential acidity on complete oxidation of sulphide.

5 Data Analysis and Interpretations

5.1 Mineralogy

The mineral composition indicates the long-term geochemical behaviour of the material. The purpose of the analysis was to identify the mineral phases present in the waste rock that could be a source of acidity, neutralisation capacity, or metals.

The laboratory prepared the samples for XRD analysis using a zero-background holder. The diffractograms were generated using a Malvern PANalytical Aeris diffractometer. The instrument used a PIXcel detector with variable divergence and receiving slits with Fe filtered Co-Kα radiation (λ = 1.789À). X'Pert Highscore Plus software was used to identify the mineral phases. The Rietveld method (Autoquan Program) was used to estimate the relative phase amounts in percentage weight, normalising them to 100%.

Digby Wells evaluated the mineralogical analysis results on the following basis:

- Occurrence - relative quantities described as predominant to trace (normalised to 100%);
- Weathering rates – dissolving, fast weathering to inert; and
- The presence and quantities of acid-forming/neutralising minerals

Table 5-1 presents a summary of the mineralogical composition of the tailings and manganese slag. The mineralogy of the tailings is as follows:

- Acid forming mineral, pyrite, occurs at trace levels, 0.2-1.2 weight percent (wt.%), in all samples apart from samples collected from the Manganese Slag, North Sands, and S-Sands_Z1 from South Sands.
- The reactive acid neutralising carbonate mineral calcite occurs in a few samples from South Sands, North Sands, and a sample 1L25_C_Z3 from 1L25 TSF ranging between 0.1 3.9 wt. %. The mineral is dissolving and will readily react with acid to consume acidity.
- Aluminosilicates occurring include chlorite, muscovite, pyrophyllite and kaolinite. The weathering rates of these minerals range from fast weathering (bassanite and gypsum) to slow (kaolinite). These minerals can react with acid and consume acidity to contribute to the overall NP of the tailing.
- Calcium sulphate minerals, gypsum and bassanite, occur in the tailings. Bassanite is a secondary basic sulphate mineral that transitions to gypsum ($CaSO_4.2H_2O$) depending on temperature. It is a metastable mineral in the transition zone between gypsum and anhydrite ($CaSO_4$) and is formed by the action of sulfuric acid on calcite.
- Quartz predominates (>50%) the mineralogy of samples except for Manganese Slag samples. Quartz is inert and does not contribute to acidity or neutralization potential.

Table 5-1: Mineralogical composition (wt.%) of tailings material - listed in order of decreasing weathering (reactivity) rates

TSF	Mineral (wt %)	Acid Forming	Acid Neutralising											
			Dissolving	Fast Weathering		Intermediate Weathering			Slow Weathering	Inert				
		Pyrite	Calcite	Bassanite*	Gypsum	Chlorite	Muscovite	Pyrophyllite	Kaolinite	Anatase	Magnetite	Hematite	Chromite	Quartz
South Sands	S Sands_Z1	-	0.0	-	-	1.3	3.1	0.5	0.2	0	0.6	0.2	-	94.2
	S Sands_Z2	0.4	0.4	-	-	1.3	2.4	2.2	0.4	0.2	0	-	-	92.7
	S Sands_Z3	0.2		-	-	2.1	2.2	2.2	3.5	0.6	0	0.3	-	89.1
North Sands	N Sands_Z1	-	0.8	-	-	-	1.8	6.9	-	-	-	0.2	-	90.4
	N Sands_Z2	-	3.9	-	-	-	2	7.2	-	-	-	-	-	86.9
	N Sands_Z3	-	0.3	-	-	-	3.6	9.9	-	-	-	-	-	86.2
1L8	1L8_Z1	0.8	-	-	-	-	-	15	1	0	0.1	0.0	-	79
	1L8_Z2	0.8	-	-	-	0.6	-	17.1	1.1	0.3	0.4	0.1	-	76.4
	1L8_Z3	-	-	-	0.1	0.4	-	24.9	1.8	-	-	-	-	69.8
1L10	1L10_Z1	-	-	-	-	-	3.9	25.4	1.7	-	-	-	-	69
	1L10_Z2	0.6	-	-	-	-	4.5	29.9	1.7	0.1	-	0.1	-	62
	1L10_Z3	0.6	-	0.2	-	-	4	30.6	1.3	0.1	-	0.0	-	61.7
1L13	1L13_A_Z1		-	-	1.8	4.3		16.4	-	-	4.1		-	73.5
	1L13_A_Z2	0.6	-	-	0.4	1.7	3.8	11.4	-	-	0.1	0.2	-	81.8
	1L13_A_Z3	0.6	-	0.4		1	2.2	12.8	2.8		0.1		-	80.2
	1L13_B_Z1	0.6	-	-	1.7	2.6	4.1	20.5	1	0.1		0.3	-	69.1

TSF	Mineral (wt %)	Acid Forming	Acid Neutralising											
			Dissolving	Fast Weathering		Intermediate Weathering			Slow Weathering	Inert				
		Pyrite	Calcite	Bassanite*	Gypsum	Chlorite	Muscovite	Pyrophyllite	Kaolinite	Anatase	Magnetite	Hematite	Chromite	Quartz
	1L13_B_Z2	0.6	-	-	0.2	0.6	4.8	6	2	-	0.4		-	85.4
	1L13_B_Z3	0.7	-	-	1.2	1.2	3.5	11.4	4.3	-	0.3	0.1	-	77.3
1L25_	**1L25_A_Z1**	0.7	-	-	2.1	1.9	3.7	15.1	2.2	-	0.2	0.3	-	73.9
	1L25_A_Z2	0.6	-	-	0.4	0.4	5.3	9.8	1.2	-	0.3	-	-	81.9
	1L25_A_Z3	0.6	-	0.3	0.6	1.7	4.6	15.6	1.7	-	0.2	-	-	74.6
	1L25_B_Z1	0.5	-	-	0.9	5.3	4.2	13.4	-	-	0.4	0.1	-	75.2
	1L25_B_Z2	1.2	-	-	0.8	3.3	4.5	10.3	1.4	0.2	0.4	-	-	78
	1L25_B_Z3	0.9	-	-	0.2	2.8	3.9	8.8		0.2	0.4	-	-	82.8
	1L25_C_Z1	0.4	-	0.7	0.6	1.9	3.6	14.3	1.2	0.3	0.2	0.1	-	77.4
	1L25_C_Z2	1	-	1.4	-	2.3	3.5	14.3	1.5	-	0.1	-	-	75.9
	1L25_C_Z3	0.7	0.1	0.6	-	3.3	3.3	10.9	1.8	-	0.5	-	-	78.2
1L28	**1L28_Z1**	0.4	-	0.9	0.7	3.6	5.1	15	-	-	0.5	-	-	73.9
	1L28_Z2	0.7	-	0.5	5.7	1.8	3.8	24.6	1.9	-	0.2	-	-	60.9
	1L28_Z3	0.8	-	-	0.8	1.8	1.7	23.4	0.8	0	0.1	0.8	-	69.7
Manganese Slag	**IL 28 M1**	-	-	-	47.8	-	-	-	-	-	33.9	-	18.3	-
	IL 28 M2	-	-	-	64.2	-	-	-	-	-	35.8	-		-

Notes

Predominant	>50%	(pink)	Anatase - TiO_2	Chromite- Cr_2FeO_4	Magnetite - Fe_3O_4	Quartz - SiO_2
Abundant	20-50%	(orange)	Bassanite - $CaSO_4(H_2O)_{0.5}$	Gypsum- $Ca(SO_4)(H_2O)_2$	Muscovite - $KAl_2((OH)_2AlSi_3O_{10})$	
Less abundant	10-20%	(lilac)	Calcite - $CaCO_3$	Hematite- Fe_2O_3	Pyrite - FeS2	
Minor	3-10%	(blue)	Chlorite - $(Mg, Fe)_5Al(AlSi_3O_{10})(OH)_8$	Kaolinite - $Al_2Si_2O_5(OH)_4$	Pyrophyllite - $Al(Si_2O_5)(OH\ )$	
Trace	<3%	(white)				

In summary, acid-forming mineral pyrite was detected in the tailings from all the facilities in traces ranging between 0.2 and 1.2 wt. %. Calcite, a highly dissolving acid neutralising carbonate mineral was detected at 0.1 - 3.9 wt. % in the North, South Sands TSF, and one sample from 1L25 TSF. In addition, aluminosilicates (kaolinite) and phyllosilicates (pyrophyllite, muscovite, chlorite, and talc) occur at varying concentrations in the tailings. . The weathering rates of these minerals range from fast to slow. These minerals can react with and consume acidity contributing to the overall NP in the tailings in the long term. Manganese Slag is dominated by gypsum and magnetite.

5.2 Acid Rock Drainage Potential

Table 5-2 presents a summary of the ABA and sulphur speciation results for the tailing samples. The acid-generating and neutralising characteristics of the tails are as follows:

- The paste pH ranges from acidic to neutral (pH 2.4 – 7.8);
- Total sulphur ranged between 0.01 and 5.16 %. The lowest concentrations were detected in South Sands and the highest concentrations were detected in the Manganese Slag;
- The AP ranges from 0.028 kg $CaCO_3$/t to 164 kg $CaCO_3$/t with the South Sands samples being the lowest and the Manganese Slag having the highest concentration;
- The NP ranges from -4.40 kg $CaCO_3$/t to 15.21 kg $CaCO_3$/t with the lowest concentration detected in 1L10 TSF and the highest concentration detected in 1L28 TSF.
- The NAG pH ranged from pH 4.5 and 6.5;
- Assessment of the AP and NP indicates that all tailings samples are PAF apart from one sample from South Sands TSF that is inconclusive as shown in Figure 5-1. The ARD characteristics of the tailings can be summarised per facility as follows:
  - South Sands – 66% of the samples are PAF and 33%inconclusive in the short term;
  - North Sands – 100% PAF in the short term;
  - 1L8 – 100% PAF, 66% in the short term and 33% in the long term;
  - 1L10 – 100% PAF, 66% in the short term and 33% in the long term;
  - 1L13 – 100% PAF, 66% in the short term and 33% in the long term;
  - 1L25 – 100% PAF, 33% in the short term and 66% in the long term;
  - 1L28 – 100% PAF, 66% in the short term and 33% in the long term; and
  - Manganese Slag – 100% PAF long term

Table 5-2: ABA, NAG, SS% and classification results

TSF	Sample ID	AP	NP	NNP	NPR	paste-pH	Total Sulphur	SO_4^{2-}-S	S^{2-}-S	NAG pH: (H2O2) pH-7	NAG (kg H2SO4 / t) pH-7	NAG pH: (H2O2) pH-4.5	NAG (kg H2SO4 / t) pH-4.5	Organic Carbon (%) (LECO) [s]	Inorganic Carbon (%) (LECO) [s]	ABA Classification	NAG Classification	
	Units	kg/t	kg $CaCO_3$ /t			s.u	%S			s.u	kg H_2SO_4 / t	s.u	kg H_2SO_4 / t				Classification pH-7	Classification pH-4.5
South Sands	S Sands_Z1	1.39	0.01	-1.38	0.01	4.30	0.04	<0.01	0.04	4.50	9.60	3.80	0.39	0.04	<0.01	PAF Medium Risk	PAF High Risk	PAF High Risk
	S Sands_Z2	5.71	-1.22	-6.93	0.21	3.10	0.18	0.02	0.16	4.50	1.18	2.40	10	0.03	0.01	PAF Medium Risk	PAF High Risk	PAF High Risk
	S Sands_Z3	0.82	-1.22	-2.03	1.49	2.70	0.03	<0.01	0.03	4.50	1.18	2.20	12	0.03	<0.01	Inconclusive	PAF High Risk	PAF High Risk
North Sands	N Sands_Z1	5.03	-0.24	-5.27	0.05	5.60	0.02	<0.01	0.02	4.50	13.00	4.50	<0.01	0.29	<0.01	PAF Medium Risk	PAF High Risk	Inconclusive
	N Sands_Z2	0.28	0.01	-0.27	0.04	4.70	0.01	<0.01	0.01	4.70	16.00	4.40	<0.01	0.34	0.04	PAF Medium Risk	PAF High Risk	Inconclusive
	N Sands_Z3	0.35	0.01	-0.34	0.03	4.30	0.01	<0.01	0.01	4.70	13.00	4.70	<0.01	0.08	0.01	PAF Medium Risk	PAF High Risk	Inconclusive
1L8	1L8_Z1	7.08	-1.46	-8.54	0.21	2.60	0.23	0.02	0.21	4.50	1.37	2.30	18	0.04	<0.01	PAF Medium Risk	PAF High Risk	PAF High Risk
	1L8_Z2	7.11	-1.95	-9.06	0.27	2.70	0.62	0.03	0.59	4.50	1.76	2.40	17	0.04	<0.01	PAF High Risk	PAF High Risk	PAF High Risk
	1L8_Z3	20.00	-0.48	-20.00	0.03	4.70	0.14	<0.01	0.14	4.50	1.57	2.20	23	0.06	0.03	PAF Medium Risk	PAF High Risk	PAF High Risk
1L10	1L10_Z1	4.25	0.75	-3.50	0.18	6.00	0.24	<0.01	0.24	4.50	1.96	2.30	17	0.05	0.01	PAF Medium Risk	PAF High Risk	PAF High Risk
	1L10_Z2	7.36	-4.16	-12.00	0.57	2.40	0.23	0.14	0.09	4.50	1.37	2.80	2.80	0.05	<0.01	PAF Medium Risk	PAF High Risk	PAF High Risk
	1L10_Z3	7.26	-4.40	-12.00	0.61	2.70	0.91	0.11	0.79	4.50	2.74	2.40	2.40	0.06	0.02	PAF High Risk	PAF High Risk	PAF High Risk
1L13	1L13_A_Z1	28.00	3.93	-24.00	0.14	7.80	0.74	0.33	0.41	4.50	1.96	2.40	2.4	0.10	0.04	PAF High Risk	PAF High Risk	PAF High Risk
	1L13_A_Z2	23.00	2.46	-21.00	0.11	5.50	0.37	0.26	0.12	4.50	1.76	2.60	2.60	0.06	0.03	PAF Medium Risk	PAF High Risk	PAF High Risk
	1L13_A_Z3	12.00	2.95	-8.64	0.26	7.00	0.43	0.31	0.13	4.50	2.16	2.40	2.4	0.03	0.02	PAF Medium Risk	PAF High Risk	PAF High Risk
	1L13_B_Z1	14.00	1.24	-12.00	0.09	6.50	0.89	0.23	0.66	4.50	2.35	2.40	16	0.12	0.01	PAF High Risk	PAF High Risk	PAF High Risk
	1L13_B_Z2	28.00	0.26	-28.00	0.01	4.30	0.20	0.17	0.03	4.50	3.33	2.70	7.64	0.06	<0.01	PAF Medium Risk	PAF High Risk	PAF High Risk
	1L13_B_Z3	28.00	0.26	-28.00	0.01	4.20	0.44	0.27	0.17	4.50	3.72	2.70	7.64	0.04	0.05	PAF Medium Risk	PAF High Risk	PAF High Risk
1L25	1L25_A_Z1	6.16	-2.44	-8.60	0.40	6.00	0.80	0.38	0.42	4.50	2.74	2.40	14	0.17	0.10	PAF High Risk	PAF High Risk	PAF High Risk
	1L25_A_Z2	14.00	-1.95	-16.00	0.14	6.20	0.48	0.02	0.46	4.50	3.14	2.40	15	0.03	<0.01	PAF High Risk	PAF High Risk	PAF High Risk
	1L25_A_Z3	4.65	0.26	-4.39	0.06	5.60	0.42	0.40	0.02	4.50	2.35	2.50	9.8	0.10	0.04	PAF Medium Risk	PAF High Risk	PAF High Risk
	1L25_B_Z1	9.99	0.99	-9.00	0.10	6.90	1.00	0.56	0.43	4.50	1.96	2.50	11	0.06	0.04	PAF High Risk	PAF High Risk	PAF High Risk
	1L25_B_Z2	26.00	1.73	-24.00	0.07	6.30	0.28	0.21	0.07	4.50	2.55	2.30	21	0.00	0.05	PAF High Risk	PAF High Risk	PAF High Risk
	1L25_B_Z3	26.00	4.42	-22.00	0.17	7.00	0.32	0.22	0.10	4.50	3.33	2.60	12	0.01	0.04	PAF High Risk	PAF High Risk	PAF High Risk
	1L25_C_Z1	31.00	2.95	-28.00	0.10	6.90	0.83	0.51	0.33	4.50	2.55	2.60	8.43	0.07	0.02	PAF High Risk	PAF High Risk	PAF High Risk
	1L25_C_Z2	37.00	6.14	-30.00	0.17	6.50	0.83	0.31	0.52	4.50	2.16	3.20	1.96	0.10	0.02	PAF Medium Risk	PAF High Risk	PAF High Risk
	1L25_C_Z3	37.00	4.67	-32.00	0.13	6.50	0.99	0.39	0.60	4.50	1.76	3.40	1.37	0.16	0.01	PAF Medium Risk	PAF High Risk	PAF High Risk
1L28	1L28_Z1	51.00	5.16	-46.00	0.10	7.00	1.18	0.85	0.33	4.50	3.14	2.80	4.31	0.20	0.08	PAF High Risk	PAF High Risk	PAF High Risk
	1L28_Z2	31.00	2.22	-29.00	0.07	6.80	1.64	1.35	0.30	4.50	3.14	2.50	11	0.25	0.02	PAF High Risk	PAF High Risk	PAF High Risk

TSF	Sample ID	AP	NP	NNP	NPR	paste-pH	Total Sulphur	SO_4^{2-}-S	S^{2-}-S	NAG pH: (H2O2) pH-7	NAG (kg H2SO4 / t) pH-7	NAG pH: (H2O2) pH-4.5	NAG (kg H2SO4 / t) pH-4.5	Organic Carbon (%) (LECO) [s]	Inorganic Carbon (%) (LECO) [s]	ABA Classification	NAG Classification	
	Units	kg/t	kg $CaCO_3$ /t			s.u	%S			s.u	kg H_2SO_4 / t	s.u	kg H_2SO_4 / t				Classification pH-7	Classification pH-4.5
	1L28_Z3	13	15.21	-120.00	0.11	5.00	1.00	0.43	0.57	6.40	0.39	6.40	<0.01	0.14	0.06	PAF High Risk	PAF High Risk	Inconclusive
Manganese Slag	IL 28 M1	16	14.96	-146.00	0.09	5.00	4.34	0.21	4.13	6.50	0.59	6.50	<0.01	3.76	0.18	PAF High Risk	PAF High Risk	Inconclusive
	IL 28 M2	164	15.21	-149.00	0.09	4.90	5.16	0.22	4.95	6.40	0.78	6.40	<0.01	4.38	0.18	PAF High Risk	PAF High Risk	Inconclusive

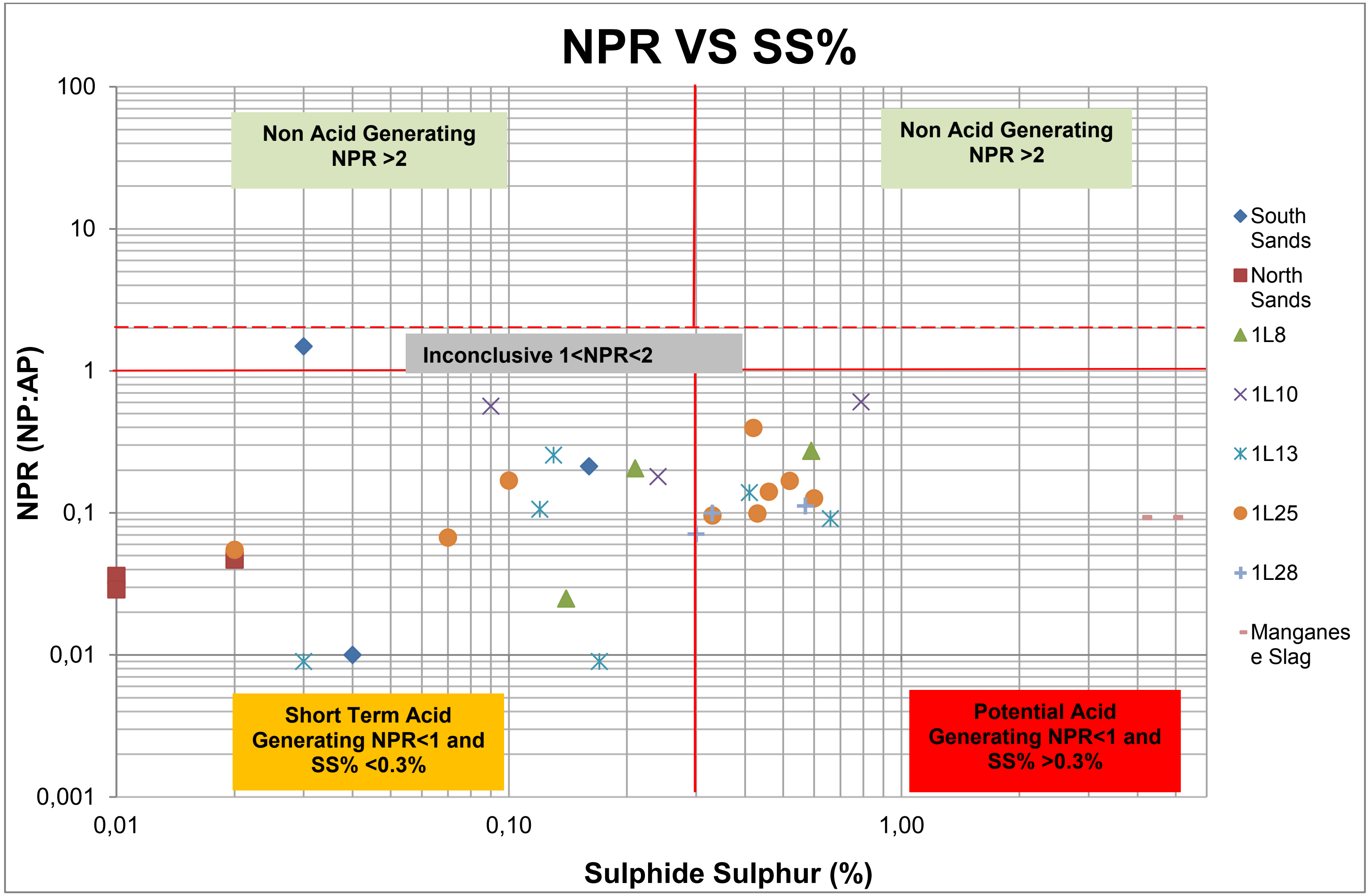

Figure 5-1: NPR versus SS% for tailing materials

In summary, the paste-pH of the tailings materials ranges from acidic to neutral (pH 2.4 – 7.8). The titration value at pH 4.5 and pH 7 for the NAG pH values are all acidic with the final pH ranging from 4.5 - 6.5. Assessment of the AP and NP indicates that all tailings samples are PAF apart from one sample from South Sands that is inconclusive. In total 50% of the samples are PAF in the short term, 47% PAF in the long term.

5.3 Elemental Enrichment

The total metal analysis was undertaken to identify elements enriched in the materials that may be of environmental concern relative to the average crustal abundance levels (Fortescue, 1992). The use of crustal abundance data is an industrially accepted approach of identifying enrichment and is commonly used in Environmental, Health, and Social-Economic Baseline Studies (EHSEBS).

Table 5-3 presents the elemental concentrations and GAI values for the tailing. A GAI value of 0 indicates that the element is present at a concentration equal to or less than the crustal abundance. A GAI of six indicates approximately a 100-fold, or more, enrichment above crustal abundance. As a general guide, a GAI of three or above is significant in triggering environmental concerns.

Elements that are significantly enriched (GAI ≥3) in the samples are

- Silver (44 – 43 mg/kg);
- Arsenic (6 – 450 mg/kg);
- Barium (7 326 mg/kg for Manganese Slag at the same concentration);
- Chromium (1 578 mg/kg);
- Potassium (266 – 2 930 mg/kg);
- Lead (149 – 1 166) and
- Uranium (25 – 70 mg/kg).

The significant enrichment demonstrated by the elements does not necessarily imply environmental risk. The risk that these enriched elements present is a function of their mobility assessed in the next section of this geochemistry report.

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Table 5-3: Elemental concentrations and GAI values for the tailings

TSF		South Sand			North Sand			1L8 Dump			1L10 Dump			1L13 Dump						1L25 Dump									1L28 Dump			Manganese Slag	
Sample ID	ACA	S Sands_Z1	S Sands_Z2	S Sands_Z3	N Sands_Z1	N Sands_Z2	N Sands_Z3	1L8_Z1	1L8_Z2	1L8_Z3	1L10_Z1	1L10_Z2	1L10_Z3	1L13_A_Z1	1L13_A_Z2	1L13_A_Z3	1L13_B_Z1	1L13_B_Z2	1L13_B_Z3	1L25_A_Z1	1L25_A_Z2	1L25_A_Z3	1L25_B_Z1	1L25_B_Z2	1L25_B_Z3	1L25_C_Z1	1L25_C_Z2	1L25_C_Z3	1L28_Z1	1L28_Z2	1L28_Z3	IL28M1	IL28M2
Ag	0.08	<8.33			<8.33			<8.33			<8.33			<8.33						<8.33									<8.33			44	43
Al	83600	7992	7659	7659	4662	4662	4662	4995	5328	5328	5328	6660	5994	8658	7659	5661	8991	6327	6660	9990	6660	8325	9324	7659	8325	8991	9990	8325	11322	12654	9990	3996	4329
As	1.8	24.64	47.29	38.30	7.66	7.99	5.66	36.30	53.95	49.28	40.29	69.26	57.28	59.61	74.59	95.57	58.28	76.26	107.89	143.86	75.59	92.57	58.28	94.24	100.57	63.27	152.51	80.59	166.17	336.33	449.55	20.98	21.65
Ba	390	27	25	20	48	31	27	42	46	51	42	47	45	151	95	54	114	55	73	93	42	89	53	41	39	39	109	109	180	142	98	7326	7326
Be	2	<8.33			<8.33			<8.33			<8.33			<8.33						<8.33									<8.33			<8.33	
Bi	0.082	<8.33			<8.33			<8.33			<8.33			<8.33						<8.33									<8.33			<8.33	
Ca	46600	666	666	666	666	666	333	<33	333	999	666	2331	2664	2997	2331	2331	3663	1665	1998	6660	1665	4995	5328	1998	1998	4662	7326	3663	9324	13986	7992	55611	50949
Cd	0.16	<0.333			<0.333			<0.333			<0.333			<0.33	<0.33	0.333	<0.33	<0.33	0.333	<0.333									<0.3	0.33	<0.3	<0.333	
Co	29	78	147	110	86	169	89	124	95	68	71	78	108	100	142	103	129	121	147	172	198	121	144	153	144	119	113	87	175	226	145	103	118
Cr	122	159	215	178	107	126	150	159	189	221	194	239	264	273	255	192	1578	312	446	224	221	270	301	214	229	214	222	210	238	294	311	173	140
Cu	68	<3.3	11	4	<3.33			8	16	17	7	44	31	26	25	22	29	22	18	32	30	61	25	29	27	22	27	20	26	27	23	125	146
Fe	62200	8658	13320	12654	2727	2148	3330	7659	11322	9990	5661	13653	10656	22644	17982	13320	22311	11322	18315	21312	13320	20313	21645	19314	18981	14652	18648	27639	21978	20979	20313	196470	189144
K	19	1032	1066	899	1465	1265	1199	2498	2864	2930	2631	2597	2198	1665	1898	1698	1465	1365	1532	1698	1965	2797	2231	1499	1565	1698	1399	2498	1598	2264	1565	333	266
Mg	27640	666	666	666	<333			<333			<33	333	<33	1332	666	<333	2331	333	333	1332	333	999	2331	999	999	999	1332	666	1665	666	333	999	999
Mn	1060	350	162	166	228	58	50	144	48	54	28	116	95	1718	1545	686	2537	616	892	2118	157	1802	247	235	200	288	2707	1502	4329	4329	2408	192141	183816
Mo	1.2	<8.33			<8.33			<8.33			<8.33			<8.33						<8.33									<8.3			<8.33	
Ni	99	<8.3	29	43	<8.3	13	<8.3	28	43	40	<8.3	107	102	78	88	75	152	17	131	134	84	144	105	64	84	85	123	52	128	162	143	46	48
Pb	13	13	13	13	16	15	17	30	18	27	59	81	90	82	78	183	93	242	214	141	38	49	78	31	29	53	162	48	149	513	466	1166	1029
Sb	0.2	<0.333			<0.333		0.666	0.3	0.3	0.3	0.333			<0.33	<0.33	0.333	<0.33	0.333	<0.33	<0.33	0.333	0.333	0.333	<0.33	<0.33	<0.33	<0.33	<0.33	<0.3	0.33	0.67	<0.33	
Se	0.05	<0.333			<0.333			<0.333			<0.333			<0.333						<0.333									<0.33			<0.33	

TSF		South Sand			North Sand			1L8 Dump			1L10 Dump			1L13 Dump						1L25 Dump									1L28 Dump			Manganese Slag	
Sample ID	ACA	S Sands_Z1	S Sands_Z2	S Sands_Z3	N Sands_Z1	N Sands_Z2	N Sands_Z3	1L8_Z1	1L8_Z2	1L8_Z3	1L10_Z1	1L10_Z2	1L10_Z3	1L13_A_Z1	1L13_A_Z2	1L13_A_Z3	1L13_B_Z1	1L13_B_Z2	1L13_B_Z3	1L25_A_Z1	1L25_A_Z2	1L25_A_Z3	1L25_B_Z1	1L25_B_Z2	1L25_B_Z3	1L25_C_Z1	1L25_C_Z2	1L25_C_Z3	1L28_Z1	1L28_Z2	1L28_Z3	IL28M1	IL28M2
Sn	**2.1**		<0.33		<0.3	<0.3	1.665		<0.333			<0.333				<0.33				<0.33	<0.33	<0.33	0.666	<0.33	<0.33	<0.33	<0.33	<0.33		<0.33		<0.33	
Sr	**384**	11	12	11	19	18	16	16	15	20	17	17	19	24	22	14	25	18	17	27	23	38	24	20	19	21	28	23	41	35	36	2944	2927
Ti	**6320**	1315	1362	1265	1179	1275	1162	1429	1332	1275	1359	1382	1485	1429	1462	1175	1072	1419	1349	1279	1315	1342	1142	1139	1439	1505	1136	1778	1235	1192	1215	277	293
Th	**8.1**	<8.3	<8.3	8		<8.33			<8.33			<8.33				<8.33								<8.33						<8.3		<8.33	
U	**2.3**	3	13	17	3	3	3	10	16	19	9	43	31	47	34	44	62	26	50	70	25	43	26	33	27	49	56	32	47	66	79	1	1
V	**136**		<8.33			<8.33			<8.33			<8.33		40	<8.33	<8.33	11	<8.33	<8.33					<8.33						<8.3		81	78
Zn	**76**	<8.3	47	46	<8.3	<8.3	<8.3	20	34	38	12	360	181	131	107	135	216	82	189	210	99	165	201	111	77	202	193	94	179	287	244	309	353
Ag		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	8
Al		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
As		3	4	4	2	2	1	4	4	4	4	5	4	4	5	5	4	5	5	6	5	5	4	5	5	5	6	5	6	7	7	3	3
Ba		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4
Be		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bi		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ca		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cd		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Co		1	2	1	1	2	1	2	1	1	1	1	1	1	2	1	2	1	2	2	2	1	2	2	2	1	1	1	2	2	2	1	1
Cr		0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	3	1	1	0	0	1	1	0	0	0	0	0	0	1	1	0	0
Cu		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Fe		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
K		5	5	5	6	5	5	6	7	7	7	7	6	6	6	6	6	6	6	6	6	7	6	6	6	6	6	6	6	6	6	4	3
Mg		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mn		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	1	1	7	7
Mo		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ni		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pb		0	0	0	0	0	0	1	0	0	2	2	2	2	2	3	2	4	3	3	1	1	2	1	1	1	3	1	3	5	5	6	6
Sb		0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0

TSF	South Sand			North Sand			1L8 Dump			1L10 Dump			1L13 Dump						1L25 Dump									1L28 Dump			Manganese Slag	
Sample ID ACA	S Sands_Z1	S Sands_Z2	S Sands_Z3	N Sands_Z1	N Sands_Z2	N Sands_Z3	1L8_Z1	1L8_Z2	1L8_Z3	1L10_Z1	1L10_Z2	1L10_Z3	1L13_A_Z1	1L13_A_Z2	1L13_A_Z3	1L13_B_Z1	1L13_B_Z2	1L13_B_Z3	1L25_A_Z1	1L25_A_Z2	1L25_A_Z3	1L25_B_Z1	1L25_B_Z2	1L25_B_Z3	1L25_C_Z1	1L25_C_Z2	1L25_C_Z3	1L28_Z1	1L28_Z2	1L28_Z3	IL28M1	IL28M2
Se	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
Ti	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Th	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
U	0	2	2	0	0	0	2	2	2	1	4	3	4	3	4	4	3	4	4	3	4	3	3	3	4	4	3	4	4	5	0	0
V	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zn	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	1	0	1	1	0	1	1	0	0	1	1	0	1	1	1	1	2

5.4 Leaching potential

The mobility of the metals and salts from materials is typically assessed using the leach test for solid samples. The tailings samples were subjected to deionised water leach test at 1:4 water-rock ratio.

Digby Wells has assessed the leachate quality against the General Limits for the discharge of wastewater into a water resource and the WUL Groundwater Quality Limits. It is noted that laboratory leachate tests do not directly replicate metal release under field conditions and apply only as a guide.

Table 5-4 presents a summary of the assessment of the quality of the leachates against the General Limits. The study assessed the quality of the data by balancing the reported cation and anion concentrations. An ion imbalance within ± 10% represents an acceptable level of analytical accuracy. The assessment indicates the following:

- The tailings leachate ranges from acidic to neutral (pH 2.6 – 7.7). The leachates from all the dumps and the Manganese Slag are acidic relative to the General Limits (pH 5.5 – 9.5) except dump 1L28 leachate (pH 6.4-7.0) that is neutral and within the General Limits;
- Conductivity (55 – 320 mS/m) exceeds the General and WUL Groundwater Quality Limits (150 µS/cm) in the leachates from all the dumps and the Manganese Slag except South Sands (60-124 µS/cm), North Sands (55-71 µS/cm) and 1L8 dump (89-99 µS/cm); and
- The following parameters exceed the General and WUL Groundwater Quality Limits in the tailings and Manganese Slag:
  - South Sands - pH, Fe, SO_4, and Zn;
  - North Sands - pH, Ca, and Zn;
  - 1L8 Dump - pH, Ca, Fe, Pb, SO_4, and Zn;
  - 1L10 Dump - pH, EC, Ca, Fe, Hg, Pb, SO_4, and Zn;
  - 1L13 Dump - pH, EC, B, Ca, Mn, SO_4, and Zn;
  - 1L25 Dump - pH, EC, Ca, Hg, Mn, SO_4, and Zn;
  - 1L28 Dump - EC, Ca, Mn, and SO_4; and
  - Manganese Slag - pH, EC, B, Ca, Mn, and SO_4

In summary, the leaching assessment indicates that the tailings will be acidic (pH 2.6 – 7.7). The leachates from all the dumps and the Manganese Slag are acidic relative to the General Limits (pH 5.5 – 9.5) except dump 1L28 leachate (pH 6.4-7.0). The parameters that require close monitoring include pH, EC, B, Ca, Fe, Hg, Mn, Pb, SO_4, and Zn..

Table 5-4: Deionised water leachate quality results for the tailings against the background groundwater quality

Parameters	South Sands			North Sands			1L8 Dump			1L10 Dump			1L13 Dump						1L25 Dump									1L28 Dump			Manganese Slag		General Limit (2013)	WUL (Nov 2013) Groundwater Limits
	S Sands_Z1	S Sands_Z2	S Sands_Z3	N Sands_Z1	N Sands_Z2	N Sands_Z3	1L8_Z1	1L8_Z2	1L8_Z3	1L10_Z1	1L10_Z2	1L10_Z3	1L13_A_Z1	1L13_A_Z2	1L13_A_Z3	1L13_B_Z1	1L13_B_Z2	1L13_B_Z3	1L25_A_Z1	1L25_A_Z2	1L25_A_Z3	1L25_B_Z1	1L25_B_Z2	1L25_B_Z3	1L25_C_Z1	1L25_C_Z2	1L25_C_Z3	1L28_Z1	1L28_Z2	1L28_Z3	IL28 M1	IL28 M2		
Physicochemical Parameters in mg/L except EC at uS/cm and pH without unit																																		
pH	4.4	3.7	3.3	5.6	4.6	4.4	3.3	4.4	6.6	2.6	3.2	7.5	6.7	6.9	6.6	4.9	6.4	6.2	6.3	4.7	6.6	7.0	5.2	7.0	7.2	7.2	7.2	7.0	6.5	6.4	4.6	4.6	5.5-9.5	9,5-10
EC	60	99	124	71	60	55	93	89	99	309	306	156	242	192	231	320	186	196	256	144	236	245	174	179	299	241	247	257	248	238	226	232	150	150
Alkalinity		<5		<5	8	<5	<5	<5	16	<5	<5	52	28	24	16	12	16	16	16	<5	16	40	8	20	52	20	32	20	12	8.0	8.0	8.0	Ns	
TDS	430	808	1,008	526	434	382	652	694	802	3,168	3,514	1,468	2,500	1,898	2,310	3,714	1,810	1,936	2,726	1,346	2,368	2,496	1,688	1,702	3,142	2,516	2,420	2,676	2,506	2,390	2,312	2,384	Ns	
Inorganic Anions in mg/L																																		
Cl		<2			<2		<2	<2	6.0	2.0	2.0	19	4.0	6.0	5.0	2.0	<2	3.0	4.0	5.0	5.0	5.0	6.0	6.0	548	7.0	5.0	4.0	7.0	6.0	<2	<2	Ns	
SO_4	269	516	667	325	272	234	404	423	485	1,967	2,191	842	1,502	1,156	1,391	2,234	1,097	1,168	1,653	809	1,451	1,505	1,070	1,041	1,979	1,500	1,513	1,629	1,559	1,454	1,417	1,452	Ns	400
NO_3-N	0.20	<0.1	<0.1	<0.1	0.10	<0.1	0.10	0.10	0.20	0.10	0.10	<0.1	<0.1	0.10	<0.1	<0.1	<0.1	<0.1	<0.1	0.20	0.10	<0.1	<0.1	<0.1	0.20	<0.1	0.10		<0.1		2.0	4.2	15	15
F		<0.2			<0.2			<0.2			<0.2		<0.2	0.20	<0.2	0.20	0.20	0.20	0.20	0.20	0.40	0.30	0.30	0.30	0.30	0.40	0.40	0.40	0.60	0.50	0.30	0.20	1.0	1.0
Metals and Metalloids in mg/L and ionic balance in %																																		
Ag		<0.025			<0.025			<0.025			<0.025		<0.025	<0.025	<0.025	0.07	<0.025	<0.025					<0.025						<0.025		<0.025		Ns	
Al	<0.100	29	44		<0.100		28	<0.100	<0.100	151	112	<0.100			<0.100								<0.100						<0.100		<0.100		Ns	
As	0.0013	0.0071	0.011		<0.001		0.01	<0.001	0.0015	0.02	0.005	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	0	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001		0.02	
B		<0.025			<0.025			<0.025		<0.025	0.04	0.07	0.99	0.61	0.12	1.2	0.23	0.22	0.14	<0.025	0.29	0.036	<0.025	<0.025	0.046	0.12	0.38	0.96	0.32	0.17	12	2.2	1.0	
Ba		<0.025			<0.025			<0.025			<0.025				<0.025								<0.025					<0.025	<0.025	0.046	<0.025		Ns	
Be		<0.025			<0.025			<0.025			<0.025				<0.025								<0.025						<0.025		0.19	<0.025	Ns	
Bi		<0.025			<0.025			<0.025			<0.025				<0.025								<0.025					<0.025	<0.025	0.040	4.9	<0.025	Ns	
Ca	107	109	104	142	188	103	66	166	205	177	491	362	557	410	585	522	519	527	563	318	824	571	451	459	620	633	637	545	457	629	422	623	Ns	150
Cd	<0.001	0.0023	0.003		<0.001		0.0	0.0015	<0.001	0.003	0.009	<0.001			<0.001								<0.001						<0.001		<0.001		0.005	
Co	0.041	0.76	1.2		<0.025		1.36	1.1	0.24	2.4	4.9	0.14	0.67	0.03	0.16	1.9	0.42	0.41	0.73	1.0	0.33	0.19	0.28	0.05	0.41	<0.025	0.26	0.22	0.08	0.071	0.23	<0.025	Ns	
Cr total	<0.025	0.085	0.19		<0.025		0.18	<0.025	<0.025	2.0	0.24	<0.025	0	<0.025	<0.025	0	<0.025	0	0	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.08	0.04	0.032	0.99	<0.025	0.05	
Cr (VI)		<0.010			<0.010		0.01	<0.010	<0.010	0.023	0.023	<0.010			<0.010								<0.010						<0.010		<0.010		Ns	
Cu	<0.010	1.1	0.46		<0.010		1.7	0.12	<0.010	5.1	4.5	<0.010	<0.010	<0.010	<0.010	0.013	<0.010	<0.010	<0.010	0	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.26	0.32	<0.010	0.01	
Fe	0.062	13	37	<0.025	<0.025	0.070	26	0.21	<0.025	221	122	0.065	<0.025	<0.025	<0.025	0.052	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.051	0.048	0.030	<0.025	<0.025	0.050	0.029	<0.025	0.3	
Hg	<0.001	<0.001	<0.001		<0.001		<0.001	<0.001	0.003	<0.001	<0.001	0.010			<0.001				0.0016	<0.001	<0.001	0.0012	<0.001	<0.001	0.006	<0.001	<0.001	<0.001	0.002	<0.001	<0.001		0.005	
K	0.83	<0.5	<0.5	1.0	1.5	1.3	<0.5	3.2	7.3	<0.5	0.7	3.5	5.7	7.0	6.6	1.6	3.1	4.0	2.2	6.4	10	5.7	5.8	4.1	5.5	4.7	12	5.8	9.1	10	0.56	1.5	Ns	

Parameters	South Sands			North Sands			1L8 Dump			1L10 Dump			1L13 Dump						1L25 Dump									1L28 Dump			Manganese Slag		General Limit (2013)	WUL (Nov 2013) Groundwater Limits
	S Sands_Z1	S Sands_Z2	S Sands_Z3	N Sands_Z1	N Sands_Z2	N Sands_Z3	1L8_Z1	1L8_Z2	1L8_Z3	1L10_Z1	1L10_Z2	1L10_Z3	1L13_A_Z1	1L13_A_Z2	1L13_A_Z3	1L13_B_Z1	1L13_B_Z2	1L13_B_Z3	1L25_A_Z1	1L25_A_Z2	1L25_A_Z3	1L25_B_Z1	1L25_B_Z2	1L25_B_Z3	1L25_C_Z1	1L25_C_Z2	1L25_C_Z3	1L28_Z1	1L28_Z2	1L28_Z3	IL28 M1	IL28 M2		
Mg	4.0	15	22	1.0	2.0	<1	6.0	11	5.0	51	67	12	38	21	6.0	78	12	10	54	9.0	23	75	15	8.0	210	17	24	33	27	13	1.0	3.0	Ns	100
Mn	3.0	7.5	4.4	0.72	0.89	0.70	5.3	2.7	1.3	1.5	6.2	0.91	79	36	19	361	39	47	98	13	22.0	3.7	3.0	1.3	19	0.078	27	96	69	58	0.23	67	0.10	
Mo		<0.025			<0.025			<0.025			<0.025				<0.025								<0.025						<0.025		<0.025		Ns	
Na	1.0	<1	<1	2.0	2.0	1.0	<1	2.0	6.0	<1	2.0	13	6.0	7.0	9.0	3.0	2.0	2.0	3.0	8.0	6.0	3.0	4.0	4.0	3.0	4.0	7.0	10	8.0	11	3.0	6.0	Ns	200
Ni	0.21	2.7	4.2	0.077	0.17	0.13	4.3	3.8	1.1	5.5	15	0.46	3.0	0.16	0.42	9.1	0.47	1.9	3.6	4.5	1.4	0.61	1.7	0.17	1.9	<0.025	0.10	0.60	0.19	0.22	<0.025		Ns	
P		<0.025			<0.025		<0.025	<0.025	<0.025		<0.025		<0.025	0	<0.025	0	<0.025	<0.025	0.059	<0.025	<0.025	0.026	<0.025	<0.025	0.072	0.027	<0.025	<0.025	0.031	0.036	<0.025		Ns	
Pb		<0.001			<0.001		0.019	0.002	<0.001	<0.001	0.47	<0.001	<0.001	<0.001	0.002	0.029	0.002	0.005	0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.002	<0.001		0.01	
Sb		<0.001			<0.001			<0.001			<0.001				<0.001								<0.001						<0.001		<0.001		Ns	
Se		<0.001			<0.001			<0.001			<0.001				<0.001								<0.001						<0.001		<0.001		0.02	
Si	1.6	1.6	1.3	2.0	2.1	1.3	2.6	4.6	4.6	2.9	10	6.3	7.9	3.6	4.0	7.4	5.2	6.6	6.3	5.5	4.0	3.6	4.3	3.9	6.0	<0.2	5.4	6.4	3.0	4.1	6.4	<0.2	Ns	
Sn		<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001					<0.001						<0.001		<0.001		Ns	
Sr	0.14	0.07	0.050	0.25	0.19	0.12	0.007	0.17	0.18	0.07	0.31	0.21	1	1	0	1	0	0	0.78	0.21	0.78	0.39	0.24	0.18	0.27	0.54	0.65	0.75	0.55	0.72	3.8	3.8	Ns	
Th	<0.001	0.005	0.031		<0.001		0.01	<0.001	0.0015	0.35	0.11	<0.001			<0.001								<0.001						<0.001		<0.001		Ns	
Ti		<0.025			<0.025			<0.025			<0.025				<0.025								<0.025						<0.025		3.1	<0.025	Ns	
Tl		<0.025			<0.025			<0.025			<0.025				<0.025								<0.025					<0.025	<0.025	0.19	33	0.035	Ns	
U	0.001	0.76	2.2	0.001	<0.001	<0.001	1.1	0.19	0.006	1.7	6.0	0.6	0.058	0.11	0.02	0.46	0.002	0.002	0.02	0.007	0.01	0.05	0.002	0.09	0.65	0.11	0.16	0.06	0.005	0.005	<0.001		Ns	
V		<0.025			<0.025			<0.025			<0.025		0.030	<0.025	<0.025	0.10	<0.025	<0.025	0.04				<0.025					0.04	<0.025	0.043	<0.025	0.021	0-0.1	
Zn	0.21	0.73	2.1	<0.025	0.38	<0.025	4.1	2.8	0.15	3.5	30	0.047	0.68	<0.025	0.044	11	0.058	0.22	0.60	2.0	0.053	0.074	0.23	<0.025	0.37	<0.025	<0.025	0.03	<0.025	<0.025	<0.025		0.1	
Ion Balance	99	97	67	97	77	97	61	97	99	97	79	97	98	97	99	97	93	97	96	97	83	96	97	97	97	98	97	93	97	96	97	99		

5.5 Tailings Classification

The study assessed the liner requirements for the material against the N&S for the Assessment of Waste for Landfill Disposal and the N&S for Disposal of Waste to Landfills.

The type of waste was determined by comparing the TC and LC of the elements and chemical substances in the waste with the Total Concentration Threshold (TCT) and Leachate Concentration Threshold (LCT) limits. Based on the TC and LC limits of the elements and chemical substances in the materials exceeding the corresponding TCT and LCT limits respectively, the waste type and the landfill disposal requirements were determined. For this study, the leachate water/rock ratio is 20:1 for both DI and borax leachate tests.

5.5.1 Total Concentration Threshold

Table 5-6 present a summary of the assessment of total concentrations against the TCT. The assessment indicates the following for the total leachable concentration:

The following parameters exceed the TCT0 in the tailings and Manganese Slag:

- South Sands -As, Co and Hg;
- North Sands – As; Co and Hg;
- 1L8 Dump - As, Co, Cu, Hg and Pb;
- 1L10 Dump - As, Co, Cu, Hg, Ni, Pb and Zn;
- 1L13 Dump - As, Ba, Co, Cu, Hg, Mn, Ni and Pb;
- 1L25 Dump - As, Ba, Co, Cu, Hg Mn, Ni and Pb;
- 1L28 Dump - As, Ba, Co, Cu, Hg, Mn, Ni, Pb and Zn; and
- Manganese Slag - As, Co, Cu, Hg, Pb and Zn.

The following parameters exceed the TCT1 and TCT2 in the Manganese Slag:

- Barium greater than TCT1 guideline at 7 326 mg/kg; and
- Manganese above the TCT2 guideline with concentrations of 183 816 and 192 141 mg/kg.

5.5.2 Leachable Concentration Threshold

A high ionic charge balance is observed in samples N Sands_Z2 and N Sands_Z3 from North Sands TSF and 1L10_Z2 from 1L10 TSF at 56.90%, 31.15% and 31.15 % respectively. The deviation from < 10% ion imbalance requirement is because the leachates are acid waters in which H^+ is the major cation but cannot be introduced directly into the charge balance from the pH measurements resulting in less cations. To achieve a proper charge balance, the activity coefficient for H+ must be used to convert pH to H+ equivalents.

The type of waste was determined by comparing the TC and LC of the elements and chemical substances in the waste with the Total Concentration Threshold (TCT) and Leachate Concentration Threshold (LCT) limits.

Deionised water leachable concentrations

Table 5-7 presents a summary of the assessment of deionised water leachable concentrations. The assessment indicates the following for the leachable concentrations above the LCT0 but below LCT1:

- South Sands – SO_4, As, Co, Cr total, Mn and Ni;
- North Sands – TDS, SO_4, Cd, Co Cr total, Cr(VI), Cu, Mn, Ni and Zn;
- 1L8 Dump – TDS, SO_4, B, Co, Mn, Ni, Pb and Zn;
- 1L10 Dump – TDS, SO_4, Cd, Co, Cr total, Cu, Hg, Ni, and Pb;
- 1L13 Dump – TDS, SO_4, B, Ba, Co, Hg, Mn, Ni and V;
- 1L25 Dump – TDS, SO_4, Ba, Co, Hg Mn and Ni;
- 1L28 Dump – TDS, SO_4, Ba, Hg and Ni; and
- Manganese Slag – TDS, SO_4 and B.

The assessment indicates the following for the leachable concentrations above the LCT1 but below LCT2:

- 1L8 Dump – Mn;
- 1L13 Dump – Mn and Ni;
- 1L25 Dump – Mn;
- 1L28 Dump – Mn; and
- Manganese Slag – Mn.

The assessment indicates the following for the leachable concentrations above the LCT2 but below LCT3:

- North Sands – Ni; and
- 1L13 Dump – Ni.

Borax leachable concentrations

Table 5-8 presents a summary of the assessment of Borax leachable concentrations. The assessment indicates the following for the borax water above the LCT0 but below LCT1:

- South Sands – SO_4, As and Pb ;
- North Sands – As, Mo and Pb;
- 1L8 Dump – SO_4, As, Hg, Mo, Ni, Pb and Se;

- 1L10 Dump – SO_4, As, Hg, Mo, Ni, Pb and Se;
- 1L13 Dump – SO_4, As, Hg, Mn and Pb;
- 1L25 Dump – SO_4, As, Hg Mn, Ni and Pb;
- 1L28 Dump – TDS, SO_4, As, Mn and Mo; and
- Manganese Slag – TDS, SO_4 and Mo.

Based on the TC and LC limits of the elements and chemical substances in the materials exceeding the corresponding TCT and LCT limits respectively, the waste type for the tailings from the different facilities are as summarised in Table 5-5.

Table 5-5: Overall waste classification for tailings

TSF	Overall Type of Waste
South Sands	Type 3
North Sands	Type 1
1L8 Dump	Type 2
1L10 Dump	Type 1
1L13 Dump	Type 1
1L25 Dump	Type 2
1L28 Dump	Type 2
Manganese Slag	Type 1

Table 5-6: Total concentrations in mg/kg for the tailings against the TCT

Elements substances in tails		As	B	Ba	Cd	Co	Cr total	Cr (VI)	CN total	Cu	F	Hg	Mn	Mo	Ni	Pb	Sb	Se	V	Zn
Leachable Concentrations Threshold (mg/l)	**TCT0**	5.8	150	62.5	7.5	50	46000	6.5	14	16	100	0.93	1000	40	91	20	10	10	150	240
	TCT1	500	15000	6250	260	5000	800000	500	10500	19500	10000	160	25000	1000	10600	1900	75	50	2680	160000
	TCT2	2000	6000	25000	1040	20000	N/A	2000	42000	78000	40000	640	100000	4000	42400	7600	300	200	10720	640000
South Sand	S Sands_Z1	25	<8.33	26.6	<0.333	78	159	<2	<1.55	<3.33	1.57	5.33	350	<8.33	<8.33	13	<0.333	<0.333	<8.33	<8.33
	S Sands_Z2	47	<8.33	25.0	<0.333	147	215	<2	<1.55	11	<0.5	6.99	162	<8.33	28.6	13	<0.333	<0.333	<8.33	46.95
	S Sands_Z3	38.30	<8.33	19.65	<0.333	110.22	178	2	<1.55	4.33	<0.5	5.66	166	<8.33	43.3	13	<0.333	<0.333	<8.33	45.95
North Sand	N Sands_Z1	7.7	<8.33	47.95	<0.333	86.25	107	<5	<1.55	<3.33	<0.5	4.66	228	<8.33	<8.33	16	<0.333	<0.333	<8.33	<8.33
	N Sands_Z2	8	15.0	30.6	<0.333	169	126	<2	<1.55	<3.33	1.22	8.66	58.3	<8.33	13	15.3	<0.333	<0.333	<8.33	<8.33
	N Sands_Z3	5.66	<8.33	27.0	<0.333	88.58	150	<2	<1.55	<3.33	<0.5	4.66	50	<8.33	<8.33	17	1	<0.333	<8.33	<8.33
1L8 Dump	1L8_Z1	36	8.3	41.63	<0.333	124	159	<2	<1.55	7.99	<0.5	5.33	144	<8.33	28	30	0.333	<0.333	<8.33	20
	1L8_Z2	53.95	<8.33	45.95	<0.333	94.91	189	<2	<1.55	15.98	1.31	3.00	48	<8.33	43	18	0.333	<0.333	<8.33	33.6
	1L8_Z3	49	<8.33	50.62	<0.333	67.6	221	<2	<1.55	17	0.96	2.33	54.3	<8.33	40	27	0.3	<0.333	<8.33	38
1L10 Dump	1L10_Z1	40	<8.33	41.96	<0.333	71.3	194	<2	<1.55	6.66	<0.5	2.66	28	<8.33	<8.33	59	0.3	<0.333	<8.33	12
	1L10_Z2	69	<8.33	46.62	0.33	78	239	<2	<1.55	44	<0.5	1.33	116	<8.33	107	81	<0.333	<0.333	<8.33	360
	1L10_Z3	57.28	21.0	44.62	0.33	108.23	264	<2	<1.55	31	0.73	3.00	94.9	<8.33	102	90	0.333	<0.333	<8.33	181
1L13 Dump	1L13_A_Z1	60	12.0	151	<0.333	100.2	273	<2	<1.55	26	2.40	2.33	1718	<8.33	78	82	<0.333	<0.333	40.29	131
	1L13_A_Z2	75	35.3	95	<0.333	142	255	<2	<1.55	25	0.70	4.33	1545.12	<8.33	88	78	<0.333	<0.333	<8.33	107
	1L13_A_Z3	96	<8.33	54	0.33	103	192	<2	<1.55	22	<0.5	2.66	686	<8.33	75	183	0.33	<0.333	<8.33	135
	1L13_B_Z1	58.28	10.3	114.22	<0.333	128.87	1578	<2	<1.55	29	<0.5	4.00	2537.5	<8.33	152	93	<0.333	<0.333	11.0	216
	1L13_B_Z2	76.26	25.0	54.61	<0.333	120.88	312	<2	<1.55	22	0.55	3.66	616	<8.33	17	242	0.3	<0.333	<8.33	82
	1L13_B_Z3	108	<8.33	73	0.33	147	446	<2	<1.55	18	0.58	4.00	892	<8.33	131	214	<0.333	<0.333	<8.33	189
1L25 Dump	1L25_A_Z1	143.86	<8.33	92.57	<0.333	172.49	224	<2	<1.55	32	1.26	4.00	2118	<8.33	134	141	<0.333	<0.333	<8.33	210
	1L25_A_Z2	76	26.3	42.3	<0.333	198	221	<2	<1.55	30	0.56	6.33	157	<8.33	84	38	0.333	<0.333	<8.33	99
	1L25_A_Z3	93	21.0	89	<0.333	121	270	<2	<1.55	61	0.62	2.00	1802	<8.33	144	49	0.3	<0.333	<8.33	165
	1L25_B_Z1	58	16.3	53	<0.333	144	301	<2	<1.55	25	<0.5	4.00	247	<8.33	105	78	0.3	<0.333	<8.33	201
	1L25_B_Z2	94	<8.33	41	<0.333	153	214	<2	<1.55	29	<0.5	3.66	235	<8.33	64	31	<0.333	<0.333	<8.33	111
	1L25_B_Z3	101	18.6	39.3	<0.333	144	229	<2	<1.55	27	<0.5	4.66	200	<8.33	84	29	<0.333	<0.333	<8.33	77
	1L25_C_Z1	63.27	19.3	38.63	<0.333	118.88	214	<2	<1.55	22	<0.5	3.00	288	<8.33	85	53	<0.333	<0.333	<8.33	202
	1L25_C_Z2	153	<8.33	109	<0.333	113	222	<2	<1.55	27	<0.5	3.00	2707	<8.33	123	162	<0.333	<0.333	<8.33	193
	1L25_C_Z3	81	<8.33	109	<0.333	87	210	<2	<1.55	20	1.83	2.00	1502	<8.33	52	48	<0.333	<0.333	<8.33	94
1L28 Dump	1L28_Z1	166.2	13.7	180	<0.333	175	238	<2	<1.55	26	<0.5	5.00	4329.0	<8.33	128	149	<0.333	<0.333	<8.33	179
	1L28_Z2	336.33	22.6	141.86	0.33	226.11	294	<2	<1.55	27	<0.5	5.33	4329	<8.33	162	513	0.3	<0.333	<8.33	287
	1L28_Z3	449.55	10.0	97.57	<0.333	144.86	311	<2	<1.55	23	<0.5	3.00	2407.6	<8.33	143	466	0.666	<0.333	<8.33	244
	IL 28 M1	20.979	14.7	7326	<0.333	102.564	173	<2	<1.55	125	<0.5	<0.333	192141	<8.33	46	1166	<0.333	<0.333	81	309
	IL 28 M2	21.645	16.7	7326	<0.333	117.549	140	<2	<1.55	146	<0.5	<0.333	183816	<8.33	48	1029	<0.333	<0.333	78	353

Table 5-7: Deionised water leachable concentration results for the tailings against the LCT

Elements & Chemical substances in waste		ASLP (20:1) - Reagent water pH 7.0																						
		Inorganic Anions (mg/L)						Metal Ions (mg/L)																
		TDS	Cl	SO_4	NO_3-N	F	CN total	As	B	Ba	Cd	Co	Cr total	Cr(VI)	Cu	Hg	Mn	Mo	Ni	Pb	Sb	Se	V	Zn
Leachable Concentrations Threshold (mg/l)	LCT0 mg/l	1000	300	250	11	1.5	0.07	0.01	0.5	0.7	0.003	0.5	0.1	0.05	2	0.006	0.5	0.07	0.07	0.01	0.02	0.01	0.2	5
	LCT1 mg/l	12500	15000	12500	550	75	3.5	0.5	25	35	0.15	25	5	2.5	100	0.3	25	3.5	3.5	0.5	1	0.5	10	250
	LCT2 mg/l	25000	30000	25000	1100	150	7	1	50	70	0.3	50	10	5	200	0.6	50	7	7	1	2	1	20	500
South Sand	S Sands_Z1	196	<2	130	<0.1	<0.2	<0.07	<0.001	<0.025	<0.025	<0.001	<0.025	<0.025	<0.010	<0.010	<0.001	0.34	<0.025	0.066	<0.001	<0.001	<0.001	<0.025	<0.025
	S Sands_Z2	408	<2	278	<0.1	<0.2	<0.07	0.015	<0.025	<0.025	0.0046	0.76	0.11	<0.010	1.4	<0.001	2.9	<0.025	2.4	0.007	<0.001	<0.001	<0.025	1.927
	S Sands_Z3	310	2.0	195	<0.1	<0.2	<0.07	0.0010	<0.025	<0.025	<0.001	0.15	<0.025	<0.010	<0.010	<0.001	0.59	<0.025	0.70	<0.001	<0.001	<0.001	<0.025	0.149
North Sand	N Sands_Z1	442	3.0	281	<0.1	<0.2	<0.07	0.0018	<0.025	<0.025	<0.001	0.16	<0.025	<0.010	<0.010	<0.001	0.69	<0.025	0.75	<0.001	<0.001	<0.001	<0.025	0.172
	N Sands_Z2	1,842	<2	1,281	<0.1	<0.2	<0.07	0.0080	<0.025	<0.025	0.003	1.4	1.095	0.072	3.4	<0.001	0.85	<0.025	3.4	0.001	<0.001	<0.001	<0.025	2.164
	N Sands_Z3	1,994	<2	1,356	<0.1	<0.2	<0.07	0.0088	<0.025	<0.025	0.012	2.7	0.122	0.020	3.6	<0.001	2.6	<0.025	7.9	0.11	<0.001	<0.001	<0.025	20
1L8 Dump	1L8_Z1	1,336	4.0	882	<0.1	<0.2	<0.07	0.0012	0.074	<0.025	0.0050	1.0	<0.025	<0.010	0.359	<0.001	2.7	<0.025	3.0	0.16	<0.001	<0.001	<0.025	5.5
	1L8_Z2	1,362	2.0	812	<0.1	<0.2	<0.07	<0.001	0.57	0.025	<0.001	0.24	<0.025	<0.010	<0.010	<0.001	39	<0.025	1.1	<0.001	<0.001	<0.001	<0.025	0.200
	1L8_Z3	990	3.0	655	<0.1	<0.2	<0.07	0.0018	0.34	0.031	<0.001	<0.025	<0.025	<0.010	<0.010	<0.001	20	<0.025	0.09	<0.001	<0.001	<0.001	<0.025	<0.025
1L10 Dump	1L10_Z1	1,202	3.0	774	<0.1	<0.2	<0.07	0.0023	0.081	<0.025	<0.001	0.12	<0.025	<0.010	<0.010	<0.001	13	<0.025	0.26	0.001	<0.001	<0.001	<0.025	0.035
	1L10_Z2	1,994	<2	1,356	<0.1	<0.2	<0.07	0.0088	<0.025	<0.025	0.012	2.7	0.12	0.020	3.6	<0.001	2.6	<0.025	7.9	0.11	<0.001	<0.001	<0.025	20
	1L10_Z3	1,336	4.0	882	<0.1	<0.2	<0.07	0.0012	0.074	<0.025	0.0050	1.0	<0.025	<0.010	0.36	<0.001	2.7	<0.025	3.0	0.16	<0.001	<0.001	<0.025	5.5
1L13 Dump	1L13_A_Z1	1,362	2.0	812	<0.1	<0.2	<0.07	<0.001	0.57	0.025	<0.001	0.24	<0.025	<0.010	<0.010	<0.001	39	<0.025	1.1	<0.001	<0.001	<0.001	<0.025	0.20
	1L13_A_Z2	990	3.0	655	<0.1	<0.2	<0.07	0.0018	0.34	0.031	<0.001	<0.025	<0.025	<0.010	<0.010	<0.001	20	<0.025	0.090	<0.001	<0.001	<0.001	<0.025	<0.025
	1L13_A_Z3	1,202	3.0	774	<0.1	<0.2	<0.07	0.0023	0.081	<0.025	<0.001	0.12	<0.025	<0.010	<0.010	<0.001	13	<0.025	0.26	0.001	<0.001	<0.001	<0.025	0.035
	1L13_B_Z1	2,114	2.0	1,371	<0.1	<0.2	<0.07	<0.001	0.83	<0.025	0.0021	1.42	0.066	0.037	<0.010	<0.001	164	<0.025	5.0	0.010	<0.001	<0.001	0.027	4.9
	1L13_B_Z2	924	<2	613	<0.1	<0.2	<0.07	0.0014	0.12	<0.025	<0.001	0.28	<0.025	<0.010	<0.010	<0.001	20	<0.025	0.32	0.001	<0.001	<0.001	<0.025	0.060
	1L13_B_Z3	930	2	612	<0.1	<0.2	<0.07	0.0051	0.10	<0.025	<0.001	0.16	<0.025	<0.010	<0.010	<0.001	17	<0.025	0.72	0.004	<0.001	<0.001	<0.025	0.080
1L25 Dump	1L25_A_Z1	2,446	3.0	1,629	<0.1	<0.2	<0.07	<0.001	0.13	<0.025	<0.001	0.35	<0.025	<0.010	<0.010	<0.001	44	<0.025	1.7	<0.001	<0.001	<0.001	<0.025	0.27
	1L25_A_Z2	694	4.0	473	<0.1	<0.2	<0.07	0.0018	<0.025	<0.025	0.001	0.59	<0.025	<0.010	0.023	<0.001	5.8	<0.025	2.1	0.002	<0.001	<0.001	<0.025	1.5
	1L25_A_Z3	1,762	3.0	1,168	<0.1	0.20	<0.07	<0.001	0.21	<0.025	<0.001	0.12	<0.025	<0.010	<0.010	<0.001	11	<0.025	0.45	<0.001	<0.001	<0.001	<0.025	0.028
	1L25_B_Z1	2,334	3.0	1,547	<0.1	<0.2	<0.07	<0.001	0.026	<0.025	<0.001	0.096	<0.025	<0.010	<0.010	<0.001	2.3	<0.025	0.35	<0.001	<0.001	<0.001	<0.025	0.036
	1L25_B_Z2	982	5.0	651	<0.1	<0.2	<0.07	0.0011	<0.025	<0.025	<0.001	0.16	<0.025	<0.010	<0.010	<0.001	1.7	<0.025	0.84	<0.001	<0.001	<0.001	<0.025	0.12
	1L25_B_Z3	870	4.0	573	<0.1	0.20	<0.07	0.0013	<0.025	<0.025	<0.001	<0.025	<0.025	<0.010	<0.010	<0.001	0.63	<0.025	0.054	<0.001	<0.001	<0.001	<0.025	0.022
	1L25_C_Z1	2,306	3.0	1,524	<0.1	<0.2	<0.07	<0.001	0.027	<0.025	<0.001	0.20	<0.025	<0.010	<0.010	<0.001	9.3	<0.025	0.82	<0.001	<0.001	<0.001	<0.025	0.18
	1L25_C_Z2	2,592	3.0	1,708	<0.1	0.20	<0.07	<0.001	0.076	<0.025	<0.001	0.060	<0.025	<0.010	<0.010	<0.001	28	<0.025	0.08	<0.001	<0.001	<0.001	<0.025	<0.025
	1L25_C_Z3	1,444	2.0	964	<0.1	0.20	<0.07	<0.001	0.22	0.026	<0.001	0.14	<0.025	<0.010	<0.010	<0.001	14	<0.025	0.06	<0.001	<0.001	<0.001	<0.025	<0.025
1L28 Dump	1L28_Z1	2,460	3.0	1,628	<0.1	0.20	<0.07	<0.001	0.41	<0.025	<0.001	0.085	<0.025	<0.010	<0.010	<0.001	45	<0.025	0.14	<0.001	<0.001	<0.001	<0.025	<0.025
	1L28_Z2	2,404	5.0	1,601	<0.1	0.30	<0.07	<0.001	0.18	<0.025	<0.001	0.032	<0.025	<0.010	<0.010	<0.001	36	<0.025	0.13	<0.001	<0.001	<0.001	<0.025	<0.025
	1L28_Z3	2,332	3.0	1,540	<0.1	0.30	<0.07	<0.001	0.087	<0.025	<0.001	0.047	<0.025	<0.010	<0.010	<0.001	30	<0.025	0.15	0.002	<0.001	<0.001	<0.025	<0.025
	IL 28 M1	2,294	<2	1,514	1.4	<0.2	<0.07	<0.001	0.60	0.026	<0.001	<0.025	<0.025	<0.010	<0.010	<0.001	29	<0.025	0.038	0.003	<0.001	<0.001	<0.025	<0.025
	IL 28 M2	2,318	<2	1,526	2.4	<0.2	<0.07	<0.001	1.0	<0.025	<0.001	<0.025	<0.025	<0.010	<0.010	<0.001	41	<0.025	0.046	<0.001	<0.001	<0.001	<0.025	<0.025

Table 5-8: Borax water leachable concentration results for the tailings against the LCT

Elements & Chemical substances in waste		ASLP (20:1) - Tetraborate pH 8.5																						
		Inorganic Anions (mg/L)						Metal Ions (mg/L)																
		TDS	Cl	SO_4	NO_3-N	F	CN total	As	B	Ba	Cd	Co	Cr total	Cr(VI)	Cu	Hg	Mn	Mo	Ni	Pb	Sb	Se	V	Zn
Leachable Concentrations Threshold (mg/l)	LCT0 mg/l	1000	300	250	11	1.5	0.07	0.01	0.5	0.7	0.003	0.5	0.1	0.05	2	0.006	0.5	0.07	0.07	0.01	0.02	0.01	0.2	5
	LCT1 mg/l	12500	15000	12500	550	75	3.5	0.5	25	35	0.15	25	5	2.5	100	0.3	25	3.5	3.5	0.5	1	0.5	10	250
	LCT2 mg/l	25000	30000	25000	1100	150	7	1	50	70	0.3	50	10	5	200	0.6	50	7	7	1	2	1	20	500
South Sand	S Sands_Z1	47	<50	216	<10	<1.00	<0.07	0.078	UTD	<0.070	<0.003	<0.400	<0.003	<0.020	<1.00	<0.006	<0.500	<0.070	<0.070	0.013	<0.020	<0.010	<0.200	<2.00
	S Sands_Z2	80	<50	456	<10	1.1	<0.07	0.13	UTD	<0.070	<0.003	<0.400	0.009	<0.020	<1.00	<0.006	<0.500	<0.070	<0.070	0.044	<0.020	<0.010	<0.200	<2.00
	S Sands_Z3	107	<50	552	<10	1.2	<0.07	0.091	UTD	<0.070	<0.003	<0.400	<0.003	<0.020	<1.00	<0.006	<0.500	<0.070	<0.070	0.023	<0.020	<0.010	<0.200	<2.00
North Sand	N Sands_Z1	107	<50	<50.0	<10	<1.00	<0.07	0.011	UTD	0.19	<0.003	<0.400	<0.003	<0.020	<1.00	<0.006	<0.500	0.075	<0.070	0.048	<0.020	<0.010	<0.200	<2.00
	N Sands_Z2	67	<50	100	<10	<1.00	<0.07	0.022	UTD	<0.070	<0.003	<0.400	<0.003	<0.020	<1.00	<0.006	<0.500	0.076	<0.070	0.031	<0.020	<0.010	<0.200	<2.00
	N Sands_Z3	40	<50	<50.0	<10	<1.00	<0.07	<0.010	UTD	<0.070	<0.003	<0.400	<0.003	<0.020	<1.00	<0.006	<0.500	<0.070	<0.070	0.051	<0.020	<0.010	<0.200	<2.00
1L8 Dump	1L8_Z1	54	<50	438	<10	1.3	<0.07	0.26	UTD	<0.070	<0.003	<0.400	<0.003	<0.020	<1.00	0.016	<0.500	<0.070	<0.070	0.041	<0.020	0.027	<0.200	<2.00
	1L8_Z2	80	<50	325	<10	<1.00	<0.07	0.17	UTD	<0.070	<0.003	<0.400	<0.003	<0.020	<1.00	0.010	<0.500	<0.070	<0.070	0.081	<0.020	0.014	<0.200	<2.00
	1L8_Z3	141	<50	432	<10	<1.00	<0.07	0.23	UTD	<0.070	<0.003	<0.400	<0.003	<0.020	<1.00	0.008	<0.500	0.080	<0.070	0.036	<0.020	0.013	<0.200	<2.00
1L10 Dump	1L10_Z1	369	<50	998	<10	1.1	<0.07	0.23	UTD	<0.070	<0.003	<0.400	0.040	0.043	<1.00	0.008	<0.500	0.085	0.085	0.013	<0.020	0.011	<0.200	<2.00
	1L10_Z2	415	<50	1,217	<10	<1.00	<0.07	0.13	UTD	<0.070	<0.003	<0.400	<0.003	<0.020	<1.00	0.007	<0.500	0.081	<0.070	0.076	<0.020	<0.010	<0.200	<2.00
	1L10_Z3	161	<50	766	<10	<1.00	<0.07	0.32	UTD	<0.070	<0.003	<0.400	<0.003	<0.020	<1.00	0.007	<0.500	0.11	<0.070	0.066	<0.020	0.011	<0.200	<2.00
1L13 Dump	1L13_A_Z1	308	<50	902	<10	<1.00	<0.07	0.088	UTD	0.12	<0.003	<0.400	<0.003	<0.020	<1.00	<0.006	4.8	<0.070	<0.070	0.027	<0.020	<0.010	<0.200	<2.00
	1L13_A_Z2	255	<50	851	<10	<1.00	<0.07	0.18	UTD	0.14	<0.003	<0.400	<0.003	<0.020	<1.00	<0.006	4.9	<0.070	<0.070	0.054	<0.020	<0.010	<0.200	<2.00
	1L13_A_Z3	261	<50	986	<10	<1.00	<0.07	0.19	UTD	<0.070	<0.003	<0.400	<0.003	<0.020	<1.00	<0.006	1.4	<0.070	<0.070	0.054	<0.020	<0.010	<0.200	<2.00
	1L13_B_Z1	449	<50	1,351	<10	<1.00	<0.07	0.036	UTD	<0.070	<0.003	<0.400	<0.003	<0.020	<1.00	<0.006	17	<0.070	<0.070	0.054	<0.020	<0.010	<0.200	<2.00
	1L13_B_Z2	201	<50	888	<10	<1.00	<0.07	<0.010	UTD	0.10	<0.003	<0.400	<0.003	<0.020	<1.00	0.007	2.9	<0.070	<0.070	0.048	<0.020	<0.010	<0.200	<2.00
	1L13_B_Z3	208	<50	911	<10	<1.00	<0.07	0.020	UTD	0.12	<0.003	<0.400	<0.003	<0.020	<1.00	0.010	3.7	<0.070	<0.070	0.045	<0.020	<0.010	<0.200	<2.00
1L25 Dump	1L25_A_Z1	811	<50	1,782	<10	<1.00	<0.07	0.061	UTD	<0.070	<0.003	<0.400	<0.003	<0.020	<1.00	<0.006	2.3	<0.070	<0.070	<0.010	<0.020	<0.010	<0.200	<2.00
	1L25_A_Z2	188	<50	673	<10	<1.00	<0.07	0.16	UTD	<0.070	<0.003	<0.400	<0.003	<0.020	<1.00	<0.006	0.61	<0.070	<0.070	0.019	<0.020	<0.010	<0.200	<2.00
	1L25_A_Z3	362	<50	739	<10	<1.00	<0.07	0.093	UTD	<0.070	<0.003	<0.400	<0.003	<0.020	<1.00	<0.006	1.2	<0.070	<0.070	0.032	<0.020	<0.010	<0.200	<2.00
	1L25_B_Z1	442	<50	1,149	<10	<1.00	<0.07	0.071	UTD	<0.070	<0.003	<0.400	<0.003	<0.020	<1.00	<0.006	<0.500	0.072	<0.070	<0.010	<0.020	<0.010	<0.200	<2.00
	1L25_B_Z2	221	<50	886	<10	<1.00	<0.07	0.17	UTD	<0.070	<0.003	<0.400	<0.003	<0.020	<1.00	0.007	<0.500	0.12	<0.070	0.074	<0.020	<0.010	<0.200	<2.00
	1L25_B_Z3	295	<50	803	<10	<1.00	<0.07	0.22	UTD	<0.070	<0.003	<0.400	<0.003	<0.020	<1.00	<0.006	<0.500	0.094	<0.070	0.012	<0.020	<0.010	<0.200	<2.00
	1L25_C_Z1	590	<50	1,378	<10	<1.00	<0.07	0.097	UTD	<0.070	<0.003	<0.400	0.011	<0.020	<1.00	<0.006	1.9	<0.070	0.081	<0.010	<0.020	<0.010	<0.200	<2.00
	1L25_C_Z2	750	<50	1,953	<10	<1.00	<0.07	0.10	UTD	<0.070	<0.003	<0.400	0.0070	<0.020	<1.00	<0.006	2.2	<0.070	<0.070	<0.010	<0.020	<0.010	<0.200	<2.00
	1L25_C_Z3	389	<50	840	<10	<1.00	<0.07	0.14	UTD	<0.070	<0.003	<0.400	<0.003	<0.020	<1.00	<0.006	1.6	<0.070	<0.070	<0.010	<0.020	<0.010	<0.200	<2.00
1L28 Dump	1L28_Z1	938	<50	2,476	<10	<1.00	<0.07	0.059	UTD	<0.070	<0.003	<0.400	<0.003	<0.020	<1.00	<0.006	4.7	<0.070	<0.070	<0.010	<0.020	<0.010	<0.200	<2.00
	1L28_Z2	1,333	<50	3,900	<10	<1.00	<0.07	0.089	UTD	<0.070	<0.003	<0.400	<0.003	<0.020	<1.00	<0.006	2.7	0.077	<0.070	<0.010	<0.020	<0.010	<0.200	<2.00
	1L28_Z3	891	<50	2,506	<10	<1.00	<0.07	0.10	UTD	<0.070	<0.003	<0.400	<0.003	<0.020	<1.00	<0.006	3.3	<0.070	<0.070	<0.010	<0.020	<0.010	<0.200	<2.00
Manganese Slag	IL 28 M1	2,486	<50	7,619	<10	<1.00	<0.07	<0.010	UTD	<0.070	<0.003	<0.400	<0.003	<0.020	<1.00	<0.006	<0.500	0.13	<0.070	<0.010	<0.020	<0.010	<0.200	<2.00
	IL 28 M2	2,432	<50	7,395	<10	<1.00	<0.07	<0.010	UTD	<0.070	<0.003	<0.400	<0.003	<0.020	<1.00	<0.006	<0.500	0.13	<0.070	<0.010	<0.020	<0.010	<0.200	<2.00

6 Geochemical Implications and Recommendations

Pan African Resources PLC (PAR) plans to reprocess the tailings and deposit the reprocessed tailings in a new TSF. Geochemical characterisation of the tailings indicates that the tailings are PAF (97% PAF and 3% Inconclusive). The potential contaminants from the tailings have been determined by leach tests to include PH, electrical conductivity, total dissolved solids, boron, calcium, iron, manganese, mercury, lead, sulphate, and zinc.

The tailings range from Type 3 to Type 1. The results imply that a liner consistent with design requirements for the disposal of Type 3 waste at a minimum would theoretically be required to be placed underneath the new TSF for the reprocessed tailings and engagements with DWS are required.

The geochemical risk is that the seepage and runoff from the tailings and manganese slag will be acidic to neutral (pH 2.6-7.7) and containing boron, calcium, iron, manganese, mercury, lead, sulphate, and zinc. The seepage and runoff may impact the quality of the surface and groundwater depending on site conditions if not managed appropriately.

7 Recommendations

Digby wells recommends the following measures to manage the tailings and manganese slag during operations to closure:

- Reprocessing the tailings is supported as a measure to remove the existing ARD/ML TSFs and manganese slag as potential contaminant source footprints at the site;
- The tailings and manganese slag should be handled expeditiously to minimise exposure to oxidation, weathering and leaching during reclamation and processing;
- Clean surface water should be diverted away from the operation using runoff control diversions;
- Dirty water from percolation and runoff from the TSFs and manganese slag should be collected in toe paddocks and channelled to the return water dam for management (recycled for use in the plant, dust suppression, treatment before discharge, and establishing vegetation);
- The reprocessing operations would require monitoring the quality of toe seepage collecting in toe paddocks, return water dam, surface water, and groundwater for potential constituents of concern to include pH, electrical conductivity, total dissolved solids, boron, calcium, iron, manganese, mercury, lead, sulphate, and zinc; and
- The results imply that a liner consistent with design requirements for the disposal of Type 3 waste at a minimum would theoretically be required to be placed underneath the new TSF for the reprocessed tailings and and engagements with DWS are required.

8 Conclusion

This study has characterised the tailings and manganese slag for the Mogale Cluster. The study constitutes the Environmental Geochemistry Assessment Pre-Feasibility to describe the baseline environmental conditions and assess the potential geochemical impacts of the Project. Table 8-1 presents a summary of the results of the study.

Table 8-1: Summary of the tailings and manganese slag characterisation

Material		Tailings (n=32)	Manganese Slag (n=2)
Geochemical Characteristics	**Current pH**	Acidic to slightly alkaline (paste pH 2.4-7.8)	Acidic (Paste pH 4.9-5,0)
	Future pH	97% Potentially Acid Forming (PAF) and 3% Inconclusive	100% PAF
		NAG-pH is acidic (pH 4.5 - 6.5)	
	Mineralogy	Acid Forming - pyrite (0.2 -1.2 wt.%)	Gypsum (48-64%), magnetite (34-36%), and chlorite (18%)
		Acid Neutralising: • Carbonates - calcite (0.1 - 3.9 wt.%); • Aluminosilicates - chlorite, muscovite, pyrophyllite and kaolinite	
	Leachate quality	Acidic to alkaline (pH 3.9 - 12)	Acidic (Paste pH 4.6)
		Potential constituents of concern - pH, electrical conductivity, calcium, iron, mercury, lead, sulphate, and zinc	Potential constituents of concern - pH, EC, B, Ca, Mn, and SO_4
Geochemical Risks		Acidic seepage and runoff from the tailings and manganese slag containing boron, calcium, iron, manganese, mercury, lead, sulphate, and zinc pose a risk to surface and groundwater quality. Other parameters of concern are pH, electrical conductivity, and TDS.	

Management measures for the proposed reprocessing and the new TSF (Operations to closure)	• Reprocessing the tailings is supported as a measure to remove the existing ARD/ML TSFs and manganese slag as potential contaminant source footprints at the site; • The tailings and manganese slag should be handled expeditiously to minimise exposure to oxidation, weathering and leaching during reclamation and processing; • Clean surface water should be diverted away from the operation using runoff control diversions; • Dirty water from percolation and runoff from the TSFs and manganese slag should be collected in toe paddocks and channelled to the return water dam for management (recycled for use in the plant, dust suppression, treatment before discharge, and establishing vegetation); • The reprocessing operations would require to monitor the quality of toe seepage collecting in toe paddocks, return water dam, surface water, and groundwater for potential constituents of concern to include pH, electrical conductivity, total dissolved solids, boron, calcium, iron, manganese, mercury, lead, sulphate, and zinc; and • The results imply that a liner consistent with design requirements for the disposal of Type 3 waste at a minimum would theoretically be required to be placed underneath the new TSF for the reprocessed tailings and engagements with DWS are required.

The tailing characterised in this study are the existing tailings before reprocessing. The geochemistry presented in this report therefore indicates the baseline geochemistry before reprocessing the tailings. The reprocessed tailings were not available for characterisation at the time of the writing of this report. It is recommended that the reprocessed tailings and manganese slag are characterised to update this report when available.

9 References

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Appendix A: Laboratory Certificates

WATERLAB (Pty) Ltd

Reg. No.: 1983/009165/07 V.A.T. No.: 4130107891

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e-mail: admin@waterlab.co.za

sanas Testing Laboratory

T0391

CERTIFICATE OF ANALYSES
GENERAL WATER QUALITY PARAMETERS

Date received: 2022-03-30 **Date completed:** 2022-04-14

Project number: 1000 **Report number:** 108663 **Order number:** PAR7273

Client name: Digby Wells Environmental **Contact person:** Ms. Kgaugelo Thobejane

Address: Turnberry Office Park, 48 Grosvenor Rd, Bryanston, JHB 2191 **e-mail:** kgaugelo.thobejane@digbywells.com

Telephone: 011 789 9498 **Facsimile:** 011 069 6801 **Mobile:** 076 221 9137

Analyses in mg/ℓ (Unless specified otherwise)		Method Identification	Sample Identification: IL13-L15-1 Supernatent
Sample Number			157348
Date\Time Sampled			N/A
pH - Value @ 25 ºC	A	WLAB065	9.0
Electrical Conductivity in mS/m @ 25°C	A	WLAB065	456
Total Dissolved Solids @ 180°C	A	WLAB003	4116
Total Acidity as $CaCO_3$	A	WLAB022	<5
Chloride as Cl	A	WLAB046	174
Sulphate as SO_4	A	WLAB046	2267
Sulphur as S (Dissolved)	S	---	507.7
Fluoride as F	N	WLAB014	1.1
Nitrate as N	A	WLAB046	<0.1
Total Cyanide as CN	S	---	134.40
Free and Saline Ammonia as N	A	WLAB046	8.3
Sodium as Na	A	WLAB015	476
Potassium as K	A	WLAB015	219
Calcium as Ca	A	WLAB015	554
Magnesium as Mg	A	WLAB015	44
Aluminium as Al (Dissolved)	A	WLAB015	0.456
Antimony as Sb (Dissolved)	A	WLAB050	0.003
Arsenic as As (Dissolved)	A	WLAB050	0.060
Barium as Ba (Dissolved)	A	WLAB015	<0.025
Beryllium as Be (Dissolved)	N	WLAB015	<0.025
Bismuth as Bi (Dissolved)	N	WLAB015	<0.025
Boron as B (Dissolved)	A	WLAB015	0.109
Cadmium as Cd (Dissolved)	A	WLAB050	0.033
Total Chromium as Cr (Dissolved)	A	WLAB015	<0.025
Hexavalent Chromium as Cr	A	WLAB032	0.013
Cobalt as Co (Dissolved)	A	WLAB015	3.53
Copper as Cu (Dissolved)	A	WLAB015	3.93
Iron as Fe (Dissolved)	A	WLAB015	0.609

A. van de Wetering - Chemical Technical Signatory

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Sample condition acceptable unless specified on the report.

WATERLAB

WATERLAB (Pty) Ltd

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sanas Testing Laboratory
T0391

CERTIFICATE OF ANALYSES
GENERAL WATER QUALITY PARAMETERS

Date received: 2022-03-30 **Date completed:** 2022-04-14
Project number: 1000 **Report number:** 108663 **Order number:** PAR7273

Client name: Digby Wells Environmental **Contact person:** Ms. Kgaugelo Thobejane
Address: Turnberry Office Park, 48 Grosvenor Rd, Bryanston, JHB 2191 **e-mail:** kgaugelo.thobejane@digbywells.com
Telephone: 011 789 9498 **Facsimile:** 011 069 6801 **Mobile:** 076 221 9137

Analyses in mg/ℓ (Unless specified otherwise)		Method Identification	Sample Identification
			IL13-L15-1 Supernatent
Sample Number			157348
Date\Time Sampled			N/A
Lead as Pb (Dissolved)	A	WLAB050	<0.001
Manganese as Mn (Dissolved)	A	WLAB015	2.35
Mercury as Hg (Dissolved)	A	WLAB050	0.005
Molybdenum as Mo (Dissolved)	N	WLAB015	<0.025
Nickel as Ni (Dissolved)	A	WLAB015	1.73
Phosphorus as P (Dissolved)	N	WLAB015	0.080
Selenium as Se (Dissolved)	A	WLAB050	0.012
Silicon as Si (Dissolved)	N	WLAB015	4.0
Silver as Ag (Dissolved)	N	WLAB015	<0.025
Strontium as Sr (Dissolved)	N	WLAB015	0.536
Thallium as Tl (Dissolved)	N	WLAB015	<0.025
Thorium as Th (Dissolved)	N	WLAB050	0.001
Titanium as Ti (Dissolved)	N	WLAB015	<0.025
Uranium as U (Dissolved)	A	WLAB050	0.307
Vanadium as V (Dissolved)	A	WLAB015	<0.025
Zinc as Zn (Dissolved)	A	WLAB015	13

A. van de Wetering - Chemical Technical Signatory

Appendix B: Unprocessed Tailings Laboratory Certificates of Analysis

WATERLAB (Pty) Ltd

Reg. No.: 1983/009165/07 V.A.T. No.: 4130107891

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sanas Testing Laboratory T0391

CERTIFICATE OF ANALYSES

GENERAL WATER QUALITY PARAMETERS

Date received: 2021-10-04 **Date completed:** 2021-10-27

Project number: 1000 **Report number:** 104155 **Order number:**

Client name: Digby Wells Environmental **Contact person:** Kgaugelo Thobejane

Address: Turnberry Office Park, 48 Grosvenor Rd, Bryanston, JHB 219 **e-mail:** kgaugelo.thobejane@digbywells.com

Telephone: 011 789 9498 **Facsimile:** 011 069 6801 **Mobile:** 076 221 9137

Analyses in mg/ℓ (Unless specified otherwise)		**Method Identification**	Sample Identification		
			South Sand	IL23/IL25	IL13
Sample Number			140942	140943	140944
Date/Time Sampled			N/A	N/A	N/A
pH - Value @ 25 ºC	A	WLAB065	2.4	2.8	2.5
Electrical Conductivity in mS/m @ 25°C	A	WLAB002	960	435	839
Total Dissolved Solids @ 180°C	A	WLAB003	14094	4166	11544
Total Acidity as $CaCO_3$	A	WLAB022	6280	760	3480
Chloride as Cl	A	WLAB046	24	37	227
Sulphate as SO_4	A	WLAB046	8606	2475	5448
Fluoride as F	N	WLAB014	0.4	0.3	0.3
Nitrate as N	A	WLAB046	<0.1	0.1	<0.1
Total Cyanide as CN	S	---	<0.07	<0.07	<0.07
Free and Saline Ammonia as N	A	WLAB046	5.0	41	58
Sodium as Na	A	WLAB015	382	67	335
Potassium as K	A	WLAB015	52	25	11.5
Calcium as Ca	A	WLAB015	474	512	475
Magnesium as Mg	A	WLAB015	455	164	625
Aluminium as Al	A	WLAB015	674	52	84
Antimony as Sb	A	WLAB050	<0.001	<0.001	<0.001
Arsenic as As	A	WLAB050	0.789	0.013	0.450
Barium as Ba	A	WLAB015	0.067	0.066	0.052
Beryllium as Be	N	WLAB015	<0.025	<0.025	<0.025
Bismuth as Bi	N	WLAB015	<0.025	<0.025	<0.025
Boron as B	A	WLAB015	<0.025	1.03	<0.025
Cadmium as Cd	A	WLAB050	0.060	0.005	0.003
Total Chromium as Cr	A	WLAB015	5.62	1.02	0.994
Hexavalent Chromium as Cr	A	WLAB032	<0.010	0.059	<0.010
Cobalt as Co	A	WLAB015	13	2.30	1.34
Copper as Cu	A	WLAB015	25	0.356	0.817
Iron as Fe	A	WLAB015	628	44	931
Lead as Pb	A	WLAB050	0.070	0.022	0.009

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Sample condition acceptable unless specified on the report.

WATERLAB (Pty) Ltd

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T0391

CERTIFICATE OF ANALYSES

GENERAL WATER QUALITY PARAMETERS

Date received: 2021-10-04 **Date completed:** 2021-10-27
Project number: 1000 **Report number:** 104155 **Order number:**

Client name: Digby Wells Environmental **Contact person:** Kgaugelo Thobejane
Address: Turnberry Office Park, 48 Grosvenor Rd, Bryanston, JHB 219 **e-mail:** kgaugelo.thobejane@digbywells.com
Telephone: 011 789 9498 **Facsimile:** 011 069 6801 **Mobile:** 076 221 9137

Analyses in mg/ℓ (Unless specified otherwise)		**Method Identification**	Sample Identification		
			South Sand	IL23/IL25	IL13
Sample Number			140942	140943	140944
Date/Time Sampled			N/A	N/A	N/A
Manganese as Mn	A	WLAB015	26	110	258
Mercury as Hg	A	WLAB047	<0.001	<0.001	0.001
Molybdenum as Mo	N	WLAB015	<0.025	<0.025	<0.025
Nickel as Ni	A	WLAB015	27	3.10	2.62
Phosphorus as P	N	WLAB015	3.39	1.40	2.64
Selenium as Se	A	WLAB050	0.047	0.004	0.003
Silicon as Si	N	WLAB015	132	48	66
Silver as Ag	N	WLAB015	<0.025	<0.025	<0.025
Strontium as Sr	N	WLAB015	0.201	1.22	1.56
Thallium as Tl	N	WLAB015	<0.025	<0.025	<0.025
Thorium as Th	N	WLAB050	1.49	0.023	0.184
Tin as Sn	N	WLAB050	<0.001	<0.001	<0.001
Titanium as Ti	N	WLAB015	0.507	0.462	0.429
Uranium as U	A	WLAB050	0.027	0.775	0.947
Vanadium as V	A	WLAB015	0.055	0.026	0.132
Zinc as Zn	A	WLAB015	18	3.52	2.56

A. van de Wetering - Chemical Technical Signatory

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Sample condition acceptable unless specified on the report.

Appendix C: Reprocessed Tailings Laboratory Certificates of Analysis

WATERLAB

WATERLAB (PTY) LTD

Reg. No.: 1983/009165/07 V.A.T. No.: 4130107891

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Prelim CERTIFICATE OF ANALYSES

Index

Date received:	**2022/03/29**	**Date completed:**	**2022/05/05**
Project number:	**1000** **Report number: 108629**	**Order number:**	**PAR7273**

Client name:	**Digby Wells Environmental**	**Contact person:**	**Kgaugelo Thobejane**
Address:	**Digby Wells House, Turnberry Office Park, 48 Grosvenor Road, Bryanston, 2191**	**Email:**	**kgaugelo.thobejane@digbywells.com**
Telephone:	**011 789 9495**	**Email:**	**levi.ochieng@digbywells.com**
Facsimile:	**011 789 9498**	**Email:**	**creditors@digbywells.com**

S. Laubscher ____________________
Assistant Geochemistry Project Manager

WATERLAB (PTY) LTD

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CERTIFICATE OF ANALYSES

DISTILLED WATER EXTRACTION

Date received:	**2022/03/29**		**Date completed:**	**2022/04/22**
Project number:	**1000**	**Report number: 108629**	**Order number:**	**PAR7273**

Client name:	**Digby Wells Environmental**	**Contact person:**	**Kgaugelo Thobejane**
Address:	**Digby Wells House, Turnberry Office Park, 48 Grosvenor Road, Bryanston, 2191**	**Email:**	**kgaugelo.thobejane@digbywells.com**
Telephone:	**011 789 9495**	**Email:**	**levi.ochieng@digbywells.com**
Facsimile:	**011 789 9498**	**Email:**	**creditors@digbywells.com**

Analyses	**IL13-L15-1**		**IL13-L15-2**	
Sample Number	**157163**		**157164**	
TCLP / Acid Rain / Distilled Water / H_2O_2	**Distilled Water**		**Distilled Water**	
Dry Mass Used (g)	**250**		**250**	
Volume Used (mℓ)	**1000**		**1000**	
pH Value at 25˚C	7,5		7,6	
Electrical Conductivity in mS/m at 25˚C	225		190	
Inorganic Anions	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**
Total Alkalinity as $CaCO_3$	24	96	40	160
Chloride as Cl	6	24	4	16
Sulphate as SO_4	1282	5128	1032	4128
Nitrate as N	0,1	0,4	0,1	0,4
Fluoride as F	0,2	0,8	0,2	0,8
Hexavalent Chromium as Cr^{6+}	<0.010	<0.04	<0.010	<0.04
ICP-OES Quant	See ICP DW tab			
ICP-MS Quant				

S. Laubscher
Assistant Geochemistry Project Manager

WATERLAB (PTY) LTD

CERTIFICATE OF ANALYSES

ICP-OES QUANTITATIVE ANALYSIS

Date received:	2022/03/29	**Date Completed:**	2022/04/22
Project number:	1000	**Report number:**	108629

Client name:	Digby Wells Environmental	**Contact person:**	Kgaugelo Thobejane
Adress:	Digby Wells House, Turnberry Office Park,	**Email:**	kgaugelo.thobejane@digbywells.com
	48 Grosvenor Road, Bryanston, 2191	**Email:**	levi.ochieng@digbywells.com
Telephone:	011 789 9495	**Email:**	creditors@digbywells.com

Extract	Sample Dry Mass	Volume	Mass (g/l)	Factor
Distilled Water	250	1000	250	4

Sample Id	Sample number	Ag	Ag	Al	Al	As*	As*
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.100	<0.100	<0.400	<0.001	<0.004
IL13-L15-1	157163	<0.025	<0.100	<0.100	<0.400	0,030	0,119
IL13-L15-2	157164	<0.025	<0.100	<0.100	<0.400	0,029	0,114

Sample Id	Sample number	B	B	Ba	Ba	Be	Be
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.100	<0.025	<0.100	<0.025	<0.100
IL13-L15-1	157163	0,077	0,310	<0.025	<0.100	<0.025	<0.100
IL13-L15-2	157164	0,071	0,283	<0.025	<0.100	<0.025	<0.100

Sample Id	Sample number	Bi	Bi	Ca	Ca	Cd*	Cd*
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.100	<1	<4	<0.001	<0.004
IL13-L15-1	157163	<0.025	<0.100	500	2000	<0.001	<0.004
IL13-L15-2	157164	<0.025	<0.100	425	1700	<0.001	<0.004

Sample Id	Sample number	Co	Co	Cr	Cr	Cu	Cu
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.100	<0.025	<0.100	<0.010	<0.040
IL13-L15-1	157163	0,417	1,67	<0.025	<0.100	<0.010	<0.040
IL13-L15-2	157164	0,306	1,23	<0.025	<0.100	<0.010	<0.040

Sample Id	Sample number	Fe	Fe	Hg*	Hg*	K	K
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.100	<0.001	<0.004	<0.5	<2.0
IL13-L15-1	157163	0,294	1,18	0,001	0,004	31	124
IL13-L15-2	157164	0,252	1,01	<0.001	<0.004	26	104

Sample Id	Sample number	Li	Li	Mg	Mg	Mn	Mn
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.100	<1	<4	<0.025	<0.100
IL13-L15-1	157163	<0.025	<0.100	9	36	0,764	3,06
IL13-L15-2	157164	<0.025	<0.100	8	32	0,617	2,47

Sample Id	Sample number	Mo	Mo	Na	Na	Ni	Ni
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.100	<1	<4	<0.025	<0.100
IL13-L15-1	157163	<0.025	<0.100	37	148	0,101	0,404
IL13-L15-2	157164	<0.025	<0.100	32	128	0,052	0,210

Sample Id	Sample number	P	P	Pb*	Pb*	Sb*	Sb*
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.100	<0.001	<0.004	<0.001	<0.004
IL13-L15-1	157163	<0.025	<0.100	<0.001	<0.004	0,002	0,008
IL13-L15-2	157164	<0.025	<0.100	<0.001	<0.004	0,002	0,008

Sample Id	Sample number	Se*	Se*	Si	Si	Sr	Sr
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.004	<0.2	<0.8	<0.025	<0.100
IL13-L15-1	157163	0,004	0,015	4,7	19,0	0,353	1,41

IL13-L15-2	157164	<0.001	<0.004	5,1	20	0,340	1,36

Sample Id	Sample number	Th*	Th*	Ti	Ti	U*	U*
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.004	<0.025	<0.100	<0.001	<0.004
IL13-L15-1	157163	<0.001	<0.004	<0.025	<0.100	0,244	0,975
IL13-L15-2	157164	<0.001	<0.004	<0.025	<0.100	0,220	0,881

Sample Id	Sample number	V	V	Zn	Zn
		mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.100	<0.025	<0.100
IL13-L15-1	157163	<0.025	<0.100	<0.025	<0.100
IL13-L15-2	157164	<0.025	<0.100	<0.025	<0.100

[*] = Element analysed on ICP-MS Instrument

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CERTIFICATE OF ANALYSES
SPLP EXTRACTION

Date received: 2022/03/29
Project number: 1000
Report number: 108629
Date completed: 2022/04/22
Order number: PAR7273

Client name: Digby Wells Environmental
Address: Digby Wells House, Turnberry Office Park, 48 Grosvenor Road, Bryanston, 2191
Telephone: 011 789 9495
Facsimile: 011 789 9498
Contact person: Kgaugelo Thobejane
Email: kgaugelo.thobejane@digbywells.com
Email: levi.ochieng@digbywells.com
Email: creditors@digbywells.com

Analyses	IL13-L15-1		IL13-L15-2	
Sample Number	157163		157164	
TCLP / Acid Rain / Distilled Water / H_2O_2	SPLP		SPLP	
Dry Mass Used (g)	50		50	
Volume Used (mℓ)	1000		1000	
pH Value at 25˚C	7,2		7,4	
Electrical Conductivity in mS/m at 25˚C	65,3		54,7	
Inorganic Anions	mg/ℓ	mg/kg	mg/ℓ	mg/kg
Total Alkalinity as $CaCO_3$	16	320	16	320
Chloride as Cl	<2	<40	<2	<40
Sulphate as SO_4	270	5400	222	4440
Nitrate as N	<0.1	<2.0	<0.1	<2.0
Fluoride as F	<0.2	<0.4	<0.2	<0.4
Hexavalent Chromium as Cr^{6+}	<0.010	<0.20	<0.010	<0.20
ICP-OES Quant	See ICP-SPLP tab			
ICP-MS Quant				

S. Laubscher
Assistant Geochemistry Project Manager

WATERLAB (PTY) LTD

CERTIFICATE OF ANALYSES

ICP-OES QUANTITATIVE ANALYSIS

Date received:	2022/03/29	**Date Completed:**	2022/04/22
Project number:	1000	**Report number:**	108629

Client name:	Digby Wells Environmental	**Contact person:**	Kgaugelo Thobejane
Adress:	Digby Wells House, Turnberry Office Park,	**Email:**	kgaugelo.thobejane@digbywells.com
	48 Grosvenor Road, Bryanston, 2191	**Email:**	levi.ochieng@digbywells.com
Telephone:	011 789 9495	**Email:**	creditors@digbywells.com

Extract	Sample Dry Mass	Volume	Mass (g/l)	Factor
SPLP	50	1000	50	20

Sample Id	Sample number	Ag	Ag	Al	Al	As*	As*
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.500	<0.100	<2.00	<0.001	<0.020
IL13-L15-1	157163	<0.025	<0.500	<0.100	<2.00	0,021	0,420
IL13-L15-2	157164	<0.025	<0.500	<0.100	<2.00	0,019	0,378

Sample Id	Sample number	B	B	Ba	Ba	Be	Be
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.500	<0.025	<0.500	<0.025	<0.500
IL13-L15-1	157163	0,030	0,597	0,028	0,566	<0.025	<0.500
IL13-L15-2	157164	<0.025	<0.500	0,031	0,622	<0.025	<0.500

Sample Id	Sample number	Bi	Bi	Ca	Ca	Cd*	Cd*
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.500	<1	<20	<0.001	<0.020
IL13-L15-1	157163	<0.025	<0.500	114	2280	<0.001	<0.020
IL13-L15-2	157164	<0.025	<0.500	87	1740	<0.001	<0.020

Sample Id	Sample number	Co	Co	Cr	Cr	Cu	Cu
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.500	<0.025	<0.500	<0.010	<0.200
IL13-L15-1	157163	0,083	1,66	<0.025	<0.500	<0.010	<0.200
IL13-L15-2	157164	0,093	1,85	<0.025	<0.500	<0.010	<0.200

Sample Id	Sample number	Fe	Fe	Hg*	Hg*	K	K
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.500	<0.001	<0.020	<0.5	<10.0
IL13-L15-1	157163	0,085	1,70	0,002	0,043	7,3	145
IL13-L15-2	157164	0,079	1,58	<0.001	<0.020	6,6	131

Sample Id	Sample number	Li	Li	Mg	Mg	Mn	Mn
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.500	<1	<20	<0.025	<0.500
IL13-L15-1	157163	<0.025	<0.500	2	40	0,174	3,49
IL13-L15-2	157164	<0.025	<0.500	2	40	0,130	2,59

Sample Id	Sample number	Mo	Mo	Na	Na	Ni	Ni
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.500	<1	<20	<0.025	<0.500
IL13-L15-1	157163	<0.025	<0.500	8	160	<0.025	<0.500
IL13-L15-2	157164	<0.025	<0.500	9	180	<0.025	<0.500

Sample Id	Sample number	P	P	Pb*	Pb*	Sb*	Sb*
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.500	<0.001	<0.020	<0.001	<0.020
IL13-L15-1	157163	<0.025	<0.500	<0.001	<0.020	<0.001	<0.020
IL13-L15-2	157164	<0.025	<0.500	<0.001	<0.020	<0.001	<0.020

Sample Id	Sample number	Se*	Se*	Si	Si	Sr	Sr
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.2	<4.0	<0.025	<0.500
IL13-L15-1	157163	<0.001	<0.020	2,6	52	0,108	2,16
IL13-L15-2	157164	<0.001	<0.020	2,3	47	0,095	1,89

Sample Id	Sample number	Th*	Th*	Ti	Ti	U*	U*
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg

Det Limit		<0.001	<0.020	<0.025	<0.500	<0.001	<0.020
IL13-L15-1	157163	<0.001	<0.020	<0.025	<0.500	0,051	1,03
IL13-L15-2	157164	<0.001	<0.020	<0.025	<0.500	0,042	0,839

Sample Id	Sample number	V	V	Zn	Zn
		mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.500	<0.025	<0.500
IL13-L15-1	157163	<0.025	<0.500	<0.025	<0.500
IL13-L15-2	157164	<0.025	<0.500	<0.025	<0.500

[*] = Element analysed on ICP-MS Instrument

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CERTIFICATE OF ANALYSES
TOTALS

Date received:	**2022/03/29**		**Date completed:**	**2022/04/22**
Project number:	**1000**	**Report number: 108629**	**Order number:**	**PAR7273**

Client name:	**Digby Wells Environmental**	**Contact person:**	**Kgaugelo Thobejane**
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Analyses	**IL13-L15-1**		**IL13-L15-2**	
Sample Number	**157163**		**157164**	
Digestion	**HNO3 : HF**		**HNO3 : HF**	
Dry Mass Used (g)	**0,25**		**0,25**	
Volume Used (mℓ)	**100**		**100**	
Paste pH	7,6		7,7	
Paste Electrical Conductivity	275		263	
Units	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**
Sulphate[o]	---	587,10	---	3615,00
Chloride [o]	---	81,61	---	101,30
Fluoride [o]	---	<0.5	---	<0.5
Nitrate [o]	---	<5	---	<5
Hexavalent Chromium [o]	---	<2	---	<2
Units	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**
ICP-OES Quant	See ICP-Digestion tab			
ICP-MS Quant				

S. Laubscher__________________
Assistant Geochemistry Project Manager

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Prelim CERTIFICATE OF ANALYSES

ICP-MS QUANTITATIVE ANALYSIS

Date received:	2022/03/29	Date Completed:	2022/05/05
Project number:	1000	Report number:	108629

Client name:	Digby Wells Environmental	Contact person:	Kgaugelo Thobejane
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	48 Grosvenor Road, Bryanston, 2191	Email:	levi.ochieng@digbywells.com
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Extract	Sample Dry Mass	Volume	Mass (g/l)	Factor
HNO3 : HF	0,25	100	3	400

Sample Id	Sample number	Ag	Ag	Al	Al	As*	As*
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<10	<0.100	<40	<0.001	<0.400
IL13-L15-1	157163	<0.025	<10	29	11600	0,278	111
IL13-L15-2	157164	<0.025	<10	32	12800	0,267	107

Sample Id	Sample number	B	B	Ba	Ba	Be	Be
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<10	<0.025	<10	<0.025	<10
IL13-L15-1	157163	<0.025	<10	0,084	34	<0.025	<10
IL13-L15-2	157164	<0.025	<10	0,097	39	<0.025	<10

Sample Id	Sample number	Bi	Bi	Ca	Ca	Cd*	Cd*
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<10	<1	<400	<0.001	<0.400
IL13-L15-1	157163	<0.025	<10	2	800	0,001	0,400
IL13-L15-2	157164	<0.025	<10	3	1200	0,001	0,400

Sample Id	Sample number	Co	Co	Cr	Cr	Cu	Cu
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<10	<0.025	<10	<0.010	<4.00
IL13-L15-1	157163	0,072	29	0,974	390	0,074	30
IL13-L15-2	157164	0,071	29	1,11	446	0,068	27

Sample Id	Sample number	Fe	Fe	Hg*	Hg*	K	K
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<10	<0.001	<0.400	<0.5	<200
IL13-L15-1	157163	39	15600	<0.001	<0.400	6,0	2405
IL13-L15-2	157164	41	16400	<0.001	<0.400	5,1	2052

Sample Id	Sample number	Li	Li	Mg	Mg	Mn	Mn
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<10	<1	<400	<0.025	<10
IL13-L15-1	157163	<0.025	<10	2	800	1,58	631
IL13-L15-2	157164	<0.025	<10	3	1200	1,50	598

Sample Id	Sample number	Mo	Mo	Na	Na	Ni	Ni
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<10	<1	<400	<0.025	<10
IL13-L15-1	157163	<0.025	<10	2	800	0,279	112
IL13-L15-2	157164	<0.025	<10	1	400	0,268	107

Sample Id	Sample number	P	P	Pb*	Pb*	Sb*	Sb*
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<10	<0.001	<0.400	<0.001	<0.400
IL13-L15-1	157163	0,215	86	0,458	183	<0.001	<0.400
IL13-L15-2	157164	0,144	58	0,385	154	<0.001	<0.400

Sample Id	Sample number	Se*	Se*	Si	Si	Sr	Sr
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.400	<0.2	<80	<0.025	<10
IL13-L15-1	157163	<0.001	<0.400	957	382800	<0.025	<10

IL13-L15-2	157164	<0.001	<0.400	1008	403200	0,030	12

Sample Id	Sample number	Th*	Th*	Ti	Ti	U*	U*
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.400	<0.025	<10	<0.001	<0.400
IL13-L15-1	157163	<0.001	<0.400	3,24	1296	0,100	40
IL13-L15-2	157164	<0.001	<0.400	3,20	1282	0,100	40

Sample Id	Sample number	V	V	Zn	Zn
		mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<10	<0.025	<10
IL13-L15-1	157163	<0.025	<10	0,419	168
IL13-L15-2	157164	<0.025	<10	0,296	118

[*] = Element analysed on ICP-MS Instrument

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

Date received:	**2022/03/29**		**Date completed:**	**2022/04/22**
Project number:	**1000**	**Report number: 108629**	**Order number:**	**PAR7273**

Client name:	**Digby Wells Environmental**	**Contact person:**	**Kgaugelo Thobejane**
Address:	**Digby Wells House, Turnberry Office Park, 48 Grosvenor Road, Bryanston, 2191**	**Email:**	**kgaugelo.thobejane@digbywells.com**
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Acid – Base Accounting	Sample Identification		
Modified Sobek (EPA-600)	**IL13-L15-1**	**IL13-L15-2**	**IL13-L15-2**
Sample Number	**157163**	**157164**	**157164 D**
Paste pH	7,6	7,7	7,7
Total Sulphur (%) (LECO)	0,67	0,79	0,78
Acid Potential (AP) (kg/t)	21	25	24
Neutralization Potential (NP)	2,00	0,750	1,50
Nett Neutralization Potential (NNP)	-19	-24	-23
Neutralising Potential Ratio (NPR) (NP : AP)	0,096	0,030	0,061
Rock Type	I	I	I

*** 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.**

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 potentiall 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

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 consider 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

NET ACID GENERATION

Date received:	**2022/03/29**	**Date completed:**	**2022/04/22**
Project number:	**1000** Report number: 108629	**Order number:**	**PAR7273**

Client name:	**Digby Wells Environmental**	**Contact person:**	**Kgaugelo Thobejane**
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	Sample Identification: pH 4.5		
	IL13-L15-1	IL13-L15-2	IL13-L15-2
Sample Number	**157163**	**157164**	**157164 D**
NAG pH: (H_2O_2)	2,7	2,7	2,9
NAG (kg H_2SO_4 / t)	7,64	10	10

	Sample Identification: pH 7		
	IL13-L15-1	IL13-L15-2	IL13-L15-2
Sample Number	**157163**	**157164**	**157164 D**
NAG pH: (H_2O_2)	4,5	4,5	4,5
NAG (kg H_2SO_4 / t)	3,72	2,94	2,94

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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CERTIFICATE OF ANALYSES
SULPHUR SPECIATION

Date received:	**2022/03/29**	**Date completed:**	**2022/04/22**
Project number:	**1000** Report number: 108629	**Order number:**	**PAR7273**

Client name:	**Digby Wells Environmental**	**Contact person:**	**Kgaugelo Thobejane**
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Facsimile:	**011 789 9498**	**Email:**	**creditors@digbywells.com**

	Sample Identification:		
	IL13-L15-1	IL13-L15-2	IL13-L15-2
Sample Number	**157163**	**157164**	**157164 D**
Total Sulphur (%) (ELTRA)	0,67	0,79	0,78
Sulphate Sulphur as S (%)	0,27	0,19	0,19
Sulphide Sulphur (%)	0,40	0,60	0,60

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CERTIFICATE OF ANALYSES
X-RAY DIFFRACTION [o]

Date received:	**2022/03/29**		**Date completed:**	**2022/04/22**
Project number:	**1000**	**Report number: 108629**	**Order number:**	**PAR7273**

Client name:	**Digby Wells Environmental**	**Contact person:**	**Kgaugelo Thobejane**
Address:	**Digby Wells House, Turnberry Office Park, 48 Grosvenor Road, Bryanston, 2191**	**Email:**	**kgaugelo.thobejane@digbywells.com**
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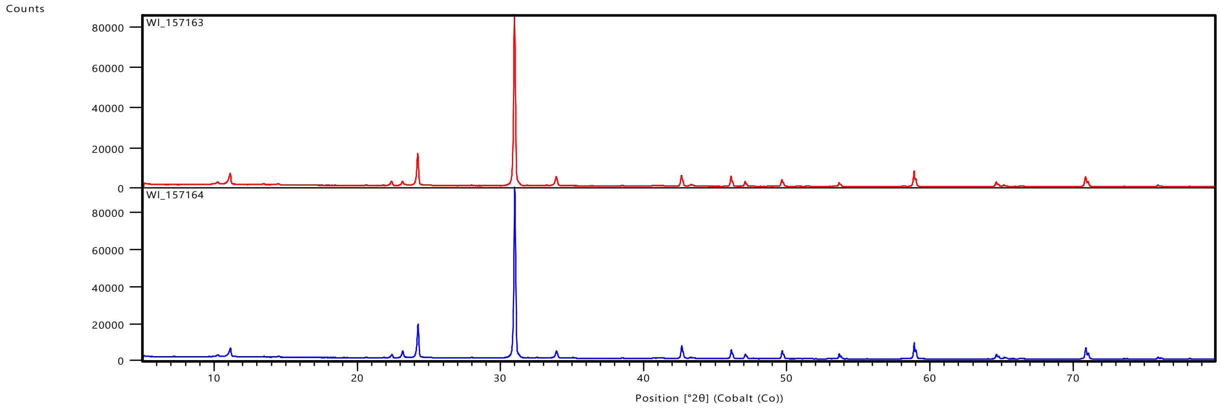
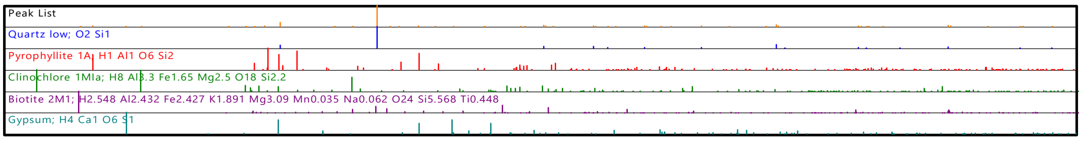
Facsimile:	**011 789 9498**	**Email:**	**creditors@digbywells.com**

	Sample Identification	
	IL13-L15-1	**IL13-L15-2**
Sample Number	**157163**	**157164**
Mineral Amount (weight %)	**Composition (%) [o]**	
Quartz	87,8	92,0
Pyrophyllite	10,1	5,5
Chlorite	1,4	1,5
Gypsum	0,6	0,4
Biotite	0,3	0,6

[o] = Outsourced





Note:

The material was prepared for XRD analysis using a back loading preparation method.
Diffractograms were obtained using a Malvern Panalytical Aeris diffractometer with PIXcel detector and fixed slits with Fe filtered Co-Kα 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 results.
- Mineral names may not reflect the actual compositions of minerals identified, but rather the mineral group.
- Smectite, lizardite (serpentine), vermiculite, chlorite and kaolinite peaks overlap and further test would be necessary to distinguish. Identification is largely based on peak shapes and positions.
- Due to preferred orientation and crystallite size effects, results may not be as accurate as shown.
- Traces of additional phases may be present. Amounts below 0.5 weight % may be unreliable.
- Amorphous phases, if present, were not taken into consideration during quantification.

Ideal Mineral compositions:

Compound Name	Chemical Formula
Biotite	K(Mg,Fe)3 ((OH)2 Al Si3 O10)
Chlorite	(Mg,Fe)5Al(AlSi3O10)(OH)8
Gypsum	Ca(SO4)(H2O)2
Pyrophyllite	Al(Si2O5)(OH)
Quartz	SiO2