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Mokala Manganese Project

Geochemical Assessment
In support of the Environmental Impact Assessment

SLR Project No.: 720.09012.00003
Report No.: 1

October 2015

MOKALA
MANGANESE MINE

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Mokala Manganese (Pty) Limited

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EXECUTIVE SUMMARY

SLR Consulting (South Africa) (Pty) Limited ("SLR") has undertaken a geochemical assessment to characterise material excavated and exposed during mining operations at the proposed Mokala Manganese Mine near Hotazel in the Northern Cape.

SLR was provided with boreholes logs and plans from extensive prospecting on the project area. The borehole logs were reviewed and the lithologies likely to be disturbed through mining, identified.

A total of twenty (20) samples were selected from the 10 main lithologies present at the site. The majority of samples were taken from cores on site. Samples of calcrete were collected directly from the wall of an existing quarry on site and samples of Lower Manganese Ore were selected from ore samples held by SGS that remained from metallurgical tests work. Samples from the site were collected by Orex Exploration who are subcontracted by Mokala.

Samples were submitted to an accredited commercial laboratory in Johannesburg for geochemical characterisation tests. The geochemical test work undertaken as part of this assessment included static Acid-Base Accounting (ABA), mineralogical testing and SPLP leach testing.

Eleven (11) of the twenty (20) samples were submitted for ABA test work. The ABA results show that the total sulphur content and more importantly the sulphide sulphur content of all samples are low, with the majority below the laboratory detection limit of <0.01%. The low sulphide sulphur content suggests the potential to generate acid is negligible for all samples. In addition, the neutralising potential ratio (NPR) of all samples is above 2, (minimum NPR 392), which implies all lithologies have sufficient neutralising potential to offset the low acid potential.

Mineralogy test work confirmed the presence of highly soluble minerals such as calcite and dolomite in overburden samples suggesting that the pH of mine drainage may be controlled by calcite dolomite dissolution. This would result in mine drainage with a generally neutral pH.

Leach test results are not an indicator of drainage quality as the conditions of the test, especially the liquid-to-solid ratio, do not represent actual field conditions. Therefore, leachate concentrations are not representative of seepage or run-off that could emanate from site. However, the results may indicate chemicals of concern (CoCs) in mine drainage through comparison with water quality limits. The leach tests suggest that the soluble components of the samples result in leachate quality that is generally within relevant water quality standards. However, two elements were noted as potential chemicals of concern, including manganese and nitrate.

Potential overburden seepage was simulated using the PHREEQC equilibrium geochemical modelling code (Parkhurst and Appelo 1999). Based on the assumed conditions in the overburden, the modelling results indicate that seepage may have the following general characteristics:

• Neutral pH (controlled by calcite dissolution).

• High alkalinity.

• High salinity (in the form of elevated calcium, sodium, magnesium, chloride, nitrate and sulphate concentrations).

• Low or non-detect concentrations of most trace elements.

Chemicals of concern indicated by the modelling include: aluminium, chloride, fluoride, manganese, sodium, sulphate and vanadium.

A source term was developed for the overburden stockpile and the backfilled opencast pit as presented below.

Conceptual Model	Water quality component	Seepage volume [m^3/year]	Seepage quality [mg/L]	Contaminant mass [kg/year]
Overburden Stockpile	Chloride as Cl	1 005	392	394
	Sulphate as SO$_4$	1 005	359	361
Pit Backfill	Chloride as Cl	4 000	392	1 568
	Sulphate as SO$_4$	4 000	359	1 436

Under the dry climate conditions of Mokala, leachable salt mass from pit sidewalls is likely to fall within the ranges modelled for the overburden stockpile.

The movement and dilution of the contaminant mass can be simulated in a numerical groundwater model to indicate the potential impact of the overburden stockpile on groundwater quality.

GEOCHEMICAL ASSESSMENT

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ACRONYMS AND ABBREVIATIONS

Below is a list of acronyms and abbreviations used in this report.

Acronyms / Abbreviations	Definition
ABA	Acid Base Accounting
AP	Acid Potential
ARD	Acid Rock Drainage
BIF	Banded Iron Formation
BPG	Best Practice Guidelines
CoC	Chemicals of Concern
DMR	Department of Mineral and Resources
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
E.N	Electro Neutrality
IFC	International Financial Corporation
KMF	Kalahari Manganese Formation
mamsl	Metres above mean sea level
MAP	Mean Annual Precipitation
mbgl	Metres below ground level
MPRDA	Mineral and Petroleum Resources Development Act
NAG	Net Acid Generating
NNP	Net Neutralising Potential
NPR	Neutralising Potential Ratio
NP	Neutralising Potential
PAG	Potentially Acid Generating
ROM	Run of Mine
SANAS	South African National Accreditation System
SANS	South African National Standards
SPLP	Synthetic Precipitation Leaching Procedure
WHO	World Health Organisation
XRD	X-Ray Diffraction

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NATIONAL ENVIRONMENTAL MANAGEMENT ACT (NEMA) REGULATIONS (2014) APPENDIX 6: SPECIALIST REPORTING REQUIREMENTS CHECKLIST

Below is a checklist showing information required by specialists in terms of Appendix 6 of NEMA

Item	NEMA Regulations (2014): Appendix 6	Relevant Section in Report
1(a)(i)	Details of the specialist who prepared the report	Page 30
1(a)(ii)	The expertise of that person to compile a specialist report including a curriculum vitae	Appendix B
1(b	A declaration that the person is independent in a form as may be specified by the competent authority	Page 30
1©	An indication of the scope of, and the purpose for which, the report was prepared	Section 1.2 (Page 1)
1(d)	The date and season of the site investigation and the relevance of the season to the outcome of the assessment	Section 3.1 (Page 8)
1€	A description of the methodology adopted in preparing the report or carrying out the specialised process	Section 3 (Page 8 to 11
1(f)	The specific identified sensitivity of the site related to the activity and its associated structures and infrastructure	Section 5.4 (Page 25)
1(g)	An identification of any areas to be avoided, including buffers	None identified
1(h)	A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	Figure 2-2 (Page 6)
1(i)	A description of any assumptions made and any uncertainties or gaps in knowledge;	Section 5.2 (Page 22)
1(j)	A description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives, on the environment	Section 6 (Page 26)
1(k)	Any mitigation measures for inclusion in the EMPr	Section 7 (Page 28)
1(l)	Any conditions for inclusion in the environmental authorisation	Section 7 (Page 28)
1(m)	Any monitoring requirements for inclusion in the EMPr or environmental authorisation	Section 7 (Page 28)
1(n)(i)	A reasoned opinion as to whether the proposed activity or portions thereof should be authorised and	Section 7 (Page 29)
1(n)(ii)	If the opinion is that the proposed activity or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan	Section 7 (Page 29)
1(o)	A description of any consultation process that was undertaken during the course of carrying out the study	None undertaken
1(p)	A summary and copies if any comments that were received during any consultation process	N/A
1(q)	Any other information requested by the competent authority.	No other information

GEOCHEMICAL ASSESSMENT

1   INTRODUCTION

SLR Consulting (South Africa) (Pty) Limited ("SLR") has been appointed by Mokala Manganese (Pty) Limited ("Mokala") to undertake a geochemical assessment for a proposed manganese mine on the remaining extent of farm Gloria 266 near Hotazel in the Northern Cape Province, South Africa.

1.1   BACKGROUND

Mokala currently hold a prospecting right (DMR Ref No. NC 30/5/1/1/2/1250EM) for the remaining extent of farm Gloria 266 (Gloria). As part of the Environmental Impact Assessment (EIA) and Environmental Management Programme (EMP) required as part of mining right application, a geochemical assessment is necessary to characterise the material likely to be mined.

As part of the EIA process, the public were consulted in the form of public participation meetings. No issues with regards to the geochemical assessment were raised.

1.2   OBJECTIVES

The objectives of this report are:

- To geochemically characterise material from the mine; including ore body material, non-ore body material and waste material.
- To identify material that would be potentially acid generating or would produce poor quality drainage.
- To estimate drainage quality.

1.3   REPORT STRUCTURE

The report has been divided accordingly:

- Section 2 presents the general site setting determined through a high level desk study;
- Section 3 summarises the geochemical characterisation methodologies;
- Section 4 details the results of the geochemical test work;
- Section 5 discusses the results;
- Section 6 summarises and concludes the report; and
- Section 7 presents recommendations for further work.

2   BASELINE

This section presents a brief review of available hydrogeological, geochemical and geological information.

2.1   SITE SETTING

The Mokala project area consists of the remaining extent of farm Gloria 266 (Gloria) and portions of Umtu 281 and Kipling 271, located approximately 5 km north-west of the town of Hotazel in the Northern Cape The remaining extent of the farm Gloria covers an area of approximately 447 hectares (Ha). The location of the project area is presented in Figure 2-1.

The topography of the project area is relatively flat with a gentle slope towards the east. The eastern section of the project area falls relatively steeply towards the Ga-Mogara River, a non-perennial river that forms the eastern boundary of the project area.

The elevation of the project area ranges from approximately 1018 metres above mean sea level (mamsl) in the river bed to 1040 towards the western end of the site. The pre-mining land use is a mixture of natural bushveld and farming activities such as livestock grazing and game farming.

The project area is located in a semi-arid climatic region of South Africa characterised by seasonal rainfall, hot temperatures in summer, and colder temperatures in winter. The average annual precipitation, based on the mean annual precipitation (MAP) for Winton (0392148 W) weather station (approximately 40 km to the south-west of the sites) is 335 mm (SLR, 2015). Rainfall is usually intense, in the form of thunderstorms, and predominantly occurs during the summer months of October to April. Due to the semi-arid nature of the region, evaporation rates are high.

FIGURE 2-1: SITE LOCATION PLAN

2.2 GEOLOGICAL SETTING

The Mokala project area is located on the south-western outer rim of the Kalahari Manganese Field (KMF).

Mokala wish to exploit the manganese from the Hotazel Formation (Transvaal Supergroup). The general stratigraphic column for the project area is presented in Table 2-1 and presented in Figure 2-2.

TABLE 2-1: GENERAL STRATIGRAPHIC PROFILE FOR THE KALAHARI MANGANESE FIELD

Supergroup / Group / Subgroup / Formation				Geological Description	Approximate Thickness (m)
Kalahari Group				Sand, clay, gravels and calcrete	70.00
Kalahari Unconformity					
Karoo Supergroup				Dwyka Tillite	30.00
Dwyka Unconformity					
Olifantshoek Supergroup			Lucknow Formation	Quartzite	Not present
			Mapedi Formation	Red and Grey Shales and quartzites	Not present
Olifantshoek Unconformity					
Transvaal Supergroup	Postmansburg Group	Voelwater Subgroup	Mooidraai Formation	Dolomite	30.00
			Hotazel Formation	Upper Banded Iron Formation	20.00
				Upper Mn Ore Body (UMO)	10.00
				Middle Banded Iron Formation	10.00
				Middle Mn Ore Body (MMO)	-
				Middle Banded Iron Formation	15.00
				Lower Mn Ore Body (LMO)	20.00
				Lower Banded Iron Formation	5.00
		Ongeluk Formation		Basaltic Lava	-

Note: Thickness is based on average thickness from borehole logs

The **Hotazel Formation** consists of Banded Iron Formation (BIF). The ore is contained within a mineralised zone which is made up of three manganese rich zones; the Upper Manganese Ore Body (UMO), the Middle Manganese Ore Body (MMO) and the Lower Manganese Ore Body (LMO).

The **Hotazel Formation** is underlain by basaltic lava of the **Ongeluk Formation** (Transvaal Supergroup) and directly overlain by dolomite of the **Moodraai Formation** (Transvaal Supergroup), which is predominantly dolomite.

Regionally, the Transvaal Supergroup is overlain unconformably by the **Olifantshoek Supergroup** which consists of arenaceous sediments, typically interbedded shale, quartzite and lavas overlain by coarser quartzite and shale, however, the two formations present in the local area (Mapedi and Lucknow units) are not present beneath the site.

The Transvaal Supergroup beneath the site is therefore overlain by **Dwyka Formation** which forms the basal part of the Karoo Supergroup. This consists of tillite (diamictite) and is covered by sands, clay and calcrete of the **Kalahari Group.**

2.3 MINING PLAN

The proposed mine layout is presented in Figure 2-3.

The ore deposits will be extracted from an open pit using conventional open-pit excavation methods encompassing drilling, blasting, loading and hauling (truck and shovel method). The open pit will be a boxcut design whereas overburden material extracted from the open pit will be backfilled into the mining area on an ongoing basis (continuous rehabilitation). The boxcut overburden storage area will be approximately 15 Ha based on a 30 m high overburden dump, and is located to the north-west of the open pit.

The Run of Mine (ROM) ore will be loaded into haul trucks utilising hydraulic excavators and taken to ROM stockpiles. Processing will comprise of crushing and dry screening. Product would be stockpiled ready for loading and dispatch. There will be no fine tailings produced on site.

The depth of the manganese resource at the mining start point is approximately 65 m below surface extending to approximately 170 m or more below surface.

Potential sources of mine drainage include the overburden stockpile and the walls of the open pit.

LEGEND

| | PROPOSED PROJECT AREA |
| | SAMPLING POINTS |

STRATIGRAPHY

	KALAHARI
	DOLOMITE
	UPPER BIFS
	UPPER BODY
	MIDDLE BIFS
	LOWER BODY
	LOWER BIFS
	DYKE
	LAVA

MOKALA MANGANESE EXPLORATION PLAN
GEOLOGICAL SETTING AND SAMPLE LOCATION

| Date : | 08.2015 | Scale : | N.T.S |
| Project No : 720.09012.00003 | | FIGURE 2-2 | |
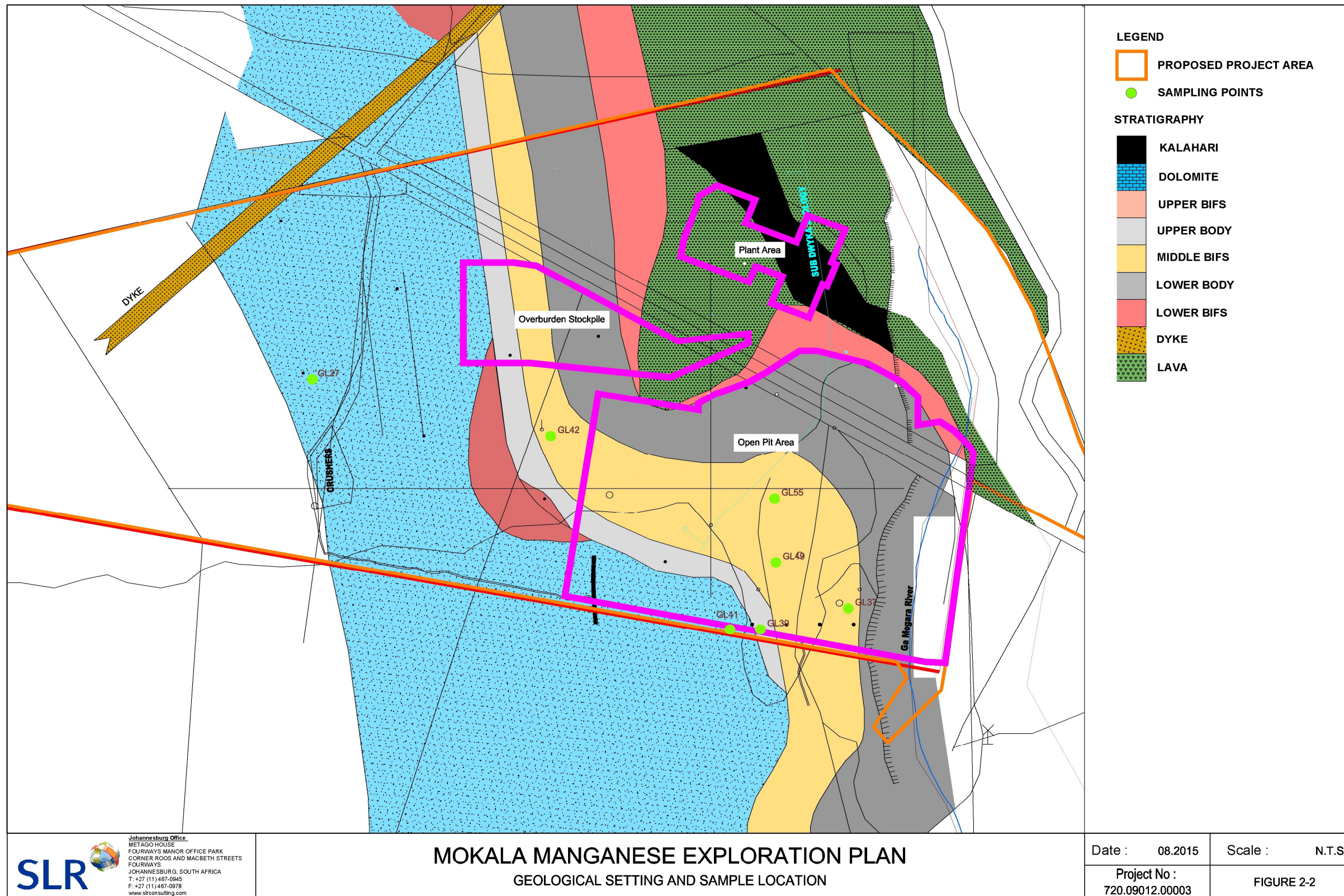
FIGURE 2-2: GEOLOGICAL SETTING
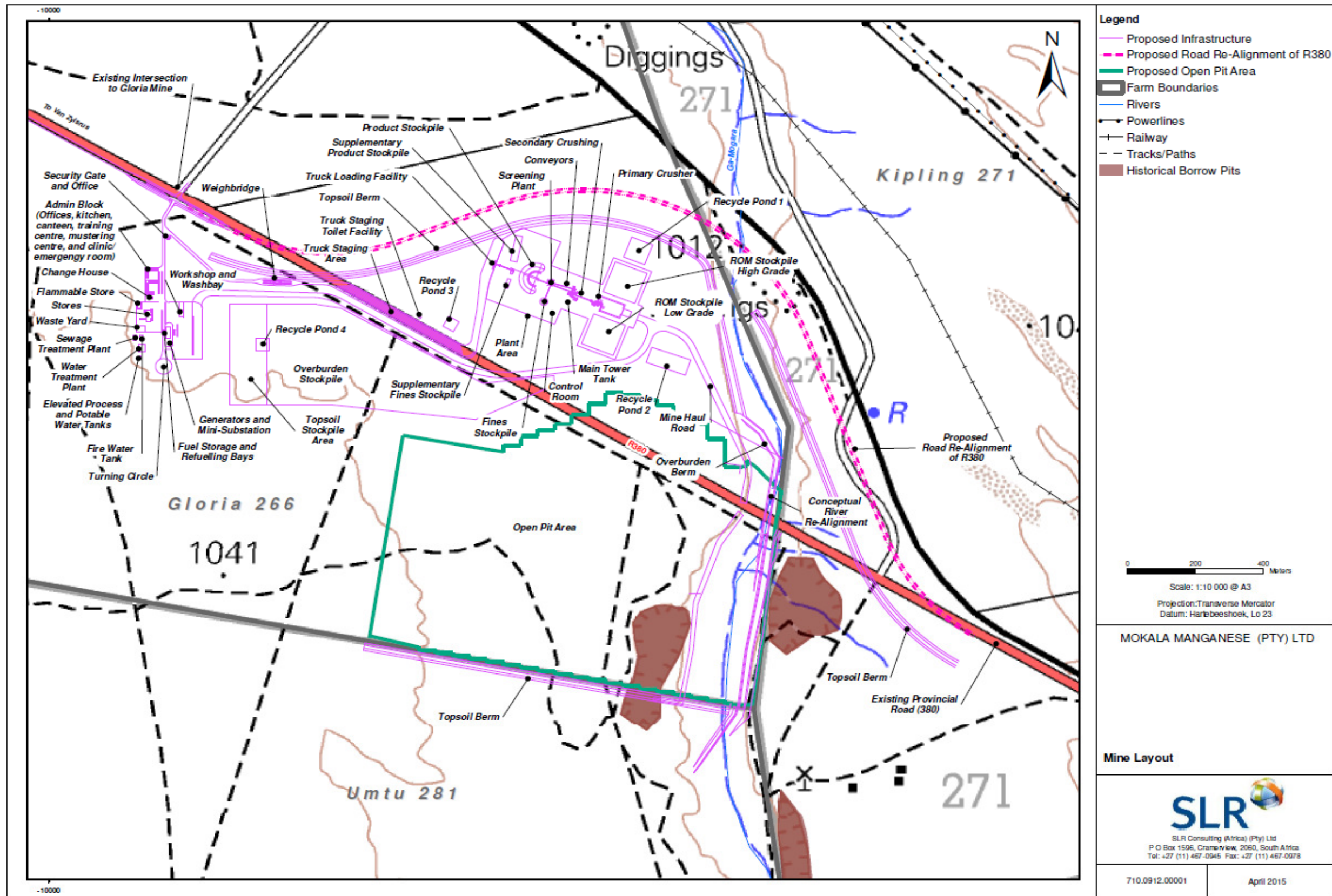
FIGURE 2-3: MOKALA MINE PLAN

3   GEOCHEMICAL CHARACTERISATION

The following section describes how samples were selected and collected and the methods undertaken to geochemically characterise the waste material.

3.1   SAMPLE SELECTION AND COLLECTION

SLR was provided with boreholes logs and plans from extensive prospecting on the project area. The borehole logs were reviewed and 10 lithologies likely to be disturbed through mining were identified.

Since the objective of the study is to provide an initial geochemical characterisation, the sampling rationale was to collect one to three samples of the main lithologies exposed by mining. SLR prepared a sampling plan with suggested boreholes and depth intervals for sampling.

It was confirmed by the client that the Lower Manganese Ore body would not be fully excavated and the Lower BIF would not be exposed, therefore samples of the Lower BIF have not been collected.

A total of twenty (20) samples were selected. The majority of samples were taken from cores on site. Samples of calcrete were collected directly from the wall of an existing quarry on site and samples of Lower Manganese Ore were selected from ore samples held by SGS that remained from metallurgical tests work. Samples from the site were collected during the months of November 2014 to January 2015 by Orex Exploration who are subcontracted by Mokala. The dates and seasons in which samples were collected have no relevance to the outcome of this assessment.

Due to the air percussion drilling technique used in the upper portion of the prospecting boreholes, the Kalahari samples were composite samples made up of sub samples collected from the entire thickness of the Kalahari Formation.

Details of the samples are presented in Table 3.1.

TABLE 3-1: SAMPLE DETAILS FOR SAMPLES COLLECTED FOR MOKALA

Sample ID	Mokala Samples ID	Sample Type	Borehole ID	Sample Depth (mbgl)		Lithology
				From	**To**	
MO01	50001	Core	GL42	0.00	90.00	Kalahari
MO02	50004	Core	GL39	0.00	69.00	Kalahari
MO03	50016	Core	GL49	0.00	63.00	Kalahari
MO06	50002	Core	GL42	90.00	100.00	Dwyka
MO07	50005	Core	GL39	69.00	84.00	Dwyka
MO08	50022	Core	GL27	100.00	159.00	Mooidraai
MO09	47816	Core	GL55	0.00	5.00	Sand
MO10	50045	Core	GL41	83.50	84.00	Upper BIF
MO11	50024	Core	GL27	159.00	175.00	Upper BIF

Sample ID	Mokala Samples ID	Sample Type	Borehole ID	Sample Depth (mbgl)		Lithology
MO12	50003	Core	GL42	100.00	101.00	Upper Mn Ore
MO13	50006	Core	GL39	84.00	88.00	Upper Mn Ore
MO14	50013	Core	GL42	122.78	123.78	Middle BIF
MO15	50046	Core	GL41	86.50	87.00	Middle BIF
MO16	50012	Core	GL42	116.54	117.54	Middle Mn Ore
MO18	46253	Mn Sample from SGS	GL42	151.67	-	Lower Mn Ore
MO19	27541	Mn Sample from SGS	GL37	98.99	-	Lower Mn Ore
MO22	50007	Grab sample	Quarry	-	-	Calcrete
MO23	50008	Grab sample	Quarry	-	-	Calcrete
MO24	50009	Grab sample	Quarry	-	-	Calcrete
MO25	50010	Grab sample	Quarry	-	-	Calcrete

The number of samples is considered sufficient for a preliminary assessment of acid drainage risk and indicative estimates of drainage quality.

3.2 LABORATORY ANALYSIS

All samples were sent to SGS Laboratory in Johannesburg, South Africa. SGS is a SANAS (South African National Accreditation System) accredited laboratory according to ISO/IEC 17025:2005 standards.

The following laboratory tests were undertaken on selected samples:

- Acid Base Accounting (ABA);
  - ο Acid Potential (AP) analysis;
  - ο Neutralising Potential (NP) analysis;
  - ο Paste pH;
  - ο Sulphur speciation;
- Mineralogical testing by X-ray Diffraction (XRD);
- Synthetic Precipitation Leaching Procedure (SPLP) test using distilled water.

The tests are described in further detail in the following sections.

3.2.1 ACID BASE ACCOUNTING

3.2.1.1 Acid Potential and Neutralising Potential

Acid–Base Accounting (ABA) is an internationally accepted analytical procedure that was developed to screen the acid-producing and acid-neutralizing potential of rocks.

The Acid Generating Potential (AP) is due to the oxidation of sulphide minerals in a rock sample and is calculated as the total sulphide sulphur content in % multiplied by 31.25.

The Acid Neutralising Potential (NP) is a measure of the total acid a material is capable of neutralising and is predominantly a result of neutralising bases, mostly carbonates and exchangeable alkali and alkali earth cations.

AP and NP are both reported as Kg $CaCO_3$./Tonne.

3.2.1.2 Net Neutralising Potential (NNP)

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

$$NNP = NP – AP$$

Results are reported in kg of calcium carbonate per tonne of overburden (or parts per thousand). For a sample:

- Negative NNP indicates potential to generate acid; and
- Positive NNP indicates excess acid-neutralising potential.

3.2.1.3 Neutralising Potential Ratio (NPR)

The Neutralising Potential Ratio is calculated by dividing the Neutralising Potential (NP) by the acid potential (AP):

$$NPR = NP/AP$$

In the assessment:
- NPR ratios larger than 2 indicate non-potentially acid generation (Non-PAG);
- ratios between 1 and 2 are considered inconclusive / possibly acid generating; and
- NPR ratios below 1 indicate potential acid generation (PAG).

3.2.2 PASTE PH

Paste pH analysis is undertaken in conjunction with the ABA test. The test is a simple, rapid, and inexpensive screening tool that indicates the presence of readily available NP (generally from carbonate) or stored acidity and involves the placement of 'crushed' sample with distilled water at a low solid to liquid ratio (to produce a paste) and the pH measured after approximately two minutes.

The outcome of the test is governed by the surficial properties of the solid material being tested, and more particularly, the extent of soluble minerals, which may provide useful information regarding

anticipated mine water quality. It represents more closely the water to solid ratio of pore waters in wastes than other analysis procedures

3.2.3 SULPHUR SPECIATION

Some of the sulphur in a sample may be present in non-acid producing sulphates or native sulphur. If a significant part of the total sulphur occurs as sulphate sulphur instead of potentially acid generating sulphide sulphur, the overall risk of acid generation is reduced. However, significant water quality impacts may result from leaching of sulphate sulphur into local water resources.

3.2.4 MINERALOGY

Minerals are the building blocks of rocks. Mine drainage quality is generally a function of mineral present dissolution (or precipitation) during interaction of rocks with water. X-ray Diffraction (XRD) analysis identifies the main crystalline mineral phases in each sample.

3.2.5 SYNTHETIC PRECIPITATION LEACHING PROCEDURE (SPLP)

Synthetic Precipitation Leaching Procedure is a laboratory extraction method designed to determine the leachability of both organic and inorganic elements present in liquids, soils, and wastes under certain conditions. The solid phase is extracted over 18 hours with an extraction fluid, and liquid-to-solid ratio of 3:1 (Price, 2009). Following extraction, the liquid extract is separated from the solid phase by filtration and analysed.

4   RESULTS AND INTERPRETATION

The results of the testing are presented in the following sections. Copies of laboratory reports are provided in Appendix A.

4.1   DATA VALIDATION

The accuracy of the chemical analysis can be assessed through calculating the electro neutrality for each sample. The electro neutrality (E.N) is calculated using the following equation:

$$E.N.[\%] = \frac{\sum cations\left(\frac{meq}{l}\right) - \sum anions\left(\frac{meq}{l}\right)}{\sum cations\left(\frac{meq}{l}\right) + \sum anions\left(\frac{meq}{l}\right)} * 100\% < 10\%$$

Samples with a calculated E.N value of less than 10% are considered to show an acceptable level of accuracy. Where samples have an error percentage above 10%, results are considered to show an unacceptable level of accuracy and results / interpretation of results should be considered with caution.

The E.N calculation was applied to the leach data. A number of samples (10) showed an unacceptable level of accuracy due to the naturally high concentrations of nitrate found within the samples. By excluding nitrate from the calculations, all but one sample showed an acceptable level of accuracy. The results indicated that care should be taken when considering nitrate concentrations within calculations in this assessment.

Comparison of the results of the laboratory duplicates indicates that the methods applied show an acceptable level of reproducibility.

4.2   ABA

The potential for acid generation from lithologies of the Kalahari Manganese Field is low, therefore only eleven (11) of the twenty (20) samples were submitted for ABA test work. One (1) sample of each lithology likely to be disturbed through mining was tested. The ABA results for these samples are presented in Table 4.1.

The Acid Base Accounting (ABA) results show that the total sulphur content and more importantly the sulphide sulphur content of all samples are low, with the majority below the laboratory detection limit of <0.01%. The low sulphide sulphur content suggests the potential to generate acid is negligible for all samples. In addition, the neutralising potential ratio (NPR) of all samples is above 2, (minimum NPR 392), which implies all lithologies have sufficient neutralising potential to offset the low acid potential. A graph showing the sulphide sulphur content plotted against the NPR is presented as Figure 4-1 and

illustrates that based on these two criteria, all eleven samples are classified as Non-Potentially Acid Generating (Non-PAG).

The paste pH for all samples was neutral to alkaline and indicates that there is little potential for the generation of short-term acidity.

TABLE 4-1: ACID BASE ACCOUNTING RESULTS FOR MOKALA SAMPLES

Sample ID	Lab ID	Mokala ID	Borehole	Lithology	Paste pH	Acid Potential (AP) (kg/t)	Neutralization Potential (NP)	Nett Neutralization Potential (NNP) (NP-AP)	Neutralising Potential Ratio (NPR) (NP : AP)	Total Sulphur (%)	Sulphate Sulphur (%)	Sulphide Sulphur (%)	Classification
Criteria					*>5.5 (Non-PAG)*	*-*	*-*	*NNP>0 (Non-PAG)*	*>2 (Non-PAG)*	*-*	*-*	*Sulphide-S <0.3 (Short-term PAG)*	
MO1	JB14-05836.001	50001	GL42	Kalahari	8.4	<0.31	206.00	206	666	<0.01	<0.03	<0.01	Non-PAG
MO2	JB14-05836.004	50004	GL39	Kalahari	8.1	<0.31	139.00	139	449	<0.01	<0.03	<0.01	Non-PAG
MO6	JB14-05836.002	50002	GL42	Dwyka	7.9	<0.31	173.00	173	559	<0.01	<0.03	<0.01	Non-PAG
MO8	JB15-06166.002	50022	GL27	Mooidraai Dolomite	8.4	<0.31	208.00	208	673	0.03	0.07	<0.01	Non-PAG
MO11	JB15-06166.001	50024	GL27	Upper BIF	8.6	0.31	123.00	122	392	0.03	0.05	0.01	Non-PAG
MO12	JB14-05836.003	50003	GL42	Upper Mn Ore	8.6	<0.31	355.00	355	1150	<0.01	<0.03	<0.01	Non-PAG
MO14	JB14-05836.012	50013	GL42	Middle BIF	9.1	<0.31	404.00	404	1310	<0.01	<0.03	<0.01	Non-PAG
MO16	JB14-05836.011	50012	GL42	Middle Mn Ore	8.6	<0.31	149.00	149	482	<0.01	<0.03	<0.01	Non-PAG
MO18	JB15-06166.003	46253	GL42	Lower Mn Ore	8.9	<0.31	347.00	347	1120	<0.01	<0.03	<0.01	Non-PAG
MO22	JB14-05836.007	50007	Quarry	Calcrete	8.9	<0.31	775.00	774	2500	<0.01	<0.03	<0.01	Non-PAG
MO23	JB14-05836.008	50008	Quarry	Calcrete	8.6	<0.31	719.00	719	2330	<0.01	<0.03	<0.01	Non-PAG

Note: PAG refers to Potentially Acid Generating and Non-PAG refers to Non Potentially Acid Generating
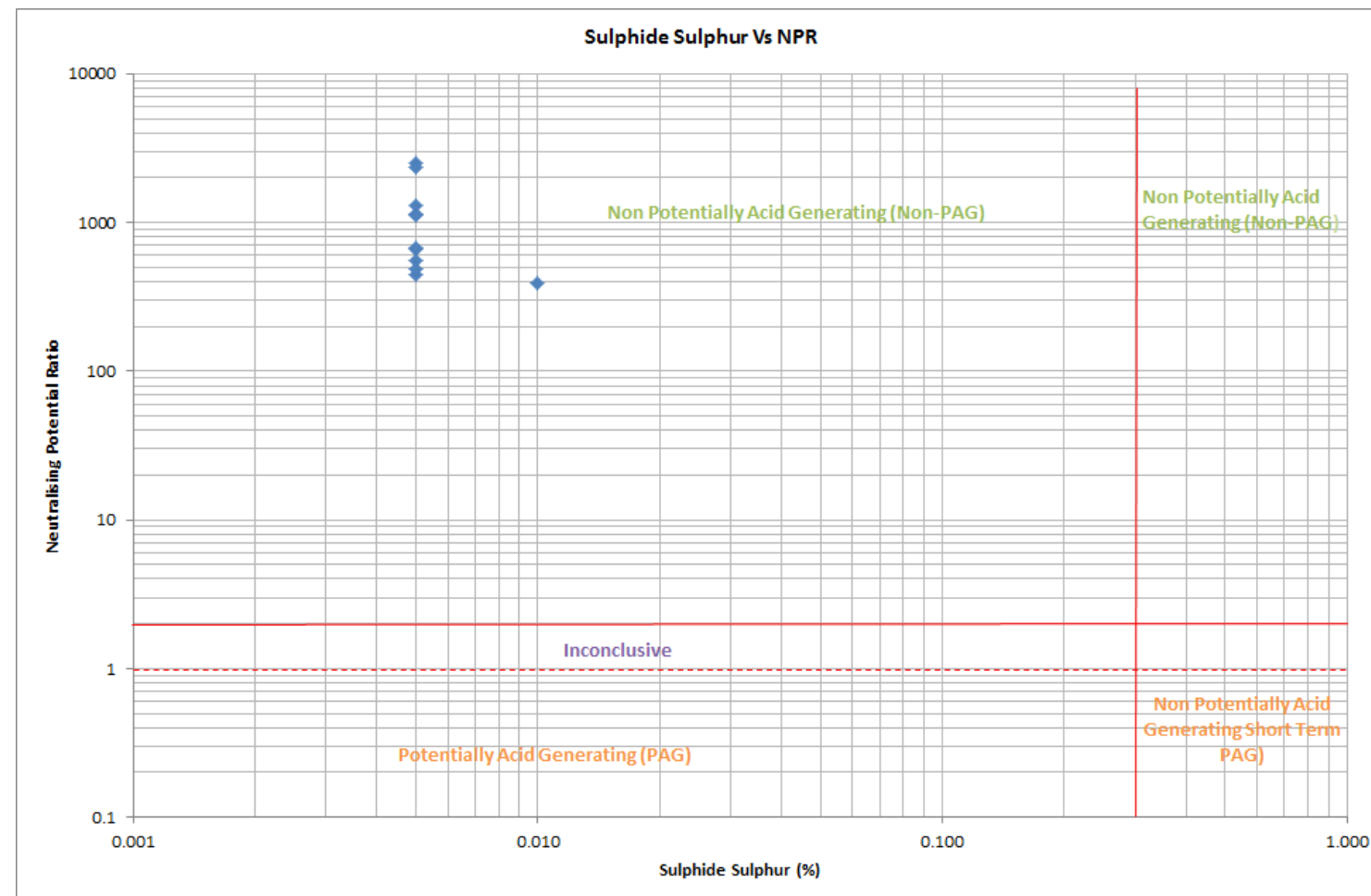
FIGURE 4-1: SULPHIDE SULPHUR CONTENT VERSUS NEUTRALIZING POTENTIAL RATIO FOR MOKALA SAMPLES

4.3 MINERALOGY

Fifteen (15) of the twenty (20) samples were submitted for mineralogical analysis.

The crystalline mineralogy of the fifteen samples is detailed in Table 4-2 and presented graphically in Figure 4-2.

The key minerals of each of the nine samples are consistent with the different lithological units mined at the site:

- Quartz, the weathered clay mineral smectite, and calcite are dominant in samples of the Kalahari Formation (sand, calcrete, clay and quartzite).
- Calcite was the dominant mineral in three of the four calcrete samples, as expected. Dolomite was dominant in sample MO22. The minerals smectite, palygorskite (magnesium aluminium phyllosilicate) and quartz were also present.
- The two Dwyka samples were consistent with smectite and quartz being the key minerals.
- The manganese ore samples were highly variable with respect to key minerals as Figure 4-2 shows.
- The Upper and Middle BIF samples showed variance with only hematite being a common mineral. Quartz made up 36% of the Upper BIF sample whereas only present below 1% in the Middle BIF. Dolomite was also present in the Upper BIF samples which could indicate heterogeneity of the BIF lithology or potential contamination from other lithologies.
- Dolomite was the key mineral in the Mooidraai Dolomite sample, as expected, followed by quartz.

The presence of highly soluble minerals such as calcite and dolomite in overburden samples suggests that the pH of mine drainage may be controlled by calcite dolomite dissolution. This would result in mine drainage with a generally neutral pH. Geochemical modelling is required to confirm this.

TABLE 4-2: MINERALOGY (%) FOR SAMPLES COLLECTED FROM THE MOKALA PROJECT AREA

Mineral Name	Approx. Formula / Sample ID	MO01	MO06	MO12	MO02	MO07	MO13	MO22	MO23	MO24	MO25	MO16	MO14	MO11	MO8	MO18
	Borehole	GL42	GL42	GL42	GL39	GL39	GL39	Quarry	Quarry	Quarry	Quarry	GL42	GL42	GL27	GL27	GL42
	Sample Depth From (m)	0	90	100	0	69	84	-	-	-	-	116.54	122.78	159	100	98.99
	Sample Depth to (m)	90	100	101	69	84	88	-	-	-	-	117.54	123.78	175	159	-
	Lithology of Sample	Kalahari	Dwyka	Upper Mn Ore	Kalahari	Dwyka	Upper Mn Ore	Calcrete	Calcrete	Calcrete	Calcrete	Middle Mn Ore	Middle BIF	Upper BIF	Mooidraai Dolomite	Lower Mn Ore
Quartz	SiO_2	49	32.8	6	40.2	27.8	18.7	9.8	7.3	11.3	13.3	38.5	0.5	36		17.6
Magnetite	Fe_3O_4														18.7	
Hematite	Fe_2O_3	0.9	1.4	8.3	0.7	3.1	4.7	0.4	0.1		0.2	-	29.1	12.5		
Dolomite	$CaMg(CO_3)_2$	18.5	11.5		11.4	2.4	7.3	68.3	5.7	0.3	2.5			13.6	70.5	
Braunite	Mn_7SiO_{12}			35.4	-	0.1	6							1.5		56.2
Calcite	$CaCO_3$	1.4	5.5	25.2	4.3	9.7	24.1	10.1	72.6	77.6	72.3	12.9				
Smectite	$(Ca, Na, H)(Al, Mg, Fe, Zn)_2(Si, Al)_4O_{10}(OH)_2 - xH_2O$	26.8	39.4		33.9	50.5	30.9	5.1	7.8	4.2	6					
Palygorskite	$(Mg,Al)_2Si_4O_{10}(OH)_4(H_2O)$	2.8	8.7		9	6.4	7.2	6.2	6.5	6.2	5.4					
Kaolinite	$Al_2Si_2O_5(OH)_4$											7.8				
Lizardite	$Mg_3Si_2O_5(OH)_4$											6.1	12.7			
Magnetite	Fe_3O_4	0.3	0.4		0.5		0.8	0.2	0.1	0.4	0.3	29.3				
Rutile	TiO_2	0.4	0.2							0.2						
Clinopyroxene	$CaMgSi_2O_6$												38.4			
Bixbyite	$(Mn{+++}.Fe{+++})_2O_3$			0.5		0.1	0.3									
Thaumasite	$Ca_3Si(CO_3)(SO_4)(OH)_6 12H_2O$											4.2				
Titanite	$CaTiO(SiO_4)$											1.2				
Kurchatovite	$Ca(Mg,Mn,Fe)B_2O_5$													17.7		
Ankerite	$Ca(Fe,Mg,Mn)(CO_3)_2$														11.9	
Kutnohorite	$Ca(Mn,Mg,Fe)(CO_3)_2$			15.9										19.4		34.3
Hausmannite	Mn_3O_4			8.7												9.5
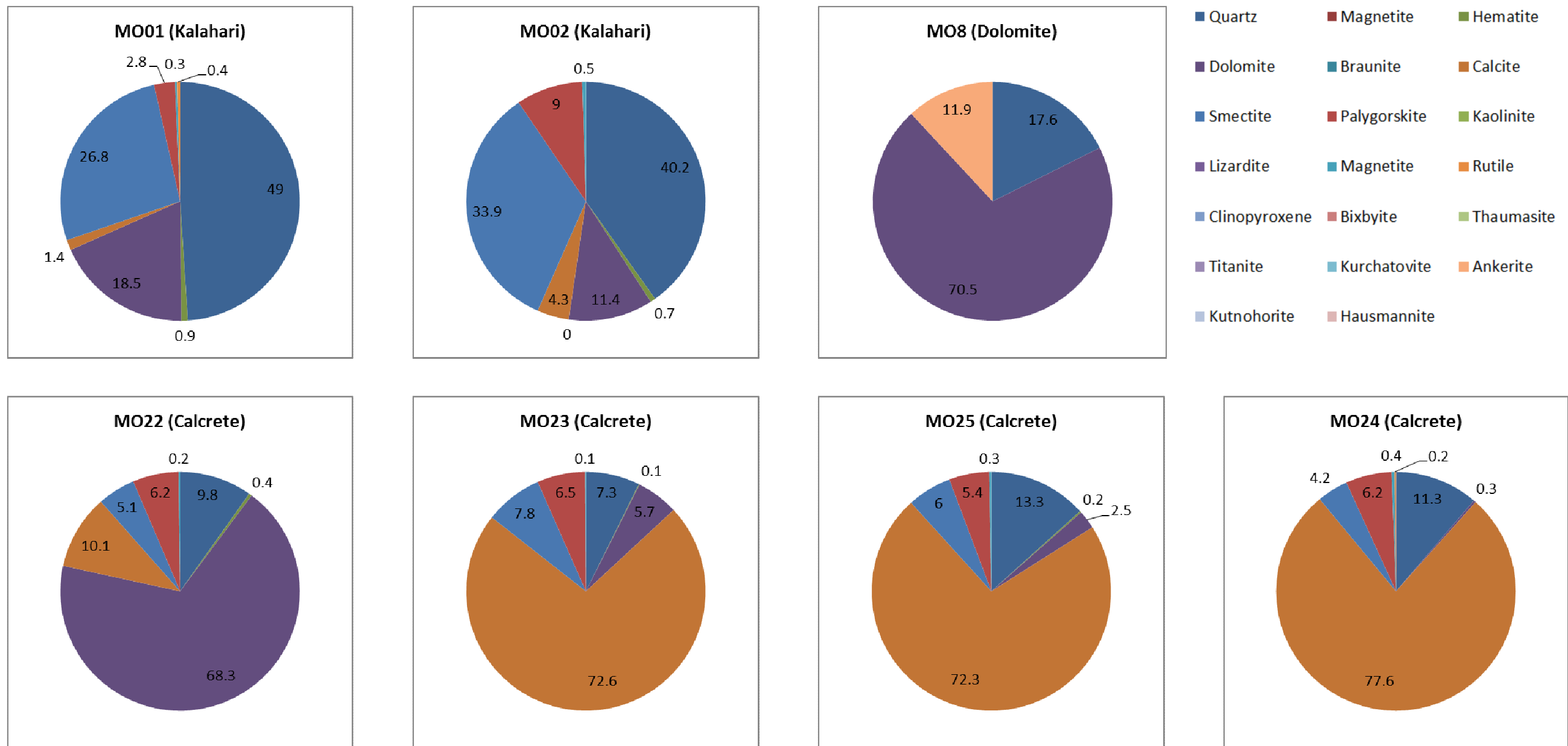
FIGURE 4-2: MINERALOGY OF THE MOKALA SAMPLES
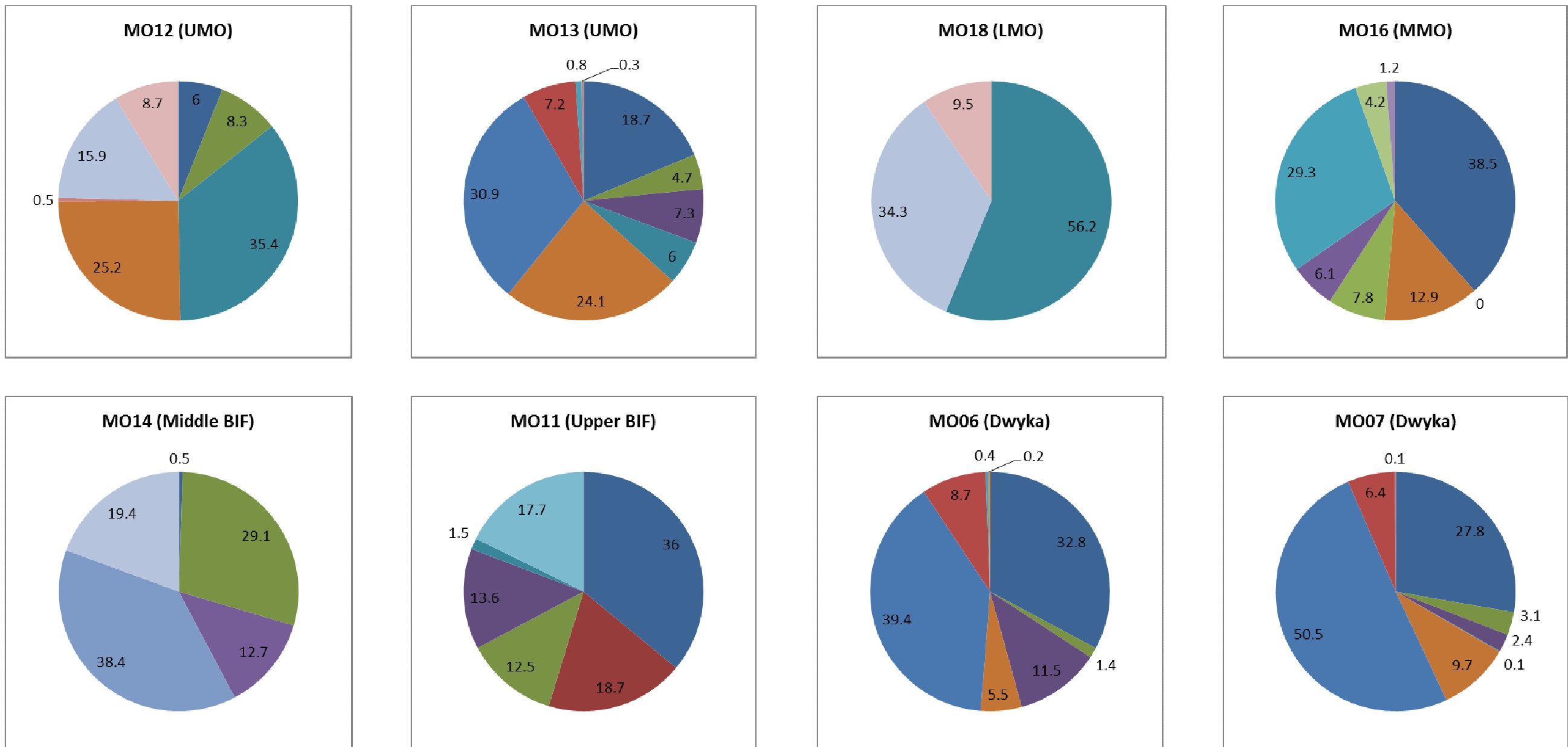
FIGURE 4-2: MINERALOGY OF THE MOKALA SAMPLES - CONTINUED

4.4   METAL LEACHING POTENTIAL

All twenty (20) samples were submitted to the laboratory for SPLP leach tests. The results are presented in Table 4-3.

The final pH of the leachates was higher than the initial pH 7, which indicates the presence of leachable alkalinity in the Mokala samples.

4.5   PRELIMINARY RISK ASSESSMENT

Leach test results are not an indicator of drainage quality as the conditions of the test, especially the liquid-to-solid ratio, do not represent actual field conditions. Therefore, leachate concentrations are not representative of seepage or run-off that could emanate from site. However, the results may indicate chemicals of concern (CoCs) in mine drainage.

As part of this assessment, SPLP tests were undertaken using distilled water (pH 7) to represent neutral drainage conditions, as suggested by the limited acid generating potential.

As a preliminary screening to identify potential CoCs, the leachates were compared to the following relevant water quality and effluent standards:

- World Health Organisation (WHO) Guidelines for drinking-water quality (WHO, 2011).
- International Finance Corporation (IFC) Guidelines for Mining Effluents (IFC, 2007).
- South African National Standards (SANS) 241 (2011) Drinking Water (SANS 241:2011).

Use of drinking water guidelines does not suggest that leachates and drainage from mine activities will be used for drinking purposes. Use of these guidelines is purely intended as a preliminary indicator of potential environmental risk.

Based on the guideline comparison:

- A number of elements are leachable at concentrations in excess of relevant water quality standards including manganese (Mn), and nitrate (NO3).

Modelled drainage quality, which considers potential site conditions in more detail, will provide an improved indicator of potential water quality risks.

TABLE 4-3: SPLP RESULTS FOR SAMPLES COLLECTED FROM MOKALA PROJECT AREA

						Analyte Name	Alkalinity (Phenolphthalein) as CaCO3	Bicarbonate Alkalinity as CaCO3	Carbonate Alkalinity as CaCO3	Alkalinity (Total) as CaCO3	Aluminium	Ammonia	Ammonia as N	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chloride	Chromium	Cobalt	Conductivity	Copper
SANS 241 (2011) Operational											0.3													
SANS 241 (2011) Aesthetic													1.5							300			170	
SANS 241 (2011) Acute Heath																								
SANS 241 (2011) Chronic Health														0.02	0.01	0.002	0.0001	0.003				0.05	0.5	2
IFC (2007)															0.1			0.05				0.1		0.3
WHO (2011)														0.02	0.01	0.7		0.003				0.05		2
						Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mS/m	mg/l
Sample Name	Mokala ID	BH	From	To	Description	Lab ID	12	12	12	12	0.02	0.1	0.08	0.02	0.01	0.002	0.0001	0.001	0.5	0.05	0.002	0.005	2	0.02
MO01	50001	GL42	0	90	Kalahari	JB14-05838.001	<12	67.00	20.00	87.00	<0.02	0.24	0.20	<0.02	<0.01	0.14	<0.0001	<0.001	16.00	33.00	<0.002	<0.005	39.00	<0.02
MO02	50004	GL39	0	69	Kalahari	JB14-05838.004	17.00	32.00	35.00	67.00	<0.02	0.18	0.15	<0.02	<0.01	0.15	<0.0001	<0.001	21.00	56.00	<0.002	<0.005	52.00	<0.02
MO03	50016	GL49	0	63	Kalahari	JB15-06164.004	13.00	53.00	25.00	78.00	<0.02	<0.1	<0.08	<0.02	<0.01	0.09	<0.0001	<0.001	15.00	35.00	<0.002	<0.005	41.00	<0.02
MO06	50002	GL42	90	100	Dwyka	JB14-05838.002	<12	42.00	<12	52.00	<0.02	0.15	0.12	<0.02	<0.01	0.11	<0.0001	<0.001	64.00	272.00	<0.002	<0.005	180.00	<0.02
MO07	50005	GL39	69	84	Dwyka	JB14-05838.005	<12	42.00	20.00	62.00	<0.02	0.23	0.19	<0.02	<0.01	0.09	<0.0001	<0.001	47.00	198.00	<0.002	<0.005	137.00	<0.02
MO08	50022	GL27	100	159	Mooidraai	JB15-06164.005	18.00	75.00	35.00	110.00	<0.02	<0.1	0.08	<0.02	<0.01	0.09	<0.0001	<0.001	15.00	37.00	<0.002	<0.005	50.00	<0.02
MO09	47816	GL55	0	5	Sand	JB15-06164.006	<12	38.00	20.00	58.00	0.64	<0.1	<0.08	<0.02	<0.01	0.17	<0.0001	<0.001	16.00	0.63	<0.002	<0.005	14.00	<0.02
MO10	50045	GL41	83.5	84	Upper BIF	JB15-06164.001	<12	25.00	15.00	40.00	<0.02	0.13	0.11	<0.02	<0.01	0.04	<0.0001	<0.001	11.00	12.00	0.01	<0.005	17.00	<0.02
MO11	50024	GL27	159	175	Upper BIF	JB15-06164.002	18.00	65.00	35.00	100.00	<0.02	0.12	0.10	<0.02	<0.01	0.07	<0.0001	<0.001	19.00	31.00	<0.002	<0.005	40.00	<0.02
MO12	50003	GL42	100	101	Upper Mn Ore	JB14-05838.003	12.00	65.00	25.00	90.00	<0.02	0.30	0.25	<0.02	<0.01	0.16	<0.0001	<0.001	11.00	34.00	<0.002	<0.005	42.00	<0.02
MO13	50006	GL39	84	88	Upper Mn Ore	JB14-05838.006	<12	55.00	15.00	70.00	<0.02	0.38	0.31	<0.02	<0.01	0.10	<0.0001	<0.001	29.00	118.00	<0.002	<0.005	89.00	<0.02
MO14	50013	GL42	122.78	123.78	Middle BIF	JB14-05838.012	12.00	27.00	25.00	52.00	<0.02	0.43	0.35	<0.02	<0.01	0.43	<0.0001	<0.001	7.50	3.50	<0.002	<0.005	15.00	<0.02
MO15	50046	GL41	86.5	87	Middle BIF	JB15-06164.003	15.00	113.00	30.00	143.00	<0.02	0.18	0.15	<0.02	<0.01	0.05	<0.0001	<0.001	18.00	16.00	<0.002	<0.005	42.00	<0.02
MO16	50012	GL42	116.54	117.54	Middle Mn Ore	JB14-05838.011	<12	42.00	15.00	57.00	<0.02	0.49	0.40	<0.02	<0.01	0.15	<0.0001	<0.001	14.00	4.00	<0.002	<0.005	15.00	<0.02
MO18	46253	GL42	151.67	-	Lower Mn Ore	JB15-06164.007	15.00	48.00	30.00	78.00	<0.02	0.12	0.10	<0.02	<0.01	0.06	<0.0001	<0.001	10.00	3.90	<0.002	<0.005	19.00	<0.02
MO19	27541	GL37	98.99	-	Lower Mn Ore	JB15-06164.008	<12	33.00	<12	38.00	<0.02	<0.1	0.08	<0.02	<0.01	0.35	<0.0001	<0.001	16.00	12.00	<0.002	<0.005	17.00	<0.02
MO22	50007	Quarry	-	-	Calrete	JB14-05838.007	<12	37.00	15.00	52.00	<0.02	0.34	0.28	<0.02	<0.01	0.09	<0.0001	<0.001	15.00	20.00	<0.002	<0.005	30.00	<0.02
MO23	50008	Quarry	-	-	Calrete	JB14-05838.008	<12	37.00	20.00	57.00	<0.02	0.81	0.67	<0.02	<0.01	0.13	<0.0001	<0.001	13.00	0.87	<0.002	<0.005	14.00	<0.02
MO24	50009	Quarry	-	-	Calrete	JB14-05838.009	<12	42.00	15.00	57.00	<0.02	0.46	0.38	<0.02	<0.01	0.13	<0.0001	<0.001	8.10	0.46	<0.002	<0.005	14.00	<0.02
MO25	50010	Quarry	-	-	Calrete	JB14-05838.010	<12	30.00	15.00	45.00	<0.02	0.35	0.29	<0.02	<0.01	0.09	<0.0001	<0.001	12.00	0.64	<0.002	<0.005	14.00	<0.02

						Analyte Name	Final pH	Fluoride	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Nitrate	Potassium	Selenium	Silver	Sodium	Strontium	Sulphate	TDS	Thorium	Vanadium	Zinc
SANS 241 (2011) Operational							5 - 9.7																			
SANS 241 (2011) Aesthetic									0.3			0.1								200			1200			5
SANS 241 (2011) Acute Heath																11						250				
SANS 241 (2011) Chronic Health								1.5		2	0.01		0.006		0.07			0.01				500			0.2	
IFC (2007)							6-9		2	0.2			0.002		0.5											0.5
WHO (2011)								1.5		0.01			0.006		0.07	11		0.04								
						Units	mg/l	mg/l		0.05	0.01	0.01	0.01	0.0001	0.005	0.005	0.1	mg/l	0.01	0.002	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Sample Name	Mokala ID	BH	From	To	Description	Lab ID	0.1	0.05	0.05	0.01	0.01	0.01	0.0001	0.005	0.005	0.1	0.2	0.01	0.002	0.5	0.001	21	0.04	0.001	0.01
MO01	50001	GL42	0	90	Kalahari	JB14-05838.001	8.40	0.33	<0.05	<0.01	13.00	<0.01	<0.0001	0.01	<0.005	29.00	5.60	<0.01	<0.002	19.00	0.21	23.00	246.00	<0.04	0.015	<0.01
MO02	50004	GL39	0	69	Kalahari	JB14-05838.004	8.30	0.30	<0.05	<0.01	17.00	<0.01	<0.0001	<0.005	<0.005	51.00	6.30	<0.01	<0.002	22.00	0.23	27.00	344.00	<0.04	0.01	0.01
MO03	50016	GL49	0	63	Kalahari	JB15-06164.004	7.90	1.20	<0.05	<0.01	14.00	<0.01	<0.0001	<0.005	<0.005	17.00	6.30	<0.01	<0.002	31.00	0.16	32.00	220.00	<0.04	0.02	<0.01
MO06	50002	GL42	90	100	Dwyka	JB14-05838.002	8.00	0.40	<0.05	<0.01	59.00	0.01	<0.0001	0.02	<0.005	250.00	12.00	<0.01	<0.002	76.00	0.94	70.00	1502.00	<0.04	0.00	0.03
MO07	50005	GL39	69	84	Dwyka	JB14-05838.005	8.10	0.40	<0.05	<0.01	44.00	<0.01	<0.0001	<0.005	<0.005	176.00	9.20	<0.01	<0.002	68.00	0.43	119.00	1036.00	<0.04	0.00	0.02
MO08	50022	GL27	100	159	Mooidraai	JB15-06164.005	8.30	0.36	<0.05	<0.01	38.00	0.02	<0.0001	0.02	<0.005	6.40	2.70	<0.01	<0.002	16.00	0.09	38.00	318.00	<0.04	<0.001	<0.01
MO09	47816	GL55	0	5	Sand	JB15-06164.006	7.90	0.32	0.46	<0.01	3.60	<0.01	<0.0001	<0.005	<0.005	1.80	4.20	<0.01	<0.002	1.20	0.06	0.84	90.00	<0.04	<0.001	0.02
MO10	50045	GL41	83.5	84	Upper BIF	JB15-06164.001	7.70	0.25	<0.05	<0.01	5.70	<0.01	<0.0001	0.01	<0.005	7.10	0.80	<0.01	<0.002	8.80	0.08	5.30	104.00	<0.04	<0.001	<0.01
MO11	50024	GL27	159	175	Upper BIF	JB15-06164.002	8.20	0.96	<0.05	<0.01	15.00	0.03	<0.0001	<0.005	<0.005	<0.1	1.50	<0.01	<0.002	28.00	0.16	25.00	190.00	<0.04	<0.001	<0.01
MO12	50003	GL42	100	101	Upper Mn Ore	JB14-05838.003	8.40	0.08	<0.05	<0.01	8.90	0.17	<0.0001	<0.005	<0.005	29.00	14.00	<0.01	<0.002	30.00	0.22	11.00	254.00	<0.04	0.00	0.01
MO13	50006	GL39	84	88	Upper Mn Ore	JB14-05838.006	8.10	0.24	<0.05	<0.01	27.00	0.02	<0.0001	<0.005	<0.005	81.00	7.00	<0.01	<0.002	43.00	0.18	114.00	602.00	<0.04	<0.001	0.02
MO14	50013	GL42	122.78	123.78	Middle BIF	JB14-05838.012	9.10	0.12	<0.05	<0.01	6.30	0.21	<0.0001	<0.005	<0.005	0.70	0.60	<0.01	<0.002	7.10	0.16	4.30	96.00	<0.04	<0.001	<0.01
MO15	50046	GL41	86.5	87	Middle BIF	JB15-06164.003	8.40	0.97	<0.05	<0.01	17.00	0.04	<0.0001	<0.005	<0.005	5.10	2.50	<0.01	<0.002	37.00	0.01	14.00	240.00	<0.04	<0.001	<0.01
MO16	50012	GL42	116.54	117.54	Middle Mn Ore	JB14-05838.011	8.40	<0.05	<0.05	<0.01	3.90	0.03	<0.0001	<0.005	<0.005	1.40	0.40	<0.01	<0.002	3.40	0.54	2.50	94.00	<0.04	<0.001	<0.01
MO18	46253	GL42	151.67	-	Lower Mn Ore	JB15-06164.007	8.20	<0.05	<0.05	<0.01	12.00	0.12	<0.0001	<0.005	<0.005	1.90	2.40	<0.01	<0.002	5.10	0.11	1.10	84.00	<0.04	<0.001	<0.01
MO19	27541	GL37	98.99	-	Lower Mn Ore	JB15-06164.008	7.80	0.26	<0.05	<0.01	4.40	0.09	<0.0001	<0.005	<0.005	2.10	0.50	<0.01	<0.002	4.80	0.30	11.00	98.00	<0.04	<0.001	<0.01
MO22	50007	Quarry	-	-	Calrete	JB14-05838.007	8.40	0.19	<0.05	<0.01	8.50	<0.01	<0.0001	<0.005	<0.005	12.00	3.50	<0.01	<0.002	16.00	0.08	37.00	192.00	<0.04	0.01	<0.01
MO23	50008	Quarry	-	-	Calrete	JB14-05838.008	8.10	0.19	<0.05	<0.01	3.80	<0.01	<0.0001	<0.005	<0.005	3.20	2.60	<0.01	<0.002	1.30	0.05	4.50	108.00	<0.04	0.01	0.02
MO24	50009	Quarry	-	-	Calrete	JB14-05838.009	8.40	0.30	<0.05	<0.01	8.80	<0.01	<0.0001	<0.005	<0.005	1.20	1.60	<0.01	<0.002	1.20	0.09	1.40	82.00	<0.04	0.09	<0.01
MO25	50010	Quarry	-	-	Calrete	JB14-05838.010	8.40	0.20	<0.05	<0.01	4.70	<0.01	<0.0001	<0.005	<0.005	1.60	3.10	<0.01	<0.002	1.30	0.07	3.30	96.00	<0.04	0.01	<0.01

Note: highlighted cells indicate an exceedence of the corresponding water quality limit

5   DRAINAGE QUALITY

This section presents the modelled quality of drainage from overburden and ore under assumed conditions at Mokala Mine. Drainage quality presented in this section has been based on the available data.

The drainage quality estimation is generally consistent with South African best practice, as described in Best Practice Guidelines (BPG) G4 (DWAF 2006a). The approach includes development of a conceptual model, use of laboratory results, and equilibrium geochemical modelling. Note that the number of samples is limited and sufficient for indicative estimates of drainage quality.

5.1   CONCEPTUAL MODELS

5.1.1   OVERBURDEN STOCKPILE

The overburden stockpile will consist of loose, excavated material. Rainfall on the stockpile will be absorbed into the pore space of the material and little runoff is anticipated. Given the arid climatic conditions, much of the absorbed rainfall will be evaporated. The overburden moisture content is unknown but is estimated to be 10% for the purposes of drainage quality estimation. This corresponds to a water:rock ratio of 1:10.

5.1.2   PIT WALLS

Rock lining the open pit is likely to be partially broken and fractured from blasting, excavation and vehicle traffic. This will provide surfaces for water from rainfall and/or groundwater inflow to interact with the lithologies exposed in the pit. However, evaporation is likely to limit the volume of water and water:rock ratio of 1:10 may apply.

5.1.3   PIT BACKFILL

Overburden returned to the pit as backfill will be broken from mining and excavation. This will significantly increase the surface area for interaction with groundwater. Groundwater flow through the backfill will mobilise salts from the backfill material. The water:rock ratio in saturated backfill will depend on the porosity of the backfill. At an estimated porosity of 10%, the water:rock ratio will be 1:10.

5.2   METHOD, APPROACH AND ASSUMPTIONS

The leach tests for the twenty (20) samples at a solution-solid ratio of 3:1 were used as a starting point for estimating drainage quality. The PHREEQC equilibrium geochemical modelling code (Parkhurst and Appelo 1999) was used to simulate the solution composition at the water-rock ratio indicated by the conceptual model.

It is generally impossible to determine precisely the physical and geochemical characteristics of mine facilities that do not yet exist. Therefore, assumptions are required to predict water qualities by means of geochemical modelling. General assumptions include:

- The water chemistries used in the modelling are representative of input sources. Input water qualities are obtained from the results of the geochemical characterisation programme. The water compositions used in the modelling do not represent actual water samples but "theoretical" compositions from sample analysis results.

- Predicting field-scale leaching from lab-scale leach tests is an approximation. Leaching of salts and metals at the field scale is variable through time and controlled by factors not fully applied at the lab scale. These factors include temperature, nature of the leaching solution, the solution to solid ratio, solution-solid contact time, particle size of the solid, and so on.

- Modelled waters are in full thermodynamic equilibrium. Equilibrium is the computational basis of PHREEQC. Equilibrium is unlikely to be the case for all chemical components throughout all mine waters. However, research has shown that assuming equilibrium conditions may usefully describe the composition of natural and mine water.

- The PHREEQC model appropriately simulates chemical reactions and contains the appropriate thermodynamic constants.

Due to the assumptions and inherent limitations of predictive modelling, the model results presented in this report are order of magnitude estimates. Therefore, results do not indicate modelled concentrations less than 0.1 mg/L.

5.2.1 OVERBURDEN SEEPAGE QUALITY

Speciation modelling indicated that the leachates from the sampled rock types were generally in equilibrium with the mineral calcite. This is consistent with the mineralogy results, which indicated calcite in the majority of samples.

Evaporation was simulated using PHREEQC to achieve the moisture content of 10% assumed in the conceptual model. As a conservative consideration, elements of environmental concern not detected in the leachates were assumed to be present at concentrations of one half the detection limit. This included arsenic, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, nickle, selenium, silver and thorium. Simulations allowed geochemically credible mineral phases to precipitate as the simulated "pore water" became concentrated.

Table 5-1 indicates drainage quality assuming that all the sampled lithologies are present in the overburden stockpile material. Given the limited sampling and uncertainties inherent in the model, field concentrations may vary by an order of magnitude.

TABLE 5-1: INDICATIVE OVERBURDEN SEEPAGE QUALITY

Element	SANS 241 (2011)		Modelled Concentration (mg/L)
	Limit (mg/L)	Level	
pH	-	-	6.5
Aluminium as Al	0.3	Operational	<0.1
Alkalinity as CaCO3	-	-	1011
Barium as Ba	-	-	2.7
Calcium as Ca	-	-	179
Chloride as Cl	300	Aesthetic	392
Fluoride as F	1.5	Chronic health	7.2
Iron as Fe	0.3	Aesthetic	<0.1
Potassium as K	-	-	73
Magnesium as Mg	-	-	259
Manganese as Mn	0.1 0.5	*Aesthetic* Chronic Health	*0.4*
Molybdenum Mo	-	-	0.1
Nitrate**	11	Acute Health	36
Sodium as Na	200	Aesthetic	315
Sulphate as SO$_4$	250 500	*Acute Health* Chronic Health	*359*
Strontium as Sr			4.1
Vanadium as V	0.2	Chronic Health	<0.1
Zinc as Zn	5	Aesthetic	0.2

Notes:

* Values highlighted in red exceed SANS 241 (2011) Limits for drinking water and used for screening purposes

** Nitrate not included in modelling. Values are averaged laboratory reported results

Nitrate concentrations from the leach tests were initially used as input parameters for the PHREEQC model. Concentrations were elevated above typical groundwater baseline concentrations and caused significant convergence errors in the initial geochemical model.

For the purposes of drainage quality modelling, nitrate was removed from the models. Although excluded from the model, nitrate is expected to be present in seepage from overburden stockpiles. The nitrate concentrations may be higher than leach test results owing to the use of nitrogen-bearing blasting agents. The impact of these cannot be determined in samples selected from drilled cores such as those used in this study.

5.2.2 PIT WALL RUNOFF QUALITY

The variability of rainfall and significant evaporation in the project area is likely to give rise to a very wide range of water:rock ratios in the pit walls. The leach test results indicate the potential mass of salts that may be released from pit sidewall rock through weathering. Portions of this salt mass will be mobilised

into the mine water system after rainfall events when rainwater washes salts from the sidewall into the pit. As an indicative estimate, pit runoff concentrations may be similar to the values in Table 5-1.

5.2.3   PIT BACKFILL SEEPAGE QUALITY

As an indicative estimate, pit backfill seepage may be similar to the values in Table 5-1.

5.3   SOURCE TERMS

A 'source term' is the mass of contaminant per unit time. It is required to assess the potential impact of contaminated seepage on groundwater quality. The source term is the product of seepage concentration and the seepage rate through the contaminant source.

In the case of Mokala, two main sources of contamination are relevant:

- The overburden stockpile.
- The backfilled opencast pit.

Seepage concentrations from these two sources have been based on the modelled seepage qualities as per Table 5-1.

Groundwater recharge is estimated at 1% of MAP through the sandy surface topsoils. Seepage through the overburden stockpile footprint was estimated at 2% of MAP, or 6.7 mm/yr. This is likely to be an overestimate as the low rainfall, high evaporation and high daily temperatures are expected to result in a negative water balance in the stockpile. Most moisture entering the overburden stockpile is expected to be removed by evaporative process rather than infiltrating to groundwater.

The estimated recharge over the 15 ha footprint area of the overburden stockpile amounts to a seepage volume of 1 005 m^3 per year[1].

Groundwater flow through the pit backfill may be of the order of 4 000 m^3 per year considering the dimensions of the pit[2], an average hydraulic conductivity of 0.001 m/d and a groundwater gradient of 0.05[3]. Source terms have been estimated for chloride and sulphate as they account for approximately 50% of the modelled dissolved load in seepage. They generally behave conservatively in groundwater as they undergo no chemical degradation and little retardation. Table 5-2 presents estimated source terms for Cl and SO$_4$.

---

[1] Seepage of 6.7 mm/yr through overburden stockpile multiplied by 15 ha footprint of the overburden stockpile

[2] Information obtained from Mokala Manganese (Pty) Limited

TABLE 5-2: SOURCE TERMS FOR OVERBURDEN STOCKPILE AND PIT BACKFILL

Conceptual Model	Water quality component	Seepage volume [m³/year]	Seepage quality [mg/L]	Contaminant mass [kg/year]
Overburden Stockpile	Chloride as Cl	1 005	392	394
	Sulphate as SO$_4$	1 005	359	361
Pit Backfill	Chloride as Cl	4 000	392	1 568
	Sulphate as SO$_4$	4 000	359	1 436

Note: Seepage volume estimated based on available information.

Contaminant mass is a product of the seepage volume and the seepage quality

The movement and dilution of the contaminant mass can be simulated in a numerical groundwater model to indicate the potential impact of the overburden stockpile on groundwater quality.

5.4   IDENTIFIED AREAS OF SENSITIVITY

The areas identified as 'sensitive', with regards to this geochemical assessment would be:

- Areas in proximity to the open pit.
- Areas in proximity to overburden stockpile.

The potential impact of the overburden stockpile on groundwater quality can be simulated in a numerical groundwater model and will be assessed in the groundwater assessment.

---

[3] Based on available information from site

---

6   CONCLUSIONS

The geochemical assessment undertaken and presented in the report has characterised the material likely to be excavated and exposed during mining operations at Mokala Manganese mine in the Northern Cape. The following conclusions are of significance with respect to water quality at the mine:

- The sampled rocks are not acid generating. Therefore, the risk of acid mine drainage forming at Mokala is low to negligible.
- The mineralogy of the sampled rocks is dominated by calcite ($CaCO_3$) and quartz. This is a source of neutralising potential and may be expected to buffer mine water at neutral pH.
- Leach tests suggest chemicals of concern in seepage from overburden and backfill are manganese and nitrate. Salinity of seepage will also be elevated.

Indicative drainage quality was simulated using the PHREEQC equilibrium geochemical modelling code (Parkhurst and Appelo 1999). Based on the assumed water:rock ratio in the overburden, the modelling results indicate that seepage may have the following general characteristics:

- Neutral pH (controlled by calcite dissolution).
- High alkalinity.
- High salinity (in the form of elevated calcium, sodium, magnesium, chloride, nitrate and sulphate concentrations).
- Low or non-detect concentrations of most trace elements.
- Chemicals of concern indicated by the modelling include: aluminium, chloride, fluoride, manganese, sodium, sulphate and vanadium.

A source term was developed for the overburden stockpile and the backfilled opencast pit as presented below. Under the dry climate conditions of Mokala, leachable salt mass from pit sidewalls is likely to fall within the ranges modelled for the overburden stockpile.

Conceptual Model	Water quality component	Seepage volume [m³/year]	Seepage quality [mg/L]	Contaminant mass [kg/year]
Overburden Stockpile	Chloride as Cl	1 005	392	394
	Sulphate as SO₄	1 005	359	361
Pit Backfill	Chloride as Cl	4 000	392	1 568
	Sulphate as SO₄	4 000	359	1 436

Note: Seepage volume estimated based on available information.

Contaminant mass is a product of the seepage volume and the seepage quality

The movement and dilution of the contaminant mass can be simulated in a numerical groundwater model to indicate the potential impact of the overburden stockpile on groundwater quality.

7 RECOMMENDATIONS

Based on the outcomes of this preliminary geochemistry study, SLR makes the following recommendations:

- As a mitigation measure, runoff and seepage from the overburden stockpile is classified as "dirty water". Mokala should take measures to intercept water from these areas thereby preventing the operation from increasing inorganic nitrogen concentrations in local surface water and groundwater resources. This should be considered in more detail during the design of storm water management for the overburden stockpiles.
- The potential impact of overburden and pit backfill seepage on local groundwater quality should be assessed using a numerical groundwater model and the indicative concentrations and/or source terms presented in this report.
- Mokala institute a groundwater and surface water (when in flow) quality monitoring programme. The programme should allow for:
  - ο Regular collection of representative water samples.
  - ο Analysis of the samples by a SANAS-accredited laboratory for the analytical suite indicated in Table 7-1.
  - ο The water quality results should be assessed by a suitably-qualified professional registered with the South African Council for Natural Scientific Professional (SACNASP).

TABLE 7-1: PROPOSED ANALYTICAL SUITE FOR WATER QUALITY MONITORING PROGRAMME

Elements	Groundwater	Surface Water
General Parameters		
pH	√	√
Electrical Conductivity	√	√
Total Dissolved Solids	√	√
Total Suspended Solids		√
Total Alkalinity	√	√
Ammonia	√	√
Anions		
Chloride	√	√
Fluoride	√	√
Nitrate	√	√
Sulphate	√	√
Metals by ICP		
Al, As, B, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, Sb, Se, Si, Sn, Sr, Ti, Th, V, W, Y, Zn	√ Dissolved Metals	√ Total Metals

It is recommended that the groundwater and surface water quality monitoring programme is included as a condition of the environmental authorisation.

Based on the information available for this assessment, and assuming the recommendations set out above are carried out, there is no reason why this activity should not be authorised.

Declaration of Independence

I, *Jenny Ellerton* hereby declare that *SLR Consulting (South Africa) (Pty) Limited*, an independent consulting firm, has no interest or personal gains in this project whatsoever, except receiving fair payment for rendering an independent professional service.

Consultant name: Jenny Ellerton

Signature:

Date:13th October 2015

Jenny Ellerton	**Natasha Daly**	**Terry Harck**
Hydrogeologist		**Hydrogeochemist**
(Report Author)	**(Project Manager)**	**(Project Reviewer)**

Curriculum Vitae of the Report Author and Project Reviewer are presented in Appendix B.

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SLR Consulting (Africa) Pty Limited (2015b) Mokala Manganese Project. Waste Assessment for Compliance with the National Environment Waste Act, 2008 (Act 59 of 2008) SLR Ref.: 720.09012.00003 (DRAFT)

APPENDIX A: LABORATORY CERTIFICATES

SGS

PRELIMINARY REPORT

Contact	Kobus Bezuidenhout
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Project	(Not specified)
Order Number	**To Follow**
Samples	12
Sample matrix	SOIL

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Laboratory Manager	
SGS Reference	JB14-05836 R0
Report Number	0000008048
Date Received	2014/10/22 08:08:48AM
Date Reported	2014/11/05 02:53:53PM

COMMENTS

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

SIGNATORIES

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Environmental Services

259 Kent Avenue, Ferndale
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Member of the SGS Group

			Sample Number Sample Name	JB14-05836.001 MO 1 - 50001	JB14-05836.002 MO 6 - 50002	JB14-05836.003 MO 12 - 50003	JB14-05836.004 MO 2- 50004	JB14-05836.005 MO 7- 50005
Parameter		**Units**	**LOR**					

Paste pH and conductivity and 10% pH in soil   Method: ME-AN-024

Parameter	Units	LOR	.001	.002	.003	.004	.005
Paste pH	-	1	8.4	7.9	8.6	8.1	-

Neutralising Potential (NP)   Method: ME-AN-025

Parameter	Units	LOR	.001	.002	.003	.004	.005
Fizz Rating	-	-	3	3	4	3	-
Sample Weight	g	-	2.00	2.00	2.00	2.00	-
Normality of standardised HCl	N	-	0.100	0.100	0.501	0.100	-
Volume of HCl added	ml	-	104.8	90.6	32.2	87.2	-
Normality of standardised NaOH	N	-	0.100	0.100	0.500	0.100	-
Titre of NaOH	ml	-	22.8	21.8	3.8	32.0	-
NP as kg CaCO3/T	kg CaCO3/T	0.1	206	173	355	139	-

SUB_Sulphur and carbon species by LECO   Method: SUB

Parameter	Units	LOR	.001	.002	.003	.004	.005
Total sulphur as S^	%	0.01	<0.01	<0.01	<0.01	<0.01	-
Sulphide as S^	%	0.01	<0.01	<0.01	<0.01	<0.01	-
Sulphate as SO4^	%	0.03	<0.03	<0.03	<0.03	<0.03	-
Total carbon as C^	%	0.01	2.36	2.13	4.52	1.62	-
Carbonate as CO3^	%	0.05	10.40	8.20	20.10	6.75	-

Calculation of acid/base balances   Method: ME-AN-025

Parameter	Units	LOR	.001	.002	.003	.004	.005
Acid potential	kg CaCO3/T	0.31	<0.31	<0.31	<0.31	<0.31	-
Net neutralising potential	kg CaCO3/T	-	206	173	355	139	-
NP AP ratio	-	-	666	559	1150	449	-
Classification	-	-	PAN	PAN	PAN	PAN	-

SUB_XRD   Method: SUB

Parameter	Units	LOR	.001
XRD scan^	No unit	0.1	-

SUB_SGS Booysens   Method: SUB

Parameter	Units	LOR	.001	.002	.003	.004	.005
Arsenic^	ppm	1	4.0	6.0	8.0	4.0	-
Boron^	ppm	0.022					-
Barium^	ppm	1	308	345	463	355	-
Cadmium^	ppm	0.02	0.10	0.13	0.030	0.090	-
Cobalt^	ppm	0.1	18	38	46	19	-
Chromium^	ppm	1					-
Copper^	ppm	0.5	46	88	9.6	36	-
Mercury^	ppm	0.01					-
Manganese^	ppm	2	860	2451	>10000	1570	-
Molybdenum^	ppm	0.05	5.2	5.0	1.6	3.1	-
Nickel^	ppm	0.5	31	58	14	36	-
Lead^	ppm	0.5	8.3	10	2.3	7.7	-
Antimony^	ppm	0.05	0.94	0.57	<0.050	0.50	-
Selenium^	ppm	2	<2.0	<2.0	<2.0	<2.0	-
Vanadium^	ppm	2	85	112	<2.0	104	-
Zinc^	ppm	1	23	37	27	37	-

Hexavalent Chromium by Discrete Analyser on Leachates   Method: ME-AN-040

Parameter	Units	LOR	.001
Hexavalent Chromium	mg/l	0.01	-

			Sample Number Sample Name	JB14-05836.006 MO 13- 50006	JB14-05836.007 MO 22- 50007	JB14-05836.008 MO 23- 50008	JB14-05836.009 MO 24- 50009	JB14-05836.010 MO 25- 50010
Parameter		**Units**	**LOR**					

Paste pH and conductivity and 10% pH in soil   Method: ME-AN-024

Report number   0000008048
Client reference: **To Follow**

Sample Number Sample Name			JB14-05836.006 MO 13- 50006	JB14-05836.007 MO 22- 50007	JB14-05836.008 MO 23- 50008	JB14-05836.009 MO 24- 50009	JB14-05836.010 MO 25- 50010
Parameter	**Units**	**LOR**					

Paste pH and conductivity and 10% pH in soil   Method: ME-AN-024 (continued)

Parameter	Units	LOR					
Paste pH	-	1	-	8.9	8.6	-	-

Neutralising Potential (NP)   Method: ME-AN-025

Parameter	Units	LOR					
Fizz Rating	-	-	-	4	4	-	-
Sample Weight	g	-	-	2.00	2.00	-	-
Normality of standardised HCl	N	-	-	0.501	0.501	-	-
Volume of HCl added	ml	-	-	65.3	60.2	-	-
Normality of standardised NaOH	N	-	-	0.500	0.500	-	-
Titre of NaOH	ml	-	-	3.4	2.7	-	-
NP as kg CaCO3/T	kg CaCO3/T	0.1	-	775	719	-	-

SUB_Sulphur and carbon species by LECO   Method: SUB

Parameter	Units	LOR					
Total sulphur as S^	%	0.01	-	<0.01	<0.01	-	-
Sulphide as S^	%	0.01	-	<0.01	<0.01	-	-
Sulphate as SO4^	%	0.03	-	<0.03	<0.03	-	-
Total carbon as C^	%	0.01	-	9.15	8.41	-	-
Carbonate as CO3^	%	0.05	-	9.15	8.41	-	-

Calculation of acid/base balances   Method: ME-AN-025

Parameter	Units	LOR					
Acid potential	kg CaCO3/T	0.31	-	<0.31	<0.31	-	-
Net neutralising potential	kg CaCO3/T	-	-	774	719	-	-
NP AP ratio	-	-	-	2500	2330	-	-
Classification	-	-	-	PAN	PAN	-	-

SUB_XRD   Method: SUB

Parameter	Units	LOR					
XRD scan^	No unit	0.1	-	-	-		

SUB_SGS Booysens   Method: SUB

Parameter	Units	LOR					
Arsenic^	ppm	1	-	<1.0	5.0	-	-
Boron^	ppm	0.022	-			-	-
Barium^	ppm	1	-	114	59	-	-
Cadmium^	ppm	0.02	-	0.15	0.14	-	-
Cobalt^	ppm	0.1	-	25	116	-	-
Chromium^	ppm	1	-			-	-
Copper^	ppm	0.5	-	24	442	-	-
Mercury^	ppm	0.01	-			-	-
Manganese^	ppm	2	-	1907	294	-	-
Molybdenum^	ppm	0.05	-	0.70	1.4	-	-
Nickel^	ppm	0.5	-	22	32	-	-
Lead^	ppm	0.5	-	3.6	4.3	-	-
Antimony^	ppm	0.05	-	<0.050	0.25	-	-
Selenium^	ppm	2	-	<2.0	<2.0	-	-
Vanadium^	ppm	2	-	17	14	-	-
Zinc^	ppm	1	-	10	8.0	-	-

Hexavalent Chromium by Discrete Analyser on Leachates   Method: ME-AN-040

Parameter	Units	LOR					
Hexavalent Chromium	mg/l	0.01	-	-	-		

Sample Number Sample Name			JB14-05836.011 MO 16- 50012	JB14-05836.012 MO 14- 50013
Parameter	**Units**	**LOR**		

Paste pH and conductivity and 10% pH in soil   Method: ME-AN-024

Report number   0000008048
Client reference: **To Follow**

Sample Number			JB14-05836.011	JB14-05836.012
Sample Name			MO 16- 50012	MO 14- 50013
Parameter	**Units**	**LOR**		

Paste pH and conductivity and 10% pH in soil   Method: ME-AN-024 (continued)

Parameter	Units	LOR	JB14-05836.011	JB14-05836.012
Paste pH	-	1	8.6	9.1

Neutralising Potential (NP)   Method: ME-AN-025

Parameter	Units	LOR	JB14-05836.011	JB14-05836.012
Fizz Rating	-	-	4	4
Sample Weight	g	-	2.00	2.00
Normality of standardised HCl	N	-	0.100	0.100
Volume of HCl added	ml	-	86.0	211.0
Normality of standardised NaOH	N	-	0.100	0.100
Titre of NaOH	ml	-	26.7	50.0
NP as kg CaCO3/T	kg CaCO3/T	0.1	149	404

SUB_Sulphur and carbon species by LECO   Method: SUB

Parameter	Units	LOR	JB14-05836.011	JB14-05836.012
Total sulphur as S^	%	0.01	<0.01	<0.01
Sulphide as S^	%	0.01	<0.01	<0.01
Sulphate as SO4^	%	0.03	<0.03	<0.03
Total carbon as C^	%	0.01	1.83	5.80
Carbonate as CO3^	%	0.05	8.10	16.90

Calculation of acid/base balances   Method: ME-AN-025

Parameter	Units	LOR	JB14-05836.011	JB14-05836.012
Acid potential	kg CaCO3/T	0.31	<0.31	<0.31
Net neutralising potential	kg CaCO3/T	-	149	404
NP AP ratio	-	-	482	1310
Classification	-	-	PAN	PAN

SUB_XRD   Method: SUB

SUB_SGS Booysens   Method: SUB

Parameter	Units	LOR	JB14-05836.011	JB14-05836.012
Arsenic^	ppm	1	7.0	17
Barium^	ppm	1	72	199
Cadmium^	ppm	0.02	0.020	0.070
Cobalt^	ppm	0.1	8.7	47
Copper^	ppm	0.5	2.9	6.0
Manganese^	ppm	2	2628	>10000
Molybdenum^	ppm	0.05	6.8	2.1
Nickel^	ppm	0.5	5.7	9.5
Lead^	ppm	0.5	2.4	3.0
Antimony^	ppm	0.05	<0.050	<0.050
Selenium^	ppm	2	<2.0	<2.0
Vanadium^	ppm	2	46	<2.0
Zinc^	ppm	1	18	22

Hexavalent Chromium by Discrete Analyser on Leachates   Method: ME-AN-040

METHOD	METHODOLOGY SUMMARY
ME-AN-024	Paste pH/EC is determined by mixing a portion of sample with water at a low liquid to solid ratio and measuring the pH/EC of the resulting paste. Based on MEND 1.20.1. 10% pH/EC is determined by mixing a portion of sample with water at a liquid to solid ratio of 10:1 for a given period of time and measuring the pH/EC of the supernatant.
ME-AN-025	The acid production (AP) is calculated by assuming that all the sulphide sulphur present converts to sulphuric acid (sulphate) at a production of four moles of hydrogen ion per mole of pyrite oxidised. AP = acid potential = sulphide x 31.25. Where sulphide is reported as below the MDL, 0.099 is used for the calculation.
ME-AN-025	The acid/base balances (net NP, NP/AP ratio) are calculated and used to classify the sample as either having a potential to generate acidity, a potential for acid neutralisation or, if the results fall within a certain range, uncertainty with respect to net acid generation potential. Net NP = NP – AP PAG: Potentially acid generating, based on interpretation of ABA data alone. PAN: Potentially acid neutralising, based on interpretation of ABA data alone. U: Uncertain with respect to potential acid generation or neutralisation, based on interpretation of ABA data alone. Based on MEND 1.20.1.
ME-AN-040	Hexavalent chromium, when reacted with diphenylcarbizide in acid solution, produces a red-violet colour which is measured photometrically at wavelength 540 nm.

FOOTNOTES

IS	Insufficient sample for analysis.		QFH	QC result is above the upper tolerance
LNR	Sample listed, but not received.		QFL	QC result is below the lower tolerance
*	This analysis is not covered by the scope of accreditation.		-	The sample was not analysed for this analyte
^	Performed by outside laboratory.			
LOR	Limit of Reporting			
↑↓	Raised or Lowered Limit of Reporting			

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

Solid samples expressed on a dry weight basis.

SGS

TEST REPORT

CLIENT DETAILS

Contact	Kobus Bezuidenhout
Client	Mokala Manganese (PTY) LTD
Address	17 Termo Avenue
	Techno Park
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Telephone	011 218 8221
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Email	kobezb@vodamali.co.za
Project	(Not specified)
Order Number	**To Follow**
Samples	12
Sample matrix	SOIL

LABORATORY DETAILS

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SGS Reference	JB14-05836 R0
Report Number	0000008232
Date Received	2014/10/22 08:08:48AM
Date Reported	2014/11/20 12:59:04PM

COMMENTS

The document is issued in accordance with SANAS's accreditation requirements.
Accredited for compliance with ISO/IEC 17025. SANAS accredited laboratory T0107.

sanas
Testing Laboratory
T0107

Analysis of metals was subcontracted.
Analysis of XRD was subcontracted to SGS Mineralogy Lab. Results are contained in their report, appended.
Analysis of sulphur and carbon species completed by SGS Analytical Services Booysens .

PAG: Potentially acid generating, based on interpretation of ABA data alone .
PAN: Potentially acid neutralising, based on interpretation of ABA data alone .
U: Uncertain with respect to potential acid generation or neutralisation, based on interpretation of ABA data alone .

The Modified ABA test method merely provides an indication of the potential for acid generation . Whether or not acidic
drainage will result depends on the mineralogy, the availability of each acid generating and neutralising
mineral present, the physical characteristics of the material and the environmental setting.

SIGNATORIES

_____
James Drynan
Contracted Technical Signatory

_____
Martin Olivier
Operations Manager

SGS South Africa (Pty) Limited
Environmental Services

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Member of the SGS Group

ANALYTICAL REPORT

JB14-05836 R0

Report number: 0000008232

Client reference: **To Follow**

Sample Number Sample Name			JB14-05836.001 MO 1 - 50001	JB14-05836.002 MO 6 - 50002	JB14-05836.003 MO 12 - 50003	JB14-05836.004 MO 2- 50004	JB14-05836.005 MO 7- 50005
Parameter	**Units**	**LOR**					

Paste pH and conductivity and 10% pH in soil   Method: ME-AN-024

Parameter	Units	LOR					
Paste pH	-	1	8.4	7.9	8.6	8.1	-

Neutralising Potential (NP)   Method: ME-AN-025

Parameter	Units	LOR					
Fizz Rating	-	-	3	3	4	3	-
Sample Weight	g	-	2.00	2.00	2.00	2.00	-
Normality of standardised HCl	N	-	0.100	0.100	0.501	0.100	-
Volume of HCl added	ml	-	104.8	90.6	32.2	87.2	-
Normality of standardised NaOH	N	-	0.100	0.100	0.500	0.100	-
Titre of NaOH	ml	-	22.8	21.8	3.8	32.0	-
NP as kg CaCO3/T	kg CaCO3/T	0.1	206	173	355	139	-

SUB_Sulphur and carbon species by LECO   Method: SUB

Parameter	Units	LOR					
Total sulphur as S^	%	0.01	<0.01	<0.01	<0.01	<0.01	-
Sulphide as S^	%	0.01	<0.01	<0.01	<0.01	<0.01	-
Sulphate as SO4^	%	0.03	<0.03	<0.03	<0.03	<0.03	-
Total carbon as C^	%	0.01	2.36	2.13	4.52	1.62	-
Carbonate as CO3^	%	0.05	10.40	8.20	20.10	6.75	-

Calculation of acid/base balances   Method: ME-AN-025

Parameter	Units	LOR					
Acid potential*	kg CaCO3/T	0.31	<0.31	<0.31	<0.31	<0.31	-
Net neutralising potential*	kg CaCO3/T	-	206	173	355	139	-
NP AP ratio*	-	-	666	559	1150	449	-
Classification*	-	-	PAN	PAN	PAN	PAN	-

SUB_XRD   Method: SUB

Parameter	Units	LOR					
XRD scan^	No unit	0.1	MIN 14/784	MIN 14/784	MIN 14/784	MIN 14/784	-

SUB_SGS Booysens   Method: SUB

Parameter	Units	LOR					
Arsenic^	ppm	1	4.0	6.0	8.0	4.0	-
Boron^	ppm	0.022	<0.022	<0.022	184	<0.022	-
Barium^	ppm	1	308	345	463	355	-
Cadmium^	ppm	0.02	0.10	0.13	0.030	0.090	-
Cobalt^	ppm	0.1	18	38	46	19	-
Chromium^	ppm	1	41	92	8.0	36	-
Copper^	ppm	0.5	46	88	9.6	36	-
Mercury^	ppm	0.01	0.69	0.66	0.31	0.53	-
Manganese^	ppm	2	860	2451	>10000	1570	-
Molybdenum^	ppm	0.05	5.2	5.0	1.6	3.1	-
Nickel^	ppm	0.5	31	58	14	36	-
Lead^	ppm	0.5	8.3	10	2.3	7.7	-
Antimony^	ppm	0.05	0.94	0.57	<0.050	0.50	-
Selenium^	ppm	2	<2.0	<2.0	<2.0	<2.0	-
Vanadium^	ppm	2	85	112	<2.0	104	-
Zinc^	ppm	1	23	37	27	37	-

Hexavalent Chromium in Soil   Method: ME-AN-040

Parameter	Units	LOR					
Hexavalent Chromium*	mg/kg	0.4	12	21	<0.4	<0.4	-

Sample Number Sample Name			JB14-05836.006 MO 13- 50006	JB14-05836.007 MO 22- 50007	JB14-05836.008 MO 23- 50008	JB14-05836.009 MO 24- 50009	JB14-05836.010 MO 25- 50010
Parameter	**Units**	**LOR**					

Paste pH and conductivity and 10% pH in soil   Method: ME-AN-024

Sample Number Sample Name	Units	LOR	JB14-05836.006 MO 13- 50006	JB14-05836.007 MO 22- 50007	JB14-05836.008 MO 23- 50008	JB14-05836.009 MO 24- 50009	JB14-05836.010 MO 25- 50010
Parameter							

Paste pH and conductivity and 10% pH in soil   **Method: ME-AN-024 (continued)**

	Units	LOR	.006	.007	.008	.009	.010
Paste pH	-	1	-	8.9	8.6	-	-

Neutralising Potential (NP)   **Method: ME-AN-025**

	Units	LOR	.006	.007	.008	.009	.010
Fizz Rating	-	-	-	4	4	-	-
Sample Weight	g	-	-	2.00	2.00	-	-
Normality of standardised HCl	N	-	-	0.501	0.501	-	-
Volume of HCl added	ml	-	-	65.3	60.2	-	-
Normality of standardised NaOH	N	-	-	0.500	0.500	-	-
Titre of NaOH	ml	-	-	3.4	2.7	-	-
NP as kg CaCO3/T	kg CaCO3/T	0.1	-	775	719	-	-

SUB_Sulphur and carbon species by LECO   **Method: SUB**

	Units	LOR	.006	.007	.008	.009	.010
Total sulphur as S^	%	0.01	-	<0.01	<0.01	-	-
Sulphide as S^	%	0.01	-	<0.01	<0.01	-	-
Sulphate as SO4^	%	0.03	-	<0.03	<0.03	-	-
Total carbon as C^	%	0.01	-	9.15	8.41	-	-
Carbonate as CO3^	%	0.05	-	9.15	8.41	-	-

Calculation of acid/base balances   **Method: ME-AN-025**

	Units	LOR	.006	.007	.008	.009	.010
Acid potential*	kg CaCO3/T	0.31	-	<0.31	<0.31	-	-
Net neutralising potential*	kg CaCO3/T	-	-	774	719	-	-
NP AP ratio*	-	-	-	2500	2330	-	-
Classification*	-	-	-	PAN	PAN	-	-

SUB_XRD   **Method: SUB**

	Units	LOR	.006	.007	.008	.009	.010
XRD scan^	No unit	0.1	-	MIN 14/784	MIN 14/784	-	-

SUB_SGS Booysens   **Method: SUB**

	Units	LOR	.006	.007	.008	.009	.010
Arsenic^	ppm	1	-	<1.0	5.0	-	-
Boron^	ppm	0.022	-	<0.022	<0.022	-	-
Barium^	ppm	1	-	114	59	-	-
Cadmium^	ppm	0.02	-	0.15	0.14	-	-
Cobalt^	ppm	0.1	-	25	116	-	-
Chromium^	ppm	1	-	13	16	-	-
Copper^	ppm	0.5	-	24	442	-	-
Mercury^	ppm	0.01	-	0.34	0.36	-	-
Manganese^	ppm	2	-	1907	294	-	-
Molybdenum^	ppm	0.05	-	0.70	1.4	-	-
Nickel^	ppm	0.5	-	22	32	-	-
Lead^	ppm	0.5	-	3.6	4.3	-	-
Antimony^	ppm	0.05	-	<0.050	0.25	-	-
Selenium^	ppm	2	-	<2.0	<2.0	-	-
Vanadium^	ppm	2	-	17	14	-	-
Zinc^	ppm	1	-	10	8.0	-	-

Hexavalent Chromium in Soil   **Method: ME-AN-040**

	Units	LOR	.006	.007	.008	.009	.010
Hexavalent Chromium*	mg/kg	0.4	-	<0.4	12	-	-

Sample Number Sample Name	Units	LOR	JB14-05836.011 MO 16- 50012	JB14-05836.012 MO 14- 50013
Parameter				

Paste pH and conductivity and 10% pH in soil   **Method: ME-AN-024**

Sample Number Sample Name			JB14-05836.011 MO 16- 50012	JB14-05836.012 MO 14- 50013
Parameter	**Units**	**LOR**		

Paste pH and conductivity and 10% pH in soil   Method: ME-AN-024 (continued)

Paste pH	-	1	8.6	9.1

Neutralising Potential (NP)   Method: ME-AN-025

Fizz Rating	-	-	4	4
Sample Weight	g	-	2.00	2.00
Normality of standardised HCl	N	-	0.100	0.100
Volume of HCl added	ml	-	86.0	211.0
Normality of standardised NaOH	N	-	0.100	0.100
Titre of NaOH	ml	-	26.7	50.0
NP as kg CaCO3/T	kg CaCO3/T	0.1	149	404

SUB_Sulphur and carbon species by LECO   Method: SUB

Total sulphur as S^	%	0.01	<0.01	<0.01
Sulphide as S^	%	0.01	<0.01	<0.01
Sulphate as SO4^	%	0.03	<0.03	<0.03
Total carbon as C^	%	0.01	1.83	5.80
Carbonate as CO3^	%	0.05	8.10	16.90

Calculation of acid/base balances   Method: ME-AN-025

Acid potential*	kg CaCO3/T	0.31	<0.31	<0.31
Net neutralising potential*	kg CaCO3/T	-	149	404
NP AP ratio*	-	-	482	1310
Classification*	-	-	PAN	PAN

SUB_XRD   Method: SUB

XRD scan^	No unit	0.1	MIN 14/784	MIN 14/784

SUB_SGS Booysens   Method: SUB

Arsenic^	ppm	1	7.0	17
Boron^	ppm	0.022	65	218
Barium^	ppm	1	72	199
Cadmium^	ppm	0.02	0.020	0.070
Cobalt^	ppm	0.1	8.7	47
Chromium^	ppm	1	<1.0	<1.0
Copper^	ppm	0.5	2.9	6.0
Mercury^	ppm	0.01	0.23	0.34
Manganese^	ppm	2	2628	>10000
Molybdenum^	ppm	0.05	6.8	2.1
Nickel^	ppm	0.5	5.7	9.5
Lead^	ppm	0.5	2.4	3.0
Antimony^	ppm	0.05	<0.050	<0.050
Selenium^	ppm	2	<2.0	<2.0
Vanadium^	ppm	2	46	<2.0
Zinc^	ppm	1	18	22

Hexavalent Chromium in Soil   Method: ME-AN-040

Hexavalent Chromium*	mg/kg	0.4	<0.4	<0.4

METHOD	METHODOLOGY SUMMARY
ME-AN-024	Paste pH/EC is determined by mixing a portion of sample with water at a low liquid to solid ratio and measuring the pH/EC of the resulting paste. Based on MEND 1.20.1. 10% pH/EC is determined by mixing a portion of sample with water at a liquid to solid ratio of 10:1 for a given period of time and measuring the pH/EC of the supernatant.
ME-AN-025	The acid production (AP) is calculated by assuming that all the sulphide sulphur present converts to sulphuric acid (sulphate) at a production of four moles of hydrogen ion per mole of pyrite oxidised. AP = acid potential = sulphide x 31.25. Where sulphide is reported as below the MDL, 0.099 is used for the calculation.
ME-AN-025	The acid/base balances (net NP, NP/AP ratio) are calculated and used to classify the sample as either having a potential to generate acidity, a potential for acid neutralisation or, if the results fall within a certain range, uncertainty with respect to net acid generation potential. Net NP = NP – AP PAG: Potentially acid generating, based on interpretation of ABA data alone. PAN: Potentially acid neutralising, based on interpretation of ABA data alone. U: Uncertain with respect to potential acid generation or neutralisation, based on interpretation of ABA data alone. Based on MEND 1.20.1.
ME-AN-040	Hexavalent chromium, when reacted with diphenylcarbizide in acid solution, produces a red-violet colour which is measured photometrically at wavelength 540 nm.

FOOTNOTES

IS	Insufficient sample for analysis.
LNR	Sample listed, but not received.
*	This analysis is not covered by the scope of accreditation.
^	Performed by outside laboratory.
LOR	Limit of Reporting
↑↓	Raised or Lowered Limit of Reporting

QFH	QC result is above the upper tolerance
QFL	QC result is below the lower tolerance
-	The sample was not analysed for this analyte

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

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

sanas
Testing Laboratory

T0107

SGS

TEST REPORT

CLIENT DETAILS		LABORATORY DETAILS	
Contact	Kobus Bezuidenhout	Laboratory	SGS South Africa (Pty) Limited
Client	Mokala Manganese (PTY) LTD	Address	259 Kent Avenue
Address	P.O. BOX 652286		Ferndale, 2194
	BENMORE 2010	Telephone	+27 (0)11 781 5689
Telephone	011 218 8221		
Facsimile	27 021 8802576	Laboratory Manager	
Email	kobezb@vodamali.co.za	SGS Reference	JB14-05836A R0
Project	**14521746**	Report Number	0000008822
Order Number	**To Follow**	Date Received	2015/03/03 02:55:49PM
Samples	12	Date Reported	2015/03/11 10:41:45AM
Sample matrix	SOIL		

COMMENTS

Whilst SGS laboratories conform to ISO/IEC 17025 standards, results of analysis in this report fall outside of the current scope of accreditation.

Analysis of Cyanide was subcontracted.

SIGNATORIES

Sarah Newton
Technical Consultant/Technical Signatory

Martin Olivier
Operations Manager

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Environmental Services

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Randburg, 2194, South Africa

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ANALYTICAL REPORT

JB14-05836A R0

Report number   0000008822
Client reference: **14521746**

Sample Number Sample Name			JB14-05836A.001 MO 1 - 50001	JB14-05836A.002 MO 6 - 50002	JB14-05836A.003 MO 12 - 50003	JB14-05836A.004 MO 2- 50004	JB14-05836A.005 MO 7- 50005
Parameter	**Units**	**LOR**					

SUB_Total Cyanide in soil   Method: SUB

	Units	LOR					
Total Cyanide^	mg/kg	0.01	0.025	<0.010	<0.010	0.040	0.040

Fluoride on soils by Ion Selective Electrode   Method: ME-AN-021

	Units	LOR					
Fluoride by ISE final result	mg/kg	2	13	13	3.5	15	12

Sample Number Sample Name			JB14-05836A.006 MO 13- 50006	JB14-05836A.007 MO 22- 50007	JB14-05836A.008 MO 23- 50008	JB14-05836A.009 MO 24- 50009	JB14-05836A.010 MO 25- 50010
Parameter	**Units**	**LOR**					

SUB_Total Cyanide in soil   Method: SUB

	Units	LOR					
Total Cyanide^	mg/kg	0.01	<0.010	<0.010	<0.010	<0.010	<0.010

Fluoride on soils by Ion Selective Electrode   Method: ME-AN-021

	Units	LOR					
Fluoride by ISE final result	mg/kg	2	17	7.3	6.4	8.9	5.8

Sample Number Sample Name			JB14-05836A.011 MO 16- 50012	JB14-05836A.012 MO 14- 50013
Parameter	**Units**	**LOR**		

SUB_Total Cyanide in soil   Method: SUB

	Units	LOR		
Total Cyanide^	mg/kg	0.01	<0.010	<0.010

Fluoride on soils by Ion Selective Electrode   Method: ME-AN-021

	Units	LOR		
Fluoride by ISE final result	mg/kg	2	<2.0	3.0

11-March-2015   Page 2 of 3

METHOD — METHODOLOGY SUMMARY

FOOTNOTES

IS	Insufficient sample for analysis.		QFH	QC result is above the upper tolerance
LNR	Sample listed, but not received.		QFL	QC result is below the lower tolerance
*	This analysis is not covered by the scope of accreditation.		-	The sample was not analysed for this analyte
^	Performed by outside laboratory.			
LOR	Limit of Reporting			
↑↓	Raised or Lowered Limit of Reporting			

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

Solid samples expressed on a dry weight basis.

PRELIMINARY REPORT

CLIENT DETAILS

Contact	Richard Curtis
Client	Mokala Manganese (PTY) LTD
Address	17 Termo Avenue
	Techno Park
	Stellenbosch
Telephone	011 218 8221
Facsimile	(Not specified)
Email	richardcurtis@telkomsa.net
Project	(Not specified)
Order Number	**To Follow**
Samples	3
Sample matrix	SOIL

LABORATORY DETAILS

Laboratory	SGS South Africa (Pty) Limited
Address	259 Kent Avenue
	Ferndale, 2194
Telephone	+27 (0)11 781 5689
Laboratory Manager	
SGS Reference	JB15-06166 R0
Report Number	0000008717
Date Received	2015/01/28 08:02:46AM
Date Reported	2015/02/19 03:05:39PM

COMMENTS

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

SIGNATORIES

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Member of the SGS Group

Report number   0000008717

Client reference: **To Follow**

			Sample Number	JB15-06166.001	JB15-06166.002	JB15-06166.003
			Sample Name	GL27 - 50024	GL27 - 50022	GL42 LB - 46253
			Sample Matrix	Soil	Soil	Soil

Parameter	Units	LOR				

Paste pH and conductivity and 10% pH in soil   Method: ME-AN-024

Parameter	Units	LOR				
Paste pH	-	1		8.6	8.4	8.9

Neutralising Potential (NP)   Method: ME-AN-025

Parameter	Units	LOR				
Fizz Rating	-	-		3	3	4
Sample Weight	g	-		2.00	2.00	2.00
Normality of standardised HCl	N	-		0.101	0.101	0.101
Volume of HCl added	ml	-		88.2	117.6	204.5
Normality of standardised NaOH	N	-		0.100	0.100	0.100
Titre of NaOH	ml	-		40.1	35.5	67.7
NP as kg CaCO3/T	kg CaCO3/T	0.1		123	208	347

SUB_Sulphur and carbon species by LECO   Method: SUB

Parameter	Units	LOR				
Total sulphur as S^	%	0.01		0.03	0.03	<0.01
Sulphide as S^	%	0.01		0.01	<0.01	<0.01
Sulphate as SO4^	%	0.03		0.05	0.07	<0.03
Total carbon as C^	%	0.01		2.31	8.41	4.10
Carbonate as CO3^	%	0.05		5.75	> 30	14.20

Calculation of acid/base balances   Method: ME-AN-025

Parameter	Units	LOR				
Acid potential	kg CaCO3/T	0.31		0.31	<0.31	<0.31
Net neutralising potential	kg CaCO3/T	-		122	208	347
NP AP ratio	-	-		392	673	1120
Classification	-	-		PAN	PAN	PAN

SUB_XRD_RI   Method: SUB

METHOD	METHODOLOGY SUMMARY
ME-AN-024	Paste pH/EC is determined by mixing a portion of sample with water at a low liquid to solid ratio and measuring the pH/EC of the resulting paste. Based on MEND 1.20.1. 10% pH/EC is determined by mixing a portion of sample with water at a liquid to solid ratio of 10:1 for a given period of time and measuring the pH/EC of the supernatant.
ME-AN-025	The acid production (AP) is calculated by assuming that all the sulphide sulphur present converts to sulphuric acid (sulphate) at a production of four moles of hydrogen ion per mole of pyrite oxidised. AP = acid potential = sulphide x 31.25. Where sulphide is reported as below the MDL, 0.099 is used for the calculation.
ME-AN-025	The acid/base balances (net NP, NP/AP ratio) are calculated and used to classify the sample as either having a potential to generate acidity, a potential for acid neutralisation or, if the results fall within a certain range, uncertainty with respect to net acid generation potential. Net NP = NP – AP PAG: Potentially acid generating, based on interpretation of ABA data alone. PAN: Potentially acid neutralising, based on interpretation of ABA data alone. U: Uncertain with respect to potential acid generation or neutralisation, based on interpretation of ABA data alone. Based on MEND 1.20.1.

FOOTNOTES

IS	Insufficient sample for analysis.	QFH	QC result is above the upper tolerance
LNR	Sample listed, but not received.	QFL	QC result is below the lower tolerance
*	This analysis is not covered by the scope of accreditation.	-	The sample was not analysed for this analyte
^	Performed by outside laboratory.		
LOR	Limit of Reporting		
↑↓	Raised or Lowered Limit of Reporting		

Samples analysed as received.

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

Solid samples expressed on a dry weight basis.

SGS

TEST REPORT (Amended)

CLIENT DETAILS

Contact	Richard Curtis
Client	Mokala Manganese (PTY) LTD
Address	17 Termo Avenue
	Techno Park
	Stellenbosch
Telephone	011 218 8221
Facsimile	(Not specified)
Email	richardcurtis@telkomsa.net
Project	(Not specified)
Order Number	**To Follow**
Samples	4
Sample matrix	SOIL

LABORATORY DETAILS

Laboratory	SGS South Africa (Pty) Limited
Address	259 Kent Avenue
	Ferndale, 2194
Telephone	+27 (0)11 590 3000
Laboratory Manager	Martin Olivier
SGS Reference	JB15-06167 R1
Report Number	0000009977
Date Received	2015/01/28 08:14:11AM
Date Reported	2015/08/24 05:15:22PM

COMMENTS

Whilst SGS laboratories conform to ISO/IEC 17025 standards, results of analysis in this report fall outside of the current scope of accreditation.

Analysis of metals, total cyanide and anions was subcontracted.
This report is a re-issued copy and replaces the originally issued document dated 25/02/2015. The reason for re-issue is: The client requested that the limits be increased for Mn, so as to get an indicative value for Mn, . Even though the levels of Mn in some of the samples were higher than the upper limit they have been reported. These samples have bee diluted to fit the calibration range of the instrument, however the dilution increases the uncertainty for the results at these high levels and this has to be taken into account. it also has to be noted that the range above 1% Mn is not covered with suitable certified reference materials. The quality assurance has bee done by comparison between the two different dilutions (10 & 100).

SIGNATORIES

Sarah Newton	Martin Olivier
Technical Consultant/Technical Signatory	Operations Manager

Report number   0000009977

Client reference: **To Follow**

Parameter	Units	LOR	JB15-06167.001 GL27 - 50024 Soil	JB15-06167.002 GL27 - 50022 Soil	JB15-06167.003 GL55 - 47816 Soil	JB15-06167.004 GL42 LB - 46253 Soil
Hexavalent Chromium in Soil Method: ME-AN-040						
Hexavalent Chromium	mg/kg	0.4	1.0	17	1.6	17
SUB_SGS Booysens Method: SUB						
Arsenic^	ppm	1	11	11	1.0	8.0
Boron^	ppm	0.2	44	2.9	2.6	>100
Barium^	ppm	1	33	34	84	73
Cadmium^	ppm	0.02	<0.02	<0.02	0.030	<0.02
Cobalt^	ppm	0.1	8.4	8.7	3.3	61
Chromium^	ppm	1	8.0	11	20	11
Copper^	ppm	0.5	39	40	9.2	5.4
Mercury^	ppm	0.01	0.24	0.68	0.10	0.070
Manganese^	ppm	2	19500	12700	339	420000
Molybdenum^	ppm	0.05	5.8	1.5	0.66	<0.05
Nickel^	ppm	0.5	66	28	13	25
Lead^	ppm	0.5	1.7	1.2	4.4	2.7
Antimony^	ppm	0.05	<0.05	<0.05	<0.05	<0.05
Selenium^	ppm	2	<2	<2	<2	<2
Vanadium^	ppm	2	<2	9.0	20	<2
Zinc^	ppm	1	34	20	9.0	99
SUB_Total Cyanide in soil Method: SUB						
Total Cyanide^	mg/kg	0.01	<0.010	<0.010	<0.010	0.72
SUB_Anions in Soil for SASLP Method: SUB						
Fluoride^	%	0.1	<0.1	<0.1	<0.1	<0.1

METHOD

METHOD	METHODOLOGY SUMMARY
MS_EN_ME-AN-040	Hexavalent chromium, when reacted with diphenylcarbizide in acid solution, produces a red-violet colour which is measured photometrically at wavelength 540 nm.

TEST REPORT

SGS

CLIENT DETAILS

Contact	Kobus Bezuidenhout
Client	Mokala Manganese (PTY) LTD
Address	17 Termo Avenue
	Techno Park
	Stellenbosch
Telephone	011 218 8221
Facsimile	(Not specified)
Email	kobezb@vodamali.co.za
Project	(Not specified)
Order Number	**To Follow**
Samples	12
Sample matrix	SOIL

LABORATORY DETAILS

Laboratory	SGS South Africa (Pty) Limited
Address	259 Kent Avenue
	Ferndale, 2194
Telephone	+27 (0)11 781 5689
Laboratory Manager	
SGS Reference	JB14-05838 R2
Report Number	0000008837
Date Received	2014/10/22 10:22:15AM
Date Reported	2015/03/13 10:16:28AM

COMMENTS

The document is issued in accordance with SANAS's accreditation requirements.
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Testing Laboratory
T0107

This report/certificate is a re-issued copy and replaces the originally issued documents dated 14/ 11/2014 and 23/12/2014. The reason for re-issue is the client requested leach mass and volume be reported.
Sample(s) leached using deionised water. Results reported on leachate.

SIGNATORIES

Greg Ondrejkovic	Martin Olivier
Technical Supervisor/Technical Signatory	Operations Manager/Technical Signatory

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Member of the SGS Group

ANALYTICAL REPORT

JB14-05838 R2

Sample Number Sample Name Sample Matrix			JB14-05838.001 MO 1 - 50001 Soil	JB14-05838.002 MO 6 - 50002 Soil	JB14-05838.003 MO 12 - 50003 Soil	JB14-05838.004 MO 2 - 50004 Soil	JB14-05838.005 MO 7 - 50005 Soil
Parameter	**Units**	**LOR**					

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

Parameter	Units	LOR	.001	.002	.003	.004	.005
Fluoride	mg/l	0.05	0.33	0.40	0.08	0.30	0.40
Chloride	mg/l	0.05	33	272	34	56	178
Sulphate	mg/l	0.05	23	70	11	27	107
Nitrate	mg/l	0.1	29	250	29	51	158

Ammonia on leachates by Continuous Flow Analyser   Method: ME-AN-032

Parameter	Units	LOR	.001	.002	.003	.004	.005
Ammonia as N	mg/l	0.08	0.20	0.12	0.25	0.15	0.19
Ammonia	mg/l	0.1	0.24	0.15	0.30	0.18	0.23

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

Parameter	Units	LOR	.001	.002	.003	.004	.005
Total Alkalinity as CaCO3	mg/l	12	87	52	90	67	62
Phenolphthalein Alkalinity as CaCO3*	mg/l	12	<12	<12	12	17	<12
Bicarbonate Alkalinity as CaCO3	mg/l	12	67	42	65	32	42
Carbonate Alkalinity as CaCO3	mg/l	12	20	<12	25	35	20
Bicarbonate Alkalinity as HCO3	mg/l	12	82	52	79	40	52
Carbonate Alkalinity as CO3	mg/l	12	<12	<12	15	21	<12

Total Dissolved Solids (TDS) in leachates at 0.7um   Method: ME-AN-011

Parameter	Units	LOR	.001	.002	.003	.004	.005
TDS (0.7µm) @ 105ºC	mg/l	21	246	1502	254	344	1036

Conductivity on leachates   Method: ME-AN-007

Parameter	Units	LOR	.001	.002	.003	.004	.005
Conductivity in mS/m @ 25ºC	mS/m	2	39	180	42	52	137

ICP-OES Metals on leachates (Dissolved)   Method: ME-AN-027 D

Parameter	Units	LOR	.001	.002	.003	.004	.005
Sodium	mg/l	0.5	19	76	30	22	68
Potassium	mg/l	0.2	5.6	12	14	6.3	9.2
Calcium	mg/l	0.5	16	64	11	21	47
Magnesium	mg/l	0.01	13	59	8.9	17	44
Aluminium	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Antimony	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Arsenic	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Barium	mg/l	0.002	0.14	0.11	0.16	0.15	0.086
Beryllium	mg/l	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cadmium	mg/l	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium	mg/l	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cobalt	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Copper	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Lead	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Manganese	mg/l	0.01	<0.01	0.01	0.17	<0.01	<0.01
Molybdenum	mg/l	0.005	0.006	0.016	<0.005	<0.005	<0.005
Nickel	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Selenium	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver	mg/l	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Strontium	mg/l	0.001	0.21	0.94	0.22	0.23	0.43
Thorium*	mg/l	0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Vanadium	mg/l	0.001	0.015	0.003	0.001	0.013	0.003
Zinc	mg/l	0.01	<0.01	0.03	0.01	0.01	0.02
Iron	mg/l	0.05	<0.05	<0.05	<0.05	<0.05	<0.05

ANALYTICAL REPORT

JB14-05838 R2

Sample Number			JB14-05838.001	JB14-05838.002	JB14-05838.003	JB14-05838.004	JB14-05838.005
Sample Name			MO 1 - 50001	MO 6 - 50002	MO 12 - 50003	MO 2 - 50004	MO 7 - 50005
Sample Matrix			Soil	Soil	Soil	Soil	Soil
Parameter	**Units**	**LOR**					
Dissolved Hg on Leachates by ICP-MS Method: ME-AN-026							
Mercury	µg/l	0.1	<0.10	<0.10	<0.10	<0.10	<0.10
Calculation of Anion-Cation Balance Method: ME-AN-014							
Sum of Cation Milliequivalents*	meq/l	-	2.89	11.6	2.90	3.58	9.15
Sum of Anion Milliequivalents*	meq/l	-	3.61	14.2	3.43	4.30	11.0
Anion-Cation Balance	%	-100	-11.02	-9.88	-8.33	-9.21	-9.35
Deionised Water Leach @ 3:1 Method: IN-HOUSE							
Weight Sample*	g	-	150.0	100.0	100.0	150.0	150.0
Vol_ml*	ml	-	450	300	300	450	450
Deionised Water Leach @ 20:1 Method: ASTM D3987							
Final pH*	-	0.1	8.4	8.0	8.4	8.3	8.1

Sample Number			JB14-05838.006	JB14-05838.007	JB14-05838.008	JB14-05838.009	JB14-05838.010
Sample Name			MO 13 - 50006	MO 22 - 50007	MO 23- 50008	MO 24- 50009	MO 25- 50010
Sample Matrix			Soil	Soil	Soil	Soil	Soil
Parameter	**Units**	**LOR**					
Anions on leachates by Ion Chromatography Method: ME-AN-014							
Fluoride	mg/l	0.05	0.24	0.19	0.19	0.30	0.20
Chloride	mg/l	0.05	96	20	0.87	0.46	0.64
Sulphate	mg/l	0.05	92	37	4.5	1.4	3.3
Nitrate	mg/l	0.1	83	12	3.2	1.2	1.6
Ammonia on leachates by Continuous Flow Analyser Method: ME-AN-032							
Ammonia as N	mg/l	0.08	0.31	0.28	0.67	0.38	0.29
Ammonia	mg/l	0.1	0.38	0.34	0.81	0.46	0.35
Alkalinity on leachates by titration Method: ME-AN-001							
Total Alkalinity as CaCO3	mg/l	12	70	52	57	57	45
Phenolphthalein Alkalinity as CaCO3*	mg/l	12	<12	<12	<12	<12	<12
Bicarbonate Alkalinity as CaCO3	mg/l	12	55	37	37	42	30
Carbonate Alkalinity as CaCO3	mg/l	12	15	15	20	15	15
Bicarbonate Alkalinity as HCO3	mg/l	12	67	46	46	52	37
Carbonate Alkalinity as CO3	µg/l	12	<12	<12	<12	<12	<12
Total Dissolved Solids (TDS) in leachates at 0.7um Method: ME-AN-011							
TDS (0.7µm) @ 105ºC	mg/l	21	602	192	108	82	96
Conductivity on leachates Method: ME-AN-007							
Conductivity in mS/m @ 25ºC	mS/m	2	89	30	14	14	14

ANALYTICAL REPORT

JB14-05838 R2

Report number   0000008837

Client reference: **To Follow**

			JB14-05838.006 MO 13 - 50006 Soil	JB14-05838.007 MO 22 - 50007 Soil	JB14-05838.008 MO 23- 50008 Soil	JB14-05838.009 MO 24- 50009 Soil	JB14-05838.010 MO 25- 50010 Soil
Sample Number							
Sample Name							
Sample Matrix							
Parameter	**Units**	**LOR**					

ICP-OES Metals on leachates (Dissolved)   Method: ME-AN-027 D

Parameter	Units	LOR	JB14-05838.006	JB14-05838.007	JB14-05838.008	JB14-05838.009	JB14-05838.010
Sodium	mg/l	0.5	43	16	1.3	1.2	1.3
Potassium	mg/l	0.2	7.0	3.5	2.6	1.6	3.1
Calcium	mg/l	0.5	29	15	13	8.1	12
Magnesium	mg/l	0.01	27	8.5	3.8	8.8	4.7
Aluminium	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Antimony	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Arsenic	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Barium	mg/l	0.002	0.10	0.086	0.13	0.13	0.093
Beryllium	mg/l	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cadmium	mg/l	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium	mg/l	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cobalt	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Copper	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Lead	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Manganese	mg/l	0.01	0.02	<0.01	<0.01	<0.01	<0.01
Molybdenum	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Nickel	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Selenium	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver	mg/l	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Strontium	mg/l	0.001	0.18	0.080	0.052	0.088	0.066
Thorium*	mg/l	0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Vanadium	mg/l	0.001	<0.001	0.006	0.008	0.086	0.010
Zinc	mg/l	0.01	0.02	<0.01	0.02	<0.01	<0.01
Iron	mg/l	0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Dissolved Hg on Leachates by ICP-MS   Method: ME-AN-026

Parameter	Units	LOR	JB14-05838.006	JB14-05838.007	JB14-05838.008	JB14-05838.009	JB14-05838.010
Mercury	µg/l	0.1	<0.10	<0.10	<0.10	<0.10	<0.10

Calculation of Anion-Cation Balance   Method: ME-AN-014

Parameter	Units	LOR	JB14-05838.006	JB14-05838.007	JB14-05838.008	JB14-05838.009	JB14-05838.010
Sum of Cation Milliequivalents*	meq/l	-	5.71	2.21	1.09	1.22	1.12
Sum of Anion Milliequivalents*	meq/l	-	7.36	2.57	1.30	1.20	1.00
Anion-Cation Balance	%	-100	-12.63	-7.43	-8.88	0.86	5.41

Deionised Water Leach @ 3:1   Method: IN-HOUSE

Parameter	Units	LOR	JB14-05838.006	JB14-05838.007	JB14-05838.008	JB14-05838.009	JB14-05838.010
Weight Sample*	g	-	100.0	150.0	100.0	100.0	150.0
Vol_ml*	ml	-	300	450	300	300	450

Deionised Water Leach @ 20:1   Method: ASTM D3987

Parameter	Units	LOR	JB14-05838.006	JB14-05838.007	JB14-05838.008	JB14-05838.009	JB14-05838.010
Final pH*	-	0.1	8.1	8.4	8.1	8.4	8.4

Sample Number Sample Name Sample Matrix			JB14-05838.011 MO 16- 50012 Soil	JB14-05838.012 MO 14- 50013 Soil
Parameter	**Units**	**LOR**		

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

Parameter	Units	LOR	JB14-05838.011	JB14-05838.012
Fluoride	mg/l	0.05	<0.05	0.12
Chloride	mg/l	0.05	4.0	3.5
Sulphate	mg/l	0.05	2.5	4.3
Nitrate	mg/l	0.1	1.4	0.7

Ammonia on leachates by Continuous Flow Analyser   Method: ME-AN-032

Parameter	Units	LOR	JB14-05838.011	JB14-05838.012
Ammonia as N	mg/l	0.08	0.40	0.35
Ammonia	mg/l	0.1	0.49	0.43

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

Parameter	Units	LOR	JB14-05838.011	JB14-05838.012
Total Alkalinity as CaCO3	mg/l	12	57	52
Phenolphthalein Alkalinity as CaCO3*	mg/l	12	<12	12
Bicarbonate Alkalinity as CaCO3	mg/l	12	42	27
Carbonate Alkalinity as CaCO3	mg/l	12	15	25
Bicarbonate Alkalinity as HCO3	mg/l	12	52	33
Carbonate Alkalinity as CO3	mg/l	12	<12	15

Total Dissolved Solids (TDS) in leachates at 0.7um   Method: ME-AN-011

Parameter	Units	LOR	JB14-05838.011	JB14-05838.012
TDS (0.7µm) @ 105ºC	mg/l	21	94	96

Conductivity on leachates   Method: ME-AN-007

Parameter	Units	LOR	JB14-05838.011	JB14-05838.012
Conductivity in mS/m @ 25ºC	mS/m	2	15	15

ICP-OES Metals on leachates (Dissolved)   Method: ME-AN-027 D

Parameter	Units	LOR	JB14-05838.011	JB14-05838.012
Sodium	mg/l	0.5	3.4	7.1
Potassium	mg/l	0.2	0.4	0.6
Calcium	mg/l	0.5	14	7.5
Magnesium	mg/l	0.01	3.9	6.3
Aluminium	mg/l	0.02	<0.02	<0.02
Antimony	mg/l	0.02	<0.02	<0.02
Arsenic	mg/l	0.01	<0.01	<0.01
Barium	mg/l	0.002	0.15	0.43
Beryllium	mg/l	0.0001	<0.0001	<0.0001
Cadmium	mg/l	0.001	<0.001	<0.001
Chromium	mg/l	0.002	<0.002	<0.002
Cobalt	mg/l	0.005	<0.005	<0.005
Copper	mg/l	0.02	<0.02	<0.02
Lead	mg/l	0.01	<0.01	<0.01
Manganese	mg/l	0.01	0.03	0.21
Molybdenum	mg/l	0.005	<0.005	<0.005
Nickel	mg/l	0.005	<0.005	<0.005
Selenium	mg/l	0.01	<0.01	<0.01
Silver	mg/l	0.002	<0.002	<0.002
Strontium	mg/l	0.001	0.54	0.16
Thorium*	mg/l	0.04	<0.04	<0.04
Vanadium	mg/l	0.001	<0.001	<0.001
Zinc	mg/l	0.01	<0.01	<0.01
Iron	mg/l	0.05	<0.05	<0.05

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ANALYTICAL REPORT

JB14-05838 R2

Parameter	Units	LOR	Sample Number JB14-05838.011 Sample Name MO 16- 50012 Sample Matrix Soil	JB14-05838.012 MO 14- 50013 Soil
Dissolved Hg on Leachates by ICP-MS Method: ME-AN-026				
Mercury	µg/l	0.1	<0.10	<0.10
Calculation of Anion-Cation Balance Method: ME-AN-014				
Sum of Cation Milliequivalents*	meq/l	-	1.19	1.21
Sum of Anion Milliequivalents*	meq/l	-	1.32	1.24
Anion-Cation Balance	%	-100	-5.10	-1.15
Deionised Water Leach @ 3:1 Method: IN-HOUSE				
Weight Sample*	g	-	150.0	150.0
Vol_ml*	ml	-	450	450
Deionised Water Leach @ 20:1 Method: ASTM D3987				
Final pH*	-	0.1	8.4	9.1

METHOD	METHODOLOGY SUMMARY
ASTM D3987	Contaminants of interest in a waste material are leached out of the waste with deionised water under controlled conditions. The ratio of sample to extraction fluid is 1 to 20 by mass. The concentration of each contaminant of interest is determined in the leachate by appropriate methods after separation from the sample by filtering. The method is based on ASTM D3987.
LEACH	Contaminants of interest in a waste material are leached out of the waste with deionised water under controlled conditions. The ratio of sample to extraction fluid is 1 to 3 by mass. The concentration of each contaminant of interest is determined in the leachate by appropriate methods after separation from the sample by filtering.
ME-AN-001	An aliquot of aqueous sample is titrated first to pH 8.3 and then to 4.3 using standardised acid. The volumes of acid titrated are used to calculate the alkaline species or total alkalinity. The method is based on EPA 310.2 and APHA 2320 B.
ME-AN-007	The conductivity of an aliquot of aqueous sample is measured electrometrically using a standard cell connected to a calibrated meter with automated temperature correction. This method is based on APHA 2510.
ME-AN-011	Total dissolved solids (TDS) is determined gravimetrically on a filtered aliquot of aqueous sample by evaporating the sample to dryness in a pre-weighed container at 105 deg C. The method is based on APHA 2540 C.
ME-AN-013	The ion balance for aqueous samples is determined by calculation from the major cation, major anion and alkalinity results, determined by ICP-OES, ion chromatography and titration, respectively. The method is based on APHA 1030.
ME-AN-014	Inorganic anions (Br, Cl, F, NO3, NO2, SO4) are determined on aqueous samples by ion chromatography. The method is based on EPA 300.1 and APHA 4110 B. Br, Cl, F and NO2 are not determined on TCLP leachates.
ME-AN-027	Dissolved metals are determined on a filtered and acidified portion of aqueous sample by inductively coupled plasma optical emission spectrometry (ICP-OES). The method is based on EPA 200.7 and APHA 3120.
ME-AN-032	This method is based on ISO 11732:2005(E). In a continuously flowing, air-segmented, buffered carrier stream, ammonia reacts with hypochlorite (previously liberated from dichloroisocyanurate) to form monochloramine. This reacts with salicylate, under catalysis from nitroprusside, to form blue-green indophenol, which is measured in a flow photometer at 660nm. This is based on the modified Berthelot reaction.

FOOTNOTES

IS	Insufficient sample for analysis.
LNR	Sample listed, but not received.
*	This analysis is not covered by the scope of accreditation.
^	Performed by outside laboratory.
LOR	Limit of Reporting
↑↓	Raised or Lowered Limit of Reporting

QFH	QC result is above the upper tolerance
QFL	QC result is below the lower tolerance
-	The sample was not analysed for this analyte

Samples analysed as received.

Solid samples expressed on a dry weight basis.

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

SGS *Environmental* Services *Randburg* is accredited by *SANAS* and conforms to the requirements of ISO/IEC 17025 for specific test or calibrations as indicated on the scope of accreditation to be found at http://sanas.co.za.

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T0107

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TEST REPORT (Amended)

CLIENT DETAILS

Contact	Richard Curtis
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	BENMORE 2010
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Project	**15520125**
Order Number	**To Follow**
Samples	9
Sample matrix	SOIL

LABORATORY DETAILS

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Laboratory Manager	
SGS Reference	JB15-06164 R1
Report Number	0000008838
Date Received	2015/01/27 03:11:42PM
Date Reported	2015/03/13 10:17:56AM

COMMENTS

The document is issued in accordance with SANAS's accreditation requirements.
Accredited for compliance with ISO/IEC 17025. SANAS accredited laboratory T0107.

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This report/certificate is a re-issued copy and replaces the originally issued document dated 17/02/2015 and 25/02/2015. The reason for re-issue is the client requested the leach mass and volume be reported.
Sample(s) leached using deionised water. Results reported on leachate.

SIGNATORIES

Greg Ondrejkovic	Martin Olivier
Technical Supervisor/Technical Signatory	Operations Manager/Technical Signatory

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ANALYTICAL REPORT

JB15-06164 R1

Sample Number Sample Name Sample Matrix			JB15-06164.001 GL41 - 50045 Soil	JB15-06164.002 GL27 - 50024 Soil	JB15-06164.003 GL41 - 50046 Soil	JB15-06164.004 GL49 - 50016 Soil	JB15-06164.005 GL27 - 50022 Soil
Parameter	**Units**	**LOR**					

Deionised Water Leach @ 3:1   Method: IN-HOUSE

Parameter	Units	LOR	.001	.002	.003	.004	.005
Final pH*	-	0.1	7.7	8.2	8.4	7.9	8.3
Weight Sample*	g	-	250.0	250.0	250.0	250.0	250.0
Vol_ml*	ml	-	750	750	750	750	750

Conductivity on leachates   Method: ME-AN-007

Parameter	Units	LOR	.001	.002	.003	.004	.005
Conductivity in mS/m @ 25ºC	mS/m	2	17	40	42	41	50

Total Dissolved Solids (TDS) in leachates at 0.7um   Method: ME-AN-011

Parameter	Units	LOR	.001	.002	.003	.004	.005
TDS (0.7µm) @ 105ºC	mg/l	21	104	190	240	220	318

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

Parameter	Units	LOR	.001	.002	.003	.004	.005
Total Alkalinity as CaCO3	mg/l	12	40	100	143	78	110
Bicarbonate Alkalinity as CaCO3	mg/l	12	25	65	113	53	75
Carbonate Alkalinity as CaCO3	mg/l	12	15	35	30	25	35
Phenolphthalein Alkalinity as CaCO3*	mg/l	12	<12	18	15	13	18

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

Parameter	Units	LOR	.001	.002	.003	.004	.005
Chloride	mg/l	0.05	12	31	16	35	37
Fluoride	mg/l	0.05	0.25	0.96	0.97	1.2	0.36
Nitrate	mg/l	0.1	7.1	<0.1	5.1	17	6.4
Sulphate	mg/l	0.05	5.3	25	14	32	38

Ammonia on leachates by Continuous Flow Analyser   Method: ME-AN-032

Parameter	Units	LOR	.001	.002	.003	.004	.005
Ammonia as N	mg/l	0.08	0.11	0.10	0.15	<0.08	0.08
Ammonia	mg/l	0.1	0.13	0.12	0.18	<0.10	<0.10

ICP-OES Metals on leachates (Dissolved)   Method: ME-AN-027 D

Parameter	Units	LOR	.001	.002	.003	.004	.005
Sodium	mg/l	0.5	8.8	28	37	31	16
Potassium	mg/l	0.2	0.8	1.5	2.5	6.3	2.7
Calcium	mg/l	0.5	11	19	18	15	15
Magnesium	mg/l	0.01	5.7	15	17	14	38
Aluminium	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Antimony	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Arsenic	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Barium	mg/l	0.002	0.044	0.069	0.049	0.086	0.089
Beryllium	mg/l	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cadmium	mg/l	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium	mg/l	0.002	0.007	<0.002	<0.002	<0.002	<0.002
Cobalt	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Copper	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Lead	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Manganese	mg/l	0.01	<0.01	0.03	0.04	<0.01	0.02
Molybdenum	mg/l	0.005	0.011	<0.005	<0.005	<0.005	0.017
Nickel	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Selenium	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver	mg/l	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Strontium	mg/l	0.001	0.076	0.16	0.006	0.16	0.086
Thorium*	mg/l	0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Vanadium	mg/l	0.001	<0.001	<0.001	<0.001	0.019	<0.001
Zinc	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Iron	mg/l	0.05	<0.05	<0.05	<0.05	<0.05	<0.05

ANALYTICAL REPORT
JB15-06164 R1

Report number   0000008838
Client reference: **15520125**

Sample Number Sample Name Sample Matrix			JB15-06164.001 GL41 - 50045 Soil	JB15-06164.002 GL27 - 50024 Soil	JB15-06164.003 GL41 - 50046 Soil	JB15-06164.004 GL49 - 50016 Soil	JB15-06164.005 GL27 - 50022 Soil
Parameter	**Units**	**LOR**					

Dissolved Hg on Leachates by ICP-MS   Method: ME-AN-026

Parameter	Units	LOR					
Mercury	µg/l	0.1	<0.10	<0.10	<0.10	<0.10	<0.10

Sample Number Sample Name Sample Matrix			JB15-06164.006 GL55 - 47816 Soil	JB15-06164.007 GL42 LB- 46253 Soil	JB15-06164.008 GL37- 27541 Soil	JB15-06164.009 DI Blank
Parameter	**Units**	**LOR**				

Deionised Water Leach @ 3:1   Method: IN-HOUSE

Parameter	Units	LOR				
Final pH*	-	0.1	7.9	8.2	7.8	6.6
Weight Sample*	g	-	250.0	250.0	250.0	-
Vol_ml*	ml	-	750	750	750	750

Conductivity on leachates   Method: ME-AN-007

Parameter	Units	LOR				
Conductivity in mS/m @ 25ºC	mS/m	2	14	19	17	<2

Total Dissolved Solids (TDS) in leachates at 0.7um   Method: ME-AN-011

Parameter	Units	LOR				
TDS (0.7µm) @ 105ºC	mg/l	21	90	84	98	<21

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

Parameter	Units	LOR				
Total Alkalinity as CaCO3	mg/l	12	58	78	38	<12
Bicarbonate Alkalinity as CaCO3	mg/l	12	38	48	33	<12
Carbonate Alkalinity as CaCO3	mg/l	12	20	30	<12	<12
Phenolphthalein Alkalinity as CaCO3*	mg/l	12	<12	15	<12	<12

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

Parameter	Units	LOR				
Chloride	mg/l	0.05	0.63	3.9	12	<0.05
Fluoride	mg/l	0.05	0.32	<0.05	0.26	<0.05
Nitrate	mg/l	0.1	1.8	1.9	2.1	<0.1
Sulphate	mg/l	0.05	0.84	1.1	11	<0.05

Ammonia on leachates by Continuous Flow Analyser   Method: ME-AN-032

Parameter	Units	LOR				
Ammonia as N	mg/l	0.08	<0.08	0.10	0.08	<0.08
Ammonia	mg/l	0.1	<0.10	0.12	<0.10	<0.10

ICP-OES Metals on leachates (Dissolved)   Method: ME-AN-027 D

Parameter	Units	LOR				
Sodium	mg/l	0.5	1.2	5.1	4.8	<0.5
Potassium	mg/l	0.2	4.2	2.4	0.5	<0.2
Calcium	mg/l	0.5	16	10	16	<0.5
Magnesium	mg/l	0.01	3.6	12	4.4	<0.01
Aluminium	mg/l	0.02	0.64	<0.02	<0.02	<0.02
Antimony	mg/l	0.02	<0.02	<0.02	<0.02	<0.02
Arsenic	mg/l	0.01	<0.01	<0.01	<0.01	<0.01
Barium	mg/l	0.002	0.17	0.060	0.35	<0.002
Beryllium	mg/l	0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cadmium	mg/l	0.001	<0.001	<0.001	<0.001	<0.001
Chromium	mg/l	0.002	<0.002	<0.002	<0.002	<0.002
Cobalt	mg/l	0.005	<0.005	<0.005	<0.005	<0.005
Copper	mg/l	0.02	<0.02	<0.02	<0.02	<0.02
Lead	mg/l	0.01	<0.01	<0.01	<0.01	<0.01
Manganese	mg/l	0.01	<0.01	0.12	0.09	<0.01
Molybdenum	mg/l	0.005	<0.005	<0.005	<0.005	<0.005
Nickel	mg/l	0.005	<0.005	<0.005	<0.005	<0.005
Selenium	mg/l	0.01	<0.01	<0.01	<0.01	<0.01
Silver	mg/l	0.002	<0.002	<0.002	<0.002	<0.002

SGS

			Sample Number	JB15-06164.006	JB15-06164.007	JB15-06164.008	JB15-06164.009
			Sample Name	GL55 - 47816	GL42 LB- 46253	GL37- 27541	DI Blank
Parameter	Units	LOR		Soil	Soil	Soil	

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

Parameter	Units	LOR		JB15-06164.006	JB15-06164.007	JB15-06164.008	JB15-06164.009
Strontium	mg/l	0.001		0.059	0.11	0.30	<0.001
Thorium*	mg/l	0.04		<0.04	<0.04	<0.04	<0.04
Vanadium	mg/l	0.001		<0.001	<0.001	<0.001	<0.001
Zinc	mg/l	0.01		0.02	<0.01	<0.01	<0.01
Iron	mg/l	0.05		0.46	<0.05	<0.05	<0.05

Dissolved Hg on Leachates by ICP-MS   Method: ME-AN-026

Parameter	Units	LOR		JB15-06164.006	JB15-06164.007	JB15-06164.008	JB15-06164.009
Mercury	µg/l	0.1		<0.10	<0.10	<0.10	<0.10

METHOD	METHODOLOGY SUMMARY
LEACH	Contaminants of interest in a waste material are leached out of the waste with deionised water under controlled conditions. The ratio of sample to extraction fluid is 1 to 3 by mass. The concentration of each contaminant of interest is determined in the leachate by appropriate methods after separation from the sample by filtering.
ME-AN-001	An aliquot of aqueous sample is titrated first to pH 8.3 and then to 4.3 using standardised acid. The volumes of acid titrated are used to calculate the alkaline species or total alkalinity. The method is based on EPA 310.2 and APHA 2320 B.
ME-AN-007	The conductivity of an aliquot of aqueous sample is measured electrometrically using a standard cell connected to a calibrated meter with automated temperature correction. This method is based on APHA 2510.
ME-AN-011	Total dissolved solids (TDS) is determined gravimetrically on a filtered aliquot of aqueous sample by evaporating the sample to dryness in a pre-weighed container at 105 deg C. The method is based on APHA 2540 C.
ME-AN-014	Inorganic anions (Br, Cl, F, NO3, NO2, SO4) are determined on aqueous samples by ion chromatography. The method is based on EPA 300.1 and APHA 4110 B. Br, Cl, F and NO2 are not determined on TCLP leachates.
ME-AN-027	Dissolved metals are determined on a filtered and acidified portion of aqueous sample by inductively coupled plasma optical emission spectrometry (ICP-OES). The method is based on EPA 200.7 and APHA 3120.
ME-AN-032	This method is based on ISO 11732:2005(E). In a continuously flowing, air-segmented, buffered carrier stream, ammonia reacts with hypochlorite (previously liberated from dichloroisocyanurate) to form monochloramine. This reacts with salicylate, under catalysis from nitroprusside, to form blue-green indophenol, which is measured in a flow photometer at 660nm. This is based on the modified Berthelot reaction.

FOOTNOTES

IS	Insufficient sample for analysis.	QFH	QC result is above the upper tolerance
LNR	Sample listed, but not received.	QFL	QC result is below the lower tolerance
^	Performed by outside laboratory.	-	The sample was not analysed for this analyte
LOR	Limit of Reporting	*	*Results marked "Not SANAS Accredited" in this report are not*
↑↓	Raised or Lowered Limit of Reporting		*included in the SANAS Schedule of Accreditation for this laboratory / certification body / inspection body".*

Samples analysed as received.

Solid samples expressed on a dry weight basis.

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

sanas
Testing Laboratory

T0107

SGS

TEST REPORT (Amended)

CLIENT DETAILS

Contact	Kobus Bezuidenhout
Client	Mokala Manganese (PTY) LTD
Address	17 Termo Avenue
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	Stellenbosch
Telephone	011 218 8221
Facsimile	(Not specified)
Email	kobezb@vodamali.co.za
Project	(Not specified)
Order Number	**To Follow**
Samples	12
Sample matrix	SOIL

LABORATORY DETAILS

Laboratory	SGS South Africa (Pty) Limited
Address	259 Kent Avenue
	Ferndale, 2194
Telephone	+27 (0)11 590 3000
Laboratory Manager	
SGS Reference	JB14-05837 R0
Report Number	0000008839
Date Received	2014/10/22 09:48:45AM
Date Reported	2015/03/13 10:20:19AM

COMMENTS

The document is issued in accordance with SANAS's accreditation requirements.
Accredited for compliance with ISO/IEC 17025. SANAS accredited laboratory T0107.

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Testing Laboratory
T0107

This report/certificate is a re-issued copy and replaces the originally issued documents dated 11/12/2014 and . The reason for re-issue is the client requested the leach mass and volume are reported.

SIGNATORIES

_____
Greg Ondrejkovic
Technical Supervisor/Technical Signatory

_____
Martin Olivier
Operations Manager/Technical Signatory

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Member of the SGS Group

| Sample Number | | | JB14-05837.001 | JB14-05837.002 | JB14-05837.003 | JB14-05837.004 | JB14-05837.005 |
Sample Name			MO 1 - 50001	MO 6 - 50002	MO 12 - 50003	MO 2 - 50004	MO 7 - 50005
Parameter	**Units**	**LOR**					

Deionised Water Leach @ 20:1   Method: ASTM D3987

Parameter	Units	LOR	.001	.002	.003	.004	.005
Weight Sample*	g	-	50.0	50.0	50.0	50.0	50.0
Final pH*	-	0.1	8.4	8.0	8.6	8.4	8.2
Vol_ml*	ml	-	1000	1000	1000	1000	1000

Conductivity on leachates   Method: ME-AN-007

Parameter	Units	LOR	.001	.002	.003	.004	.005
Conductivity in mS/m @ 25ºC	mS/m	2	11	32	13	12	24

Total Dissolved Solids (TDS) in leachates at 0.7um   Method: ME-AN-011

Parameter	Units	LOR	.001	.002	.003	.004	.005
TDS (0.7µm) @ 105ºC	mg/l	21	64	234	78	70	146

Total Cyanide in leachates   Method: ME-AN-031

Parameter	Units	LOR	.001	.002	.003	.004	.005
Total Cyanide	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005

Hexavalent Chromium by Discrete Analyser on Leachates   Method: ME-AN-040

Parameter	Units	LOR	.001	.002	.003	.004	.005
Hexavalent Chromium*	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01

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

Parameter	Units	LOR	.001	.002	.003	.004	.005
Nitrate	mg/l	0.1	4.7	35	3.7	6.3	22
Sulphate	mg/l	0.05	3.1	9.8	1.4	4.1	9.5
Chloride	mg/l	0.05	4.5	40	4.3	6.9	27
Fluoride	mg/l	0.05	0.12	0.24	<0.05	0.27	0.30
Nitrite	mg/l	0.5	<0.5	<0.5	<0.5	<0.5	<0.5

ICP-OES Metals on leachates (Dissolved)   Method: ME-AN-027 D

Parameter	Units	LOR	.001	.002	.003	.004	.005
Calcium	mg/l	0.5	5.3	12	7.0	6.1	8.4
Magnesium	mg/l	0.01	4.0	11	3.6	4.3	7.8
Sodium	mg/l	0.5	4.9	16	5.8	5.4	14
Potassium	mg/l	0.2	2.2	3.6	4.2	2.2	2.5
Arsenic	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Boron	mg/l	0.005	0.054	0.13	0.10	0.052	0.12
Barium	mg/l	0.002	0.050	0.035	0.052	0.060	0.030
Cadmium	mg/l	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	mg/l	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Copper	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Manganese	mg/l	0.01	<0.01	<0.01	0.04	<0.01	<0.01
Molybdenum	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	0.005
Nickel	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Lead	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Antimony	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Selenium	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	mg/l	0.001	0.024	0.007	0.001	0.023	0.006
Zinc	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Iron	mg/l	0.05	<0.05	<0.05	<0.05	<0.05	<0.05

ANALYTICAL REPORT

JB14-05837 R0

Report number 0000008839

Client reference: **To Follow**

Sample Number Sample Name			JB14-05837.001 MO 1 - 50001	JB14-05837.002 MO 6 - 50002	JB14-05837.003 MO 12 - 50003	JB14-05837.004 MO 2 - 50004	JB14-05837.005 MO 7 - 50005
Parameter	**Units**	**LOR**					

Dissolved Hg on Leachates by ICP-MS   Method: ME-AN-026

Parameter	Units	LOR					
Mercury	µg/l	0.1	<0.10	<0.10	<0.10	<0.10	<0.10

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

Parameter	Units	LOR					
Total Alkalinity as CaCO3	mg/l	12	35	30	47	32	32
Phenolphthalein Alkalinity as CaCO3*	mg/l	12	<12	<12	<12	<12	<12
Bicarbonate Alkalinity as CaCO3	mg/l	12	35	30	27	17	32
Bicarbonate Alkalinity as HCO3	mg/l	12	43	37	33	21	40
Bicarbonate as CaCO3	mg/l	12	35	30	27	17	32
Carbonate Alkalinity as CaCO3	mg/l	12	<12	<12	20	15	<12
Carbonate Alkalinity as CO3	mg/l	12	<12	<12	<12	<12	<12
Hydroxide Alkalinity as CaCO3	mg/l	12	<12	<12	<12	<12	<12
Hydroxide as OH	mg/l	12	<12	<12	<12	<12	<12

Calculation of Anion-Cation Balance   Method: ME-AN-014

Parameter	Units	LOR					
Sum of Cation Milliequivalents*	meq/l	-	0.863	2.33	1.00	0.952	1.74
Sum of Anion Milliequivalents*	meq/l	-	0.964	2.49	0.758	0.730	1.96
Anion-Cation Balance	%	-100	-5.53	-3.37	13.84	13.22	-5.99

Sample Number Sample Name			JB14-05837.006 MO 13 - 50006	JB14-05837.007 MO 22 - 50007	JB14-05837.008 MO 23 - 50008	JB14-05837.009 MO 24 - 50009	JB14-05837.010 MO 25 - 50010
Parameter	**Units**	**LOR**					

Deionised Water Leach @ 20:1   Method: ASTM D3987

Parameter	Units	LOR					
Weight Sample*	g	-	50.0	50.0	50.0	50.0	50.0
Final pH*	-	0.1	8.5	8.8	8.8	8.6	8.8
Vol_ml*	ml	-	1000	1000	1000	1000	1000

Conductivity on leachates   Method: ME-AN-007

Parameter	Units	LOR					
Conductivity in mS/m @ 25ºC	mS/m	2	20	9	6	7	6

Total Dissolved Solids (TDS) in leachates at 0.7um   Method: ME-AN-011

Parameter	Units	LOR					
TDS (0.7µm) @ 105ºC	mg/l	21	104	54	44	44	44

Total Cyanide in leachates   Method: ME-AN-031

Parameter	Units	LOR					
Total Cyanide	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005

Hexavalent Chromium by Discrete Analyser on Leachates   Method: ME-AN-040

Parameter	Units	LOR					
Hexavalent Chromium*	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01

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

Parameter	Units	LOR					
Nitrate	mg/l	0.1	11	1.7	0.5	0.2	0.3
Sulphate	mg/l	0.05	9.2	5.1	0.62	0.27	0.59
Chloride	mg/l	0.05	17	2.8	0.19	0.15	0.18
Fluoride	mg/l	0.05	0.24	0.28	0.16	0.27	0.21
Nitrite	mg/l	0.5	<0.5	<0.5	<0.5	<0.5	<0.5

ANALYTICAL REPORT

Report number   0000008839

Client reference: **To Follow**

Sample Number Sample Name			JB14-05837.006 MO 13 - 50006	JB14-05837.007 MO 22 - 50007	JB14-05837.008 MO 23 - 50008	JB14-05837.009 MO 24 - 50009	JB14-05837.010 MO 25 - 50010
Parameter	**Units**	**LOR**					

ICP-OES Metals on leachates (Dissolved)   Method: ME-AN-027 D

Parameter	Units	LOR	.006	.007	.008	.009	.010
Calcium	mg/l	0.5	7.6	5.9	6.1	5.9	6.1
Magnesium	mg/l	0.01	5.9	2.6	1.4	3.6	2.0
Sodium	mg/l	0.5	11	3.4	<0.5	0.7	<0.5
Potassium	mg/l	0.2	2.2	1.1	0.8	0.7	1.3
Arsenic	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Boron	mg/l	0.005	0.096	0.010	<0.005	0.008	<0.005
Barium	mg/l	0.002	0.027	0.027	0.031	0.031	0.027
Cadmium	mg/l	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	mg/l	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Copper	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Manganese	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Molybdenum	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Nickel	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Lead	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Antimony	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Selenium	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	mg/l	0.001	0.003	0.007	0.006	0.081	0.011
Zinc	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Iron	mg/l	0.05	<0.05	<0.05	<0.05	0.40	<0.05

Dissolved Hg on Leachates by ICP-MS   Method: ME-AN-026

Parameter	Units	LOR	.006	.007	.008	.009	.010
Mercury	µg/l	0.1	<0.10	<0.10	<0.10	<0.10	<0.10

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

Parameter	Units	LOR	.006	.007	.008	.009	.010
Total Alkalinity as CaCO3	mg/l	12	50	30	25	30	35
Phenolphthalein Alkalinity as CaCO3*	mg/l	12	15	<12	<12	<12	<12
Bicarbonate Alkalinity as CaCO3	mg/l	12	20	15	15	30	35
Bicarbonate Alkalinity as HCO3	mg/l	12	24	18	18	37	43
Bicarbonate as CaCO3	mg/l	12	20	15	15	30	35
Carbonate Alkalinity as CaCO3	mg/l	12	30	15	<12	<12	<12
Carbonate Alkalinity as CO3	mg/l	12	18	<12	<12	<12	<12
Hydroxide Alkalinity as CaCO3	mg/l	12	<12	<12	<12	<12	<12
Hydroxide as OH	mg/l	12	<12	<12	<12	<12	<12

Calculation of Anion-Cation Balance   Method: ME-AN-014

Parameter	Units	LOR	.006	.007	.008	.009	.010
Sum of Cation Milliequivalents*	meq/l	-	1.42	0.681	0.451	0.649	0.520
Sum of Anion Milliequivalents*	meq/l	-	1.25	0.509	0.325	0.612	0.720
Anion-Cation Balance	%	-100	6.10	14.40	16.25	2.96	-16.13

Sample Number Sample Name			JB14-05837.011 MO 16 - 50012	JB14-05837.012 MO 14 - 50013
Parameter	**Units**	**LOR**		

Deionised Water Leach @ 20:1   Method: ASTM D3987

Parameter	Units	LOR		
Weight Sample*	g	-	50.0	50.0
Final pH*	-	0.1	8.9	8.7
Vol_ml*	ml	-	1000	1000

Conductivity on leachates   Method: ME-AN-007

Parameter	Units	LOR		
Conductivity in mS/m @ 25ºC	mS/m	2	5	7

Total Dissolved Solids (TDS) in leachates at 0.7um   Method: ME-AN-011

Parameter	Units	LOR		
TDS (0.7µm) @ 105ºC	mg/l	21	32	36

Total Cyanide in leachates   Method: ME-AN-031

Parameter	Units	LOR		
Total Cyanide	mg/l	0.005	<0.005	<0.005

Hexavalent Chromium by Discrete Analyser on Leachates   Method: ME-AN-040

Parameter	Units	LOR		
Hexavalent Chromium*	mg/l	0.01	<0.01	<0.01

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

Parameter	Units	LOR		
Nitrate	mg/l	0.1	0.2	0.1
Sulphate	mg/l	0.05	0.30	0.99
Chloride	mg/l	0.05	0.59	0.43
Fluoride	mg/l	0.05	<0.05	<0.05
Nitrite	mg/l	0.5	<0.5	<0.5

ICP-OES Metals on leachates (Dissolved)   Method: ME-AN-027 D

Parameter	Units	LOR		
Calcium	mg/l	0.5	6.5	7.3
Magnesium	mg/l	0.01	0.77	1.5
Sodium	mg/l	0.5	0.6	1.1
Potassium	mg/l	0.2	<0.2	<0.2
Arsenic	mg/l	0.01	<0.01	<0.01
Boron	mg/l	0.005	0.018	0.047
Barium	mg/l	0.002	0.073	0.60
Cadmium	mg/l	0.001	<0.001	<0.001
Cobalt	mg/l	0.005	<0.005	<0.005
Chromium	mg/l	0.002	<0.002	<0.002
Copper	mg/l	0.02	<0.02	<0.02
Manganese	mg/l	0.01	0.02	0.14
Molybdenum	mg/l	0.005	<0.005	<0.005
Nickel	mg/l	0.005	<0.005	<0.005
Lead	mg/l	0.01	<0.01	<0.01
Antimony	mg/l	0.02	<0.02	<0.02
Selenium	mg/l	0.01	<0.01	<0.01
Vanadium	mg/l	0.001	<0.001	<0.001
Zinc	mg/l	0.01	<0.01	<0.01
Iron	mg/l	0.05	<0.05	<0.05

Report number   0000008839
Client reference: **To Follow**

Parameter	Units	LOR	JB14-05837.011 MO 16 - 50012	JB14-05837.012 MO 14 - 50013
Sample Number			**JB14-05837.011**	**JB14-05837.012**
Sample Name			**MO 16 - 50012**	**MO 14 - 50013**

Dissolved Hg on Leachates by ICP-MS   Method: ME-AN-026

Parameter	Units	LOR		
Mercury	µg/l	0.1	<0.10	<0.10

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

Parameter	Units	LOR		
Total Alkalinity as CaCO3	mg/l	12	20	22
Phenolphthalein Alkalinity as CaCO3*	mg/l	12	<12	12
Bicarbonate Alkalinity as CaCO3	mg/l	12	20	<12
Bicarbonate Alkalinity as HCO3	mg/l	12	24	<12
Bicarbonate as CaCO3	mg/l	12	20	<12
Carbonate Alkalinity as CaCO3	mg/l	12	<12	20
Carbonate Alkalinity as CO3	mg/l	12	<12	<12
Hydroxide Alkalinity as CaCO3	mg/l	12	<12	<12
Hydroxide as OH	mg/l	12	<12	<12

Calculation of Anion-Cation Balance   Method: ME-AN-014

Parameter	Units	LOR		
Sum of Cation Milliequivalents*	meq/l	-	0.412	0.533
Sum of Anion Milliequivalents*	meq/l	-	0.426	0.479
Anion-Cation Balance	%	-100	-1.66	5.38

METHOD	METHODOLOGY SUMMARY
ASTM D3987	Contaminants of interest in a waste material are leached out of the waste with deionised water under controlled conditions. The ratio of sample to extraction fluid is 1 to 20 by mass. The concentration of each contaminant of interest is determined in the leachate by appropriate methods after separation from the sample by filtering. The method is based on ASTM D3987.
ME-AN-001	An aliquot of aqueous sample is titrated first to pH 8.3 and then to 4.3 using standardised acid. The volumes of acid titrated are used to calculate the alkaline species or total alkalinity. The method is based on EPA 310.2 and APHA 2320 B.
ME-AN-007	The conductivity of an aliquot of aqueous sample is measured electrometrically using a standard cell connected to a calibrated meter with automated temperature correction. This method is based on APHA 2510.
ME-AN-011	Total dissolved solids (TDS) is determined gravimetrically on a filtered aliquot of aqueous sample by evaporating the sample to dryness in a pre-weighed container at 105 deg C. The method is based on APHA 2540 C.
ME-AN-013	The ion balance for aqueous samples is determined by calculation from the major cation, major anion and alkalinity results, determined by ICP-OES, ion chromatography and titration, respectively. The method is based on APHA 1030.
ME-AN-014	Inorganic anions (Br, Cl, F, NO3, NO2, SO4) are determined on aqueous samples by ion chromatography. The method is based on EPA 300.1 and APHA 4110 B. Br, Cl, F and NO2 are not determined on TCLP leachates.
ME-AN-027	Dissolved metals are determined on a filtered and acidified portion of aqueous sample by inductively coupled plasma optical emission spectrometry (ICP-OES). The method is based on EPA 200.7 and APHA 3120.
ME-AN-031	This method is based on ISO 14403:2002(E) Water Quality – Determination of Total Cyanide and Free Cyanide by Continuous Flow Analysis. It is applicable to the determination of total dissolved cyanide in various types of environmental samples. The matrices applicable to this method are drinking water, surface water, groundwater, mixed industrial and domestic wastewaters and leachates.
ME-AN-040	Hexavalent chromium, when reacted with diphenylcarbizide in acid solution, produces a red-violet colour which is measured photometrically at wavelength 540 nm.

FOOTNOTES

IS	Insufficient sample for analysis.	QFH	QC result is above the upper tolerance
LNR	Sample listed, but not received.	QFL	QC result is below the lower tolerance
^	Performed by outside laboratory.	-	The sample was not analysed for this analyte
LOR	Limit of Reporting	*	*Results marked "Not SANAS Accredited" in this report are not*
↑↓	Raised or Lowered Limit of Reporting		*included in the SANAS Schedule of Accreditation for this laboratory / certification body / inspection body".*

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

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

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Attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein.
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Testing Laboratory

T0107

SGS

TEST REPORT (Amended)

CLIENT DETAILS

Contact	Richard Curtis
Client	Mokala Manganese (PTY) LTD
Address	17 Termo Avenue
	Techno Park
	Stellenbosch
Telephone	011 218 8221
Facsimile	(Not specified)
Email	richardcurtis@telkomsa.net
Project	(Not specified)
Order Number	**To Follow**
Samples	5
Sample matrix	SOIL

LABORATORY DETAILS

Laboratory	SGS South Africa (Pty) Limited
Address	259 Kent Avenue
	Ferndale, 2194
Telephone	+27 (0)11 590 3000
Laboratory Manager	
SGS Reference	JB15-06165 R1
Report Number	0000008840
Date Received	2015/01/27 03:34:31PM
Date Reported	2015/03/13 10:22:13AM

COMMENTS

The document is issued in accordance with SANAS's accreditation requirements.
Accredited for compliance with ISO/IEC 17025. SANAS accredited laboratory T0107.

This report/certificate is a re-issued copy and replaces the originally issued document dated 17/02/2015 and 25/02/2015. The reason for re-issue is the client requested the leach mass and volume appear on the report.
Sample(s) leached using deionised water. Results reported on leachate.

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Testing Laboratory
T0107

SIGNATORIES

Greg Ondrejkovic	Martin Olivier
Technical Supervisor/Technical Signatory	Operations Manager/Technical Signatory

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Environmental Services

259 Kent Avenue, Ferndale
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Member of the SGS Group

ANALYTICAL REPORT

JB15-06165 R1

			JB15-06165.001	JB15-06165.002	JB15-06165.003	JB15-06165.004	JB15-06165.005
Sample Number			**JB15-06165.001**	**JB15-06165.002**	**JB15-06165.003**	**JB15-06165.004**	**JB15-06165.005**
Sample Name			**GL27 - 50024**	**GL27 - 50022**	**GL55 - 47816**	**GL42 LB - 46253**	**DI Blank**
Sample Matrix			**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Parameter	**Units**	**LOR**					
Conductivity on leachates **Method: ME-AN-007**							
Conductivity in mS/m @ 25ºC	mS/m	2	9	15	3	6	<2
Total Dissolved Solids (TDS) in leachates at 0.7um **Method: ME-AN-011**							
TDS (0.7µm) @ 105ºC	mg/l	21	46	74	160	<21	<21
Anions on leachates by Ion Chromatography **Method: ME-AN-014**							
Chloride	mg/l	0.05	4.2	7.1	0.82	0.67	<0.05
Fluoride	mg/l	0.05	0.12	0.17	0.13	<0.05	<0.05
Nitrate	mg/l	0.1	0.6	2.4	3.8	0.4	<0.1
Sulphate	mg/l	0.05	3.6	8.1	0.12	0.13	<0.05
Hexavalent Chromium by Discrete Analyser on Leachates **Method: ME-AN-040**							
Hexavalent Chromium*	mg/l	0.09	<0.09	<0.09	<0.09	<0.09	<0.09
Total Cyanide in leachates **Method: ME-AN-031**							
Total Cyanide	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
ICP-OES Metals on leachates (Dissolved) **Method: ME-AN-027 D**							
Arsenic	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Boron	mg/l	0.005	0.020	0.007	0.047	0.035	<0.005
Barium	mg/l	0.002	0.053	0.092	0.19	0.027	<0.002
Cadmium	mg/l	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	mg/l	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Copper	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Manganese	mg/l	0.01	<0.01	<0.01	<0.01	0.03	<0.01
Molybdenum	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Nickel	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Lead	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Antimony	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Selenium	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	mg/l	0.001	<0.001	<0.001	0.001	<0.001	<0.001
Zinc	mg/l	0.01	0.01	0.03	0.13	<0.01	<0.01
Calcium	mg/l	0.5	8.7	9.3	7.0	9.3	<0.5
Magnesium	mg/l	0.01	2.7	8.2	0.97	2.7	<0.01
Sodium	mg/l	0.5	4.5	3.8	1.0	0.9	<0.5
Potassium	mg/l	0.2	<0.2	0.6	1.0	0.4	<0.2
Iron	mg/l	0.05	<0.05	<0.05	0.23	<0.05	<0.05
Dissolved Hg on Leachates by ICP-MS **Method: ME-AN-026**							
Mercury	µg/l	0.1	<0.10	<0.10	<0.10	<0.10	<0.10
Deionised Water Leach @ 20:1 **Method: ASTM D3987**							
Final pH*	-	0.1	8.8	9.0	8.1	8.7	6.6
Weight Sample*	g	-	50.0	50.0	50.0	50.0	-
Vol_ml*	ml	-	1000	1000	1000	1000	1000

METHOD	METHODOLOGY SUMMARY
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ME-AN-007	The conductivity of an aliquot of aqueous sample is measured electrometrically using a standard cell connected to a calibrated meter with automated temperature correction. This method is based on APHA 2510.
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Samples analysed as received.
Solid samples expressed on a dry weight basis.

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

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Testing Laboratory

T0107

SGS

Christopher Myles
SGS Environmental Services
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PRELIMINARY REPORT No: 15/102

Work Requested By:	Christopher Myles
On Behalf Of:	SGS Environmental Services
Proposal Number:	15/102
Date issued:	03 March 2015
Investigator/s:	Dinah Mosinyi

Quantitative Analyses of Three Samples by X-ray Diffraction

_____ _____

Dinah Mosinyi   **Annegret Lombard**
Mineralogist   **HOD: Mineralogy**

1. INTRODUCTION

Christopher Myles, on behalf of SGS Environmental Services, submitted three Mn-containing samples for quantitative analyses by X-ray diffraction (XRD). The aim of this investigation was to identify and quantify the crystalline phases present in each sample with particular emphasis on Mn-phases.

The samples were labelled:
1. 06166-001
2. 06166-002
3. 06166-003

2. METHODOLOGY

The samples were micronized and analysed by XRD utilising a Panalytical X'pert Pro Diffractometer employing Cu-Kα radiation. Data interpretation was by means of Panalytical Highscore Plus analytical software, together with the PanICSD database. The XRD analysis was used to quantify the crystalline phases present in each sample. Please note that this technique only identifies crystalline minerals with concentrations >3 mass% in the sample. In addition, some minerals diffract X-rays better than others or show preferred orientation which results in inflated mass abundances. Peak overlaps may also hamper the identification of certain mineral phases. The minerals identified were then quantified by Rietveld analysis to determine the abundances.

3. RESULTS

3.1. X-ray Diffraction Analyses

The crystalline phases that were detected by XRD are listed in Table 1, and the diffractograms of the samples are shown in Figure 1 to Figure 3. Detailed descriptions of the mineralogy of the samples are given below.

Sample 6166-001 contained fairly abundant amounts of quartz, with lesser amounts of magnetite, hematite, kurchatovite, dolomite and trace amounts of braunite. The elevated silica and iron containing phases such as magnetite and hematite were unique to this sample (Figure 1).

Sample 6166-002 contained dominant amounts of carbonaceous phases, namely dolomite and ankerite, with lesser amounts of quartz. The absence of Mn-containing phases was unique to this sample (Figure 2).

Sample 6166-003 was composed solely of Mn-containing phases namely braunite, kutnohorite and hausmannite (Figure 3).

It should be noted that due to peak overlaps and possible inflated mass abundances (particularly with Mn-containing phases), the results presented in this report are not conclusive and can only regarded as indicative. Additional analytical tests, mainly X-ray fluorescence for major element analyses are currently being conducted, upon availability of these, the report will be revised and presented as final.

Table 1. Crystalline Mineral Phases & Their Approximate Abundance as Determined by X-ray Diffraction

Mineral	Approx. Formula	6166-001	6166-002	6166-003
Quartz	SiO_2	36	17.6	-
Magnetite	Fe_3O_4	18.7	-	-
Hematite	Fe_2O_3	12.5	-	-
Dolomite	$CaMg(CO_3)_2$	13.6	70.5	-
Braunite	Mn_7SiO_{12}	1.5	-	56.2
Kurchatovite	$Ca(Mg,Mn, Fe)B_2O_5$	17.7	-	-
Ankerite	$Ca(Fe,Mg,Mn)(CO_3)_2$	-	11.9	-
Kutnohorite	$Ca(Mn,Mg,Fe)(CO_3)_2$	-	-	34.3
Hausmannite	Mn_3O_4	-	-	9.5
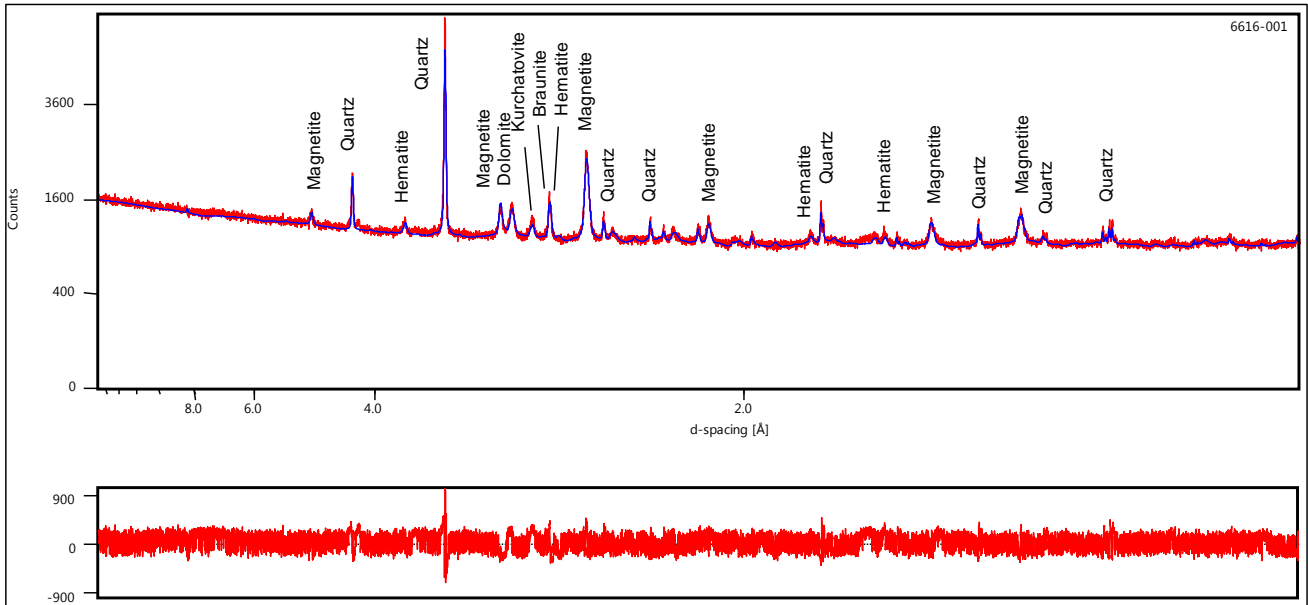
Figure 1. X-ray diffractogram of sample 6166-001. The upper red pattern is the measured diffractogram, the blue curve is the calculated pattern from the Rietveld Refinement and the lower red curve is the difference plot.
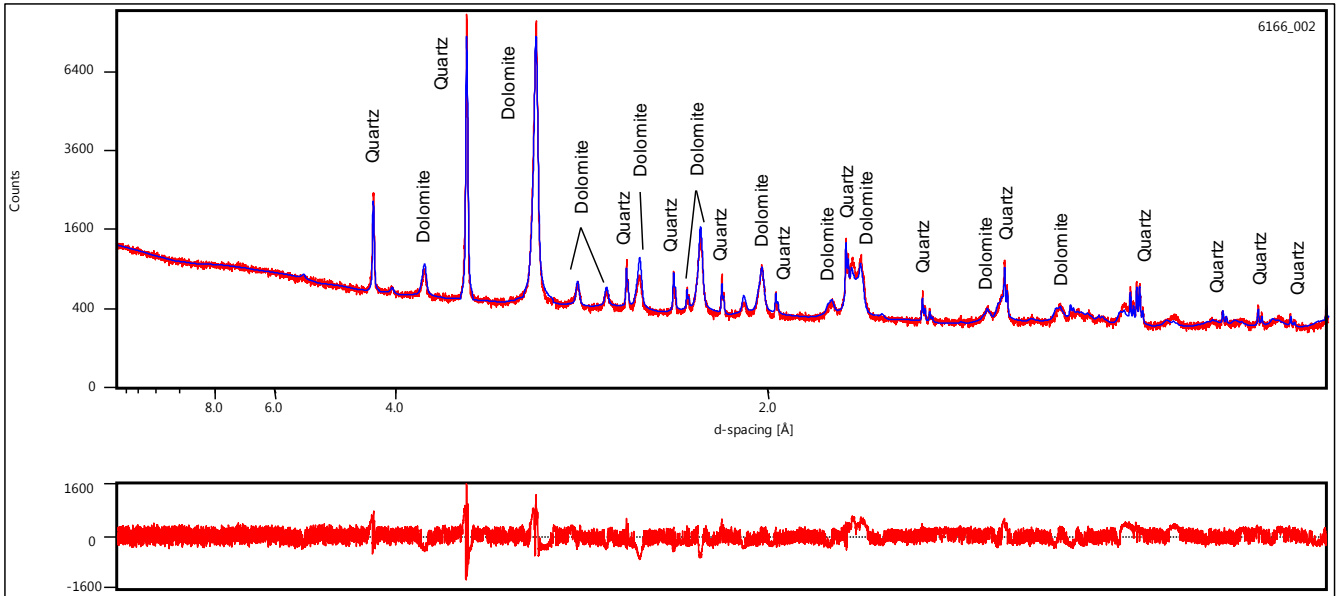
Figure 2. X-ray diffractogram of sample 6166-002. The upper red pattern is the measured diffractogram, the blue curve is the calculated pattern from the Rietveld Refinement and the lower red curve is the difference plot.
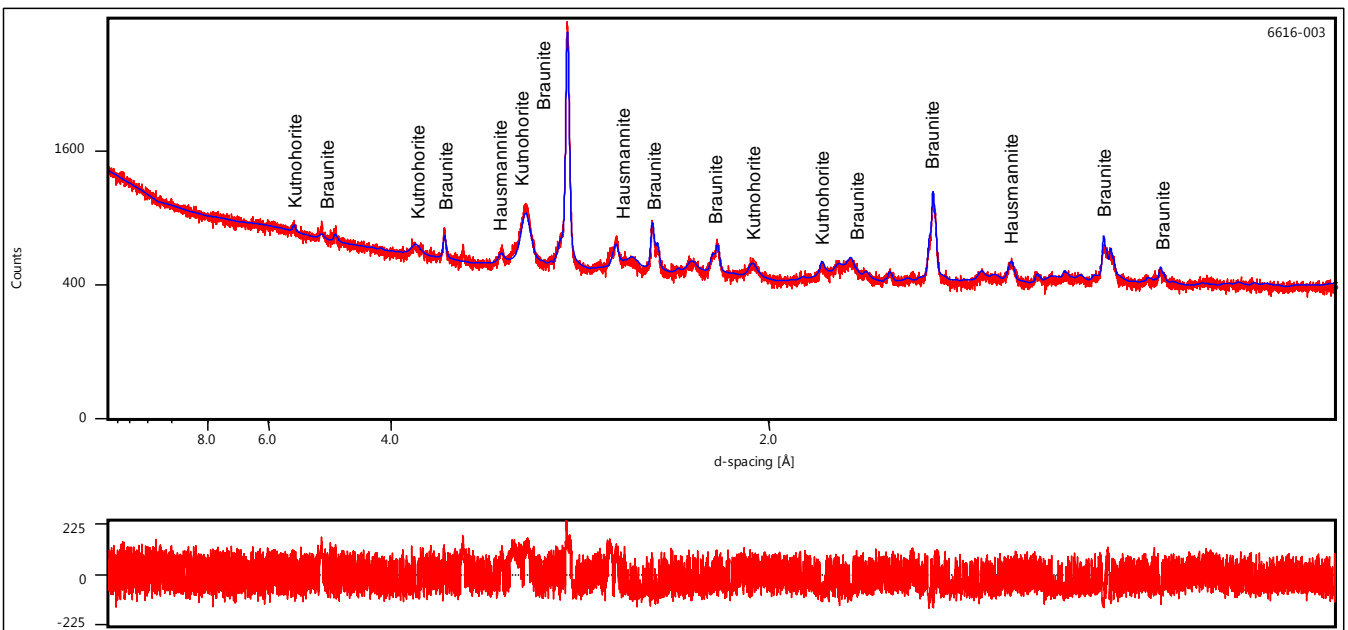
Figure 3. X-ray diffractogram of sample 6166-003. The upper red pattern is the measured diffractogram, the blue curve is the calculated pattern from the Rietveld Refinement and the lower red curve is the difference plot.

TEST REPORT

SGS South Africa (Pty)Ltd
58 Melville Street
Booysens
Johannesburg

SGS South Africa (Pty)Ltd
58 Melville Street
Booysens
Johannesburg

MINERALOGY REPORT No: 14/784

Work Requested By: SGS South Africa, Environmental

On Behalf Of: Christopher Myles

Date issued: 18 November 2014

Investigator/s: Laura Bowden

X-ray Diffraction Analysis of Twelve Samples

Laura Bowden
Mineralogist

Brandon Youlton
Manager: Mineralogy

1. INTRODUCTION

Christopher Myles, on behalf of the SGS Environmental Division, submitted 12 samples for quantitative X-ray diffraction (XRD) analysis, in order to determine the major minerals present in the samples.

The samples were labelled as:

1. 50001   7. 50007
2. 50002   8. 50008
3. 50003   9. 50009
4. 50004   10. 50010
5. 50005   11. 50012
6. 50006   12. 50013

2. METHODOLOGY

Due to the occurrence of manganese in the samples (which fluoresces when analysed with the Co tube used at SGS Booysens), the samples were analysed and interpreted by Dr Sabine Verryn of XRD Analytical and Consulting. The samples were analysed using the Panalytical diffractometer which employs Cu-Kα radiation. The data was interpreted by means of the Panalytical Highscore Plus analytical software and the PanICSD database. The abundances of each mineral were determined using Rietveld Refinement. Note that this technique only identifies crystalline minerals with concentrations >3 mass % in the sample. In addition, some minerals diffract X-rays better than others or show preferred orientation which results in inflated mass abundances. Peak overlaps may also hamper the identification of certain mineral phases. Amorphous phases are not identified.

3. RESULTS

The results of the XRD analysis are given in Table 1 and the X-ray diffractograms that were obtained in the analysis are shown in Figures 1 to 4. The majority of the samples contain variable proportions of quartz, calcite, dolomite, smectite, palygorskite, hematite and magnetite. Higher proportions of quartz are reported for the Kalahari samples 50001 and 50004 (between ~40 and 49%), the Dwyka samples 50002 and 50005 (between ~28 and 33%) and the Middle Mn (50012) sample (~39%). The calcrete (50007, 50008, 50009 and 50010), upper (50003 and 50006) and BIF middle (50013) samples contain between ~1 and 19% quartz.

Calcite is present in high proportions (~72 to 78%) in the calcrete samples, except for sample 50007 in which it is present in proportions ~10%. High proportions of dolomite are however reported for this sample at ~68%. The upper Mn (50003 and 50006) and middle Mn (50012) samples contain relatively high proportions of calcite at ~13 to 25%. The Kalahari (50001 and 50004) and Dwyka (50002 and 50005) samples contain lower proportions of calcite, between ~1 and 10%.

Sample 50013 (BIF middle) is comprised of ~29% hematite. Relatively high proportions of hematite are reported for the upper Mn samples 50003 (~8%) and 50006 (~5%). Trace quantities of magnetite is present in the majority of samples, however the middle Mn (50012) sample comprises much higher proportions of magnetite at 29%.

Manganese minerals identified during the analysis include bixbyite, braunite, hausmannite and kutnohorite. These minerals occur in the upper Mn, Dwyka and BIF middle samples in varying proportions. Sample 50003 however contains large quantities of manganese minerals. This sample is comprised of ~35% braunite, ~16% kutnohorite, ~9% hausmannite and ~1% bixbyite.

Table 1: Major Mineral Abundances as Determined by XRD.

Mineral	Formula	Sample ID											
		Kalahari	Dwyka	Upper Mn	Kalahari	Dwyka	Upper Mn	Calcrete	Calcrete	Calcrete	Calcrete	Middle Mn	BIF Middle
		50001	50002	50003	50004	50005	50006	50007	50008	50009	50010	50012	50013
Quartz	SiO_2	49.0	32.8	6.0	40.2	27.8	18.7	9.8	7.3	11.3	13.3	38.5	0.5
Calcite	$CaCO_3$	1.4	5.5	25.2	4.3	9.7	24.1	10.1	72.6	77.6	72.3	12.9	-
Dolomite	$CaMg(CO_3)_2$	18.5	11.5	-	11.4	2.4	7.3	68.3	5.7	0.3	2.5	-	-
Smectite	$(Ca, Na, H)(Al, Mg, Fe, Zn)_2(Si, Al)_4O_{10}(OH)_2 - xH_2O$	26.8	39.4	-	33.9	50.5	30.9	5.1	7.8	4.2	6.0	-	-
Palygorskite	$(Mg,Al)_2Si_4O_{10}(OH) \cdot 4(H_2O)$	2.8	8.7	-	9.0	6.4	7.2	6.2	6.5	6.2	5.4	-	-
Kaolinite	$Al_2Si2O_5(OH)_4$	-	-	-	-	-	-	-	-	-	-	7.8	-
Lizardite	$Mg_3Si_2O_5(OH)_4$	-	-	-	-	-	-	-	-	-	-	6.1	12.7
Hematite	Fe_2O_3	0.9	1.4	8.3	0.7	3.1	4.7	0.4	0.1	-	0.2	-	29.1
Magnetite	Fe_3O_4	0.3	0.4	-	0.5	-	0.8	0.2	0.1	0.4	0.3	29.3	-
Rutile	TiO_2	0.4	0.2	-	-	-	-	-	-	0.2	-	-	-
Clinopyroxene	$CaMgSi_2O_6$	-	-	-	-	-	-	-	-	-	-	-	38.4
Bixbyite	$(Mn+++.Fe+++)_2O_3$	-	-	0.5	-	0.1	0.3	-	-	-	-	-	-
Braunite	$Mn++,Mn+++_6SiO_{12}$	-	-	35.4	-	0.1	6.0	-	-	-	-	-	-
Hausmannite	$Mn++,Mn+++_2O_4$	-	-	8.7	-	-	-	-	-	-	-	-	-
Kutnohorite	$Ca(Mn,Mg,Fe++)(CO_3)_2$	-	-	15.9	-	-	-	-	-	-	-	-	19.4
Thaumasite	$Ca_3Si(CO_3)(SO_4)(OH)_612H_2O$	-	-	-	-	-	-	-	-	-	-	4.2	-
Titanite	$CaTiO(SiO_4)$	-	-	-	-	-	-	-	-	-	-	1.2	-
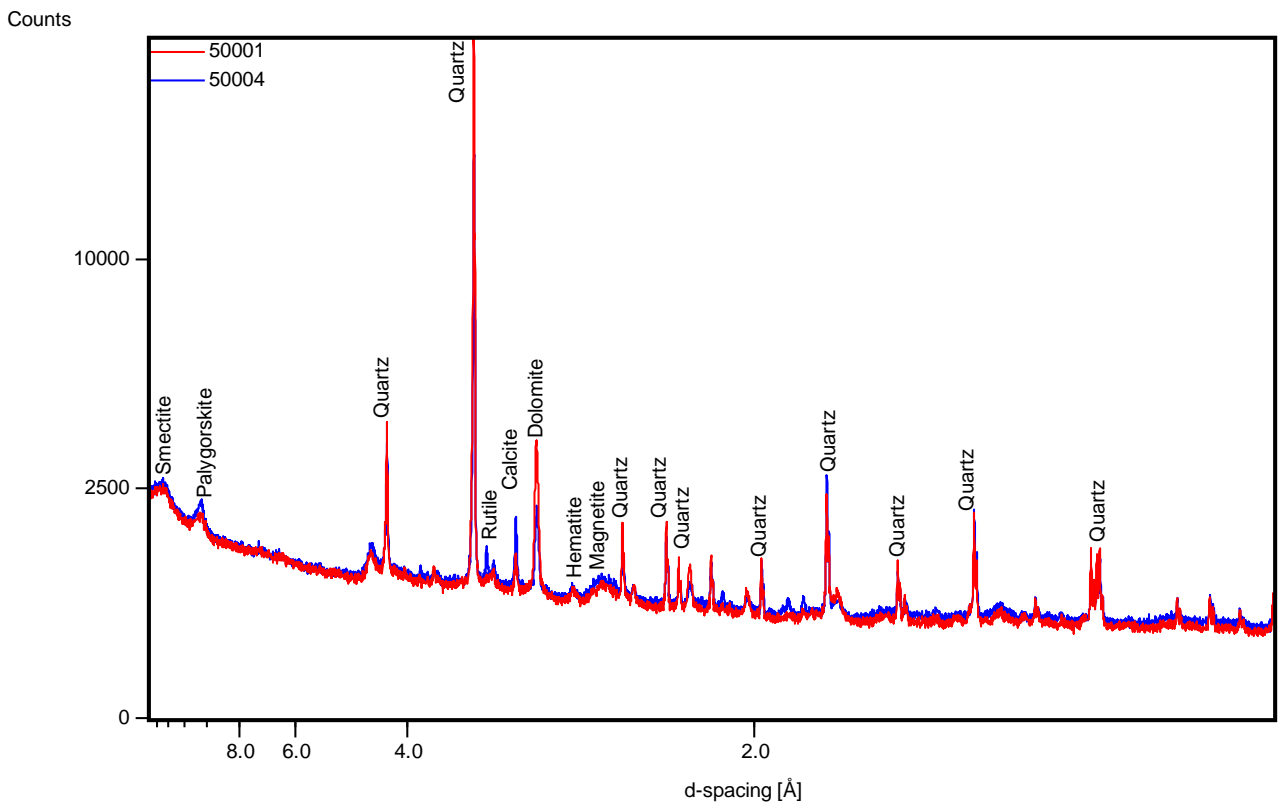
Figure 1: X-ray diffractogram showing the composition of the Kalahari samples 50001 and 50004.
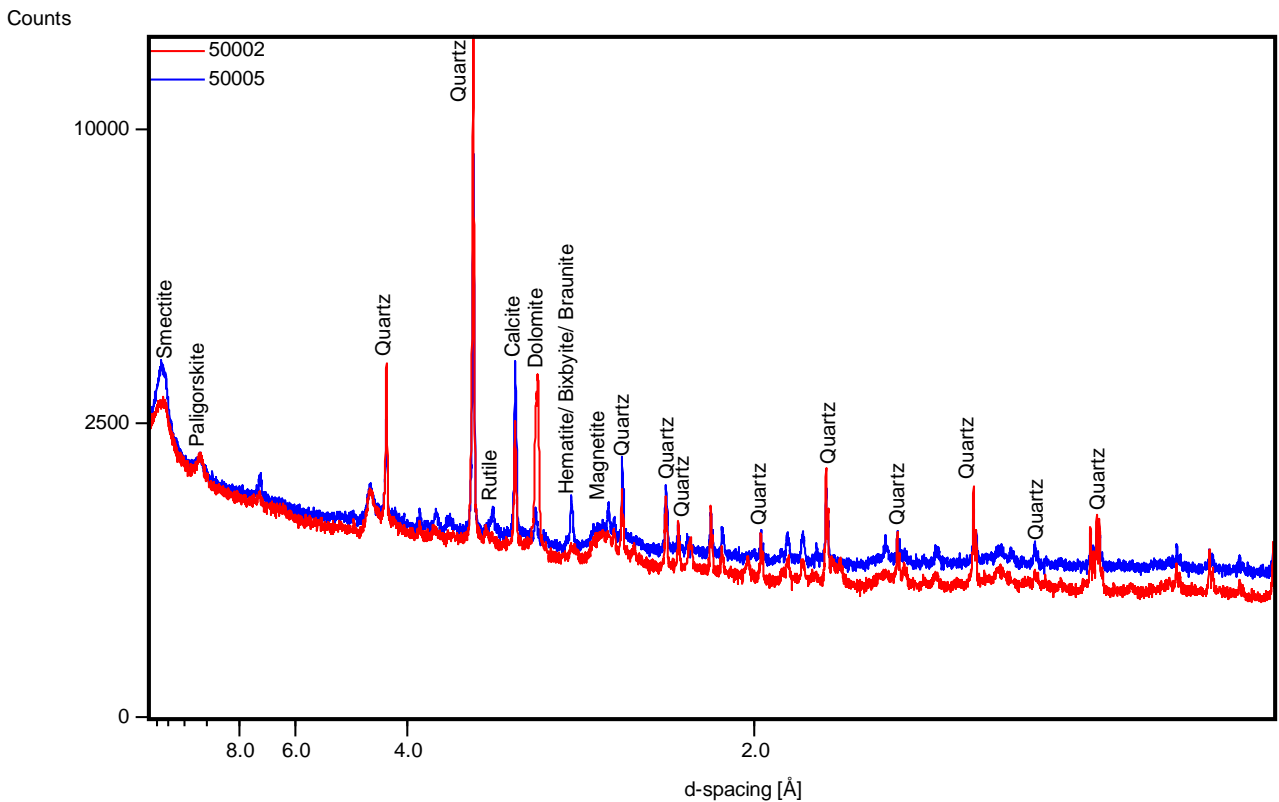
Figure 2: X-ray diffractogram showing the composition of the Dwyka samples 50002 and 50005.
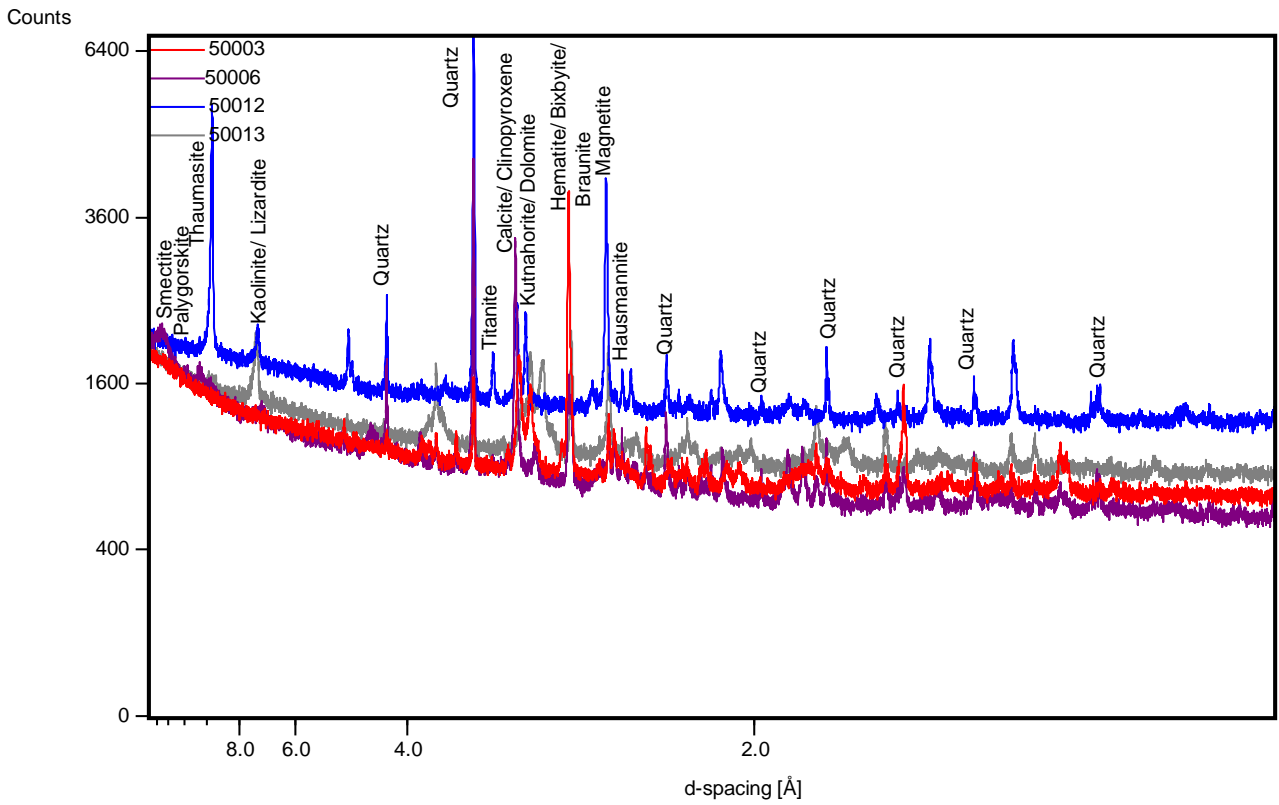
Figure 3: X-ray diffractogram showing the composition of the upper Mn (50003 and 50006), middle Mn (50012) and BIF middle (50013) samples.
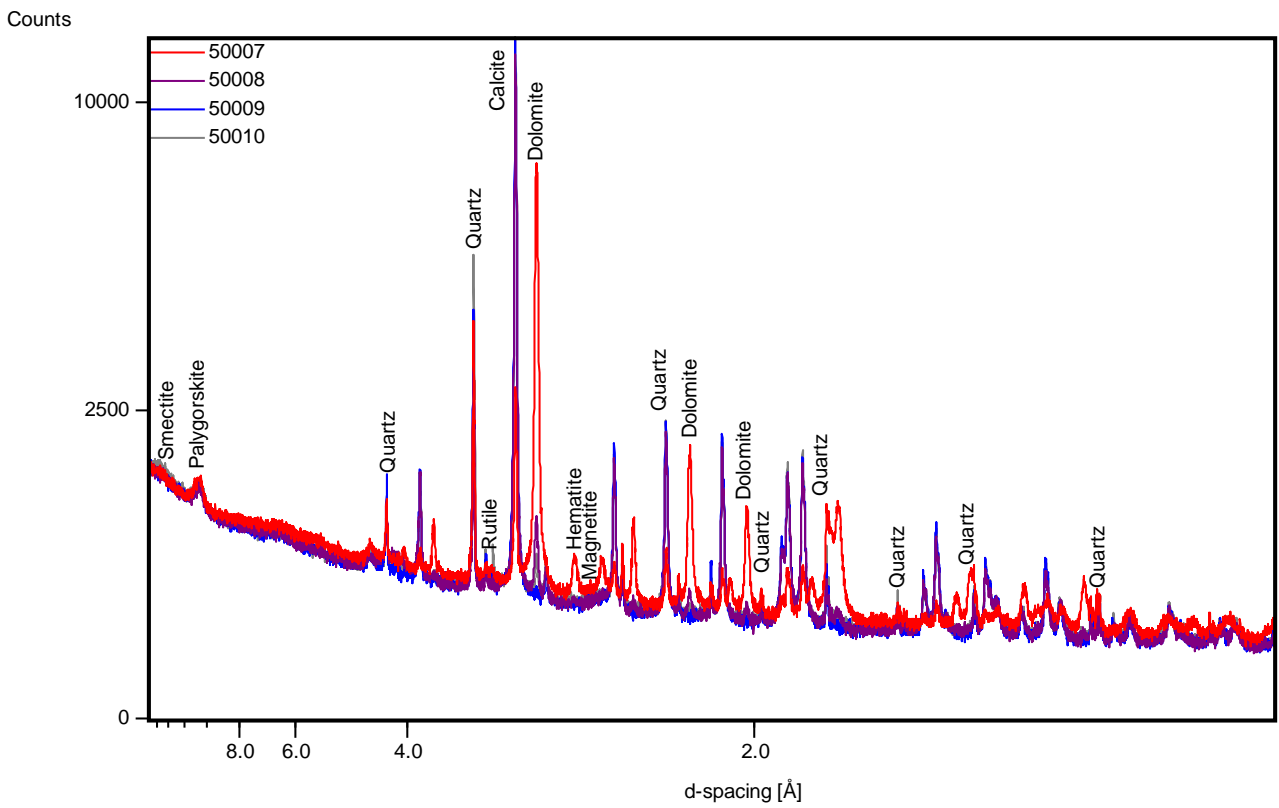

Figure 4: X-ray diffractogram showing the composition of the calcrete samples (50007, 50008, 50009, 50010).

APPENDIX B: CURRICULUM VITAE'S OF PROJECT STAFF

Jenny Ellerton
Senior Hydrogeologist / Geochemist

SLR

Curriculum Vitae

Qualifications

MSc	2005	Hydrogeology – University of Birmingham
BSc (Hons)	2002	Geology and Physical Geography Dual Honours - Keele University (Upper Second)
FGS	Since 2006	Fellow of the Geological Society

Key Areas of Expertise

Jenny has **9 years** of professional experience gained in both the UK and South Africa. Key areas of Jenny's expertise are summarised below

Acid Rock Drainage Assessments	Geochemical assessment and remediation of mine related water pollution.
Groundwater Assessments	Hydrogeological assessments for various purposes including Environmental Impact Assessments and Environmental Management Plans, Water Use Licence Applications and engineering purposes.
Hydrogeological Site Investigation	Supervising drilling contractors, for numerous types of site investigations and undertaking aquifer tests.
Environmental Monitoring	Groundwater, surface water, leachate & gas monitoring.
Development of Conceptual Site Models	Analysis & interpretation of geological and hydrogeological information.
Environmental Impact Assessment	Assessment of potential impacts of development associated with mines, wind farms, landfills, quarries and industrial / commercial developments on the water environment.
Hydrogeological Risk Assessments (HRA)	Qualitative & quantitative assessment of risks to groundwater from numerous sites, specifically landfills.
Project Management	Experience in management of field based hydrogeological studies and desk based projects.

Summary of Experience and Capability

Jenny is a Senior Hydrogeologist within SLR with 9 years of geological and hydrogeological experience gained through a master's degree and environmental consultancy both in the UK and South Africa.

Jenny has undertaken projects covering all aspects of hydrogeology and specialises in the following:

- Site investigation, including the installation of groundwater and gas monitoring boreholes and the detailed logging of soil and rock samples.
- Undertaking monitoring and sampling of surface water, groundwater, landfill gas and leachate and undertaking field permeability tests and data analysis.

- Qualitative and quantitative Hydrogeological Risk Assessments (HRAs) in support of the permitting of waste management facilities.
- Hydrogeological assessments for Environmental Statements in support of planning applications for mineral extraction operations, landfill developments, and other industrial and commercial developments.
- Geochemical and Acid Rock Drainage (ARD) assessments to characterise the expected waste rock material associated with the mineral extraction process of various types of mining operations in accordance with best practice.
- Waste classification in terms of the National Norms and Standards for the Assessment of Waste for Landfill Disposal (No. R. 635) and Disposal of Waste to Landfill (No. R 636).
- Soil contamination assessment to determine the level of soil contamination in terms of soil screening values as presented in National Norms and Standards for the Remediation of Contaminated land and Soil Quality.

Recent Project Experience

Key aspects of Jenny's recent project experience are summarised below.

Project	Date	Jenny's Role
Letlhakane Uranium Project	Current	Responsible for the selection of representative waste samples for geochemical characterisation, acid rock drainage (ARD) assessment, geochemical modelling and reporting.
Sibelo Project	December 2014	Responsible for the interpretation of lab results in terms of the National Norms and Standards for the Assessment of Waste to determine the waste type and the class of landfill (liner specification) required to dispose of the waste.
Alfred Knight Due Diligence Project	August 2014	Responsible for the selection of samples, sample analysis and interpretation of results in terms of the National Norms and Standards for the Remediation of Contaminated land and Soil Quality to determine 'baseline' condition of the soil.
Kudumane Project	July 2014	Responsible for compiling a comprehensive groundwater assessment to support both an Environmental Impact Assessment for a Mining Rights Application and a Water Use Licence Application. Responsible for project managing, interpretation of field results and reporting.
Hinda Phosphate	September 2013	Responsible for co-ordination and undertaking the supervision of the drilling of boreholes and pumping tests in the Congo. Interpretation of field data and reporting.

Publications

None to date

Terry Harck
Solution[H+]

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www.solutionhplus.com

PROFESSIONAL PROFILE

Environmental Geochemist. Mine drainage quality prediction. Acid Mine Drainage (AMD) assessment. Mine water management. Integration of geochemistry, groundwater and surface water studies.

BIOGRAPHY

Terry advises Southern African and international clients on the management of acid rock drainage and contaminated seepage at mine sites. He has been practicing as a consultant for over 20 years. He was the manager and lead consultant of a team of 11 specialists before going solo as Solution[H+].

Terry is a member of the International Mine Water Association (IMWA), the Groundwater Division of the Geological Society of South Africa (GWD-GSSA), and the South African chapter of the International Association of Hydrogeologists (IAH-SA), for which he serves as Treasurer.

PROFESSIONAL EXPERIENCE

Solution[H+], Pretoria, South Africa
Principal Consultant
Environmental Geochemist

February 2012 – present

Golder Associates Africa, Johannesburg, South Africa
Senior Geochemist and Divisional Leader
Specialist impact prediction studies with special reference to the geochemistry and groundwater aspects of mining impacts. Integration of hydrogeological and geochemical aspects of contamination assessment projects for the mining and related industries.

May 2004 – February 2012

Responsible for 10 professionals: internal coordination, marketing, developing proposals, project management, commissioning specialists, report development, client liaison and budget management.

Coffey Geosciences, Sydney, Australia
Senior Geoscientist
Led a business unit comprising four employees. Project managed mine environmental specialist studies. Business development. Internal auditor for office Quality Management System

July 1997 – December 2003

Wates, Meiring and Barnard, Johannesburg, South Africa
Contaminant Geohydrologist/Geochemist
Specialist hydrogeological and geochemical studies for mining and industrial clients.

July 1996 – June 1997

Steffen, Robertson and Kirsten, Johannesburg, South Africa
Contaminant Hydrogeologist/Geochemist
Specialist hydrogeological and geochemical studies for mining and industrial clients.

May 1995 – June 1996

E Martinelli and Associates, Johannesburg, South Africa
Geologist
Geophysical surveys, contractor supervision, groundwater development work.

January 1991 – December 1993

EDUCATION

University of Cape Town, Cape Town, South Africa
M.Sc. in Environmental Geochemistry   1995
Thesis: "A Geochemical Investigation of the Aquatic Sediments, Groundwater and Surface water of the Verlorenvlei Coastal Lake, With Special Reference to Nitrate Transformations."

University of the Witwatersrand, Johannesburg, South Africa
M.Sc. in Geology   1994
Thesis: "Depositional Systems and Syndepositional Tectonics of the Basal Griqualand West Sequence, Northern Cape"

University of the Witwatersrand, Johannesburg, South Africa
B.Sc. Honours in Geology   1987

PUBLICATIONS AND PAPERS

Pretorius JA, Harck T, and Gunther P "Brine Disposal / Storage of Brine in Underground Mining Compartments – A Case Study" Solution Mining Research Institute (SMRI) Fall 2011 Conference, 2-5 October 2011, York, UK.

T Harck "Mobilisation of salts from mine waste. A pinch or a pound?" Symposium of the International Mine Water Association. September 2010, Sydney, Nova Scotia

T Harck and M Peters "Reprocessing Kimberlite tailings: A square contaminant source in a big hole?" 11th International Mine Water Association Congress. October 2009, Pretoria, South Africa

T Harck et al "Impact prediction of the reactivation of an unused tailings dam," 11th International Mine Water Association Congress. October 2009, Pretoria, South Africa

Ochieng L, Harck T, and Peters M "Net Neutralisation Potential NNP) in Kimberley Diamond Tailings and Slimes Waste Materials" 11th International Mine Water Association Congress. October 2009, Pretoria, South Africa

T Harck "Managing the Groundwater Impact of Mine Water Treatment Waste", 10th International Mine Water Association Congress. June 2008, Karlovy Vary, Czech Republic.

T Harck "Are biodiversity offsets a licence to plunder natural resources?", IAIAsa Newsletter. August 2005, South Africa.

T Harck "Old mines yield history", Australian Geographic. July – September 2002, Australia

T Harck, Willis JP, and Fey MV "Denitrification of nitrate-rich ground water entering Verlorenvlei Lake on the west coast of South Africa" Proceedings of the 4th International symposium on Environmental Geochemistry, Oct. 5-10 1997, Vail, CO, United States

T Harck "Identification and Characterisation of a Source of Contaminated Seepage", Young Water, Environmental & Geotechnical Engineers Conference, July 1996, KwaZulu Natal, South Africa.

PRESENTATIONS AND TEACHING

University of Pretoria, Pretoria, South Africa   2012-2014
Volunteer lecturer: "Environmental Geochemistry" GTX715

*Principles of low temperature geochemistry, geochemistry and origin of acid mine
water, acid-mineral reactions; industrial effluents, remediation methods, waste
disposal, environmental sampling and data analysis, geochemical modelling.*

North West University, Potchefstroom, South Africa   2012-2013
Extraordinary lecturer

*Presented course "An introduction to Hydrogeochemistry". This included themes such as: Chemical equilibrium,
Contents of Water, and Solids and water. Topics included: equilibrium constants, pH, pe, solubility, dissolved gases,
alkalinity, speciation, redox reactions, ion exchange, colloids, sulphide mineral oxidation and introduction to the
PHREEQC geochemical modelling code.
Supervised honours degree student during their honours project fieldwork and write-up*

Golder Associates, Johannesburg, South Africa   2012-2014
Facilitator: "Understanding and Applying Best Practice Management of Acid Rock Drainage"

Developed syllabus and course structure, and coordinated the course

Golder Associates, Johannesburg, South Africa   2011
Facilitator: "Technical Writing"

Co-presented training material developed in-house

**Department of Water Affairs and Forestry and Water Institute of South   2008-2010
Africa – Mine Water Division**
Presenter: "The value of impact prediction from case studies." Second Symposium on Best Practice Guidelines"

Three geochemical prediction studies from project experience

Geological Society of South Africa – Ground Water Division   11-12 February 2009
Presenter: "Re-evaluation of Cr(VI) Contamination After Remediation"

Case study not included in the conference proceedings

**International Association for Impact Assessment – South African chapter   October 2007
(IAIAsa)**
Presenter: "Does the new Mining Act further sustainability in the mining industry?"

Discussion paper not included in the conference proceedings

University of Cape Town, Cape Town, South Africa   October 2005
Tutor

Teaching support for laboratory sessions

SLR Consulting (South Africa) (Pty) Limited

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