WASTE ASSESSMENT AND GEOCHEMICAL CHARACTERISATION

Mamatwan Mine

Prepared for: Hotazel Manganese Mines (Pty) Ltd - South32

MMT INTERNAL USE ONLY

SOUTH32

SLR Project No.: 720.019136.00002_P05
Report No.: 1
Revision No.: 2.0
April 2020

SLR

DOCUMENT INFORMATION

Title	Waste Assessment and Geochemical Characterisation
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Reviewer	Rob Hounsome
Keywords	Geochemistry, Waste
Status	Draft for client review
DEA Reference	N/A
DMR Reference	N/A
DWS Reference	N/A
Report No.	1
SLR Company	SLR Consulting (South Africa)(Pty)Ltd

DOCUMENT REVISION RECORD

Rev No.			
0	November 2019	First draft issued for client comment	CS
2.0	December 2019	Final	CS

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EXECUTIVE SUMMARY

SLR Consulting (South Africa) (Pty) Ltd (SLR), an independent firm of environmental consultants, has been appointed by South32 to undertake a waste assessment and geochemical characterisation for the Mamatwan Mine (MMT). MMT is an open pit manganese ore mine, which started operations in 1963.

Based on a review of the available data for the site, SLR prepared a sampling and analysis plan which was submitted to MMT for approval. A representative from SLR visited the site from 13-14 August 2019 to collect the required samples with the assistance of the MMT geologists and environmental officer.

A total of 17 solid samples were collected. Four (4) product samples were collected, four (4) samples from Adam's pit were collected and nine (9) waste rock samples from the exploration core.

Acid rock drainage and geochemical investigation

Due to a low sulphide and high neutralisation potential of samples they are all classified as non-PAG. The dominant phases in the samples in Adam's Pit are manganese and carbonates rich minerals. In the samples representing waste rock material quartz and carbonate rich minerals are the dominant phases. The BIF samples also have hematite as a dominant phase. The high concentration of carbonates confirms the high NP of the material.

Metal leaching potential

As part of this assessment, leach tests were undertaken using distilled water (pH 7) to represent neutral drainage conditions. As a preliminary screening to identify potential Constituents of Concern (CoCs), the leachates were compared to the water quality and effluent standards described in Section 6.5. The main CoCs identified in the product samples were Ba, pH and TSS in the MMT standard sinter stockpile (MSS) and pH in the DMS fines located in Adam's Pit. The main CoCs identified in the Adam's Pit waste samples were boron, pH, TDS, EC, chloride and sulphate in the sinter de-dust. No leachable CoCs were identified in the MMT floats/discard or tailings samples. Constituents of concern were identified in three (3) waste rock lithologies, barium, pH and TSS in calcrete-top line (MT-WR01), aluminium, iron, pH and TSS in calcrete-middle line (MMT-WR02) and TSS in the clay transition lithology (MMT-WR06).

Waste Classification in accordance with SANS10234

The tailings (M2FT) and slimes materials stored in Adam's pit were found to be non-hazardous. The sinter de-dust material is considered to be a hazardous waste in terms of health hazards. This is as a result of elevated concentrations of soluble boron in the material. The waste rock material is not hazardous.

Waste Assessment – Adam's Pit

- The sinter de-dust is classified as a Type 0 waste due to the total manganese concentrations above TCT2 and the leachable concentrations of boron, TDS and sulphate exceeding LCT0, and cannot be disposed without treatment.
- The other materials stored on Adam's Pit (slimes and tailings (M2FT)) classify as a Type 0 waste based on the TC values. However, Section 7(6) stipulates that a waste where the leachable concentration levels are below or equal to the LCT0 limit the waste should be considered as a Type 3 waste **<u>irrespective of the total concentration</u>** of the elements. This section applies when the following provisions are met:
    - Chemical substance concentration levels are below the total limits for organics and pesticides;
    - The inherent physical and chemical character of the waste is stable and will not change over time; and
    - The waste is disposed of to a landfill without any other waste.

Based on the analytical results the sinter de-dust cannot be stored in its current state. The material will have to be treated and then reassessed. The tailings (M2FT) and slimes is assessed as a Type 3.

Waste Assessment – Waste Rock

Based on analytical results the lithology samples are a Type 3 waste in terms of the total concentration and a Type 4 waste in terms of the leachable concentrations of elements. The legislation does not specify the waste type for samples with these conditions.

- In accordance with GN. R. 635 of 2013, for a waste to be **Type 3**, results must meet the following criteria:
  - Leachable concentration of any elements above the LCT0 but below or equal to LCT1; and
  - Total concentrations of ALL elements below or equal to TCT1.
- In accordance with GN R.635 of 2013, for a waste to be Type 4, samples must meet the following criteria:
  - All LC must be below or equal to the 'Leachable Concentration Threshold' LCT0 limits; and
  - All TC must be below or equal to the 'Total Concentrations Threshold' TCT0 limits.

For a waste to be a Type 3, *in addition* to the total concentrations being below TCT1, the leachable concentrations of elements need to be "*above the LCT0 but below or equal to LCT1"*. In all the MMT lithology samples except for calcrete – top line (MMT-WR01) lithology, the leachable concentrations are below the LCT0. The calcrete-top line lithology makes up 17% of the composite waste rock sample. The leachable concentrations of the composite waste rock samples were below LCT0 for all the constituents assessed. Therefore, the addition of the calcrete-top line lithology to the waste rock does not result in leachable concentrations in excess of the LCT0 value.

Correspondence (3rd March 2016) from the DWS for a mine in the Northern Cape, provides clarity where a waste assessment is inconclusive between waste types. The DWS stated that "……..*the classification is based on the principle of assessing what is leachable and if it is leachable then what is the total concentration which will influence decisions on the total polluting period*". "*In the case of",* Northern Cape Mine, *"the leachable concentrations are reported to not exceed LCT0 values for any of the samples* and hence a Class D barrier of only stripping of topsoil and foundation preparation is the requirement….".

The DWS accepted a proposal by the Chamber of Mines of South Africa to follow a risk-based approach on a case-by-case basis to allow for representations on alternative barrier systems for Mine Residue Deposits and Stockpiles based on a risk assessment (29 June 2016). The risk assessment will enable an evaluation of the efficacy of the alternative barrier system to prevent pollution as required in terms of Section 19 (1) and (2) of the NEM:WA (Singh, 2016). Since the purpose of the Norms and Standards is to protect water resources it may be appropriate to consider the potential water quality risk associated with existing facilities, rather than retroactively applying the legislated liner requirements.

Based on the results presented above, SLR undertook a risk-based approach for protection of the quality of water resources for the MMT WRD. It follows that a Class D barrier is deemed sufficient for MMT WRD's for following reasons:

- The leachable concentrations of all the constituents are below the LCT0 limit which indicates a low seepage risk;
- The material will be placed dry and not contain wastewater;
- From the geochemical study conducted by SLR it was concluded that the materials are not PAG; and
- A Class C liner is impractical for a WRD due to the possibility of failure.

The WRD's already exist at the MMT. It follows that this assessment was undertaken for completeness purposes in order to understand risk in order to manage the protection of water quality. It is understood from MMT that the current base preparations of the existing WRD's are in line with a Class D GLB-liner.

Geochemical Modelling

Source concentrations were determined for the waste rock, slimes (pumped into Adam's pit) and the Adam's pit stockpile (DMS grit, Sinter de-dust and tailings (M2FT)). These results can be used as input to the groundwater modelling and risk evaluation.

For the waste rock the modelled results indicate values above drinking water quality guidelines for aluminium, barium, boron, fluoride, nitrate and pH.

Adam's Pit contains a number of different waste types. A source terms model was developed for Adam's pit using the following proportions:

- Tailings (M2FT) – 86%
- Slimes - 6%
- Sinter de-dust – 3%
- DMS grit – 5%

The modelled results (Table 8-13) indicate the possibility of above threshold manganese and lead leachate concentrations for the mixture of waste types found in Adam's pit .

Results of the source term assessment should not be evaluated in isolation but together with groundwater modelling and assessment. The complete source, pathway and receptor should be considered in evaluating the potential risks.

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ACRONYMS AND ABBREVIATIONS

B	Boron
CaO	Calcium oxide
Cl	Chloride
CO_2	Carbon dioxide
CSM	Conceptual site model
DWS	Department of Water and Sanitation
EAP	Environmental assessment practitioner
EC	Electrical conductivity
EIA	Environmental impact assessment
EMP	Environmental management programme
Fe_2O_3	Iron Oxide
GHS	Global Harmonized System
INAP	International Network for Acid Prevention
LC	Leachable Concentration
LCT	Leachable Concentration Threshold
MAE	Mean annual evaporation
mamsl	meters above mean sea level
MAP	Mean annual precipitation
Mbgl	Meters below ground level
MDS	Dense medium separation
MgO	Magnesium oxide
Mn	Manganese
Mn_3O_4	Manganese oxide
Na	Sodium
NO_3	Nitrate
OPP	Ore Preparation Plant
Pb	Lead
RE	remaining extent
ROM	Run of mine
SABS	South African drinking water standard (SABS 0241 of 2001)
Se	Selenium
SLR	SLR Consulting (Africa) (Pty) Ltd
Tailings dam	mine residue deposit
TC	Total Concentration
TCT	Total Concentration Threshold
TDS	Total dissolved solids
TSS	Total suspended solids
WRD	Waste rock dump

1. INTRODUCTION

SLR, an independent firm of environmental consultants, has been appointed by South32 to undertake a waste assessment and geochemical characterisation for the MMT. MMT is an open pit manganese ore mine, which started operations in 1963.

South32 operates the opencast manganese MMT (forms part of the legal entity Hotazel Manganese Mines (Pty) Ltd) located approximately 25km to the south of Hotazel in the John Taolo Gaetsewe District Municipality and Joe Morolong Local Municipality of the Northern Cape Province of South Africa.

MMT holds the following environmental permits and authorisations:

- A Mining right (Reference number: NC 256 MR) issued and approved by the former Department of Minerals and Energy (DME) (currently the Department of Mineral Resources (DMR)) in May 2006;
- An EMP (Reference number: NC 6/2/2/118) issued and approved by the former DME (currently the DMR) in November 2005;
- An amended Air Emissions Licence (AEL) (Licence number: NC/AEL/JTG/MAM01/2012) issued by the Northern Cape Department of Environment and Nature Conservation (DENC) in March 2015;
- An amended Integrated Water Use Licence (IWUL) (License number: 10/D41K/KAGJ/1537) issued by the Department of Water and Sanitation (DWS) in January 2012;
- An Environmental Authorisation (Reference number: NC/KGA/HOT3/07) for bulk fuel storage issued by former Department of Tourism, Environment and Conservation (currently DENC) in July 2007; and
- An Environmental Authorisation (Reference number: NC 30/5/1/2/3/2 (252) MR for the merging of the Mamatwan Sinterfontein Waste Rock Dump with the Tshipi Eastern Waste Rock Dump from the DMR in January 2020.

The mine has expanded mining activities which requires the 2005 EMP to be updated and amended. There are also new mining projects envisaged which require authorisation. MMT have certain existing water uses that have not yet been licenced under the existing IWUL. This study aims to satisfy the requirements of an integrated regulatory approval process to ensure that MMT is legally compliant and appropriately authorised for existing and new activities.

1.1 OBJECTIVES

The objectives of the geochemical and waste assessment investigation are to:

- Carry out a preliminary acid rock drainage and geochemical investigation on the potential contaminant source material at MMT;
- Classify the waste according to South African National Standards (SANS) 10234 as per Government Notice Regulation GN R.634 (23 August 2013);
- Undertake a waste type assessment in terms of GN R. 635 (23 August 2013);
- Determine the liner requirements as per GN R. 636. (23 August 2013); and
- Develop a source term for potential sources of contamination to be included in the groundwater impact assessment.

1.2 SCOPE

The proposed scope of work to achieve the objectives listed above is as follows:

- Desk study;
- Sample selection;
- Laboratory analysis;
- Source term; and
- Data interpretation and reporting.

1.3 DETAILS OF SPECIALIST

Carl Steyn prepared this geochemistry, waste assessment, and source term report. The report review was undertaken by Rob Hounsome. The details of the report authors are provided in Table 1-1 below.

Table 1-1: Details of Report Authors and Reviewer

Details	Project manager, author	Author	Reviewer
Name	Michelle Papenfus	Carl Steyn	Rob Hounsome
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Key qualifications	M.Sc. in Soil Science	M.Sc. in Soil Science	M. Sc. in Environmental Geochemistry
Experience	Over 5 years	Over 20 years	Over 25 years
Professional registration	South African Council for Natural Scientific Professions: registration number 008204	South African Council for Natural Scientific Professions: registration number 400022/02	South African Council for Natural Scientific Professions: registration number 400088/95

1.4 DECLARATION

I, Carl Steyn hereby declare that I am an independent consultant, who has no interest or personal gains in this proposed project whatsoever, except receiving fair payment for rendering an independent professional service.

I am a registered professional scientist with the South African Council for Natural Scientific Professions.

My Curriculum Vitae is provided in Appendix A.

2. BASELINE CONDITIONS

2.1 DATA INVENTORY

The following information was reviewed for the geochemical is summarised in Table 2-1 below.

Table 2-1: Data Inventory

Date	Author	Report Number	Title
2005-06	Jones and Wagener	64/05/A095	EMP MMT
2017-05-30	GeoDyn Systems (GDS)	-	Hotazel Manganese Mines acid mine drainage and contaminant leachate assessment – MMT
2018-06	GHT Consulting Scientists	RVN823.1/1858	Geohydrological report for MMT
2020-02		RVN870.1/2003	Groundwater and surface water monitoring
2018-08-27	Golder Associates Africa	1895869-320753-1	Waste classification, assessment and chemical analysis of Manganese fines, Mamatwan Mine
2019-08-26	Webber Wentzel	-	Legal permitting review of South32's MMT

2.2 GEOLOGY

The MMT is located on the southwestern outer rim of the **Kalahari Manganese Field** (KMF). MMT mines the manganese ore from the **Hotazel Formation** (within the Transvaal Supergroup). According to the GHT report (2018), this formation was deposited between 2,200 and 2,300 million years ago, the formation is structurally confined within the Dimoten Syncline, a north-westerly plunging basin containing more than 80% of global land-based manganese reserves within an area of approximately 525 km^2. It is this basin that defines the extent of the KMF (GHT, 2018).

The **Hotazel Formation** includes a Banded Iron Formation (BIF). The ore is contained within a 30 to 40-meter-thick mineralised zone which occurs along the entire area and is made up of three manganese-rich zones:

- Upper Manganese Ore Body (UMO);
- Middle Manganese Ore Body (MMO); and
- Lower Manganese Ore Body (LMO).

The UMO is 10cm to 15cm thick and comprises moderate deposits of manganese. The poorly mineralised MMO is approximately 1m thick and not economically efficient. The LMO is a highly mineralised unit consisting of six important mineralised zones (X, Y, Z, M. C and N).

According to the GHT report (2018), the manganese ore dips in a south to south-westerly direction at approximately six degrees, has a lower grade at MMT, and is characterised by laminated, carbonate bearing, braunite rich mudstone. Exposed ore is typically massive in character, with minor vertical fracturing and bedding parting observed. The GHT report (2018) further notes that inspection of drill core and drill cuttings suggests that many of these fractures are filled with carbonate minerals at depth. Analysis of a sample taken from the MMT blast face and analysed in a study conducted in 2002/2003 indicates that the Hotazel Formation at the mine contains silica (as quartz), iron (Fe), manganese (Mn), and calcium (Ca), as well as calcareous minerals (Beuwkes and van der Westhuizen, 2002; 2003 as cited in GHT, 2018).

The **Hotazel Formation** is underlain by basaltic lava of the **Ongeluk Formation** (Transvaal Supergroup) and directly overlain by dolomite of the **Mooidraai Formation** (Transvaal Supergroup). 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. The different formations present in the project area include the Mapedi and Lucknow units. The whole Supergroup has been deformed into a succession with an east-verging dip.

The Olifantshoek Supergroup is overlain by **Dwyka Formation** which forms the basal part of the Karoo Supergroup. At the mine, this consists of tillite (diamictite) which is covered by sands, claystone and calcrete of the **Kalahari Group.**

2.2.1 Intrusive structures

The GHT report (2018) reports a sill on the Smartt-Rissik prospect adjacent to the MMT. The full extent of this sill is apparently unknown at this stage and would require further exploration drilling, however GHT notes that this sill is known to also sub-crop, presumably continuously and with relative constant thickness, on the MMT and Middelplaas mine properties. According to the GHT report (2018), sill material appears to have similar characteristics to the older Ongeluk Formation, although it can sometimes be distinguished on the basis of colour, feldspar shape, and the apparent absence of augite. When drilled using rotary air percussion equipment, the sill was generally found to be resistant to drilling, and in most instances, fresh throughout. Observed core obtained from diamond drilling was typically un-fractured, with those rare fractures typically filled with secondary minerals.

The GHT report (2018) reports a second sill during mining at the Hotazel Pit further to the north and was easily distinguished from adjacent sub-crops of sub-vertical to vertical dykes and Ongeluk Lavas due to its fibrous appearance, a consequence of the predominance of plagioclase lathes.

Various intrusive structures are close to and around MMT. These include doleritic dykes. It is expected that vertical displacement of the Hotazel Formation and the sill that intrudes it has occurred along the trend of many of these structures. It is further noted that many of the permeable voids that developed in response to faulting would have been filled during a later magmatic phase (GHT, 2018).

2.3 CLIMATE

2.3.1 Rainfall

The average daily rainfall data for the site is based on the nearest rainfall station managed by the South African Weather Services. Rainfall record extending from 1931 through to 2019 was obtained from the Milner rainfall station (0393083_1). Details of the station are provided in Table 2-2 and the monthly rainfall in Table 2-3.

Table 2-2: Milner Rainfall station Details

Station Name	Station Number	Elevation (m)	Coordinates	
			Latitude(S)	Longitude (E)
Milner	0393083_1	1124	27.3810	23.0630

Table 2-3: Average Monthly Rainfall for Milner Station

Month	Average	Min	Max
Jan	71.3	0.00	311.7
Feb	63.2	0.00	241
Mar	65.5	0.00	276
Apr	37.5	0.00	197.9
May	15.2	0.00	108.5
Jun	6.7	0.00	86.5
Jul	1.8	0.00	47.2
Aug	3.6	0.00	44.5
Sep	6.1	0.00	77.8
Oct	18.6	0.00	108.8
Nov	32.2	0.00	137
Dec	47.1	0.00	261

2.3.2 Evaporation

Average monthly evaporation for the project site is based on the Evaporation Station D4E004 sourced from DWS. Various pan coefficients ranging from 0.81 to 0.94 were used to convert the recorded S-pan evaporation to open water evaporation which is applicable for a conventional dam or pond (Table 2-4). The MMT falls within the Evaporation Zone 8A with Mean Annual Evaporation (MAE) of 2350.

Table 2-4: Monthly Evaporation Distribution

Month	Span Evaporation	Lake Evaporation Factor	Lake Evaporation
January	276.9	0.84	232.6
February	209.9	0.88	184.8
March	193.3	0.88	170.1
April	144.1	0.88	126.8

Month	Span Evaporation	Lake Evaporation Factor	Lake Evaporation
May	114.7	0.87	99.8
June	91	0.85	77.3
July	106	0.83	88.0
August	153.8	0.81	124.5
September	213	0.81	172.5
October	269.7	0.81	218.4
November	248	0.94	232.9
December	294.6	0.83	244.5
Annual	**2351**	-	**1972**

2.4 HYDROLOGICAL SETTING

The site is located within the D41K quaternary catchment, which has a total catchment area of 4 216km^2, with a net Mean Annual Runoff of 6.53 million m^3.

The nearest watercourse is the Vlermuisleegte, a non-perennial tributary of the Gamagara, which flows from south-east to north-west approximately 1.6km west of the site. Given the large distance between the mine and these watercourses, the flood-lines have not been mapped.

The entire Moloto catchment which includes D41K is classified as endoreic i.e. catchments with large areas which do not contribute to runoff.

2.5 TOPOGRAPHY

Topography in this area is almost flat, with a gentle slope (1:250) towards the north-west. Small undulations mean that stormwater ponds locally, as opposed to forming sheet flow, which runs off towards a watercourse.

2.6 WATER SUPPLY

Potable water used in the mine is from the Vaal-Gamagara. Additional water for use in dust suppression and drilling is from the collected water (seepage and rainfall) in the Adam's Pit. Water is supplied to make up water tanks from two sources, namely the Vaal-Gamagara Pipeline and underground water removed from the open pits. The dense medium separation (DMS) plant, Sinter plant, and Ore Preparation Plant (OPP) each have a closed-circuit water reticulation system.

These water uses associated with the above-mentioned purposes are registered with the DWS. The water supply scheme has since March 2008 been managed and controlled by Sedibeng Water. The existing WUL will be amended to include additional water uses.

2.7 HYDROGEOLOGY

2.7.1 Aquifer

Four aquifers occur in the region, namely the Ongeluk, Hotazel, Mooidraai, and Kalahari Formations. These aquifers are described by GHT as follows (GHT, 2018):

- The Ongeluk Formation: older geological formation, the aquifer is primarily associated with weathered horizons and zones adjacent to regional scale structures, although the aquifer is generally not favoured as a potential water supply source because of its low yield characteristics.

- Hotazel Formation: typically have higher yields with the groundwater stored in voids that developed following bed separation, within faults and periphery fractures, and along the dolerite dykes that have partially filled regional faults. The high number of dykes and fractures interpreted for the site suggest vertical hydraulic connection throughout much of the formation above an intrusive sill, with horizontal interconnection provided along bedding planes. The formation is regarded as semi-confined on the Smartt-Rissik and MMT prospects where it sub-crops at shallow depth. The higher aquifer yields are associated with the preferentially fractured, brittle BIF's adjacent to regional faults. With increasing depth, however, the Hotazel Formation aquifer can be confined, particularly when the overlying Kalahari Formation contains thick inter-beds of highly plastic red clay as observed along the southern edge of the MMT property.
- Mooidraai Formation: a dolomitic aquifer occurring in the southwest of the study area in the vicinity of the now-derelict Middelplaas Mine. This aquifer is of significance locally due to its high yielding characteristics (>10 L/s) and is currently exploited by MMT as an emergency supply source. It is noted that there is no evidence to suggest that these aquifers have been recharged in recent time.
- Kalahari Formation: On a regional scale the Kalahari Formation behaves as a semi-confined aquifer, which is hydraulically connected with aquifers in underlying formations at those sites where extensive red clay or clay-bearing Dwyka Formation beds are absent. While the aquifer is generally more porous than other site aquifers, characteristics of the aquifer vary from site to site. Yields vary significantly spatially. A paleochannel deposit has been identified to the north of the MMT pit, contain significant quantities of groundwater, however this aquifer contains high nitrate concentrations and therefore it cannot be classed as an important groundwater resource. Of significance, however, is that the inferred tributaries, which developed parallel to the contact between the older Ongeluk and Hotazel Formations, appear to have higher yields than the paleochannel itself.

Various intrusive dolerite sill and dykes have intruded the Hotazel Formation which are relatively impermeable and create groundwater compartments regionally. The groundwater table does reflect the topography when it occurs within the Kalahari Formation; however, the dykes continue to act as a barrier to flow within older, underlying formations (GHT, 2018).

GHT has determined the direction of groundwater flow to be towards the north-west at a gradient of about 1V: 200H (although this ignores the compartmentalizing effects of the intrusive structures).

According to GHT, the simplified local stratigraphy at MMT includes a sand, calcrete, gravel and clay (Kalahari formation) underlaid by Hotazel Formation. Although the water-bearing part of the aquifer occurs within the gravel contact zone between the calcrete and clay, GHT views the main exploitable aquifer (as well as receiving part of the aquifer) as the top three geological formations. The clay together with the Hotazel Formation forms a relative impermeable aquifer bottom (GHT, 2018). GHT has conceptualized the aquifer as one layer for the purpose of developing a groundwater model for MMT because the aquifer conductivities, as determined by pump tests performed by GHT, are representative of all three top formations (GHT, 2018) i.e. the three aquifers have the same basic characteristics.

2.7.2 Elevation and gradient

Groundwater levels have been measured at key locations since 2002. The regional groundwater flow from south-east towards the north-west.

According to GHT, the average groundwater elevation at MMT is 1076.40 meters above mean sea level (mamsl) and the average groundwater elevation of the third party hydrocensus boreholes is 1096.4 mamsl. The northern part of MMT has an average groundwater elevation of 1046.44 mbgl, which is 49.96 m lower than the average hydrocensus groundwater level, and this is believed to be caused by dewatering activities at the pit. GHT notes that there are no dewatering effects in the southern part of MMT, and this is partially due to an artificial groundwater mound that has developed under the old rehabilitated tailings dams. This artificial groundwater mound has caused the groundwater to flow up gradient of natural groundwater flow and topographical drainage in a south-eastern direction (GHT, 2018).

The dewatering zone of influence extends up to 2.8 km to the north of the pit, whereas to the south it extends a maximum of one kilometre due to the artificial groundwater mound by the old tailings dam (GHT, 2018).

2.7.3 Groundwater Quality

Groundwater monitoring data is available for MMT from 2003 to 2020. Based on the recent groundwater monitoring results (GHT, 2020), the inorganic water quality of Mamatwan Mine is classified as above the recommended standard limit for SANS241:2015 and is therefore unsuitable for lifetime human consumption. This is due to elevated concentrations of Electrical Conductivity (EC), Calcium (Ca), Magnesium (Mg), Chloride (Cl), Sulphate (SO_4), Nitrate (NO_3-N), Manganese (Mn) and Boron (B).

The GHT 2020 monitoring report noted that the elevated nitrate concentration is of a natural origin as can be expected for most semi-arid regions. This has been confirmed from hydrocensus work. The recharge front through the Kalahari Formation mobilizes soil nitrates, especially in areas that have been over-grazed or stripped of vegetation. Mining however does contribute to higher concentration locally at the MMT through blasting and the stripping of vegetation.

3. MMT PROCESS DESCRIPTION

A local setting of MMT is included in

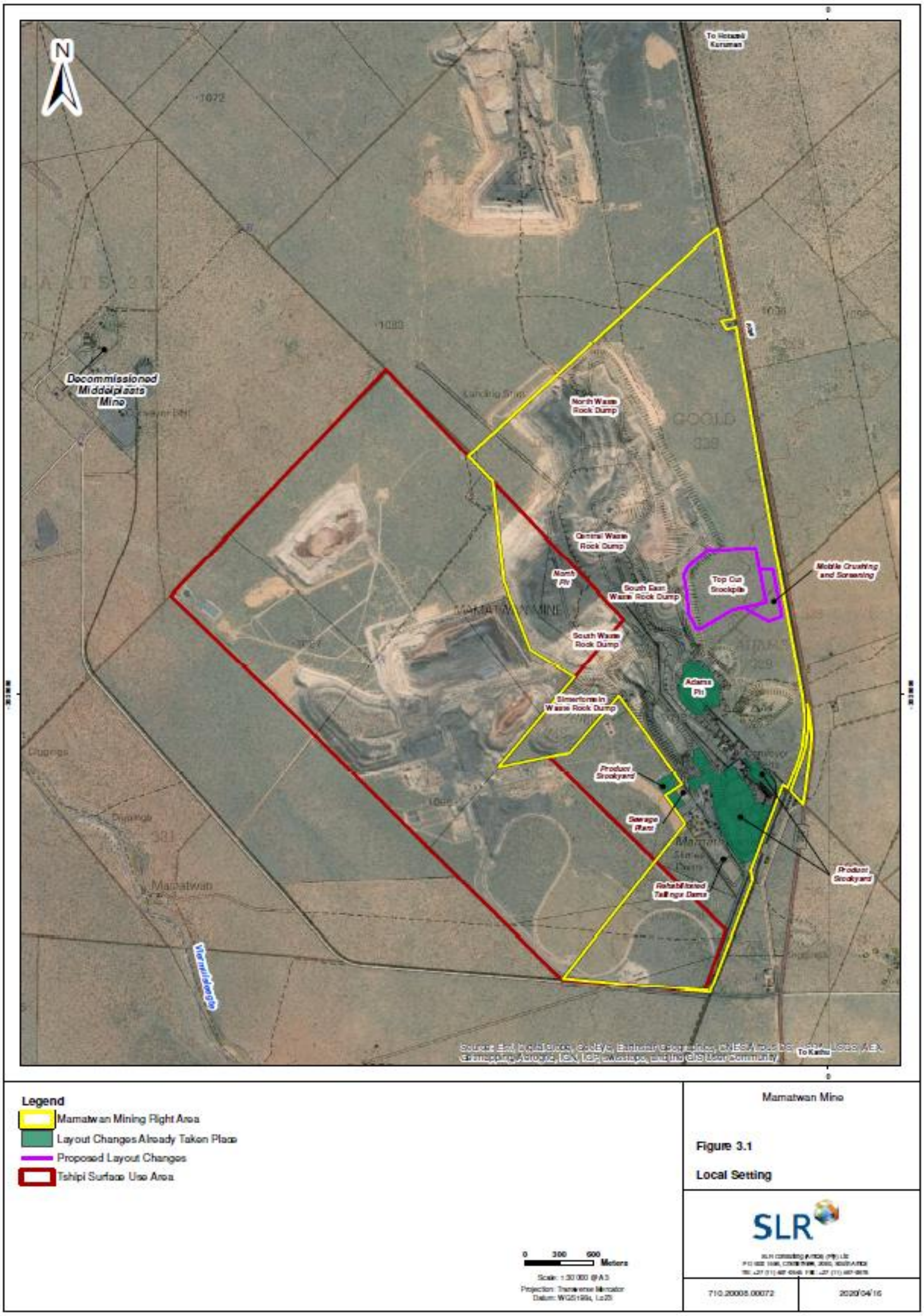

Figure 3-1. A process flow diagram detailing the waste sources is presented in Figure 3-2. MMT consists of an open pit operation that commenced in 1963. This pit is operational and is being extended to the north and west. The current run of mine for MMT is in the order of 3 million tons per annum. Manganese ore is sold to both the local and international markets. Table 3-1 below provides a summary of the mining and mineral processing activities that take place at the MMT.

Table 3-1: Overview of MMT existing operations

Activity	Detail
Stripping and stockpiling of topsoil and waste rock	MMT is a conventional opencast operation in that topsoil and waste rock is removed to uncover the manganese ore body using truck and shovel methods. Topsoil is transported via truck to designated topsoil stockpile areas for later use as part of rehabilitation. Waste rock is stripped and transported to one of the designated WRDs at the MMT. Waste rock is either backfilled into the open pit or used to flatten the slopes of existing dumps.
Access to open cast workings	Ore is drilled and blasted and hauled using front end loaders and shovels to the "in-pit" primary crusher. Crushed ore is conveyed to a product stockpile area (ROM stockpile) near the mineral processing plant. Excess ore is stored and crushed as required.
In pit crushing and screening	Oversize ore is crushed using a “in-pit” jaw crusher to reduce the size of the ore for further downstream processes. The crushed ore is conveyed to a designated Run of Mine (ROM) stockpile area.
Crushing, screening and washing (ore processing)	Ore from the ROM stockpile is conveyed to two parallel circuits comprising scalping screens, cone crushers and double-deck sizing screens and a horizontal dewatering screen at the processing plant. Lumpy material (– 75 +6 MM) from the processing plant is stockpiled in marked allocated lumpy product stockpile area (Gantry 7) prior to being sent to the load out station using front end loaders. The product is conveyed to railway trucks via the load out section for sale to third parties. Slimes material from the processing plant is sent to the tailings dam for disposal.
DMS and sintering	The natural MMT ore ideally lends itself to upgrading by technologically advanced beneficiation processes. In this regard, the -40+6MM feed from the ore processing plant is stockpiled (KAWA product stockpile Gantry 6) prior to being sent to the DMS via conveyer. The dense medium separation plant can be used to beneficiate the ore prior to sintering by recovering the upgradeable portion of the ore body. The product (low grade and high grade) from the DMS is stored on the sinter feed stockpiles prior to being subjected to the sinter plant process. Correctly graded material and size (M1FT product) from the DMS is stockpiled prior to be sent to the loading and dispatch. Fines (-6+1MM) from the ore processing plant is conveyed directly to the sinter plant. Material that is not sent to the sinter plant is stockpiled for rework. During the sintering process calcium carbonate and other impurities are driven off resulting in an increase in the grade. In this regard, the sinter plant generates a high and standard grade sinter product which is conveyed to loading and dispatching of MMT products. Fugitive dust is extracted from the process through a series of extraction ducts with the particulate matter being captured in bag houses. Dust from the baghouses are either recycled back into the sinter process or captured in bulk bags for sale as reduced sinter fines. Off gas and particulate matter is extracted and scrubbed.

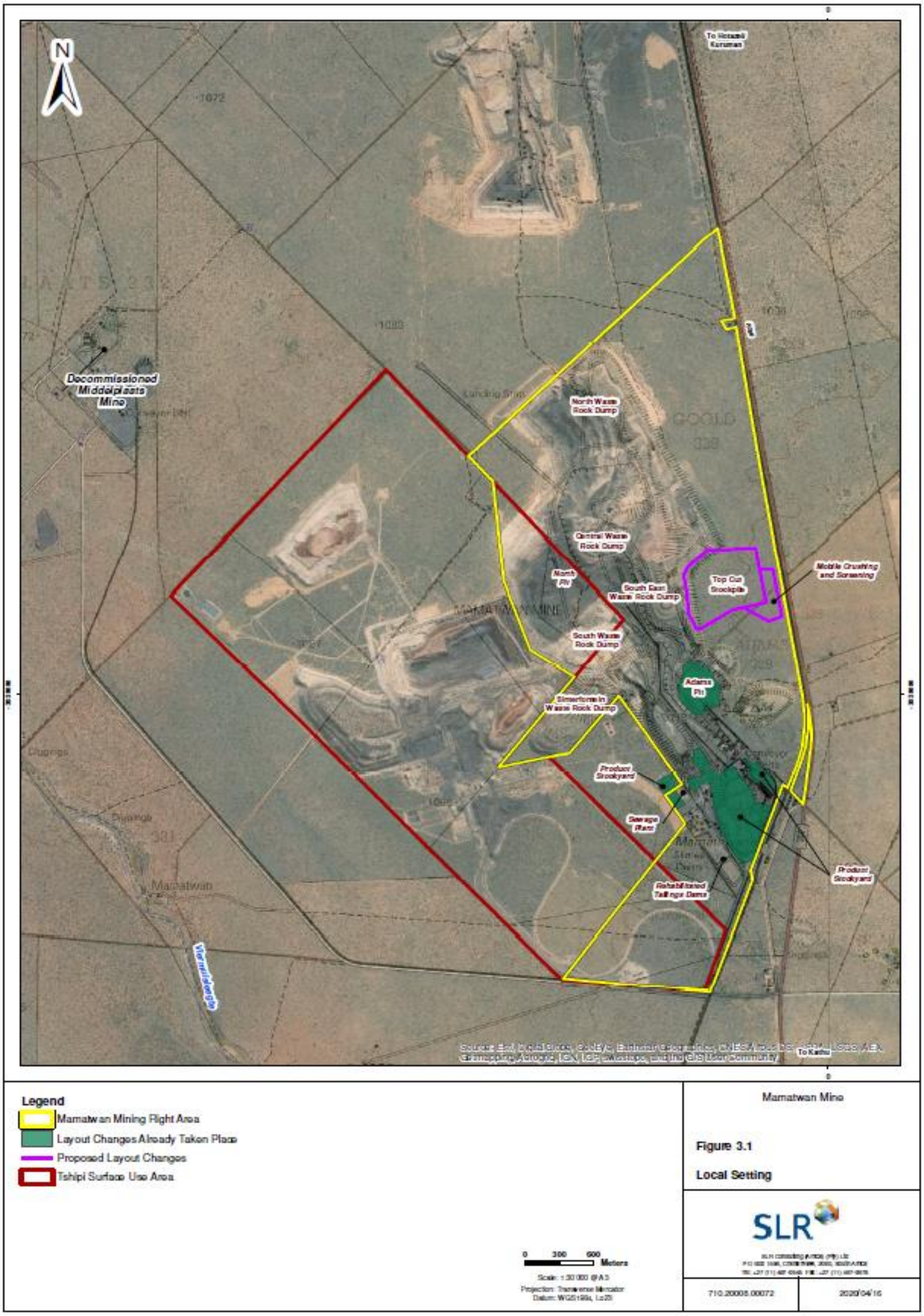

Figure 3-1: Local setting

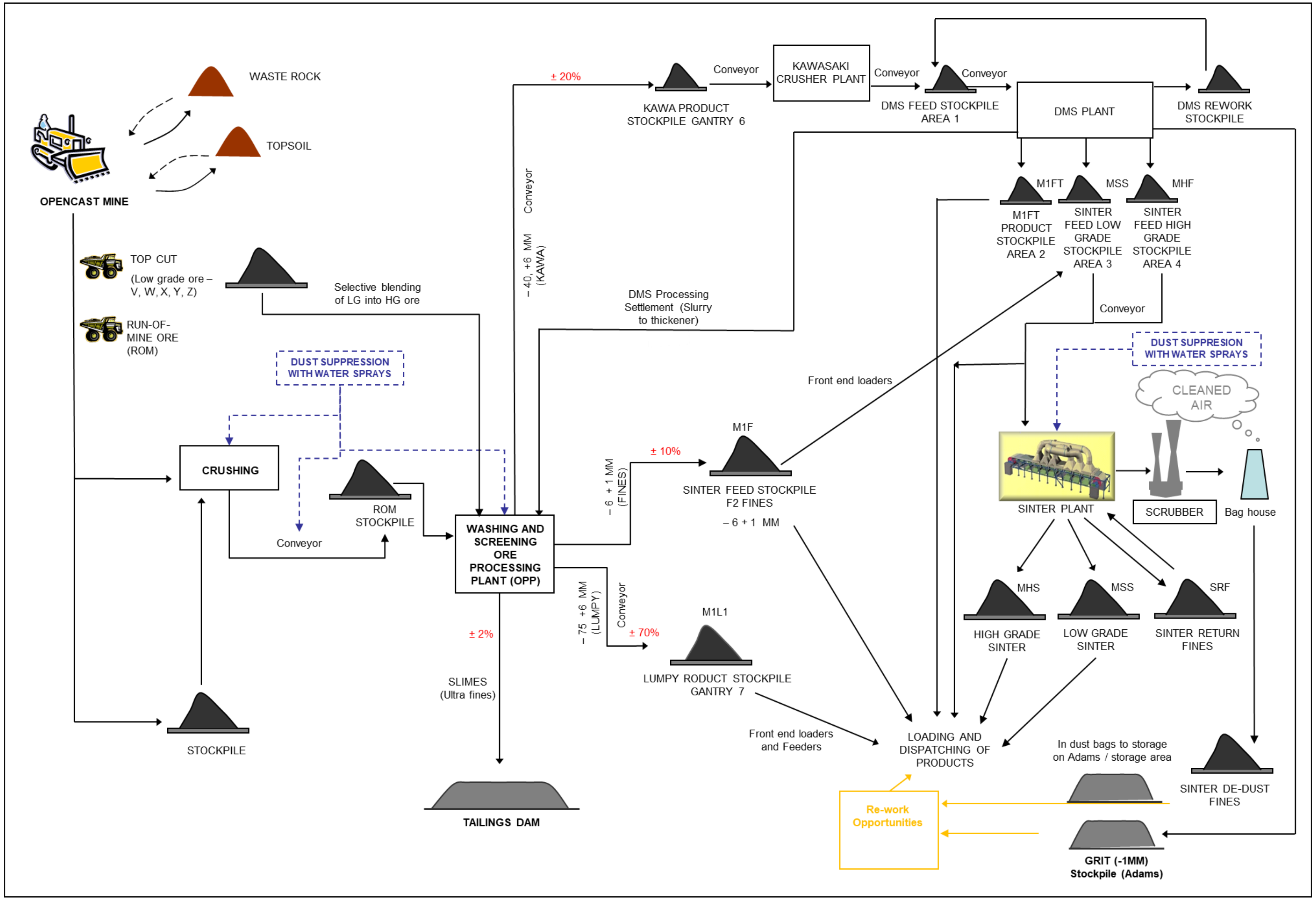

Figure 3-2: Process Flow Diagram MMT Operations

4. CURRENT POLLUTION SOURCES

Based on the hydrogeological report by GHT (2018) the following potential sources of contamination are

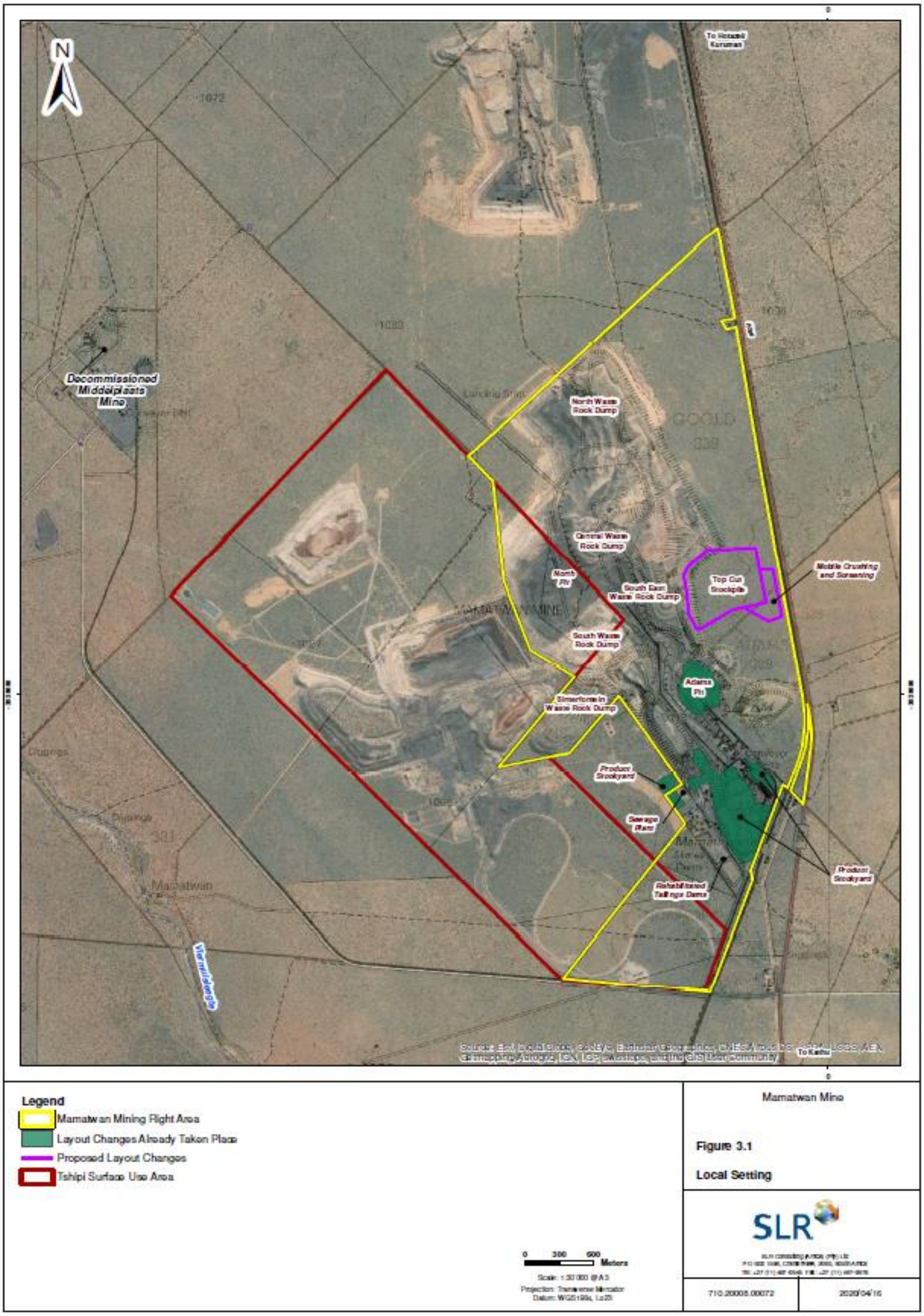

Figure 3-1 for the location of the facilities):

- Mining pits:
  - Adam's Pit;
  - MMT north pit (open pit);
- Rehabilitated Tailings dam;
- Waste rock dumps;
- Product stockpiles; and
- Sewage Plant.

The potential sources of contamination are described in more detail in the following sections. **It is important to note that these pollution sources have been described in this section for completeness purposes. As part of this study, SLR collected samples from various pollution sources as outlined in Section 6.1. These results will be used to verify the findings of the GHT 2018 groundwater report (refer to Section 8).**

4.1.1 Open pits

There are two open pits at MMT: Adam's Pit and the MMT north pit. The Adam's Pit is currently used for disposal of process water, pumps, pipelines, product, sinter de-dust and scrap products (Webber Wentzel, 2019).

4.1.2 Waste Rock Dumps

Waste rock samples were collected and assessed by GHT (2018). It is not indicated if the samples were collected by GHT or by South32 or where the samples were collected. It is also unclear how many samples were submitted for analysis. Samples were subjected to acid base accounting and leaching tests (water soluble and acid soluble). A source term was developed for the waste rock material. The results of the waste rock model leachate are shown in Table 4-1. The results should only be seen as an informed quantitative *estimate* from a risk perspective and variations can be expected. The following conclusions were made based on the analytical results and calculations conducted by GHT:

- Constituents are not readily soluble in water, even when completely oxidised;
- The acid generation potential was classified as posing a very low risk due to the relative abundance of neutralising minerals (dolomite and calcite) and the absence of sulphide minerals;
- The model indicated that the leachate from the waste rock will most likely be alkaline;
- The geochemical model indicated the waste rock is a source of calcium, magnesium bicarbonate, manganese, boron and fluoride. Of these parameters only boron has been identified as a potential constituent of concern in the groundwater quality data; and
- Only the modelled boron concentrations exceeded the groundwater quality guideline value (500µg/L).

Table 4-1: Waste Rock Source Term (GDT, 2018)

Parameter	Abbreviation	Units	Waste Rock Value
pH	pH	pH units	8.6
Total Dissolved Solids	TDS	mg/L	54

Parameter	Abbreviation	Units	Waste Rock Value
Alkalinity	Alk	mg/L	22
Calcium	Ca	mg/L	9
Magnesium	Mg	mg/L	2
Bicarbonate	HCO_3	mg/L	26
Sulphate	SO_4	mg/L	<1
Fluoride	F	mg/L	1
Manganese	Mn	µg/L	253
Boron	B	µg/L	1638

4.1.3 Tailings

The tailings dam facility at MMT has been rehabilitated. Golder conducted a geochemical and waste assessment on the manganese fines, assumed by SLR to be the slimes material generated at the plant which is currently pumped into Adam's pit. South32 sent two composite samples to Golder. It is not noted in the Golder report where the samples were collected. SLR assumes that these samples were slimes samples collected from the Plant. The samples were analysed as required per the GN R. 635 including:

- Mineralogical analysis by x-ray diffraction (XRD);
- X-ray fluorescence (XRF) and inductive coupled plasma (ICP) analysis to determine total concentrations of concern;
- Australian Standard Leach Procedure with deionised water followed by ICP scan to determine leachable concentrations of inorganic constituents of concern (CoCs) and cation and anion concentrations;
- Acid base accounting to determine acid rock drainage risk; and
- Net acid generation leach tests.

The following conclusions were made based on the analytical data and information obtained during the investigation conducted by Golder (2018):

- Tailings (assumed to be slimes) materials are not potentially acid generating due to low sulphur content and high neutralisation potential;
- The tailings (assumed to be slimes) are likely to produce alkaline drainage in the short and long term, with the pH and aluminium levels likely to exceed domestic use and irrigation water quality standards;
- The tailings (assumed to be slimes) material is not a physical, health or environmental hazard; and
- The tailings (assumed to be slimes) material classify as Type 3 waste due to low leachable concentrations of all potential CoCs although the total manganese concentration exceeds the TCT2 level.

Tailings samples (assumed to be slimes) were also collected and assessed by GHT (2018). It is not indicated if the samples were collected by GHT or by South32 or where the samples were collected. It is unclear how many samples were submitted for analysis. Samples were subjected to acid base accounting and leaching tests (water soluble and acid soluble). A source term was developed for the tailings (assumed to be slimes) material. The results are shown in Table 4-1. The results should only be seen as a quantitative estimate from a risk perspective, variations can be expected. The following conclusions were made based on the analytical results and calculations conducted by GHT:

- Constituents are not readily soluble in water, even when completely oxidised; and

- The acid generation potential was classified as posing a very low risk due to the relative abundance of neutralising minerals (dolomite and calcite) and the absence of sulphide minerals;
- The tailings and waste rock mineralogy are shown to be similar by the XRD analysis. This is because it is derived from the same basic geological material;
- The leachate results of the geochemical model show the tailings, like the waste rock, is a source of calcium, magnesium bicarbonate, manganese, boron and fluoride. Of these parameters only boron has been identified as a potential constituent of concern in the groundwater quality data; and
- Only the modelled boron concentration in the tailings exceeded the groundwater quality guideline value (500µg/L).

Table 4-2: Tailings (assumed to be slimes) Source Term (GDS, 2018)

Parameter	Abbreviation	Units	Tailings Value
pH	pH	pH units	8.8
Total Dissolved Solids	TDS	mg/L	48
Alkalinity	Alk	mg/L	16
Calcium	Ca	mg/L	6
Magnesium	Mg	mg/L	2
Bicarbonate	HCO_3	mg/L	-
Sulphate	SO_4	mg/L	<1
Fluoride	F	mg/L	1
Manganese	Mn	µg/L	466
Boron	B	µg/L	2047

4.1.4 Product Stockpile

Government Notice Regulations 634, 635 and 636 do not apply to product stockpiles as it is not classified as a waste. The product stockpiles were however identified as potential sources of contamination in the GHT (2018) groundwater investigation. The GHT (2018) report indicates that a source term for the product stockpiles was included in the groundwater model. It is unclear if the samples were analysed to determine the leachable concentrations as analytical results were not provided in the report. A number of products are produced at MMT. The products produced are summarised in the process description detailed in Section 3.

4.1.5 Sewage Plant

Government Notice Regulations 634, 635 and 636 do not apply to the sewage plant as it is regulated by the Guidelines for the Utilisation and Disposal of Wastewater Sludge (2006). The GHT report lists the sewage plant as a potential source of contamination. A source term for the sewage plant was not included in the GHT (2018) groundwater model.

5. REGULATORY REQUIREMENTS

5.1 GEOCHEMICAL INVESTIGATION

The International Network for Acid Prevention (INAP) (2009) sponsored the development of the Global Acid Rock Drainage Guide, which outlines current international best practice for the prediction, prevention and management of mine drainage. The scope described in this memorandum follows this guideline.

5.2 WASTE CLASSIFICATION IN ACCORDANCE WITH SANS10234 AND GN R. 634 OF 2013

All waste generators must ensure that their waste is classified in accordance with the Global Harmonized System (GHS) of Classification of Chemicals and Labelling (SANS 10234:2008) within 180 days of generation in accordance with section 4(2) of GN R.634 of 2013, except if it is listed in Annexure 1 (Wastes that do not require Classification and Assessment). Waste must be kept separate for the purposes of classification and must not be mixed before classification. Furthermore, waste must be re-classified every 5 years.

The SANS 10234:2008 standard covers the harmonized criteria for the classification of hazardous substances according to their health, environmental and physical hazards. The GHS does not require testing where testing has been done previously. Information or data that has been published in journals or any credible source can be utilised to classify the waste stream.

The chemical test results as well as intrinsic properties of the waste streams were used for the SANS 10234 classification. Constituents present in concentrations exceeding 1% are used for classification in terms of health hazards, except when the constituent is known to be toxic at lower concentrations (carcinogens etc.) where a cut-off value of 0.1% is applied.

Environmental hazard is based on toxicity to the aquatic ecosystem and distinguish between acute and chronic toxicity, bioaccumulation and biodegradation.

5.3 WASTE ASSESSMENT IN ACCORDANCE WITH GN R. 635 OF 2013

In terms of Regulation 8 (1)(a) of the waste classification and management regulations (WCMR), waste generators must ensure that their waste is assessed in accordance with the Norms and Standards for Assessment of Waste for Landfill Disposal (GN R. 635) prior to the disposal of the waste to landfill.

The Total Concentration (TC) of chemical substances specified in Section 6 of GN R. 635 that are known to occur, likely to occur or can reasonably be expected to occur must be determined. The TC of the chemical substances is compared to the Total Concentration Threshold (TCT) limits specified in Section 6 of GN R. 635.

The Leachable Concentrations (LC) of the chemical substances must be determined and compared to the Leachable Concentration Threshold (LCT) limits specified in Section 6 of GN R. 635.

The TC and LC limits of elements and chemical substances in the waste material exceeding the corresponding TCT and LCT limits will determine the specific waste type according to Section 7 of GN R. 635. Figure 5-1 presents a flow diagram of the general process to be followed to determine the waste type.

5.4 ASSESSMENT OF WASTE FOR LANDFILL DISPOSAL IN ACCORDANCE WITH GN R. 636 OF 2013

The South African waste classification regulations provide Norms and Standards for assessing/classifying (GN Regulation 635) waste material. Although the Norms and Standards make reference to landfills, the definition of waste in South Africa includes mine residues such as tailings and waste rock and therefore the Norms and Standards apply to mine residue classification.

The waste type and related risk-based assessment approach is used to inform the potential liner requirements. Figure 5-1 illustrates the flow diagram of the general processes to be followed to determine the waste type and then associated liner requirements.

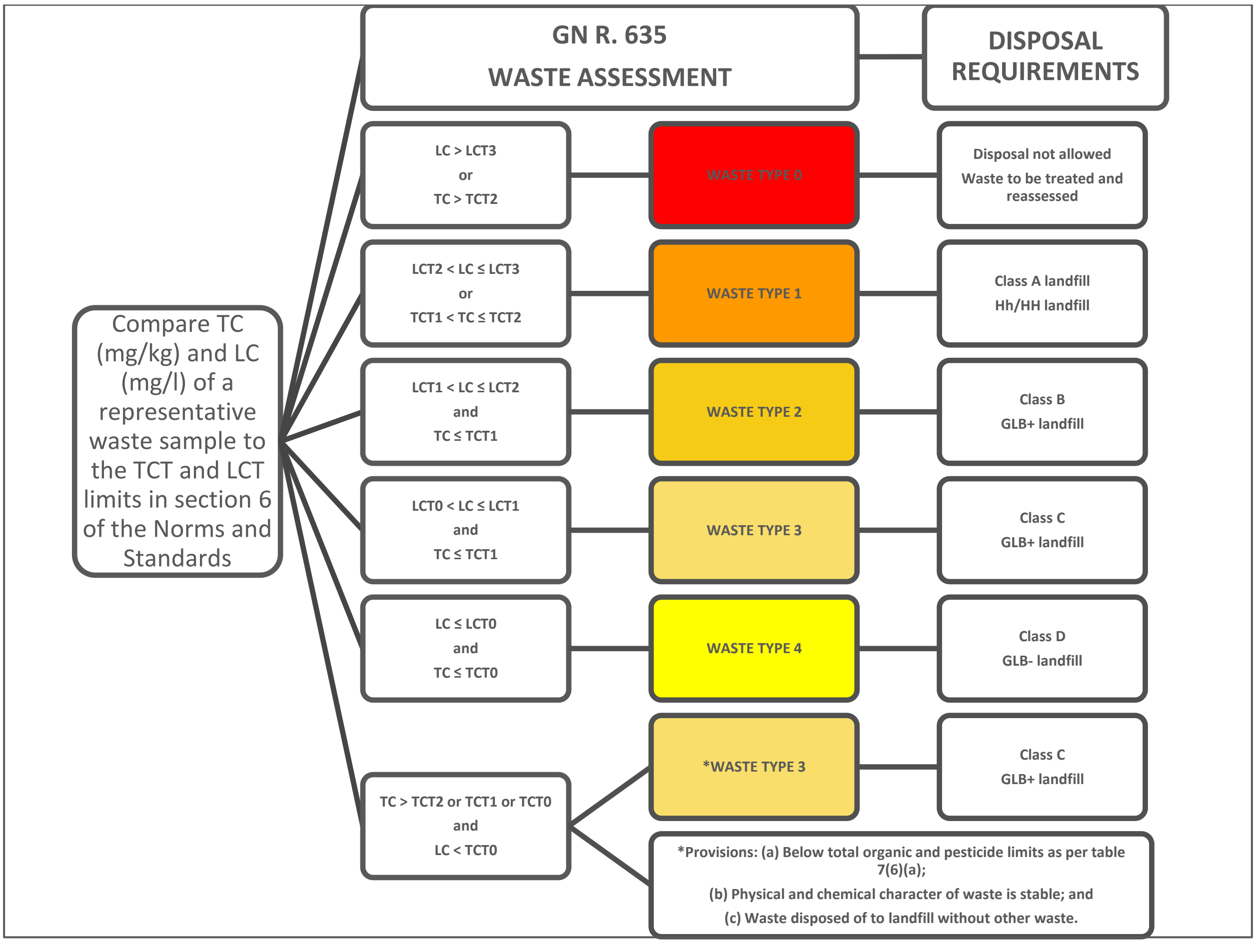

Figure 5-1: Flow Diagram for Assessing Waste in terms of South African Waste Assessment Regulations (GN R. 635 of 2013 and GN R. 636)

5.5 NATIONAL ENVIRONMENTAL MANAGEMENT ACT (NO. 107 OF 1998) (NEMA)

This report has been compiled in accordance with the reporting requirements as set out in the NEMA Environmental Impact Assessment Regulation (GNR 983 of 2014), as amended. Table 5-1 below provides a summary of the requirements, with cross references to the report sections where these requirements have been addressed.

Table 5-1: NEMA reporting requirements

Section	NEMA 2014 Regs – Appendix 6 (1) Requirement	Position in Report
1	A specialist report prepared in terms of these Regulations must contain—	

Section	NEMA 2014 Regs – Appendix 6 (1) Requirement	Position in Report
(a)	Details of - (i) the specialist who prepared the report; and (ii) the expertise of that specialist to compile a specialist report including a curriculum vitae;	Section 1.3
(b)	a declaration that the person is independent in a form as may be specified by the competent authority;	Section 1.4
(c)	an indication of the scope of, and the purpose for which, the report was prepared;	Section 1.1 and 1.2
(cA)	an indication of the quality and age of base data used for the specialist report;	Section 2
(cB)	a description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change	Section 5
(d)	the duration, date and season of the site investigation and the relevance of the season to the outcome of the assessment;	Section 6.1
(e)	a description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used;	Section 6
(f)	Details of an assessment of the specific identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure, inclusive of a site plan identifying site alternative;	N/A
(g)	an identification of any areas to be avoided, including buffers;	N/A
(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;	N/A
(i)	a description of any assumptions made and any uncertainties or gaps in knowledge;	Section 6.6.5
(j)	a description of the findings and potential implications of such findings on the impact of the proposed activity or activities;	Section 8
(k)	any mitigation measures for inclusion in the EMPr;	N/A
(l)	any conditions for inclusion in the environmental authorization;	N/A
(m)	any monitoring requirements for inclusion in the EMPr or environmental authorisation;	N/A
(n)	a reasoned opinion- (i) whether the proposed activity, activities or portions thereof should be authorised; (iA) regarding the acceptability of the proposed activity or activities; and (ii) if the opinion is that the proposed activity, activities 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;	N/A

Section	NEMA 2014 Regs – Appendix 6 (1) Requirement	Position in Report
(o)	a description of any consultation process that was undertaken during the course of preparing the specialist report;	NA
(p)	a summary and copies of any comments received during any consultation process and where applicable all responses thereto; and	NA
(q)	any other information requested by the competent authority.	NA

6. METHODOLOGY

6.1 SAMPLING

Based on a review of the available data for the site, SLR prepared a sampling and analysis plan which was submitted to MMT for approval. A representative from SLR visited the site from 13-14 August 2019 to collect the required samples with the assistance of the MMT geologists and environmental officer.

A total of 17 solid samples were collected. Four (4) product samples were collected, four (4) samples from Adam's pit were collected and nine (9) waste rock samples from the exploration core. The samples collected from Adam's pit included:

- Tailings (M2FT) – This is grit generated from the Dense Medium Separation (DMS) plant. It is understood that this material is no longer generated by the mine due to a change in process;
- Slimes – This is slurry (sludge) material that is generated as part of the ore washing within the plant and is pumped to Adam's pit through a pipe;
- DMS grit – This is low grade product with a very low particle size that has the potential to be sold to third parties; and
- Sinter de-dust – This is de-dust from the Sinter plant.

A photo log of the samples collected is attached in Appendix B of the report. The samples collected are presented in Table 6-1 and the locations are shown in Figure 6-1 and Figure 6-2.

Table 6-1: Material samples collected

Sample no.	Description	Date collected	Sample type
Product			
MMT-06	Top Cut	2019/08/14	Product
MMT-07	MMT Lumpy stockpile (M1L1)	2019/08/14	Product
MMT-08	MMT High grade Sinter Stockpile (MHS)	2019/08/14	Product
MMT-09	MMT Standard Sinter Stockpile (MSS)	2019/08/14	Product
Adam's Pit			
MMT-AP01	Adam's Pit - Sinter de-dust	2019/08/13	Sinter dust
MMT-AP02	Adam's Pit - DMS grit	2019/08/13	Product
MMT-AP03	Adam's Pit – Tailings (M2FT)	2019/08/13	Discard
MMT-AP04	Adam's Pit - Slimes	2019/08/14	Tailings
Waste Rock			

Sample no.	Description	Date collected	Sample type
MMT-WR01	Core Yard - Calcrete-top line	2019/08/14	Waste Rock
MMT-WR02	Core Yard - Calcrete-middle line	2019/08/14	Waste Rock
MMT-WR03	Core Yard - Calcrete-bottom line	2019/08/14	Waste Rock
MMT-WR04	Core Yard - Pebble bed	2019/08/14	Waste Rock
MMT-WR05	Core Yard - Clay	2019/08/14	Waste Rock
MMT-WR06	Core Yard - Clay transition	2019/08/14	Waste Rock
MMT-WR07	Core Yard - BIF1	2019/08/14	Waste Rock
MMT-WR08	Core Yard - BIF2	2019/08/14	Waste Rock
MMT-WR09	Core Yard - BIF3	2019/08/14	Waste Rock

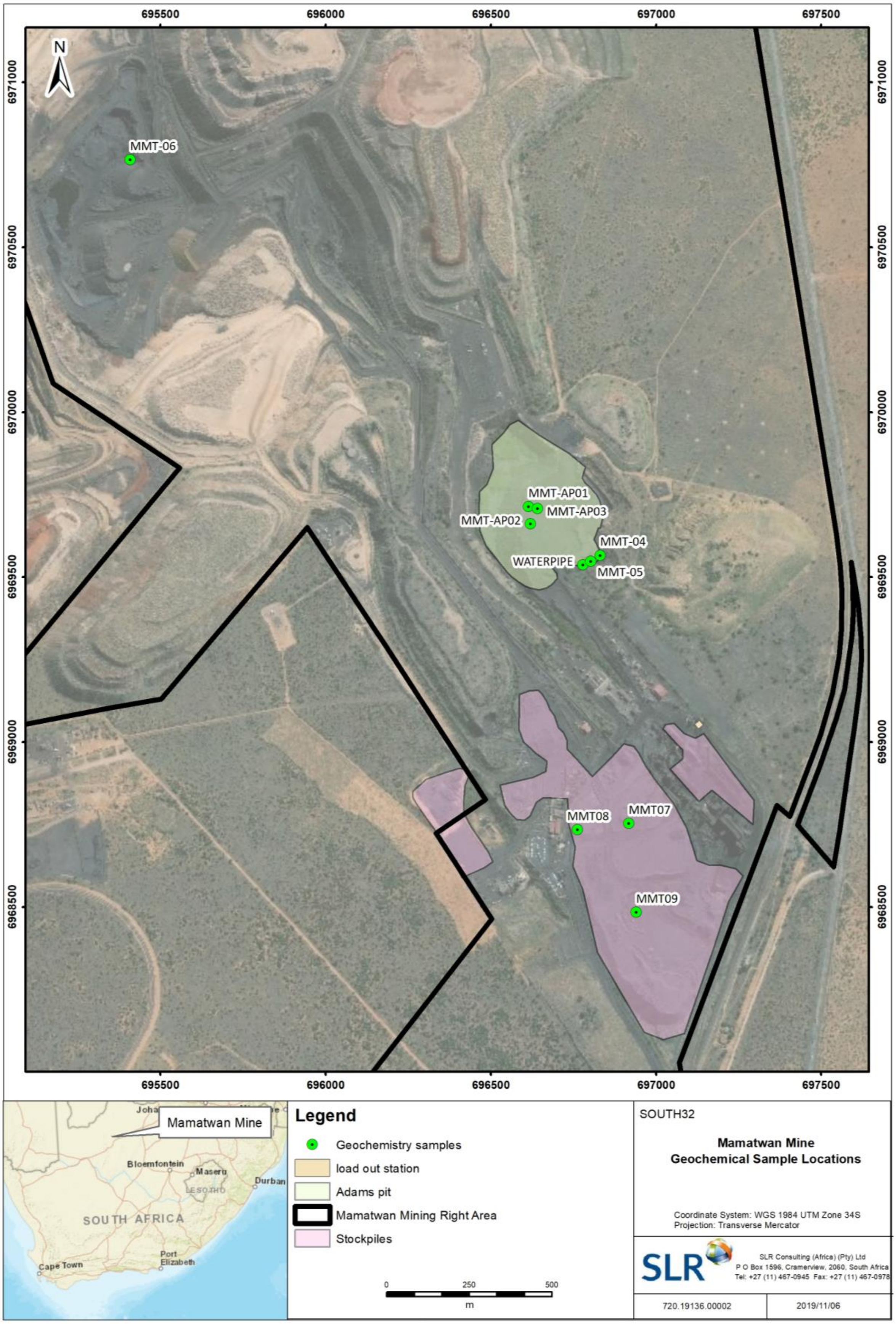

Figure 6-1: Geochem sample locations – All samples

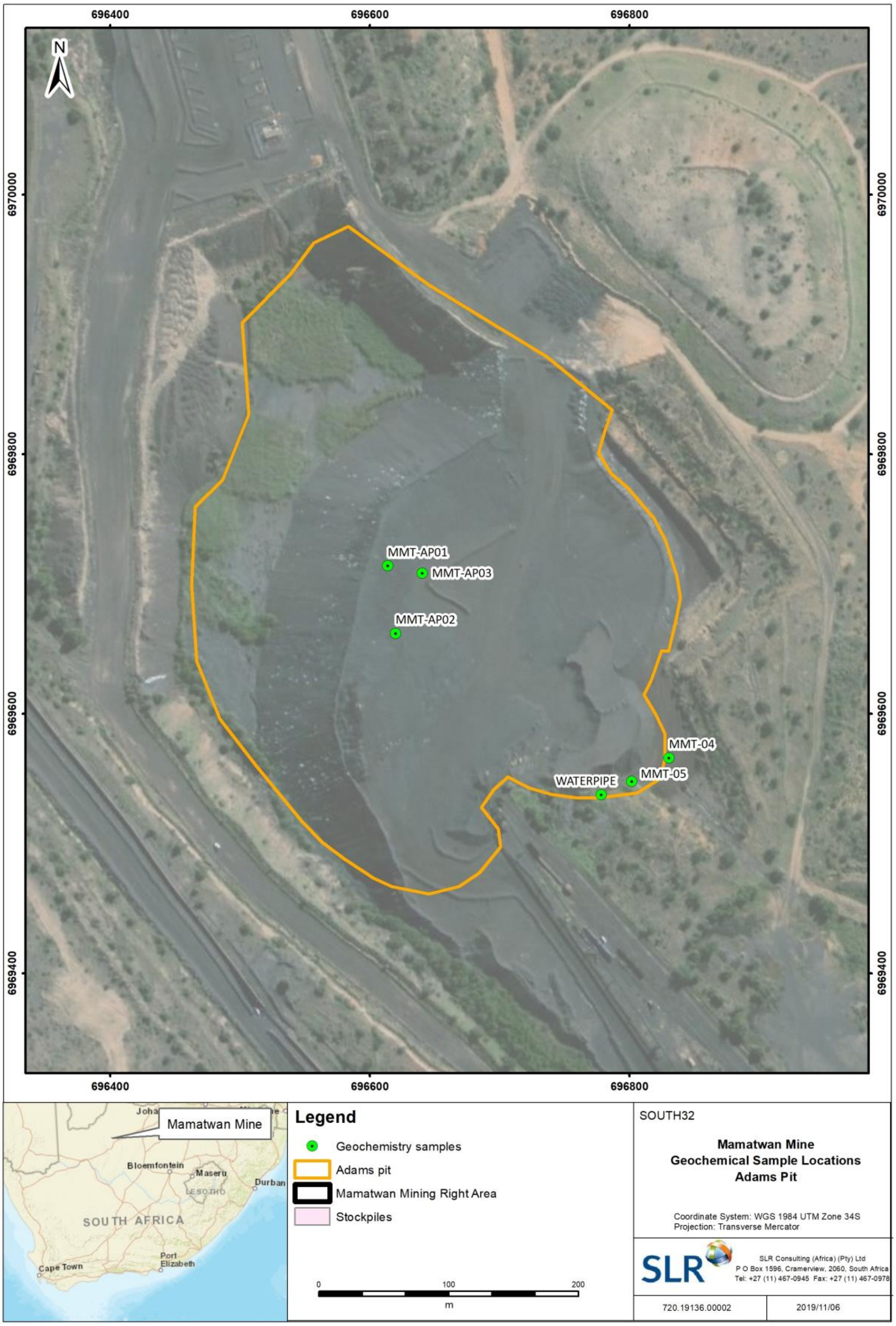

Figure 6-2: Geochem sample locations- Adam's Pit

Lithology samples were collected from the drilling cores of a representative borehole in the mining area. A composite sample was also prepared by the laboratory to be representative of the relative proportions based on the length of each lithology in the core. The composition of the composite sample as derived from the lithology lengths is presented in Table 6-2.

Table 6-2: Persentage of each lithology in the composite sample

Lithology ID	Sample ID	Depth Range of Lithology		Length Of Lithology	% of Composite Sample
		From	To		
Top line- CC	MMT-WR01	0	11.77	11.77	17.0
Mid line- CC	MMT-WR02	11.77	18.17	6.4	9.2
Bottom line- CC	MMT-WR03	18.17	25	6.83	9.8
Pebble bed	MMT-WR04	25	29.01	4.01	5.8
Competent Clay	MMT-WR05	29.01	39.38	10.37	14.9
Transition Clay	MMT-WR06	39.38	44.31	4.93	7.1
BIF1	MMT-WR07	44.31	50.36	6.05	8.7
BIF2	MMT-WR08	60.85	69.75	8.9	12.8
BIF3	MMT-WR09	72.33	82.44	10.11	14.6

6.2 GEOCHEMISTRY CHARACTERISATION

6.2.1 Acid Base Accounting (ABA)

Acid Base Accounting (ABA) provides an industry-recognized assessment of the acid generation or acid neutralisation potential of materials. The ABA method used for the characterisation of the samples is the Modified Sobek ABA method (EPA 600), which includes both laboratory analysis and empirical calculations based on acid generating potential (AP) and Neutralising potential (NP).

The classification of each material in terms of its potential to generate acid is based on the criteria shown in Table 6-3.

6.2.2 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. Paste pH values of less than 5 indicate the presence of stored acidity, whereas higher paste pH values suggest the presence of reactive neutralising minerals.

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. It should be noted that the paste pH may vary depending on the degree of weathering of the material.

6.2.3 Sulphur Speciation

The ABA tests assume that all sulphide minerals in a rock sample are acid generating. Some of the sulphur in the rock may be present in non-acid producing sulphates. If a significant part of the total sulphur occurs as sulphate sulphur instead of sulphide sulphur, the overall risk of acid generation is reduced. Samples with sulphide sulphur content below 0.3% are considered only capable of short-term acid generation (Price & Errington, 1995; Soregaroli & Lawrence, 1998).

6.2.4 Acid Potential and Neutralising Potential

An estimate of acid generation is made by assuming complete reaction between all minerals with acid generating potential and all of the minerals with NP (essentially dissolution of carbonate minerals and to very limited extent silicate minerals as the latter have very slow reaction kinetics; Bowell *et al*., 2000). 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 percentage multiplied by 31.25. The Acid 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.

The AP values are calculated from sulphide sulphur concentrations and reported as kilogram $CaCO_3$ per ton of rock (kg $CaCO_3$/ton). The NP values were determined using the modified Sobek protocol where the sample is reacted with a known quantity of acid and then the amount of acid that remains is determined by a back titration with NaOH to a pH of 8.3. The difference between the initial and the remaining quantity of acid is the NP of the sample. Neutralising potential has the same units as AP.

6.2.5 Net Neutralising Potential (NNP)

The difference between the acid generating mineral phases and acid Neutralising mineral phases is referred to as the net neutralisation potential (NNP). The NNP allows classification of the samples as potentially acid consuming or acid producing. The NNP is calculated by subtracting the AP from the Acid Neutralising Potential (NP):

NNP = NP – AP

Results are reported in kg of calcium carbonate per tonne of rock (or parts per thousand). The following criteria apply:

- NNP values below -20 indicate potential to generate acid and therefore a predicted net acid drainage water quality; and
- NNP values between -20 and 20 are considered inconclusive/possibly acid generating
- NNP values greater than +20 indicate acid NP or a predicted net alkaline drainage water quality.

6.2.6 Neutralising Potential Ratio (NPR)

Acid Base Accounting data is also described using the neutralisation potential ratio. The NPR can be used to identify potentially acid producing rocks. The NPR is calculated by dividing the NP by the AP:

NPR = NP/AP

In the assessment:

- NPR ratios larger than 4 indicate non-potentially acid generation (Non-Potentially acid generating (PAG));
- Ratios between 1 and 3 are considered inconclusive / possibly acid generating; and
- NPR ratios below 1 indicate potential acid generation (PAG) if sufficient sulphide is available (S > 0.3%).

An NPR of at least 2 is needed for complete acid neutralisation (Cravotta *et al.*, 1990). In case of preferential exposure or reactivity of sulphides the required ratio needed for complete acid neutralisation may go up to 4 (Price *et al.*, 1997) and therefore 4 is used as a precautionary screening value.

Table 6-3: Acid Mine Drainage Classification

Parameter	PAG	Uncertain/Marginal	Non-PAG	Reference
Paste pH	<3.5	3.5 - 5.5	>5.5	Price and Errington, 1994
NNP	<-20	-20 – 20	>20	Roberson and Broughton, 1992
NPR	<1	1:1 – 2:1 = Possibly 2:1 – 4:1 = Low	>4	Price *et al.,* 1997
Sulphide %	> 0.3%	-	< 0.3%	Soregaroli and Lawrence, 1998

6.2.7 Mineralogy – XRD

Minerals are the building blocks of rocks. Mine drainage quality is generally a function of mineral dissolution (or precipitation) during interaction of rocks with water. XRD analysis identifies the main crystalline mineral phases in each sample. XRD is conducted on whole rock samples that have been crushed and ground to a powder. The powdered sample is placed on a flat holder, which faces the X-ray beam. The X-rays are diffracted by the crystal planes in the minerals, with diffraction peaks at characteristic angles. The phases are identified by comparing the locations and intensities of the diffraction peak with the peaks of mineral reference standards (Price, 2009). Limitations of XRD are that it is not easy to identify non-crystalline minerals, and minerals present in low concentrations may not be detected.

6.3 WASTE CLASSIFICATION

The SANS 10234:2008 standard covers the harmonized criteria for the classification of hazardous substances according to their health, environmental and physical hazards. Only material deemed to be a waste is characterised in accordance with SANS 10234:2008.

The GHS does not require testing where testing has been done previously. Information or data that has been published in journals or any credible source can be utilised to classify the waste stream. Chemical test results as well as the intrinsic properties of the waste streams were used for the SANS10234:2008 classification. Concentrations of constituents exceeding 1% (Table 6-4) were used for classification in terms of the health and environmental hazards, except where constituents are known to be toxic at lower concentrations based on the International Agency for Research on Cancer (IARC) Monographs (WHO-IARC, 2016) in which case concentrations of constituents exceeding 0.1% were noted.

Table 6-4: Cut-off values/concentration limits for hazard classes

Hazard Class	Cut-off value (concentration limit) %
Acute toxicity	> 1.0
Skin corrosion	> 1.0
Skin irritation	> 1.0
Serious damage to eyes	> 1.0
Eye irritation	> 1.0

Hazard Class	Cut-off value (concentration limit) %
Respiratory sensitisation	> 1.0
Skin sensitisation	> 1.0
Mutagenicity: Category 1 Category 2	> 0.1 > 1.0
Carcinogenicity	> 0.1
Reproductive toxicity	> 0.1
Target organ systemic toxicity	> 1.0
Hazardous to the aquatic environment	> 1.0

6.4 WASTE ASSESSMENT

The Total Concentration (TC) of chemical substances were determined and compared to the Total Concentration Threshold (TCT) limits specified in Section 6 of GN R. 635. Only material deemed to be a waste are subjected to a waste assessment.

The LC of the chemical substances were also determined and compared to the LCT.

6.5 METAL LEACHING POTENTIAL

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 runoff that could emanate from site. However, the results may indicate chemicals of concern (CoCs) in mine drainage. As part of this assessment, leach tests were undertaken using distilled water (pH 7) to represent neutral drainage conditions. 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, 2017);
- International Finance Corporation (IFC) Guidelines for Mining Effluents (IFC, 2007); and
- South African National Standards (SANS) 241 (2011) Drinking Water (SANS 241:2015).

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.

6.6 GEOCHEMICAL MODELLING

6.6.1 Model Code

This assessment applies the pH, Redox, Equilibrium Code (PHREEQC) for hydrogeochemical modelling (Parkhurst and Appelo, 1999 and 2015).

PHREEQC is a versatile geochemical model initially developed in 1995 by the United States Geological Survey. It has undergone extensive use, testing and validation by third parties with version 3 released in January 2015. This assessment used version 3.3.10.12220 (released 12 January 2017). PHREEQC can perform low-temperature aqueous geochemical calculations, including speciation, saturation indices, batch reaction and 1-dimensional transport calculations. PHREEQC can account for aqueous, mineral, gas, solid solution, surface complexation and ion exchange equilibria, as well as kinetic reactions.

PHREEQC is widely used for environmental geochemical modelling because it is freely available, open source, and flexible. It includes thermodynamic databases for a wide range of inorganic parameters relevant to mine water quality.

6.6.2 Model Inputs

The key model inputs are the contact water quality determined from laboratory leach tests (Appendix B). Separate models were developed for the waste rock, Tailings in Adam's Pit and Stockpile in Adam's Pit.

The input data concentrations were adjusted to achieve a CBE < 10%. Concentrations indicated as below detection limit were entered as one-half of the detection limit or omitted were practical.

It is assumed that the waste rock dumps have a field moisture capacity of about 20%. The column of waste material can only generate seepage if the water content exceeds this value. For the tailings and Adam's Pit Stockpile the field moisture capacity was estimated at 30%. No analysis was conducted to confirm this.

6.6.3 Boundary Conditions

The model boundary conditions are summarised in Table 6-5.

Table 6-5: Model boundary conditions

Boundary conditions	Description
Gas phase	It is assumed that there is little biological activity in the material and the $CO_{2(g)}$ pressure was set to $10^{-3.5}$ atm.
Minerals	**Tailings**: Based on the mineralogical analysis the pure phases that can react reversibly with the aqueous phase are Calcite and Hausmannite. **Adam's Pit**: Based on the mineralogical analysis the pure phases that can react reversibly with the aqueous phase are Calcite, Hematite and Rhodochrosite. **Waste Rock:** Based on the mineralogical analysis the pure phases that can react reversibly with the aqueous phase are Calcite, Dolomite and Hematite. Mineral phases to simulate only precipitation reactions were added for each sample modelled if they were over saturated in the solution.
Adsorption surface	Metal cations can sorb to charged surfaces. In this simulation no such sorption was simulated.

6.6.4 Model Algorithm

The algorithm comprised the following:

1. For simulations were mixing of different solutions were required the solutions were proportioned according to the determined ratios.
2. Determine pore water quality by adjusting solid-liquid ratio of leach test to expected ratio at field capacity. This was done by modelling the removal of water from the solution.
3. Establish equilibrium composition of pore water in tailings, allowing relevant minerals to dissolve/precipitate.

6.6.5 Model Limitations

Predicting water qualities from a tailing's facility requires some assumptions and has limitations. The statistician George Box said: all models are wrong, but some models are useful (Box, 1976). This statement captures the essential truth that all model's approximate reality in that they reduce complex systems to a limited number of significant processes. How "useful" a model is depending on how closely the selected processes approximate reality.

Predicting the water qualities of complex systems (such as a tailings dam) demands assumptions. Even a rigorous sampling and analysis programme cannot precisely determine the physical and geochemical characteristics of the system. Nor can they precisely indicate how these characteristics may change over time.

Table 6-6 summarises the key limitations of the input data and the hydrogeochemical model used for this assessment.

Table 6-6: Model limitations

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

Considering the uncertainties outlined above, the available information is sufficient to provide the preliminary estimated tailings seepage quality presented in this report. However, even though this report presents deterministic concentration values, these should be viewed as first-order approximations[1]. As such, the predicted concentrations in this report indicate the likely order of magnitude concentrations.

[1] A first-order approximation is an estimated value of a quantity, often preliminary to more precise determination. Mathematically, it is a linear approximation of a polynomial function.

7. ASSUMPTIONS

The following assumptions apply to this study:

- Models are only as accurate as the input data provided. Refer to Section 6.6.4;
- Samples from the historical tailing's dams were not collected as these facilities have been rehabilitated;
- Multiple stockpiles are stored in the stockyard. As part of this project each individual stockpile was not sampled, rather the four samples of product that were collected (top cut, high grade, low grade and standard sinter product) provide an understanding of the various grades. The leachate results are considered to be representative of product stockpiles not sampled, as the only difference is the size of the particles and as such the constituents of concern are not anticipated to differ significantly.
- Plant spillages constitutes 1% of the overall Adam's pit stockpile and is a mixture of Sinter de-dust and product. As part of the project, it was not possible to collect a sample of the plant spillages given that this material was not easily distinguishable. Given that plant spillages constitute 1% it is unlikely that the exclusion of this proportion from the source term model for the Adam's stockpile would significantly change the results.

8. RESULTS

8.1 WASTE CHARACTERISATION

8.1.1 Acid Base Accounting (ABA)

The acid base accounting results are shown in Table 6-3. Due to the low sulphide and high neutralisation potential all the samples are classified as non-PAG. The total sulphur concentration in the sinter de-dust material (MMT-AP01) is above the 0.3% threshold. The sulphur that is found is in sulphate form and does not pose a risk of acid production.

Table 8-1: Acid Base Accounting results

Lab ID	Sample ID	Description	S (sulphate)	Paste pH	Total Sulphur	S (Sulphide)	Acid Potential (AP)	Neutralisation Potential (NP)	Nett Neutralisation Potential (NNP)	Neutralising Potential Ratio (NPR) (NP : AP)	Total Carbon	Organic Carbon	Inorganic Carbon
Non-PAG				>5.5	<0.3	<0.3	-	-	>20	>4			
Inconclusive				3.5-5.5	-	-	-	-	-20 to 20	1-4			
PAG				<3.5	>0.3	>0.3	-	-	<-20	<1			
Unit			%	%	%	%	kg CaCO3/t	kg CaCO3/t	kg CaCO3/t	NP:AP	%	%	%
PRODUCT													
656445	MMT-06	Top Cut	0.011	nd	0.0135	0.001	0.422	nd	nd	nd	6.19	0.0767	6.11
656446	MMT-07	MMT Lumpy stockpile (M1L1)	0.007	nd	0.0114	0.002	0.356	nd	nd	nd	4.68	0.0655	4.61
656447	MMT-08	MMT High grade Sinter Stockpile (MHS)	0.011	nd	0.0138	0.002	0.431	nd	nd	nd	0.0357	0.0338	0.0019
656448	MMT-09	MMT Standard Sinter Stockpile (MSS)	0.033	nd	0.0394	0.001	1.231	nd	nd	nd	0.23	0.0508	0.18
ADAM'S PIT													
656440	MMT-AP01	Adam's Pit - Sinter de-dust	0.761	12.37	0.779	0.006	24.34	335	311	13.8	3.5	2.2245	1.28
656440 QC	MMT-AP01	Adam's Pit - Sinter de-dust	0.757	12.36	0.77	0.006	24.06	337	312	14.0	3.5	2.3745	1.13
656441	MMT-AP02	Adam's Pit - DMS grit	0.006	9.28	0.00885	0.002	0.277	396	396	1433	4.51	0.1605	4.35
656442	MMT-AP03	Adam's Pit – Tailings (M2FT)	0.004	8.61	0.007	0.001	0.219	484	484	2213	5.6	0.1355	5.46
656443	MMT-AP04	Adam's Pit - Slimes	0.107	8.66	0.114	0.002	3.56	136	132	38	4.74	0.1395	4.60
WASTE ROCK													
656449	MMT-WR01	Core Yard - Calcrete-top line	0.013	9.06	0.015	<0.001	0.469	384	384	820	4.61	0.1055	4.50
656450	MMT-WR02	Core Yard - Calcrete-middle line	0.008	8.44	0.01	<0.001	0.313	408	408	1305	4.92	0.0985	4.82
656450 QC	MMT-WR02	Core Yard - Calcrete-middle line	nd	8.47	0.01	nd	0.313	406	406	1300	nd	nd	nd
656451	MMT-WR03	Core Yard - Calcrete-bottom line	0.009	8.62	0.012	0.002	0.375	575	574	1533	6.91	0.0915	6.82
656452	MMT-WR04	Core Yard - Pebble bed	0.006	8.35	0.011	0.003	0.344	149	149	435	1.77	0.1135	1.66
656444	MMT-WR05	Core Yard - Clay	0.009	8.09	0.013	0.002	0.406	214	213	526	2.56	0.2075	2.35
656454	MMT-WR06	Core Yard - Clay transition	0.004	8.42	0.005	0.001	0.156	401	401	2569	4.81	0.0985	4.71
656454 QC	MMT-WR06	Core Yard - Clay transition	0.004	nd	nd	nd	nd	nd	nd	nd	4.82	0.1075	4.71
656455	MMT-WR07	Core Yard - BIF1	0.004	8.8	0.008	0.003	0.250	386	386	1546	4.68	0.081	4.60
656456	MMT-WR08	Core Yard - BIF2	0.01	8.85	0.019	0.008	0.594	230	229	387	2.63	0.1245	2.51
656457	MMT-WR09	Core Yard - BIF3	0.005	8.25	0.007	0.001	0.219	437	437	1997	5.23	0.0806	5.15
666416	MMT-WR10	Composite WR	0.006	8.59	0.0132	0.001	0.413	362	361	877	4.98	0.242	4.74
666416 QC	MMT-WR10	Composite WR	0.006	nd	nd	nd	nd	nd	nd	nd	4.98	0.205	4.78

*nd: Not determined

8.1.2 Mineralogy

Mineralogy of the material in Adam's Pit is presented in Table 8-2 and Figure 8-1 and for the lithology samples representing the waste rock in Table 8-3 and Figure 8-2. The dominant phases in the waste samples in Adam's Pit are manganese and carbonates rich minerals. In the samples representing waste rock material quartz and carbonate rich minerals are the dominant phases. The BIF samples also have hematite as a dominant phase. The high concentration of carbonates confirms the high NP of the material.

Due to the oxidation and hydrolysis of Mn(II) minerals found in the Adam's Pit wastes, acid generation may occur but due to the association with carbonates this will be neutralised.

Table 8-2: Samples from Adam's Pit mineralogy

Sample	Ideal formula	MMT-AP01	MMT-AP02	MMT-AP03	MMT-AP04
Description		Adam's Pit - Sinter de-dust	Adam's Pit – DMS grit	Adam's Pit tailings (M2FT)	Adam's Pit - Slimes
Braunite 1	$Mn^{2+}Mn^{3+}{}_6[O_8\|SiO_4]$	22.12	46.75	38.79	48.35
Calcite	$CaCO_3$	22.79	18	32.02	21.82
Kutnohorite	$CaMn^{2+}(CO_3)_2$	2.96	22.64	18	15.84
Neltnerite	$CaMn^{3+}{}_6(SiO_4)O_8$	4.27	0.1	0	0
Hausmannite	$Mn^{2+}Mn^{3+}{}_2O_4$	38.45	10.89	10.08	12.87
Hematite	Fe_2O_3	8.51	1.16	0.81	1.12
Iron	Fe	0.89	0.45	0.29	0

Table 8-3: Waste rock lithology samples mineralogy

Sample	Ideal formula	MMT-WR01	MMT-WR02	MMT-WR03	MMT-WR04	MMT-WR05	MMT-WR06	MMT-WR07	MMT-WR08	MMT-WR09	MMT-WR10
Description		Calcrete-top line	Calcrete-middle line	Calcrete-bottom line	Pebble bed	Clay	Clay transition	BIF1	BIF2	BIF3	Composite waste rock
Hematite	Fe_2O_3	0.03	0.16	0.05	4.74	1.65	4.31	21.58	23.18	16.5	8.5
Quartz	SiO_2	52.52	28.93	13.94	44	33.04	15.42	23.33	30.78	16.62	31.3
Magnetite	$Fe^{2+}Fe^{3+}{}_2O_4$	0	0.05	0.26	0.54	0.7	0.53	8.23	9.7	0	2.9
Calcite	$CaCO_3$	45.47	29.39	20.34	24.29	6.74	9.02	28.62	9.89	27.87	21
Dolomite	$CaMg(CO_3)_2$	0.92	32.7	60.53	7.42	39.42	65.53	10.73	17.08	30.59	28.9
Smectite	2:1 platy phyllosilicates	0.48	3.45	1.52	6.34	8.14	1.04	0.85	1.19	3.93	3.9
Talc	$Mg_3Si_4O_{10}(OH)_2$	0	0.1	0.16	0.3	0.17	0.11	5.98	6.01	3.16	1.8
Kaolinite	$Al_2Si_2O_5(OH)_4$	0.06	0.39	0.48	1.43	0.6	0.34	0.47	2.05	0.93	0.9
Palygorskite	$(Mg,Al)_2Si_4O_{10}(OH)\cdot4(H_2O)$	0.04	4.84	2.58	9.5	9.54	3.62	0	0	0.11	0.6
Sepiolite	$Mg_4Si_6O_{15}(OH)_2\cdot6H_2O$	0.48	0	0.14	1.45	0	0.08	0.21	0.12	0.29	0.4

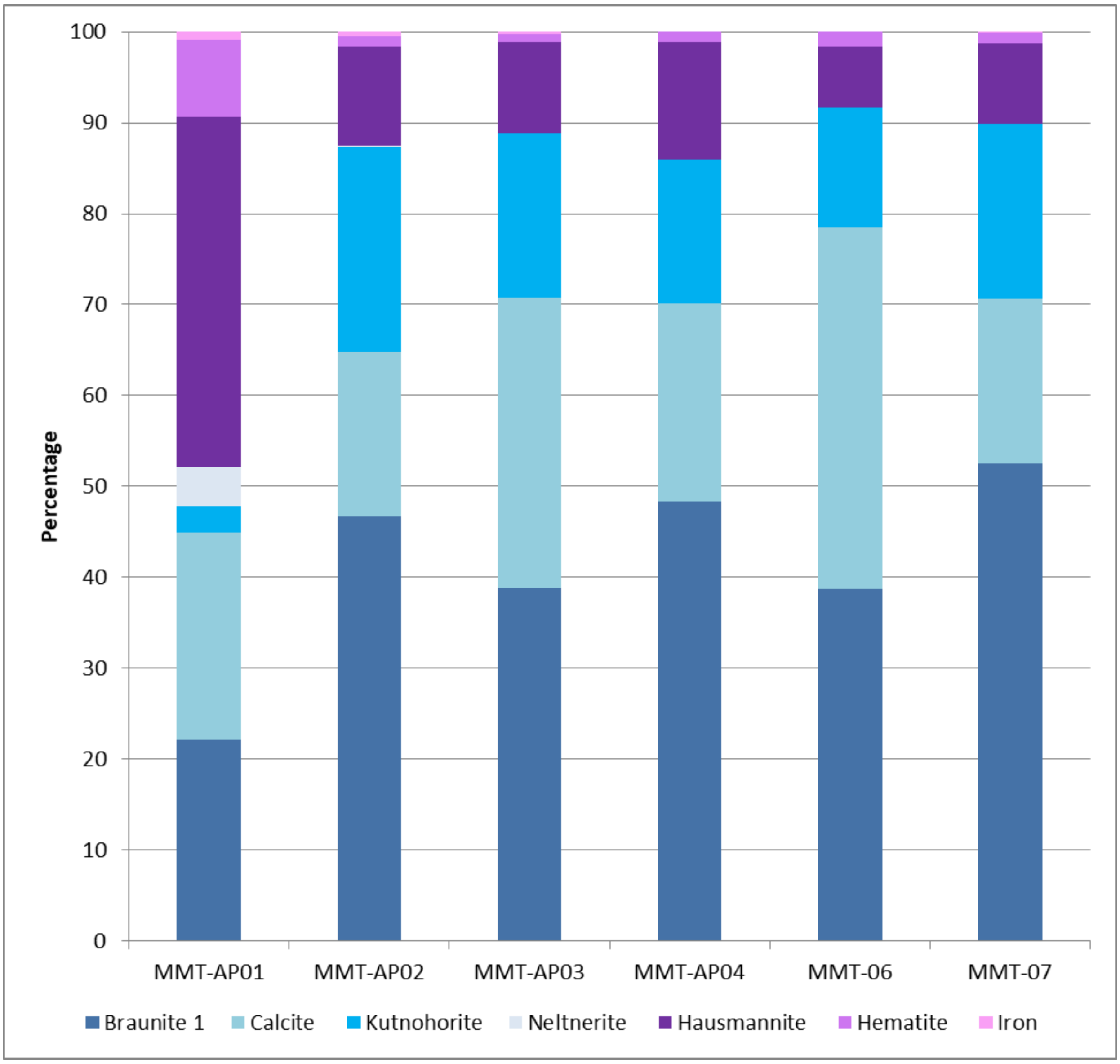

Figure 8-1: Mineralogy by XRD results for Product and Adam's Pit samples

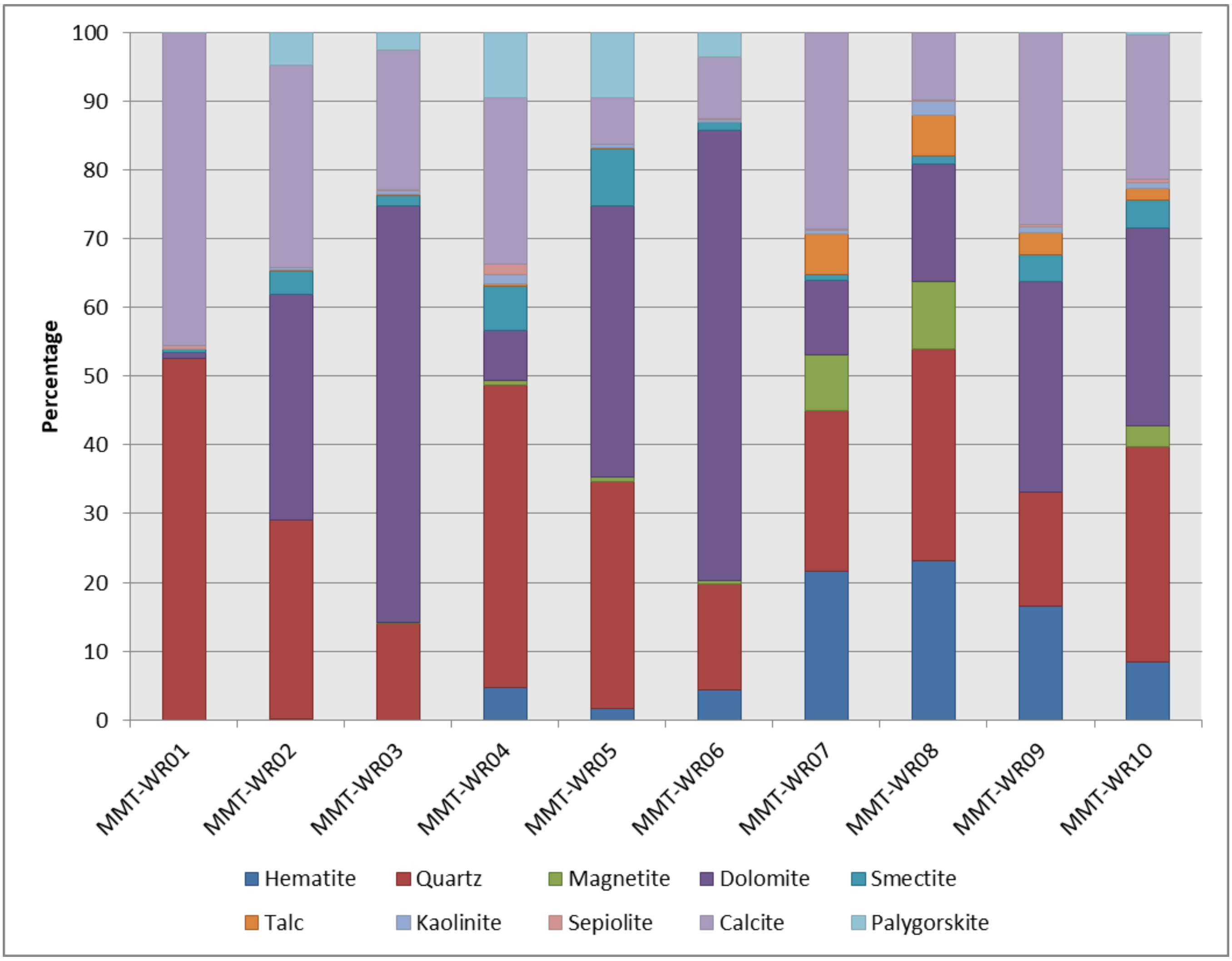

Figure 8-2: Mineralogy by XRD results for waste rock samples

8.2 METAL LEACHING POTENTIAL

As part of this assessment, leach tests were undertaken using distilled water (@pH7) to represent neutral drainage conditions. As a preliminary screening to identify potential CoCs, the leachates were compared to the water quality and effluent standards described in Section 6.5:

The concentrations in the product samples exceeded the following screening criteria:

- Barium exceeded the SANS 241 (2015) Chronic Health and WHO Standard for Drinking Water (2017) guideline in sample MMT-09;
- pH exceeded the SANS 241 (2015) Operational and IFC Mining Effluent (2007) guidelines. Sample MMT-09 exceeded both SANS 241 (2015) Operational and IFC Mining Effluent (2007) guidelines and sample MMT-AP02 exceeded only the IFC Mining Effluent (2007) guideline;
- Total suspended solids (TSS) exceeded the IFC Mining Effluent (2007) in samples MMT-06, MMT-07, MMT-08 and MMT-09; and
- The main CoCs identified in the product samples were Ba, pH and TSS in the MMT standard sinter stockpile (MSS) and pH in the DMS grit located in Adam's Pit.

The concentrations in the Adam's Pit waste samples exceeded the following screening guidelines for the assessed constituents:

- Boron exceeded the SANS 241 (2015) Chronic Health and WHO Standard for Drinking Water (2017) guidelines in sample MMT-AP01;
- pH exceeded the SANS 241 (2015) Operational and IFC Mining Effluent (2007) guidelines in sample MMT-AP01;
- Total dissolved solids (TDS) exceeded the SANS 241 (2015) Aesthetic guideline in sample MMT-AP01;
- Electrical conductivity (EC) exceeded the SANS 241 (2015) Aesthetic guideline in sample MMT-AP01;
- Sulphate (SO_4) exceeded the SANS 241 (2015) Acute Health guideline in sample in MMT-AP01; and
- The main CoCs identified in the Adam's Pit waste samples were B, pH, TDS, EC, Cl and SO_4 in the sinter de-dust. No leachable CoCs were identified in the MMT floats/discard or tailings samples.

The waste rock samples concentrations exceeded the following screening guidelines for the assessed constituents:

- Aluminium exceeded the SANS 241 (2015) Operational guideline in sample MMT-WR02;
- Barium SANS 241 (2015) Chronic Health and WHO Standard for Drinking Water (2017) guidelines in sample MMT-WR01;
- Iron exceeded the SANS 241 (2015) Aesthetic guideline in sample MMT-WR02;
- pH exceeded the SANS 241 (2015) Operational and IFC Mining Effluent (2007) guidelines. Sample MMT-WR01 exceeded both SANS 241 (2015) Operational and IFC Mining Effluent (2007) guidelines and sample MMT-WR01 exceeded only the IFC Mining Effluent (2007) guideline;
- TSS exceeded the IFC Mining Effluent (2007) guideline in samples MMT-WR01 and MMT-WR06; and
- In summary, CoCs were identified in three (3) waste rock lithologies, Ba, pH and TSS in calcrete-top line (MT-WR01), Al, Fe, pH and TSS in calcrete-middle line (MMT-WR02) and TSS in the clay transition lithology (MMT-WR06).

Table 8-4: Product leach results

Lab ID	Sample ID	Description	Ag	Al	As	Au	B	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr	Cs	Cu	Fe	Ga	Ge	Hf	Hg	Ho	Ir	K
Unit			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	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
SANS 241 (2015) Operational			N/A	0.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SANS 241 (2015) Aesthetic			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SANS 241 (2015) Acute Health			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SANS 241 (2015) Chronic Health			N/A	N/A	0.01	N/A	2.4	0.7	N/A	N/A	N/A	0.003	N/A	N/A	0.1	N/A	2.0	2.0	N/A	N/A	N/A	0.006	N/A	N/A	N/A
WHO Standard for Drinking Water (2017)			N/A	N/A	0.01	N/A	2.4	0.7	N/A	N/A	N/A	0.003	N/A	N/A	0.1	N/A	2.0	N/A	N/A	N/A	N/A	0.006	N/A	N/A	N/A
IFC Mining Effluent (2007)			N/A	N/A	0.1	N/A	N/A	N/A	N/A	N/A	N/A	0.05	N/A	N/A	N/A	N/A	0.3	2.0	N/A	N/A	N/A	0.002	N/A	N/A	N/A
PRODUCT																									
658,090	MMT-06	Top Cut	<0.001	0.024	0.002	<0.001	0.053	0.192	<0.001	<0.001	7.72	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	0.022	<0.001	<0.001	<0.001	0.0005	<0.001	<0.001	2.48
658,091	MMT-07	Mamatwan Lumpy stockpile (M1L1)	<0.001	0.023	<0.001	<0.001	0.060	0.115	<0.001	<0.001	10.5	<0.0001	<0.001	<0.001	<0.001	<0.001	0.001	0.004	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	0.32
658,092	MMT-08	Mamatwan High grade Sinter Stockpile (MHS)	<0.001	0.019	<0.001	<0.001	0.052	0.424	<0.001	<0.001	9.49	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	0.36
658,093	MMT-09	Mamatwan Standard Sinter Stockpile (MSS)	<0.001	0.038	0.003	<0.001	1.333	0.904	<0.001	<0.001	92.6	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	0.007	<0.001	<0.001	<0.001	0.0001	<0.001	<0.001	0.46
ADAM'S PIT																									
658,086	MMT-AP01	Adams pit - Sinter de-dust	<0.001	0.054	<0.001	<0.001	3.853	0.216	<0.001	<0.001	577	<0.0001	<0.001	0.001	0.007	<0.001	0.001	0.004	<0.001	<0.001	<0.001	0.0002	<0.001	<0.001	11.9
658086 QC	MMT-AP01	Adams pit - Sinter de-dust	<0.001	0.054	<0.001	<0.001	3.824	0.221	<0.001	<0.001	575	<0.0001	<0.001	0.001	0.007	<0.001	<0.001	0.009	<0.001	<0.001	<0.001	0.0002	<0.001	<0.001	11.8
658,087	MMT-AP02	Adams pit - DMS grit	<0.001	0.035	<0.001	<0.001	0.090	0.121	<0.001	<0.001	8.23	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	0.005	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	0.26
658,088	MMT-AP03	Adams pit - Tailings (M2FT)	<0.001	0.025	<0.001	<0.001	0.104	0.040	<0.001	<0.001	10.4	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	0.40
658,089	MMT-AP04	Slimes	<0.001	0.015	<0.001	<0.001	0.193	0.348	<0.001	<0.001	11.4	<0.0001	<0.001	<0.001	0.002	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	0.38
WASTE ROCK																									
658,094	MMT-WR01	Core Yard - Calcrete-top line	<0.001	0.033	0.001	<0.001	1.466	1.563	<0.001	<0.001	120	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	1.02
658,095	MMT-WR02	Core Yard - Calcrete-middle line	<0.001	0.625	0.001	<0.001	0.058	0.188	<0.001	<0.001	8.42	<0.0001	<0.001	<0.001	<0.001	<0.001	0.001	0.541	<0.001	<0.001	<0.001	0.0007	<0.001	<0.001	1.72
658,096	MMT-WR03	Core Yard - Calcrete-bottom line	<0.001	0.026	0.001	<0.001	0.029	0.074	<0.001	<0.001	7.91	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	0.024	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	1.55
658096 QC	MMT-WR03	Core Yard - Calcrete-bottom line	<0.001	0.028	0.001	<0.001	0.027	0.074	<0.001	<0.001	8.00	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	0.023	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	1.51
658,097	MMT-WR04	Core Yard - Pebble bed	<0.001	0.007	<0.001	<0.001	0.022	0.059	<0.001	<0.001	7.64	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	<0.001	<0.001	<0.001	0.0002	<0.001	<0.001	1.03
658,098	MMT-WR05	Core Yard - Clay	<0.001	0.016	0.002	<0.001	0.021	0.056	<0.001	<0.001	6.79	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	0.008	<0.001	<0.001	<0.001	0.0001	<0.001	<0.001	1.48
658,099	MMT-WR06	Core Yard - Clay transition	<0.001	0.008	0.001	<0.001	0.028	0.066	<0.001	<0.001	7.11	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	0.005	<0.001	<0.001	<0.001	0.0001	<0.001	<0.001	0.90
658,100	MMT-WR07	Core Yard - BIF1	<0.001	0.020	0.001	<0.001	0.022	0.230	<0.001	<0.001	7.28	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	0.0001	<0.001	<0.001	0.54
658,101	MMT-WR08	Core Yard - BIF2	<0.001	0.029	<0.001	<0.001	0.035	0.051	<0.001	<0.001	7.54	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	0.007	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	0.31
658,102	MMT-WR09	Core Yard - BIF3	<0.001	0.007	<0.001	<0.001	0.022	0.034	<0.001	<0.001	7.30	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	1.03
666417	MMT-WR10	Composite WR	<0.001	0.014	0.001	<0.001	0.041	0.193	<0.001	<0.001	8.93	<0.0001	<0.001	<0.001	0.001	<0.001	0.005	0.024	<0.001	<0.001	<0.001	0.0001	<0.001	<0.001	1.19
666417 QC	MMT-WR10	Composite WR	<0.001	0.014	<0.001	<0.001	0.039	0.194	<0.001	<0.001	8.80	<0.0001	<0.001	<0.001	<0.001	<0.001	0.004	0.026	<0.001	<0.001	<0.001	0.0001	<0.001	<0.001	1.17

Lab ID	Sample ID	Description	La	Li	Mg	Mn	Mo	Na	Nb	Nd	Ni	Pb	Pt	Rb	Sb	Sc	Se	Si	Sn	Sr	Ta	Te	Th	Ti	Tl
Unit			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	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
SANS 241 (2015) Operational			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SANS 241 (2015) Aesthetic			N/A	N/A	N/A	0.1	N/A	200	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SANS 241 (2015) Acute Health			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SANS 241 (2015) Chronic Health			N/A	N/A	N/A	0.4	N/A	N/A	N/A	N/A	0.07	0.01	N/A	N/A	0.02	N/A	0.04	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
WHO Standard for Drinking Water (2017)			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.07	0.01	N/A	N/A	0.02	N/A	0.04	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
IFC Mining Effluent (2007)			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.5	0.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PRODUCT																									
658,090	MMT-06	Top Cut	<0.001	0.001	4.70	0.002	<0.001	6.82	<0.001	<0.001	0.001	0.003	<0.001	<0.001	<0.001	0.002	<0.001	2.65	<0.001	0.031	<0.001	<0.001	<0.0001	0.001	<0.001
658,091	MMT-07	Mamatwan Lumpy stockpile (M1L1)	<0.001	0.001	3.66	0.005	<0.001	1.55	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	1.39	<0.001	0.042	<0.001	<0.001	<0.0001	<0.001	<0.001
658,092	MMT-08	Mamatwan High grade Sinter Stockpile (MHS)	<0.001	<0.001	4.98	<0.001	<0.001	1.33	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.97	<0.001	0.038	<0.001	<0.001	<0.0001	<0.001	<0.001
658,093	MMT-09	Mamatwan Standard Sinter Stockpile (MSS)	<0.001	<0.001	0.14	<0.001	<0.001	1.06	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	0.005	<0.001	27.5	<0.001	0.137	<0.001	<0.001	<0.0001	0.003	<0.001
ADAM'S PIT																									
658,086	MMT-AP01	Adams pit - Sinter de-dust	<0.001	0.002	0.05	0.002	0.007	5.23	<0.001	<0.001	0.020	0.006	<0.001	0.029	<0.001	<0.001	0.001	1.52	<0.001	1.192	<0.001	<0.001	<0.0001	0.005	<0.001
658086 QC	MMT-AP01	Adams pit - Sinter de-dust	<0.001	0.001	0.05	0.001	0.007	5.28	<0.001	<0.001	0.020	0.006	<0.001	0.028	<0.001	<0.001	0.001	1.54	<0.001	1.125	<0.001	<0.001	<0.0001	0.004	<0.001
658,087	MMT-AP02	Adams pit - DMS grit	<0.001	<0.001	2.80	<0.001	<0.001	1.12	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	1.56	<0.001	0.022	<0.001	<0.001	<0.0001	<0.001	<0.001
658,088	MMT-AP03	Adams pit - Tailings (M2FT)	<0.001	<0.001	4.14	<0.001	<0.001	1.40	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	1.78	<0.001	0.015	<0.001	<0.001	<0.0001	<0.001	<0.001
658,089	MMT-AP04	Slimes	<0.001	<0.001	6.71	0.009	0.004	2.68	<0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.001	2.22	<0.001	0.045	<0.001	<0.001	<0.0001	<0.001	<0.001
WASTE RICK																									
658,094	MMT-WR01	Core Yard - Calcrete-top line	<0.001	<0.001	0.12	<0.001	<0.001	1.35	<0.001	<0.001	0.004	<0.001	<0.001	0.002	<0.001	0.003	<0.001	17.2	<0.001	0.201	<0.001	<0.001	<0.0001	0.002	<0.001
658,095	MMT-WR02	Core Yard - Calcrete-middle line	<0.001	<0.001	5.00	0.005	<0.001	2.55	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.003	<0.001	1.6	<0.001	0.035	<0.001	<0.001	<0.0001	0.003	<0.001
658,096	MMT-WR03	Core Yard - Calcrete-bottom line	<0.001	<0.001	4.18	<0.001	<0.001	5.04	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	1.0	<0.001	0.026	<0.001	<0.001	<0.0001	0.002	<0.001
658096 QC	MMT-WR03	Core Yard - Calcrete-bottom line	<0.001	<0.001	4.16	<0.001	<0.001	4.96	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	1.8	<0.001	0.026	<0.001	<0.001	<0.0001	0.002	<0.001
658,097	MMT-WR04	Core Yard - Pebble bed	<0.001	<0.001	4.31	<0.001	<0.001	2.85	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.002	1.9	<0.001	0.025	<0.001	<0.001	<0.0001	<0.001	<0.001
658,098	MMT-WR05	Core Yard - Clay	<0.001	<0.001	3.57	<0.001	<0.001	3.77	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	1.50	<0.001	0.023	<0.001	<0.001	<0.0001	<0.001	<0.001
658,099	MMT-WR06	Core Yard - Clay transition	<0.001	<0.001	4.25	<0.001	0.001	3.49	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	1.22	<0.001	0.023	<0.001	<0.001	<0.0001	<0.001	<0.001
658,100	MMT-WR07	Core Yard - BIF1	<0.001	<0.001	2.87	0.005	<0.001	2.50	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	2.05	<0.001	0.055	<0.001	<0.001	<0.0001	<0.001	<0.001
658,101	MMT-WR08	Core Yard - BIF2	<0.001	<0.001	3.12	0.004	<0.001	1.78	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.005	2.54	<0.001	0.034	<0.001	<0.001	<0.0001	<0.001	<0.001
658,102	MMT-WR09	Core Yard - BIF3	<0.001	<0.001	4.82	<0.001	0.002	3.66	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	3.02	<0.001	0.011	<0.001	<0.001	<0.0001	<0.001	<0.001
666417	MMT-WR10	Composite WR	<0.001	<0.001	4.29	<0.001	<0.001	7.09	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.003	0.001	1.61	<0.001	0.045	<0.001	<0.001	<0.0001	0.003	<0.001
666417 QC	MMT-WR10	Composite WR	<0.001	<0.001	4.23	<0.001	<0.001	6.60	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	0.001	1.47	<0.001	0.043	<0.001	<0.001	<0.0001	0.003	<0.001

Lab ID	Sample ID	Description	U	V	W	Y	Zn	Zr	pH	pH Temp	TDS	EC	TDS by Sum	TDS by EC	P Alk.	M Alk.	F	Cl	NO_2	NO_3	NO_3 as N	SO_4	CN (Total)	Cr^{6+}	TSS
Unit			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	-	Deg C	mg/l	mS/m	mg/l	mg/l	mg/l CaCO3	mg/l CaCO3	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
SANS 241 (2015) Operational			N/A	N/A	N/A	N/A	N/A	N/A	5 - 9.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SANS 241 (2015) Aesthetic			N/A	N/A	N/A	N/A	5.0	N/A	N/A	N/A	1200	170	N/A	N/A	N/A	N/A	N/A	300	N/A	N/A	N/A	250	N/A	N/A	N/A
SANS 241 (2015) Acute Health			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.9	N/A	11	500	N/A	N/A	N/A
SANS 241 (2015) Chronic Health			0.03	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
WHO Standard for Drinking Water (2017)			0.03	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.5	5	N/A	N/A	50	N/A	N/A	N/A	N/A
IFC Mining Effluent (2007)			N/A	N/A	N/A	N/A	0.5	N/A	6 - 9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.0	0.1	50
PRODUCT																									
658,090	MMT-06	Top Cut	<0.0001	0.027	0.012	<0.001	0.013	<0.001	8.46	23.0	60.0	10.6	63.6	73.9	2.70	37.8	0.11	3.25	<0.2	4.42	1.00	3.83	<0.01	<0.05	179
658,091	MMT-07	Mamatwan Lumpy stockpile (M1L1)	<0.0001	<0.001	<0.001	<0.001	0.014	<0.001	8.71	23.0	50.0	8.53	49.5	59.7	3.90	40.0	<0.1	0.67	<0.2	1.07	0.24	3.64	<0.01	<0.05	48.0
658,092	MMT-08	Mamatwan High grade Sinter Stockpile (MHS)	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	8.86	23.2	48.0	9.24	48.4	64.7	4.60	38.8	<0.1	0.62	<0.2	1.35	0.30	3.80	<0.01	<0.05	149
658,093	MMT-09	Mamatwan Standard Sinter Stockpile (MSS)	<0.0001	0.004	0.003	<0.001	0.003	<0.001	11.42	23.2	270	47.5	303	332	177	214	0.11	0.66	<0.2	0.63	0.14	1.17	<0.01	<0.05	15.0
ADAMS PIT WASTE																									
658,086	MMT-AP01	Adams pit - Sinter de-dust	<0.0001	<0.001	0.004	<0.001	0.010	<0.001	12.18	22.5	1530	243	1641	1699	788	817	0.29	10.94	<0.2	1.37	0.31	534	<0.01	<0.05	24.0
658086 QC	MMT-AP01	Adams pit - Sinter de-dust	<0.0001	<0.001	0.004	<0.001	0.011	<0.001	12.18	22.7	1538	241	1646	1688	788	820	0.28	10.88	<0.2	1.35	0.30	540	<0.01	<0.05	24.0
658,087	MMT-AP02	Adams pit - DMS grit	<0.0001	<0.001	<0.001	<0.001	0.005	<0.001	9.22	22.8	24.0	6.07	39.2	42.5	6.10	28.6	<0.1	0.73	<0.2	1.65	0.37	2.71	<0.01	<0.05	78.5
658,088	MMT-AP03	Adams pit - Tailings (M2FT)	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	8.80	22.9	46.0	7.95	51.4	55.7	4.40	40.6	<0.1	0.91	<0.2	1.77	0.40	2.91	<0.01	<0.05	14.5
658,089	MMT-AP04	Slimes	<0.0001	<0.001	<0.001	<0.001	0.006	<0.001	8.78	23.0	62.0	12.4	70.9	86.7	4.50	39.5	0.22	4.30	<0.2	7.91	1.79	6.90	<0.01	<0.05	6.00
WASTE ROCK																									
658,094	MMT-WR01	Core Yard - Calcrete-top line	<0.0001	0.002	0.001	<0.001	0.004	<0.001	11.41	23.3	280	46.6	310	326	175	215	0.12	0.75	<0.2	0.75	0.17	6.58	<0.01	<0.05	121
658,095	MMT-WR02	Core Yard - Calcrete-middle line	<0.0001	0.004	0.020	<0.001	<0.001	<0.001	9.2	23.6	56.0	8.88	54	62.2	7.00	40.6	0.08	1.69	<0.2	2.54	0.57	2.16	<0.01	<0.05	22.5
658,096	MMT-WR03	Core Yard - Calcrete-bottom line	<0.0001	0.009	<0.001	<0.001	0.055	<0.001	8.94	25.0	52.0	8.63	50.7	60.4	5.30	42.2	0.15	0.92	<0.2	1.37	0.31	1.23	<0.01	<0.05	18.5
658096 QC	MMT-WR03	Core Yard - Calcrete-bottom line	<0.0001	0.009	<0.001	<0.001	<0.001	<0.001	8.91	25.1	46.0	8.82	52.2	61.7	6.50	40.7	0.13	0.96	<0.2	1.43	0.32	1.43	<0.01	<0.05	18.5
658,097	MMT-WR04	Core Yard - Pebble bed	<0.0001	0.011	0.003	<0.001	0.003	<0.001	8.91	25.2	50.0	7.49	45.7	52.4	5.90	35.6	0.11	0.87	<0.2	1.13	0.26	1.11	<0.01	<0.05	20.5
658,098	MMT-WR05	Core Yard - Clay	<0.0001	0.024	0.002	<0.001	<0.001	<0.001	8.87	25.4	40.0	7.53	43.8	52.7	5.00	32.8	0.13	1.25	<0.2	1.70	0.38	1.20	<0.01	<0.05	26.0
658,099	MMT-WR06	Core Yard - Clay transition	<0.0001	0.019	0.001	<0.001	<0.001	<0.001	8.90	25.5	48.0	8.14	45.1	57.0	5.00	32.4	0.25	2.03	<0.2	2.77	0.63	1.43	<0.01	<0.05	121
658,100	MMT-WR07	Core Yard - BIF1	<0.0001	<0.001	<0.001	<0.001	0.001	<0.001	8.97	25.4	42.0	6.97	42.3	48.8	4.90	33.4	<0.1	0.77	<0.2	0.66	0.15	1.70	<0.01	<0.05	405
658,101	MMT-WR08	Core Yard - BIF2	<0.0001	<0.001	<0.001	<0.001	0.001	<0.001	8.92	25.2	38.0	6.93	41.3	48.5	4.90	31.5	0.18	0.62	<0.2	0.76	0.17	1.08	<0.01	<0.05	208
658,102	MMT-WR09	Core Yard - BIF3	0.0001	0.002	<0.001	<0.001	0.003	<0.001	8.94	25.2	53.0	8.51	55.9	59.6	4.00	46.6	0.13	0.69	<0.2	0.92	0.21	1.15	<0.01	<0.05	141
666417	MMT-WR10	Composite WR	0.0003	0.021	0.008	<0.001	0.001	<0.001	8.99	22.9	60.0	9.05	62.3	63.4	5.30	37.4	0.19	1.77	<0.2	2.28	0.52	9.38	<0.01	<0.05	236
666417 QC	MMT-WR10	Composite WR	0.0003	0.021	0.008	<0.001	<0.001	<0.001	9.03	22.9	62.0	9.06	62.1	63.4	5.80	37.9	0.17	1.77	<0.2	2.30	0.52	10.0	<0.01	<0.05	236

8.3 WASTE CLASSIFICATION (SANS 10234)

The material in Adam's Pit and waste rock were classified in terms of SANS 10234 in Table 8-5 and Table 8-6.

Table 8-5: Material in Adam's Pit classification in terms of SANS 10234

Hazards	Evaluation	Hazard Classes & Categories
Physical Hazard	Not explosive, not flammable or oxidising and does not release toxic gases when in contact with water or acid.	Not hazardous: All streams
Health Hazard	The total concentration of carbon, calcium, iron, magnesium, manganese and silicon exceed 1% in the tailing's samples. The sinter de-dust also has aluminium above the 1% screening. Manganese is considered to be toxic and high levels of manganese exposure due to inhalation may lead to central nervous system effects (ATSDR, 1997). However, in the solid phase contained in the waste, the manganese is not considered to be hazardous to human health. Trace metals such as Cd, Ni, As and Cr (VI) have been recognized as human or animal carcinogens by IARC. However, the total concentrations of carcinogenic trace metals were <0.1% in the samples. Therefore, none of these elements constitute a health risk. The leachable concentration of boron in the sinter de-dust was found to be above the 1% threshold and can therefore be considered as a potential health hazard	Not Hazardous: Tailings (M2FT) Hazardous: Sinter de-dust
Environmental Hazard	The total content of carbon, calcium, iron, magnesium, manganese and silicon in the tailing's samples exceed the cut-off limit of 1%. However, the leachable concentrations of these elements do not exceed the 1% threshold for environmental hazard and are considered non-hazardous.	Not Hazardous: All streams

Table 8-6: Waste Rock classification in terms of SANS 10234

Hazards	Evaluation	Hazard Classes & Categories
Physical Hazard	Not explosive, not flammable or oxidising and does not release toxic gases when in contact with water or acid.	Not hazardous
Health Hazard	The total concentration of carbon, calcium, iron, aluminium, magnesium, manganese and silicon exceed 1% in the tailing's samples. Manganese and aluminium are considered to be toxic and high	Not Hazardous

Hazards	Evaluation	Hazard Classes & Categories
	levels of exposure due to inhalation may lead health effects (ATSDR, 1997). However, in the solid phase contained in the waste rock, the manganese and aluminium is not considered to be hazardous to human health. Trace metals such as Cd, Ni, As and Cr (VI) have been recognized as human or animal carcinogens by IARC. However, the total concentrations of carcinogenic trace metals were <0.1% in the samples. Therefore, none of these elements constitute a health risk.	
Environmental Hazard	The total content of carbon, calcium, iron, aluminium magnesium, manganese and silicon in the tailing's samples exceed the cut-off limit of 1%. However, the leachable concentrations of these elements do not exceed the 1% threshold for environmental hazard and are considered non-hazardous.	Not Hazardous

- The tailings (M2FT) and slimes materials stored in Adam's pit were found not to be hazardous;
- The sinter de-dust material is considered to be a hazardous waste in terms of health hazards. This is as a result of elevated concentrations of soluble boron in the material; and
- The waste rock material is not hazardous.

8.4 WASTE ASSESSMENT

8.4.1 Adam's Pit

The waste assessment for total and leachable concentrations for Adam's Pit is presented in Table 8-7 and Table 8-8. A summary of the waste type classification and associated liner requirements is presented in Table 8-9. A representation of the Class C GLB+ liner requirements are presented in Figure 8-4.

The results indicate the following:

- The sinter de-dust is classified as a Type 0 waste which cannot be disposed without treatment.
- The sinter de-dust classification is a result of total manganese concentrations above TCT2 and the leachable concentrations of boron, TDS and sulphate exceeding LCT0.
- The other materials stored on Adam's Pit (Slimes and Tailings (M2FT)) classify as a Type 0 waste based on the TC values. Section 7(6) stipulates that a waste where the leachable concentration levels are below or equal to the LCT0 limit the waste should be considered as a Type 3 waste **<u>irrespective of the total concentration</u>** of the elements. This section applies when the following provisions apply:
    - Chemical substance concentration levels are below the total limits for organics and pesticides;
    - The inherent physical and chemical character of the waste is stable and will not change over time; and
    - The waste is disposed of to a landfill without any other waste.

Based on the analytical results the sinter de-dust cannot be stored in its current state. The material will have to be treated and then reassessed to determine if it will comply with the requirements of a Type 3 waste. The tailings (M2FT) and slimes is assessed as a Type 3.

Table 8-7: Samples form Adam's Pit total concentration and screening

Elements	Unit	TCT0	TCT1	TCT2	MMT-AP01	MMT-AP03	MMT-AP04
					Sinter de-dust	MMT Tailings (M2FT)	Slimes
As	mg/kg	5.8	500	2000	13.0	9.14	9.95
B	mg/kg	150	15000	60000	976	888	865
Ba	mg/kg	62.5	6250	25000	6985	666	6642
Cd	mg/kg	7.5	260	1040	0.04	0.02	0.04
Co	mg/kg	50	5000	20000	52.1	52.8	64.5
Cr	mg/kg	46000	800000	N/A	20.0	8.01	107
Cu	mg/kg	16	19500	78000	5.58	2.84	25.8
Hg	mg/kg	0.93	160	640	0.04	0.10	0.12
Mn	mg/kg	1000	25000	100000	339204	312865	347074
Mo	mg/kg	40	1000	4000	9.22	10.3	17.8
Ni	mg/kg	91	10600	42400	19.8	13.4	46.6
Pb	mg/kg	20	1900	7600	4.66	3.37	2.02
Sb	mg/kg	10	75	300	0.38	0.25	0.40
Se	mg/kg	10	50	200	0.05	0.02	0.03
V	mg/kg	150	2680	10720	21.0	6.89	9.10
Zn	mg/kg	240	160000	640000	47.4	44.4	56.1
F	mg/kg	100	10000	40000	224	199	189
Cr6+	mg/kg	6.5	500	2000	<5	<5	<5
CN	mg/kg	14	10500	42000	<0.5	<0.5	<0.5

Table 8-8: Samples form Adam's Pit leachable concentration and screening

Elements	Unit	LCT0	LCT1	LCT2	LCT3	MMT-AP01	MMT-AP03	MMT-AP04
						Sinter de-dust	MMT Tailings (M2FT)	Slimes
As	mg/l	0.01	0.5	1	4	<0.001	<0.001	<0.001
B	mg/l	0.5	25	50	200	3.853	0.104	0.193
Ba	mg/l	0.7	35	70	280	0.216	0.040	0.348
Cd	mg/l	0.003	0.15	0.3	1.2	<0.0001	<0.0001	<0.0001
Co	mg/l	0.5	25	50	200	0.001	<0.001	<0.001
Cr	mg/l	0.1	5	10	40	0.007	<0.001	0.002
Cr 6+	mg/l	0.05	2.5	5	20	<0.05	<0.05	<0.05
Cu	mg/l	2.0	100	200	800	0.001	<0.001	<0.001
Hg	mg/l	0.006	0.3	0.6	2.4	0.0002	<0.0001	<0.0001
Mn	mg/l	0.5	25	50	200	0.002	<0.001	0.009
Mo	mg/l	0.07	3.5	7	28	0.007	<0.001	0.004
Ni	mg/l	0.07	3.5	7	28	0.020	<0.001	0.001
Pb	mg/l	0.01	0.5	1	4	0.006	<0.001	0.001
Sb	mg/l	0.02	1.0	2	8	<0.001	<0.001	<0.001
Se	mg/l	0.01	0.5	1	4	0.001	<0.001	0.001
V	mg/l	0.2	10	20	80	<0.001	<0.001	<0.001
Zn	mg/l	5.0	250	500	2000	0.010	<0.001	0.006
F	mg/l	1.5	75	150	600	0.29	<0.1	0.22
CN (Total)	mg/l	0.07	3.5	7	28	<0.01	<0.01	<0.01
TDS	mg/l	1000	12500	25000	100000	1530	46.0	62.0
Cl	mg/l	300	15000	30000	120000	10.94	0.91	4.30
NO3 as N	mg/l	11	550	1100	4400	0.31	0.40	1.79
SO4	mg/l	250	12500	25000	100000	534	2.91	6.90

Elements	Unit	LCT0	LCT1	LCT2	LCT3	MMT-AP01	MMT-AP03	MMT-AP04
						Sinter de-dust	MMT Tailings (M2FT)	Slimes
pH	-	-	-	-	-	12.2	8.80	8.78

Table 8-9: Waste type and associated liner requirement for waste from Adam's Pit

Sample ID	Description	TC	LC	Waste type	Liner required
MMT-AP01	Sinter de-dust	Type 0	Type 3	Type 0	Disposal not allowed
MMT-AP03	Tailings (M2FT)	Type 0	Type 4	Type 3	Class C GLB+
MMT-AP04	Slimes	Type 0	Type 4	Type 3	Class C GLB+

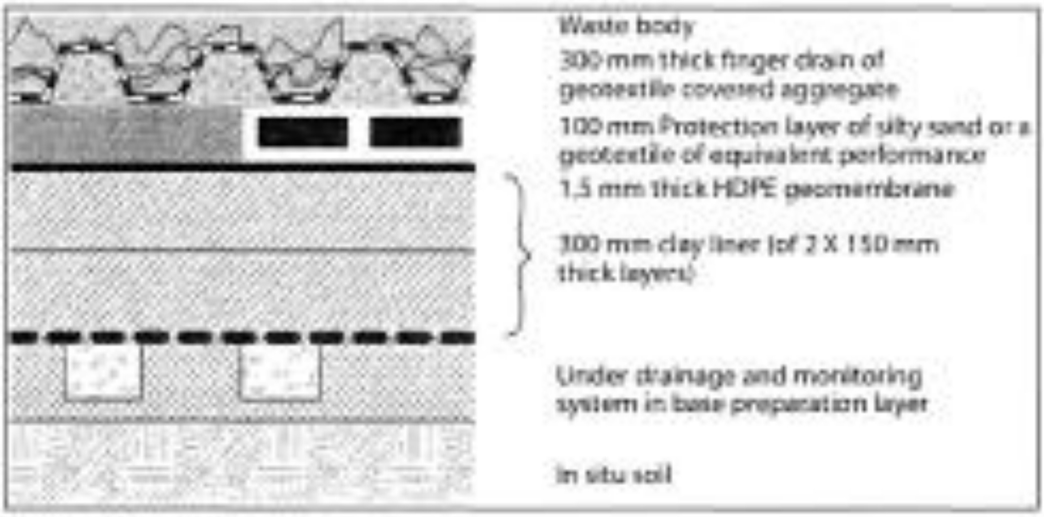

Figure 8-3: Representation of a Class C GLB- liner requirements

8.4.2 Waste Rock

The waste assessment for total and leachable concentrations for Adam's Pit is presented in Table 8-7 and Table 8-8 and in Table 8-10 and Table 8-11 for the waste rock. A summary of the waste type classification and associated liner requirements is presented in Table 8-9 and Table 8-10. Based on the results the lithology samples are assessed to be a Type 3 waste in terms of the total concentration and a Type 4 waste in terms of the leachable concentrations. The legislation does not specify the waste type for samples with these conditions:

- In accordance with GN. R. 635 of 2013, for a waste to be **Type 3**, results must meet the following criteria:
    - Leachable concentration of any elements above the LCT0 but below or equal to LCT1, and
    - Total concentrations of ALL elements below or equal to TCT1.
- In accordance with GN R.635 of 2013, for a waste to be **Type 4**, samples must meet the following criteria:
    - All LC must be below or equal to the 'Leachable Concentration Threshold' LCT0 limits; AND
    - All TC must be below or equal to the 'Total Concentrations Threshold' TCT0 limits.

For a waste to be a Type 3, *in addition* to the total concentrations being below TCT1, the leachable concentrations of elements need to be "*above the LCT0 but below or equal to LCT1*". In all the MMT lithology samples except for calcrete – top line (MMT-WR01) lithology, the leachable concentrations are below the LCT0. The calcrete-top line lithology makes up 17% of the composite waste rock sample. The leachable concentrations of the composite waste rock samples were below LCT0 for all the constituents assessed. Therefore, the addition of the calcrete-top line lithology to the waste rock does not result in leachable concentrations in excess of the LCT0 value.

Correspondence (3rd March 2016) from the DWS for a mine in the Northern Cape, provides clarity where a waste assessment is inconclusive between waste types. The DWS stated that "……..*the classification is based on the principle of assessing what is leachable and if it is leachable then what is the total concentration which will influence decisions on the total polluting period*". "*In the case of",* Northern Cape Mine, *"the leachable concentrations are reported to not exceed LCT0 values for any of the samples* and hence a Class D barrier of only stripping of topsoil and foundation preparation is the requirement….".

The DWS accepted a proposal by the Chamber of Mines of South Africa to follow a risk-based approach on a case-by-case basis to allow for representations on alternative barrier systems for Mine Residue Deposits and Stockpiles based on a risk assessment (29 June 2016). The risk assessment will enable an evaluation of the efficacy of the alternative barrier system to prevent pollution as required in terms of Section 19 (1) and (2) of the NEM:WA (Singh, 2016). Since the purpose of the Norms and Standards is to protect water resources it may be appropriate to consider the potential water quality risk associated with existing facilities, rather than retroactively applying the legislated liner requirements.

Based on the results presented above, SLR undertook a risk-based approach for protection of the quality of water resources for the MMT WRD. It follows that a Class D barrier is deemed sufficient for MMT WRD's for following reasons:

- The leachable concentrations of all the constituents are below the LCT0 limit which indicates a low seepage risk;
- The material will be placed dry and not contain wastewater;
- From the geochemical study conducted by SLR it was concluded that the materials are not PAG;
- A Class C liner is impractical for a WRD due to the possibility of failure; and
- A representation of the Class D GLB- liner requirements are presented in Figure 8-4.

The WRD's already exist at the MMT. It follows that this assessment was undertaken for completeness purposes in order to understand risk in order to manage the protection of water quality. It is understood from MMT that the current base preparations of the existing WRD's are in line with a Class D GLB-liner.

Table 8-10: Waste rock lithology samples total concentration and screening

Elements	Unit	TCT0	TCT1	TCT2	MMT-WR01	MMT-WR02	MMT-WR03	MMT-WR04	MMT-WR05	MMT-WR06	MMT-WR07	MMT-WR08	MMT-WR09	MMT-WR10
					Calcrete-top line	Calcrete-middle line	Calcrete-bottom line	Pebble bed	Clay	Clay transition	BIF1	BIF2	BIF3	Composite waste rock
As	mg/kg	5.8	500	2000	1.47	2.4	3.95	7.46	6.6	7.59	6.28	3.33	3.19	2.88
B	mg/kg	150	15000	60000	31.9	32.3	6.9	30.1	42.9	25.2	18.8	20	19.7	11.6
Ba	mg/kg	62.5	6250	25000	437	363	199	619	420	451	219	46.1	1723	463
Cd	mg/kg	7.5	260	1040	0.1	0.12	0.26	0.08	0.13	0.18	0.01	<0.01	0.04	0.06
Co	mg/kg	50	5000	20000	10.8	20.7	45.1	41.8	35.9	15.3	17.8	12	38.1	16.72
Cr	mg/kg	46000	800000	N/A	27.8	32.7	57.1	73.4	77.6	21.6	4.55	7.42	8.82	45.3
Cu	mg/kg	16	19500	78000	11.8	29.8	47.7	56.8	51.6	21.7	2.05	1.83	7.82	16.7
Hg	mg/kg	0.93	160	640	<0.01	<0.01	<0.01	<0.01	0.02	0.02	0.01	0.06	0.01	0.03
Mn	mg/kg	1000	25000	100000	1836	1046	1005	2726	3120	3469	21147	10411	77829	12496
Mo	mg/kg	40	1000	4000	0.24	0.32	0.54	0.69	0.66	0.73	0.88	0.6	3.81	0.97
Ni	mg/kg	91	10600	42400	13.4	28.5	42.7	60.3	47.8	19.7	6.4	8.19	11	18.0
Pb	mg/kg	20	1900	7600	3.87	8.39	16	14.3	12.3	6.28	1.07	0.89	4.42	5.05
Sb	mg/kg	10	75	300	0.15	0.21	0.34	0.38	0.31	0.23	0.07	0.13	0.08	0.174
Se	mg/kg	10	50	200	0.05	0.07	0.12	0.27	0.51	0.09	0.04	0.13	0.03	0.283
V	mg/kg	150	2680	10720	35.6	71.9	165	242	169	138	5.29	6.34	58.6	58.1
Zn	mg/kg	240	160000	640000	16.4	29.7	54.5	51.1	53.2	22.7	11.8	10.9	18.3	17.6
F	mg/kg	100	10000	40000	243	282	464	448	642	427	272	365	364	307
Cr^{6+}	mg/kg	6.5	500	2000	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
CN	mg/kg	14	10500	42000	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

Table 8-11: Waste rock lithology samples leachable concentration and screening

Elements	Unit	LCT0	LCT1	LCT2	LCT3	MMT-WR01 Calcrete-top line	MMT-WR02 Calcrete-middle line	MMT-WR03 Calcrete-bottom line	MMT-WR04 Pebble bed	MMT-WR05 Clay	MMT-WR06 Clay transition	MMT-WR07 BIF1	MMT-WR08 BIF2	MMT-WR09 BIF3	MMT-WR10 Composite waste rock
As	mg/l	0.01	0.5	1	4	0.001	0.001	0.001	<0.001	0.002	0.001	0.001	<0.001	<0.001	<0.001
B	mg/l	0.5	25	50	200	1.466	0.058	0.029	0.022	0.021	0.028	0.022	0.035	0.022	0.0413
Ba	mg/l	0.7	35	70	280	1.563	0.188	0.074	0.059	0.056	0.066	0.23	0.051	0.034	0.193
Cd	mg/l	0.003	0.15	0.3	1.2	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Co	mg/l	0.5	25	50	200	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cr	mg/l	0.1	5	10	40	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00112
Cr^{6+}	mg/l	0.05	2.5	5	20	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cu	mg/l	2	100	200	800	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00467
Hg	mg/l	0.006	0.3	0.6	2.4	<0.0001	0.0007	<0.0001	0.0002	0.0001	0.0001	0.0001	<0.0001	<0.0001	<0.0001
Mn	mg/l	0.5	25	50	200	<0.001	0.005	<0.001	<0.001	<0.001	<0.001	0.005	0.004	<0.001	<0.001
Mo	mg/l	0.07	3.5	7	28	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.002	<0.001
Ni	mg/l	0.07	3.5	7	28	0.004	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Pb	mg/l	0.01	0.5	1	4	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sb	mg/l	0.02	1	2	8	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Se	mg/l	0.01	0.5	1	4	<0.001	<0.001	<0.001	0.002	<0.001	0.001	<0.001	0.005	<0.001	0.00123
V	mg/l	0.2	10	20	80	0.002	0.004	0.009	0.011	0.024	0.019	<0.001	<0.001	0.002	0.0209
Zn	mg/l	5	250	500	2000	0.004	<0.001	0.055	0.003	<0.001	<0.001	0.001	0.001	0.003	0.001
F	mg/l	1.5	75	150	600	0.12	0.08	0.15	0.11	0.13	0.25	<0.1	0.18	0.13	0.19
CN (Total)	mg/l	0.07	3.5	7	28	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TDS	mg/l	1000	12500	25000	100000	280	56	52	50	40	48	42	38	53	63.35
Cl	mg/l	300	15000	30000	120000	0.75	1.69	0.92	0.87	1.25	2.03	0.77	0.62	0.69	1.77
NO_3 as N	mg/l	11	550	1100	4400	0.17	0.57	0.31	0.26	0.38	0.63	0.15	0.17	0.21	0.515
SO_4	mg/l	250	12500	25000	100000	6.58	2.16	1.23	1.11	1.2	1.43	1.7	1.08	1.15	9.38
pH	-	-	-	-	-	11.4	9.2	8.94	8.91	8.87	8.9	8.97	8.92	8.94	8.99

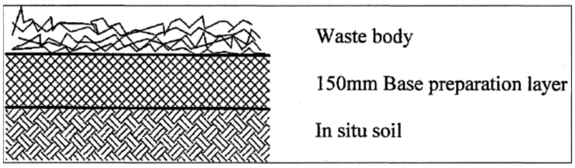

Figure 8-4: Representation of a Class D GLB- liner requirements

8.5 GEOCHEMICAL MODELLING RESULTS

8.5.1 Waste Rock Source Concentration

Four models were prepared:

- A laboratory prepared composite sample was analysed, and the result was used in the model to determine the solution quality at field capacity;
- The laboratory determined leach quality of each lithology determined separately was mixed first in the model and then the solution quality at field capacity was determined; and
- The third model was the lithology with the highest concentrations in the laboratory determined leach quality.
- The fourth option modelled top cut product and waste rock composite as per client ratio information (1:2.93) to predict field capacity leachate concentrations for the Central WRD.

The results for the four simulations are presented in Table 8-12.

The results indicate values above drinking water quality guidelines for aluminium, barium, boron, fluoride, nitrate and pH. These results can be used as inputs for the groundwater modelling.

The geochemistry study conducted by GHT (2018) indicated the waste rock is a source of calcium, magnesium bicarbonate, manganese, boron and fluoride. Of these parameters only boron has been identified as a potential constituent of concern in the groundwater quality data. Only the modelled boron concentration exceeded the groundwater quality guideline value (500µg/L).

Nitrate modelled results were not presented in the GHT 2018 report but is shown to exceed the guideline values based on the current modelling results. The current results are consistent with what was previously found.

Table 8-12: Waste rock model results

Constituent	Unit	SANS 241:2015	DWAF TWQG	MMT-WR10 Laboratory Composite	MMT-WR10 WRD mix PhREEQC estimate	MMT-WR01 (Worst Sample)	Top cut: WR Comp MMT-06: MMT-WR10 25,5% : 74,5%
pH	pH Unit	5 - 9.7	N/A	7,45	6,89	12,22	9,22
Al	mg/l	0.3	5	0,12	0,61	0,27	0,01
B	mg/l	2.4	5	0,34	2,24	11,94	0,02
Ba	mg/l	0.7	N/A	1,58	2,76	12,72	0,10
Alkalinity	mg/l as $CaCO_3$	N/A	N/A	220,09	360,85	0,47	18,77
Ca	mg/l	N/A	1000	69,01	128,97	798,35	7,18
Cl	mg/l	300	1500	14,40	8,15	6,11	1,14
F	mg/l	1.5	2	1,55	1,08	0,98	0,09
Fe	mg/l	2	10	0,00	0,00	0,03	0,00
K	mg/l	N/A	N/A	9,71	8,67	8,33	0,81
Mg	mg/l	N/A	500	2,85	5,15	0,96	0,28
Mn	mg/l	0.4	10	0,00	0,01	0,00	0,00
NO_3 as N	mg/l	11	22	18,55	10,58	6,10	6,67
Na	mg/l	200	2000	57,73	23,70	11,02	3,75
Ni	mg/l	0.07	1	0,00	0,01	0,03	0,00
SO_4	mg/l	500	1000	76,33	18,26	53,56	4,25
Si	mg/l	N/A	N/A	6,13	17,36	65,61	0,47
Sr	mg/l	N/A	N/A	0,37	0,47	1,63	0,02
V	mg/l	N/A	1	0,17	0,06	0,02	0,01
W	mg/l	N/A	N/A	0,06	0,02	0,01	0,00
Zn	mg/l	5	20	0,01	0,06	0,03	0,00
TDS	mg/l	1200	N/A	468,67	564,34	884,90	42,85

8.5.2 Adam's Pit Source Concentration

Adam's Pit contains a number of different waste types. In this regard, a source term was prepared taking the following proportions into consideration:

- Tailings (M2FT) – 86%
- Slimes - 6%
- Sinter de-dust – 3%
- DMS grit – 5%

The modelled results (Table 8-13) indicate the possibility of above threshold leachate concentrations for manganese and lead.

Table 8-13: Modelling results for the stockpile in Adam's Pit

Constituent	Unit	SANS 241:2015	DWAF TWQG	Adam's Pit Stockpile Mix
pH	pH Unit	5 - 9.7	N/A	7,89
Al	mg/l	0.3	5	0,19
B	mg/l	2.4	5	1,63
Ba	mg/l	0.7	N/A	0,50
Alkalinity	mg/l as CaCO3	N/A	N/A	87,01
Ca	mg/l	N/A	1000	43,60
Cl	mg/l	300	1500	10,37
Cr	mg/l	0.05	1	0,00
F	mg/l	1.5	2	0,50
Fe	mg/l	2	10	0,00
K	mg/l	N/A	N/A	5,44
Mg	mg/l	N/A	500	30,28
Mn	mg/l	0.4	10	0,62
Mo	mg/l	N/A	0.01	0,01
NO3 (as N)	mg/l	11	22	15,65
Na	mg/l	200	2000	11,64
Ni	mg/l	0.07	1	0,01
Pb	mg/l	0.01	0.1	0,01
Rb	mg/l	N/A	N/A	0,01
SO4	mg/l	500	1000	141,01
Si	mg/l	N/A	N/A	6,17
Sr	mg/l	N/A	N/A	0,39
V	mg/l	N/A	1	0,00
W	mg/l	N/A	N/A	0,00
Zn	mg/l	5	20	0,01

9. CONCLUSION

Acid rock drainage and geochemical investigation

Due to a low sulphide and high neutralisation potential of samples they are all **classified as non-PAG**. The dominant phases in the samples in Adam's Pit are manganese and carbonates rich minerals. In the samples representing waste rock material quartz and carbonate rich minerals are the dominant phases. The BIF samples also have hematite as a dominant phase. The high concentration of carbonates confirms the high NP of the material.

Metal leaching potential

The main CoCs identified in the product samples were Ba, pH and TSS in the MMT standard sinter stockpile (MSS) and pH in the DMS grit located in Adam's Pit. The main CoCs identified in the Adam's Pit Sinter de-dust waste samples were B, pH, TDS, EC, Cl and SO_4. No leachable CoCs were identified in the tailings (M2FT) or slimes samples. Constituents of concern were identified in three (3) waste rock lithologies, Ba, pH and TSS in calcrete-top line (MT-WR01), Al, Fe, pH and TSS in calcrete-middle line (MMT-WR02) and TSS in the clay transition lithology (MMT-WR06).

Waste Classification

The tailings (M2FT) and slimes materials stored in Adam's pit were found to be not hazardous. The sinter de-dust material is considered to be a hazardous waste in terms of health hazards. This is as a result of elevated concentrations of soluble boron in the material. The waste rock material is not hazardous.

Waste Assessment – Adam's Pit

- The sinter de-dust is classified as a type 0 waste which cannot be disposed without treatment.
- The sinter de-dust classification is a result of total manganese concentrations above TCT2 and the leachable concentrations of boron, TDS and sulphate exceeding LCT0.
- The other materials stored on Adam's Pit (slimes and tailings (M2FT)) classify as a type 0 waste based on the TC values. Section 7(6) stipulates that a waste where the leachable concentration levels are below or equal to the LCT0 limit the waste should be considered as a Type 3 waste **irrespective of the total concentration** of the elements.
- Based on the analytical results the sinter de-dust cannot be stored in its current state. The material will have to be treated and then reassessed to determine if it complies with the classification as a Type 3 waste.
- The tailings (M2FT) and slimes is assessed as a Type 3.

Waste Assessment – Waste Rock

Based on the results the lithology samples are assessed to be a Type 3 waste in terms of the total concentration and a Type 4 waste in terms of the leachable concentrations. Based on the results, SLR undertook a risk-based approach for protection of the quality of water resources for the MMT WRD. It follows that a Class D barrier is deemed sufficient for MMT WRD's for the following reasons:

- The leachable concentrations of all the constituents are below the LCT0 limit which indicates a low seepage risk;
- The material will be placed dry and not contain wastewater;
- From the geochemical study conducted by SLR it was concluded that the materials are not PAG; and
- A Class C liner is impractical for a WRD due to the possibility of failure.

The WRD's already exist at the MMT. If follows that this assessment was undertaken for completeness purposes in order to understand risk in order to manage the protection of water quality. It is understood from MMT that the current base preparations of the existing WRD's are in line with a Class D GLB-liner.

Geochemical Modelling

Source concentrations were predicted for the waste rock, top cut/waste rock and Adam's Pit Stockpiles. These results can be used as input to the groundwater modelling and risk evaluation.

For the three different waste rock models the results indicate values above drinking water quality guidelines for aluminium, boron, barium, fluoride and nitrate. The top cut and waste rock mix model indicated no CoCs for the central WRD.

Adam's Pit contains several different waste types. These include DMS grit, slimes, Sinter de-dust, plant spillages and tailings (M2FT). A source terms model was developed for Adam's pit using the following proportions:

- Tailings (M2FT) – 86%
- Slimes - 6%
- Sinter de-dust – 3%
- DMS grit – 5%

The modelled results for the Adam's pit mixture predicted elevated manganese and lead leachate concentrations under current field conditions.

Results of the source term assessment should not be evaluated in isolation but together with groundwater modelling and assessment. The complete source, pathway and receptor should be considered in evaluating the potential risks.

Carl Steyn
(Report Author)

Natasha Smyth
(Project Manager)

Rob Hounsome
(Reviewer)

10.REFERENCES

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Appendix A: Curriculum Vitae

Appendix B: Photo log

Appendix C: ANALYTICAL CERTIFICATES

ANALYTICAL REPORT: Water Leach

To: SLR Consulting Africa (Pty) Ltd
Attention: Michele Papenfus
Project ID:
Site Location:
Order No:

Date of Request :23.08.2019

UIS Analytical Services
Analytical Chemistry
Laboratories 4, 6

Fax: (012) 665 4294

analytical services

Certificate of analysis: 28764

Note: all results in parts per million (ppm) unless specified otherwise

Lims ID	Sample ID	Ag	Al	As	Au	B	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr	Cs	Cu
	WATER LEACH 1:20	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
	Leach Blank	<0.001	<0.001	<0.001	<0.001	<0.001	0.009	<0.001	<0.001	0.04	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001
658 086	MMT-AP01/WATER/LEACH	<0.001	0.054	<0.001	<0.001	3.853	0.216	<0.001	<0.001	577	<0.0001	<0.001	0.001	0.007	<0.001	0.001
658086 QC	Duplicate	<0.001	0.054	<0.001	<0.001	3.824	0.221	<0.001	<0.001	575	<0.0001	<0.001	0.001	0.007	<0.001	<0.001
658 087	MMT-AP02/WATER/LEACH	<0.001	0.035	<0.001	<0.001	0.090	0.121	<0.001	<0.001	8.23	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001
658 088	MMT-AP03/WATER/LEACH	<0.001	0.025	<0.001	<0.001	0.104	0.040	<0.001	<0.001	10.4	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001
658 089	MMT-AP04/WATER/LEACH	<0.001	0.015	<0.001	<0.001	0.193	0.348	<0.001	<0.001	11.4	<0.0001	<0.001	<0.001	0.002	<0.001	<0.001
658 090	MMT-06/WATER/LEACH	<0.001	0.024	0.002	<0.001	0.053	0.192	<0.001	<0.001	7.72	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001
658 091	MMT-07/WATER/LEACH	<0.001	0.023	<0.001	<0.001	0.060	0.115	<0.001	<0.001	10.5	<0.0001	<0.001	<0.001	<0.001	<0.001	0.001
658 092	MMT-08/WATER/LEACH	<0.001	0.019	<0.001	<0.001	0.052	0.424	<0.001	<0.001	9.49	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001
658 093	MMT-09/WATER/LEACH	<0.001	0.038	0.003	<0.001	1.333	0.904	<0.001	<0.001	92.6	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001
658 094	MMT-WR01/WATER/LEACH	<0.001	0.033	0.001	<0.001	1.466	1.563	<0.001	<0.001	120	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001
658 095	MMT-WR02/WATER/LEACH	<0.001	0.625	0.001	<0.001	0.058	0.188	<0.001	<0.001	8.42	<0.0001	<0.001	<0.001	<0.001	<0.001	0.001
658 096	MMT-WR03/WATER/LEACH	<0.001	0.026	0.001	<0.001	0.029	0.074	<0.001	<0.001	7.91	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001
658096 QC	Duplicate	<0.001	0.028	0.001	<0.001	0.027	0.074	<0.001	<0.001	8.00	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001
658 097	MMT-WR04/WATER/LEACH	<0.001	0.007	<0.001	<0.001	0.022	0.059	<0.001	<0.001	7.64	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001
658 098	MMT-WR05/WATER/LEACH	<0.001	0.016	0.002	<0.001	0.021	0.056	<0.001	<0.001	6.79	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001
658 099	MMT-WR06/WATER/LEACH	<0.001	0.008	0.001	<0.001	0.028	0.066	<0.001	<0.001	7.11	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001
658 100	MMT-WR07/WATER/LEACH	<0.001	0.020	0.001	<0.001	0.022	0.230	<0.001	<0.001	7.28	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001
658 101	MMT-WR08/WATER/LEACH	<0.001	0.029	<0.001	<0.001	0.035	0.051	<0.001	<0.001	7.54	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001
658 102	MMT-WR09/WATER/LEACH	<0.001	0.007	<0.001	<0.001	0.022	0.034	<0.001	<0.001	7.30	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001
666417	MMT-WR01/02/03/04/05/06/07/08/09/WATER/LEACH	<0.001	0.014	0.001	<0.001	0.041	0.193	<0.001	<0.001	8.93	<0.0001	<0.001	<0.001	0.001	<0.001	0.005
666417 QC	Duplicate	<0.001	0.014	<0.001	<0.001	0.039	0.194	<0.001	<0.001	8.80	<0.0001	<0.001	<0.001	<0.001	<0.001	0.004

Lims ID	Sample ID	Fe	Ga	Ge	Hf	Hg	Ho	Ir	K	La	Li	Mg	Mn	Mo	Na	Nb
	WATER LEACH 1:20	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
	Leach Blank	0.005	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	0.11	<0.001	<0.001	0.003	<0.001	<0.001	0.03	<0.001
658 086	MMT-AP01/WATER/LEACH	0.004	<0.001	<0.001	<0.001	0.0002	<0.001	<0.001	11.9	<0.001	0.002	0.05	0.002	0.007	5.23	<0.001
658086 QC	Duplicate	0.009	<0.001	<0.001	<0.001	0.0002	<0.001	<0.001	11.8	<0.001	0.001	0.05	0.001	0.007	5.28	<0.001
658 087	MMT-AP02/WATER/LEACH	0.005	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	0.26	<0.001	<0.001	2.80	<0.001	<0.001	1.12	<0.001
658 088	MMT-AP03/WATER/LEACH	0.002	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	0.40	<0.001	<0.001	4.14	<0.001	<0.001	1.40	<0.001
658 089	MMT-AP04/WATER/LEACH	0.002	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	0.38	<0.001	<0.001	6.71	0.009	0.004	2.68	<0.001
658 090	MMT-06/WATER/LEACH	0.022	<0.001	<0.001	<0.001	0.0005	<0.001	<0.001	2.48	<0.001	0.001	4.70	0.002	<0.001	6.82	<0.001
658 091	MMT-07/WATER/LEACH	0.004	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	0.32	<0.001	0.001	3.66	0.005	<0.001	1.55	<0.001
658 092	MMT-08/WATER/LEACH	0.003	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	0.36	<0.001	<0.001	4.98	<0.001	<0.001	1.33	<0.001
658 093	MMT-09/WATER/LEACH	0.007	<0.001	<0.001	<0.001	0.0001	<0.001	<0.001	0.46	<0.001	<0.001	0.14	<0.001	<0.001	1.06	<0.001
658 094	MMT-WR01/WATER/LEACH	0.004	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	1.02	<0.001	<0.001	0.12	<0.001	<0.001	1.35	<0.001
658 095	MMT-WR02/WATER/LEACH	0.541	<0.001	<0.001	<0.001	0.0007	<0.001	<0.001	1.72	<0.001	<0.001	5.00	0.005	<0.001	2.55	<0.001
658 096	MMT-WR03/WATER/LEACH	0.024	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	1.55	<0.001	<0.001	4.18	<0.001	<0.001	5.04	<0.001
658096 QC	Duplicate	0.023	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	1.51	<0.001	<0.001	4.16	<0.001	<0.001	4.96	<0.001
658 097	MMT-WR04/WATER/LEACH	0.004	<0.001	<0.001	<0.001	0.0002	<0.001	<0.001	1.03	<0.001	<0.001	4.31	<0.001	<0.001	2.85	<0.001
658 098	MMT-WR05/WATER/LEACH	0.008	<0.001	<0.001	<0.001	0.0001	<0.001	<0.001	1.48	<0.001	<0.001	3.57	<0.001	<0.001	3.77	<0.001
658 099	MMT-WR06/WATER/LEACH	0.005	<0.001	<0.001	<0.001	0.0001	<0.001	<0.001	0.90	<0.001	<0.001	4.25	<0.001	0.001	3.49	<0.001
658 100	MMT-WR07/WATER/LEACH	0.002	<0.001	<0.001	<0.001	0.0001	<0.001	<0.001	0.54	<0.001	<0.001	2.87	0.005	<0.001	2.50	<0.001
658 101	MMT-WR08/WATER/LEACH	0.007	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	0.31	<0.001	<0.001	3.12	0.004	<0.001	1.78	<0.001
658 102	MMT-WR09/WATER/LEACH	0.003	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	1.03	<0.001	<0.001	4.82	<0.001	0.002	3.66	<0.001
666417	MMT-WR01/02/03/04/05/06/07/08/09/WATER/LEACH	0.024	<0.001	<0.001	<0.001	0.0001	<0.001	<0.001	1.19	<0.001	<0.001	4.29	<0.001	<0.001	7.09	<0.001
666417 QC	Duplicate	0.026	<0.001	<0.001	<0.001	0.0001	<0.001	<0.001	1.17	<0.001	<0.001	4.23	<0.001	<0.001	6.60	<0.001

Lims ID	Sample ID	pH	pH Temp	TDS	EC	TDS by Sum	TDS by EC	P Alk.	M Alk.	F	Cl	NO2	NO3
	WATER LEACH 1:20		Deg C	mg/l	mS/m	mg/l	mg/l	mg/l CaCO3	mg/l CaCO3	mg/l	mg/l	mg/l	mg/l
	Leach Blank	6.48	22.7	<30	1.14	n/a	7.98	<0.6	6.70	<0.1	<0.25	<0.2	<0.3
658086	MMT-AP01/WATER/LEACH	12.2	22.5	1530	243	1641	1699	788	817	0.29	10.94	<0.2	1.37
658086 QC	Duplicate	12.2	22.7	1538	241	1646	1688	788	820	0.28	10.88	<0.2	1.35
658087	MMT-AP02/WATER/LEACH	9.22	22.8	24.0	6.07	39.2	42.5	6.10	28.6	<0.1	0.73	<0.2	1.65
658088	MMT-AP03/WATER/LEACH	8.80	22.9	46.0	7.95	51.4	55.7	4.40	40.6	<0.1	0.91	<0.2	1.77
658089	MMT-AP04/WATER/LEACH	8.78	23.0	62.0	12.4	70.9	86.7	4.50	39.5	0.22	4.30	<0.2	7.91
658090	MMT-06/WATER/LEACH	8.46	23.0	60.0	10.6	63.6	73.9	2.70	37.8	0.11	3.25	<0.2	4.42
658091	MMT-07/WATER/LEACH	8.71	23.0	50.0	8.53	49.5	59.7	3.90	40.0	<0.1	0.67	<0.2	1.07
658092	MMT-08/WATER/LEACH	8.86	23.2	48.0	9.24	48.4	64.7	4.60	38.8	<0.1	0.62	<0.2	1.35
658093	MMT-09/WATER/LEACH	11.4	23.2	270	47.5	303	332	177	214	0.11	0.66	<0.2	0.63
658094	MMT-WR01/WATER/LEACH	11.4	23.3	280	46.6	310	326	175	215	0.12	0.75	<0.2	0.75
658095	MMT-WR02/WATER/LEACH	9.20	23.6	56.0	8.88	54	62.2	7.00	40.6	0.08	1.69	<0.2	2.54
658096	MMT-WR03/WATER/LEACH	8.94	25.0	52.0	8.63	50.7	60.4	5.30	42.2	0.15	0.92	<0.2	1.37
658096 QC	Duplicate	8.91	25.1	46.0	8.82	52.2	61.7	6.50	40.7	0.13	0.96	<0.2	1.43
658097	MMT-WR04/WATER/LEACH	8.91	25.2	50.0	7.49	45.7	52.4	5.90	35.6	0.11	0.87	<0.2	1.13
658098	MMT-WR05/WATER/LEACH	8.87	25.4	40.0	7.53	43.8	52.7	5.00	32.8	0.13	1.25	<0.2	1.70
658099	MMT-WR06/WATER/LEACH	8.90	25.5	48.0	8.14	45.1	57.0	5.00	32.4	0.25	2.03	<0.2	2.77
658100	MMT-WR07/WATER/LEACH	8.97	25.4	42.0	6.97	42.3	48.8	4.90	33.4	<0.1	0.77	<0.2	0.66
658101	MMT-WR08/WATER/LEACH	8.92	25.2	38.0	6.93	41.3	48.5	4.90	31.5	0.18	0.62	<0.2	0.76
658102	MMT-WR09/WATER/LEACH	8.94	25.2	53.0	8.51	55.9	59.6	4.00	46.6	0.13	0.69	<0.2	0.92
666417	MMT-WR01/02/03/04/05/06/07/08/09/WATER/LEACH	8.99	22.9	60.0	9.05	62.3	63.4	5.30	37.4	0.19	1.77	<0.2	2.28
666417 QC	Duplicate	9.03	22.9	62.0	9.06	62.1	63.4	5.80	37.9	0.17	1.77	<0.2	2.30

Lims ID	Sample ID	NO3 as N	PO4	SO4	Sum of Cations	Sum of Anions	Ion Balance	NH4	NH3	Acidity to pH8.3	CN (free)	CN (Total)	Cr 6+	TSS	TOC
	WATER LEACH 1:20	mg/l	mg/l	mg/l	me/l	me/l	%	mg/l	mg/l	mg/l CaCO3	mg/l	mg/l	mg/l	mg/l	mg/l
	Leach Blank	<0.1		0.30	n/a	n/a	n/a					<0.01	<0.05	-1.50	
658086	MMT-AP01/WATER/LEACH	0.31		534	29.7	25.2	8.3					<0.01	<0.05	24.0	
658086 QC	Duplicate	0.30		540	29.6	25.4	7.7					<0.01	<0.05	24.0	
658087	MMT-AP02/WATER/LEACH	0.37		2.71	0.7	0.7	1.2					<0.01	<0.05	78.5	
658088	MMT-AP03/WATER/LEACH	0.40		2.91	0.9	0.9	1.2					<0.01	<0.05	14.5	
658089	MMT-AP04/WATER/LEACH	1.79		6.90	1.3	1.2	2.2					<0.01	<0.05	6.00	
658090	MMT-06/WATER/LEACH	1.00		3.83	1.1	1.1	3.5					<0.01	<0.05	179	
658091	MMT-07/WATER/LEACH	0.24		3.64	0.9	0.9	1.8					<0.01	<0.05	48.0	
658092	MMT-08/WATER/LEACH	0.30		3.80	1.0	0.8	7.0					<0.01	<0.05	149	
658093	MMT-09/WATER/LEACH	0.14		1.17	4.8	5.6	-7.3					<0.01	<0.05	15.0	
658094	MMT-WR01/WATER/LEACH	0.17		6.58	6.3	5.0	11.3					<0.01	<0.05	121	
658095	MMT-WR02/WATER/LEACH	0.57		2.16	1.1	0.9	7.7					<0.01	<0.05	22.5	
658096	MMT-WR03/WATER/LEACH	0.31		1.23	1.0	0.9	8.0					<0.01	<0.05	18.5	
658096 QC	Duplicate	0.32		1.43	1.0	0.9	5.7					<0.01	<0.05	18.5	
658097	MMT-WR04/WATER/LEACH	0.26		1.11	0.9	0.8	5.3					<0.01	<0.05	20.5	
658098	MMT-WR05/WATER/LEACH	0.38		1.20	0.8	0.7	5.9					<0.01	<0.05	26.0	
658099	MMT-WR06/WATER/LEACH	0.63		1.43	0.9	0.8	6.8					<0.01	<0.05	121	
658100	MMT-WR07/WATER/LEACH	0.15		1.70	0.7	0.8	-2.8					<0.01	<0.05	405	
658101	MMT-WR08/WATER/LEACH	0.17		1.08	0.7	0.8	-2.7					<0.01	<0.05	208	
658102	MMT-WR09/WATER/LEACH	0.21		1.15	1.0	1.1	-5.3					<0.01	<0.05	141	
666417	MMT-WR01/02/03/04/05/06/07/08/09/WATER/LEACH	0.52		9.38	1.15	1.03	5.4					<0.01	<0.05	236	
666417 QC	Duplicate	0.52		10.0	1.12	1.04	3.5					<0.01	<0.05	236	

Chemical elements: Ag, Al, As, Au, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Fe, Ga, Ge, Hf, Hg, Ho, Ir, K, La, Li, Mg, Mn, Mo, Na, Nb, Nd, Ni, Pb, Pt, Rb, Sb, Sc, Se, Si, Sn, Sr, Ta, Te, Th, Ti, Tl, U, V, W, Y, Zn, Zr — Anions, pH, NH4, Alkalinity, CN, Cr6+

Instrument: ICP-MS Perkin Elmer NexION 300D — Ion Chromatography — Spectrophotometer — Ion Selective Probe

Date: 18.09.2019
Analysed by: UIS Waterlab/MA Motsepe

Date: 10.11.2019
Authorised : JJ Oberholzer

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SLR

UIS analytical services

To: SLR Consulting Africa (Pty) Ltd
Attention: Michele Papenfus
Project ID:
Site Location:
Order No:

Lims ID	Sample ID	Nd	Ni	Pb	Pt	Rb	Sb	Sc	Se	Si	Sn	Sr
	WATER LEACH 1:20	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
	Leach Blank	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.09	<0.001	<0.001
658 086	MMT-AP01/WATER/LEACH	<0.001	0.020	0.006	<0.001	0.029	<0.001	<0.001	0.001	1.52	<0.001	1.192
658086 QC	Duplicate	<0.001	0.020	0.006	<0.001	0.028	<0.001	<0.001	0.001	1.54	<0.001	1.125
658 087	MMT-AP02/WATER/LEACH	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	1.56	<0.001	0.022
658 088	MMT-AP03/WATER/LEACH	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	1.78	<0.001	0.015
658 089	MMT-AP04/WATER/LEACH	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.001	2.22	<0.001	0.045
658 090	MMT-06/WATER/LEACH	<0.001	0.001	0.003	<0.001	<0.001	<0.001	0.002	<0.001	2.65	<0.001	0.031
658 091	MMT-07/WATER/LEACH	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	1.39	<0.001	0.042
658 092	MMT-08/WATER/LEACH	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.97	<0.001	0.038
658 093	MMT-09/WATER/LEACH	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	0.005	<0.001	27.5	<0.001	0.137
658 094	MMT-WR01/WATER/LEACH	<0.001	0.004	<0.001	<0.001	0.002	<0.001	0.003	<0.001	17.2	<0.001	0.201
658 095	MMT-WR02/WATER/LEACH	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.003	<0.001	1.6	<0.001	0.035
658 096	MMT-WR03/WATER/LEACH	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	1.0	<0.001	0.026
658096 QC	Duplicate	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	1.8	<0.001	0.026
658 097	MMT-WR04/WATER/LEACH	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.002	1.9	<0.001	0.025
658 098	MMT-WR05/WATER/LEACH	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	1.50	<0.001	0.023
658 099	MMT-WR06/WATER/LEACH	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	1.22	<0.001	0.023
658 100	MMT-WR07/WATER/LEACH	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	2.05	<0.001	0.055
658 101	MMT-WR08/WATER/LEACH	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.005	2.54	<0.001	0.034
658 102	MMT-WR09/WATER/LEACH	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	3.02	<0.001	0.011
666417	MMT-WR01/02/03/04/05/06/07/08/09/WATER/LEACH	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.003	0.001	1.61	<0.001	0.045
666417 QC	Duplicate	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	0.001	1.47	<0.001	0.043

Lims ID	Sample ID	Ta	Te	Th	Ti	Tl	U	V	W	Y	Zn	Zr
	WATER LEACH 1:20	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
	Leach Blank	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001
658 086	MMT-AP01/WATER/LEACH	<0.001	<0.001	<0.0001	0.005	<0.001	<0.0001	<0.001	0.004	<0.001	0.010	<0.001
658086 QC	Duplicate	<0.001	<0.001	<0.0001	0.004	<0.001	<0.0001	<0.001	0.004	<0.001	0.011	<0.001
658 087	MMT-AP02/WATER/LEACH	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.001	0.005	<0.001
658 088	MMT-AP03/WATER/LEACH	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001
658 089	MMT-AP04/WATER/LEACH	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.001	0.006	<0.001
658 090	MMT-06/WATER/LEACH	<0.001	<0.001	<0.0001	0.001	<0.001	<0.0001	0.027	0.012	<0.001	0.013	<0.001
658 091	MMT-07/WATER/LEACH	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.001	0.014	<0.001
658 092	MMT-08/WATER/LEACH	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001
658 093	MMT-09/WATER/LEACH	<0.001	<0.001	<0.0001	0.003	<0.001	<0.0001	0.004	0.003	<0.001	0.003	<0.001
658 094	MMT-WR01/WATER/LEACH	<0.001	<0.001	<0.0001	0.002	<0.001	<0.0001	0.002	0.001	<0.001	0.004	<0.001
658 095	MMT-WR02/WATER/LEACH	<0.001	<0.001	<0.0001	0.003	<0.001	<0.0001	0.004	0.020	<0.001	<0.001	<0.001
658 096	MMT-WR03/WATER/LEACH	<0.001	<0.001	<0.0001	0.002	<0.001	<0.0001	0.009	<0.001	<0.001	0.055	<0.001
658096 QC	Duplicate	<0.001	<0.001	<0.0001	0.002	<0.001	<0.0001	0.009	<0.001	<0.001	<0.001	<0.001
658 097	MMT-WR04/WATER/LEACH	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.0001	0.011	0.003	<0.001	0.003	<0.001
658 098	MMT-WR05/WATER/LEACH	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.0001	0.024	0.002	<0.001	<0.001	<0.001
658 099	MMT-WR06/WATER/LEACH	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.0001	0.019	0.001	<0.001	<0.001	<0.001
658 100	MMT-WR07/WATER/LEACH	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.001	0.001	<0.001
658 101	MMT-WR08/WATER/LEACH	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.001	0.001	<0.001
658 102	MMT-WR09/WATER/LEACH	<0.001	<0.001	<0.0001	<0.001	<0.001	0.0001	0.002	<0.001	<0.001	0.003	<0.001
666417	MMT-WR01/02/03/04/05/06/07/08/09/WATER/LEACH	<0.001	<0.001	<0.0001	0.003	<0.001	0.0003	0.021	0.008	<0.001	0.001	<0.001
666417 QC	Duplicate	<0.001	<0.001	<0.0001	0.003	<0.001	0.0003	0.021	0.008	<0.001	<0.001	<0.001

Lims ID	Sample ID
	WATER LEACH 1:20
	Leach Blank
658086	MMT-AP01/WATER/LEACH
658086 QC	Duplicate
658087	MMT-AP02/WATER/LEACH
658088	MMT-AP03/WATER/LEACH
658089	MMT-AP04/WATER/LEACH
658090	MMT-06/WATER/LEACH
658091	MMT-07/WATER/LEACH
658092	MMT-08/WATER/LEACH
658093	MMT-09/WATER/LEACH
658094	MMT-WR01/WATER/LEACH
658095	MMT-WR02/WATER/LEACH
658096	MMT-WR03/WATER/LEACH
658096 QC	Duplicate
658097	MMT-WR04/WATER/LEACH
658098	MMT-WR05/WATER/LEACH
658099	MMT-WR06/WATER/LEACH
658100	MMT-WR07/WATER/LEACH
658101	MMT-WR08/WATER/LEACH
658102	MMT-WR09/WATER/LEACH
666417	MMT-WR01/02/03/04/05/06/07/08/09/WATER/LEACH
666417 QC	Duplicate

Date: 18.09.2019
Analysed by: UIS Waterlab/MA Motsepe

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