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TSHIPI E NTLE MINE

Waste Classification Assessment for Tshipi E Ntle Mine

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REPORT

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Executive Summary

Golder Associates Africa Pty Ltd (Golder) was appointed by Tshipi é Ntle Manganese Mining (Pty) Ltd's Tshipi Borwa Mine (Tshipi to carry out a waste classification and assessment of materials on three overburden dumps generated during extraction of manganese ore from open pits. The Tshipi Borwa Mine is located in the Kalahari Manganese Field, 40 km north of Kathu, in the Northern Cape Province.

A summary of the Tshipi waste classification and assessment results from this study is presented in the table below:

Tshipi Potential Contaminant Sources	GN R.635	SANS 10234 R.634	Acid Rock Drainage Generation Potential
Northern Dump	Type 1	Non-hazardous	None
Eastern Dump	Type 1		
Western Dump	Type 1		

On the basis of the above findings, it is recommended that whilst the material is Type 1 waste, one of the following ways forward be considered:

1) Given the high manganese content (4 to 7.5%), a resource assessment could be made of the dump with a view to potentially re-mining; or

2) Motivate for no liner requirement for the dumps on the basis that whilst the material is Type 1 waste,

   a. Class A liner is impractical for a waste rock dump on the basis of geotechnical properties: likely liner failure,

   b. The waste material is non-hazardous,

   c. The waste material is non-acid-generating,

   d. The concentration of all constituents of concern in leachate is below LCT0, indicating a low risk from seepage,

   e. The dumps do not contain waste water, so the only seepage through the dumps will be from recharge by the (low) rainfall in this area, and therefore

   f. The dumps do not pose a significant risk to the water resource; or

3) Given that the assessment in this report is based upon three composite samples, a follow-up study could be commissioned to sample individual rock-types and

   a. Derive manganese content per rock-type with a view to considering economic value,

   b. Model the total and leachable concentrations of each whole dump based upon the rock-type specific results and the predicted tonnages of each rock type reporting to the dump, and

   c. This study to be done prior to motivation for no liner requirement.

Note that the barrier designs indicated by GN R. 636 will only apply should new cells or facilities be developed, subject to confirmation with the Department of Water and Sanitation. Current facilities remain legal in terms of transitional arrangements provided that the facilities have already been approved in terms of an EMPR authorised before 2 September 2014.

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1.0 INTRODUCTION

Tshipi é Ntle Manganese Mining (Pty) Ltd's Tshipi Borwa Mine (Tshipi) is located in the Kalahari Manganese Field, 40 km north of Kathu, and 80 km from Kuruman town in the Northern Cape Province (Figure 1). The mine extracts manganese ore using truck and shovel from open pits. Three dumps of overburden materials stripped during mining exist at the mine. Golder Associates Africa Pty Ltd (Golder) was appointed by Tshipi to carry out a waste classification and assessment of materials on overburden dumps.

This report documents the fieldwork conducted by Golder in 2015, laboratory and waste classification and assessment results for Tshipi overburden materials.

2.0 OBJECTIVES

The specific objectives of the Tshipi waste assessment and classification study are as follows:

- To determine the acid rock drainage (ARD) generation potential of the waste rock material on overburden stockpiles at Tshipi é Ntle Manganese mine;
- To classify waste rock on overburden stockpiles according to SANS 10234 as per Waste Classification and Management Regulations (GN R.634 of 23 August 2013);and
- To assess waste rock on overburden stockpiles as per the National Norms and Standards for the Assessment of Waste for Landfill Disposal (GN R.635 of 23 August 2013).

3.0 APPROACH AND METHODOLOGY

The scope of work is consistent with the following guidance documents and the relevant regulations and National Norms and Standards:

- *Best Practice Guidelines for Water Resource Protection in the South African Mining Industry*[1] - BPG G4 "Impact Prediction"
- Classification of waste according to SANS 10234 as *per Waste Classification and Management Regulations* (GN R.634 of 23 August 2013); and
- Waste Assessment as *per the National Norms and Standards for the Assessment of Waste for Landfill Disposal (*GN R.635 of 23 August 2013).

The approach that was followed is based on the methodology outlined in the BPG G4 Guide and included:

- Step 1: Review available information;
- Step 2: Develop conceptual understanding (models) of key geochemical and flow processes for each mining facility. This step was not conducted as part this study;
- Step 3: Develop a sampling protocol by determining the form and extent of rock and waste units that will occur in each mine component. A strategy for obtaining and testing representative samples of the geological materials and mine wastes should be developed. The strategy should identify sampling requirements (such as the number of samples to be collected, their size/mass, their description and their handling) and should specify the laboratory testing to be undertaken;
- Step 4: Conduct sampling of geological materials and mine wastes;
- Step 5: Conduct laboratory analysis of samples; and
- Step 6: Waste classification and assessment according to GN R.634 and GN R.635 and reporting.

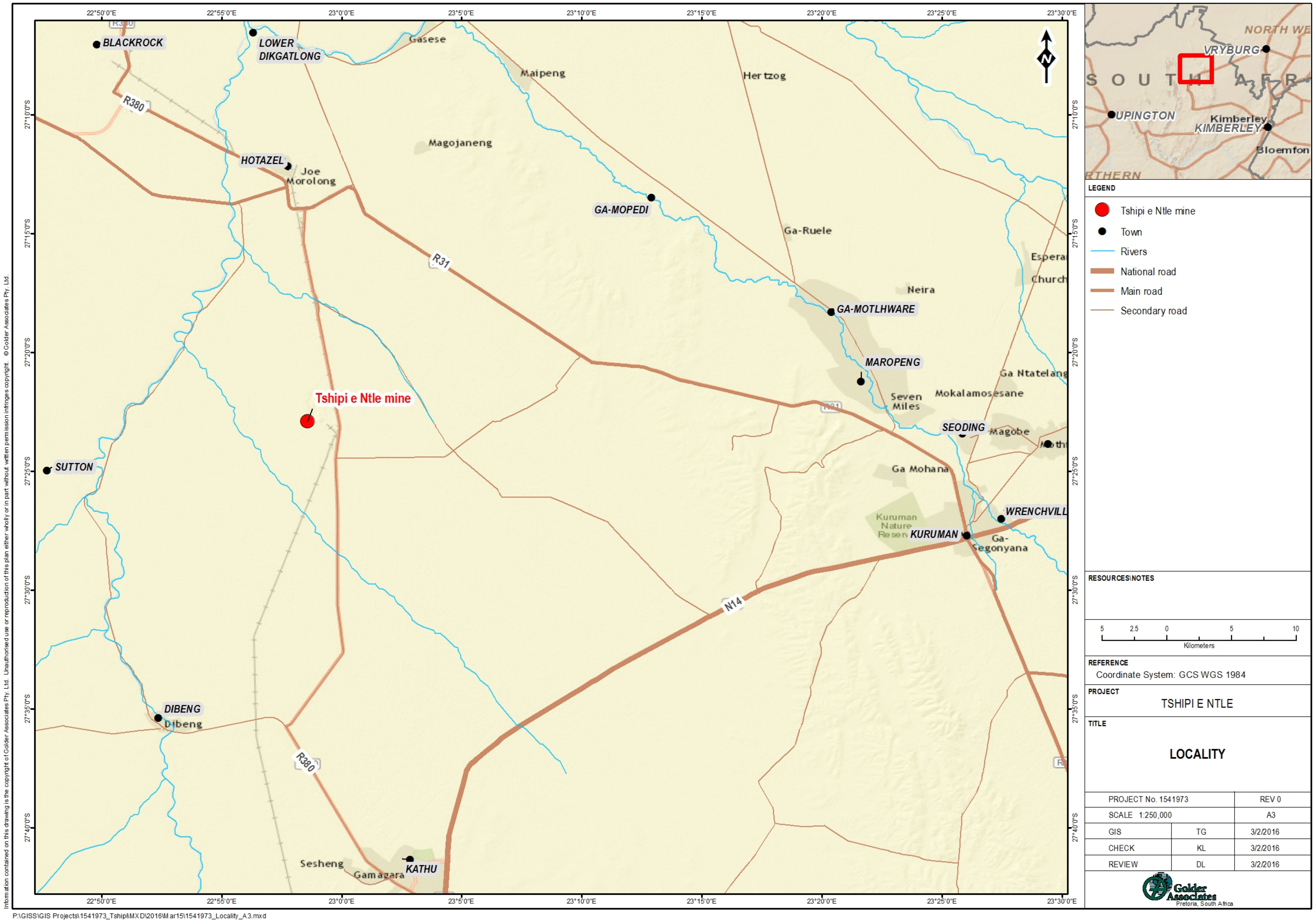

Figure 1: Location map of Tshipi e Ntle Manganese Mine

3.1 Information Review

The following documents were reviewed:

- Turgis Mining Consulting (Pty) Ltd. Feasibility study for Project Kalahari for Ntsimbintle Mining (Pty) Ltd;
- Synergistics Environmental Services. Tshipi Borwa Mine- 2nd quarterly water quality monitoring report August 2015. Report number 755.20029.00005/2015/WQM2; and
- Synergistics Environmental Services. Tshipi Borwa Mine- 3rd Annual water quality report. 4th Quarter of 2014/2015. Report 12. Report number 755.20029.00003/2014/WQM4.

3.1.1 Geology

The Tshipi Borwa mine is located on the south western margin of the Kalahari Manganese Field. A summary of the stratigraphy of the area is shown in Figure 2.

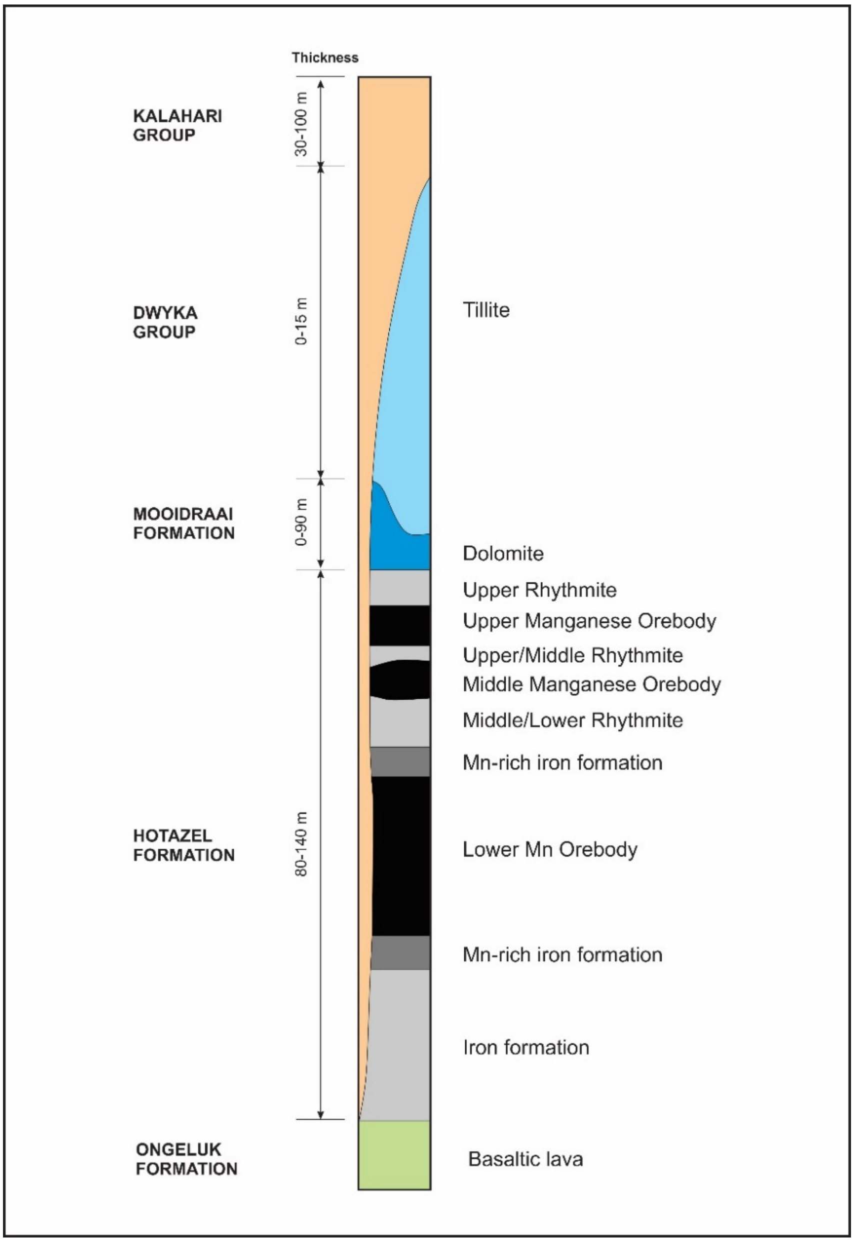

Figure 2: stratigraphic column of study area.

The manganese resource is hosted by the Hotazel Formation and consists of three ore bodies (Lower, Middle and Upper) that are intercalated with BIF and rhythmites. The Lower manganese orebody varies in thickness from 5 to 40 m and contains the highest manganese grades. It is the main ore horizon that is mined. The Middle orebody has a maximum of 2 m thickness, is poorly mineralised and is considered uneconomic. The Upper orebody is moderately mineralised and is stockpiled at the mine for possible future use. The dominant ore minerals are braunite and hausmanite. The ore is carbonate rich and sulphide minerals are rare.

The overburden consists of the 0-84 m thick dolomites of the Mooidraai Formation, which overlies the Hotazel Formation. Above the dolomites is the Dwyka Group, which consists of glacial diamitites/tillites that vary in thickness from 0 m to 90 m. These are covered by 30-100 m thick gravels, clays, calcretes and aeolian sands of the Kalahari Group. The Mooidraai Formation and upper parts of the Hotazel Formation have been eroded in the southern portion of the mine area.

3.1.2 Monitored water quality

Surface and groundwater monitoring is carried out on a quarterly basis at Tshipi Borwa mine. Deep fractured aquifer groundwater is monitored from nine boreholes, five of which are downstream of the mine within the project area (TSH01-TSH05). Surface water monitoring points include two points on the ephemeral Vlermuisleegte Stream and four from the mine water dam. Reviewed data was for the period between April 2012 to January 2015, and the month of July 2015. The water monitoring results show that:

- All the boreholes within the mine area (TSH01-TSH05) were characterised by slightly alkaline to alkaline pH conditions (7.7-9.3) and all boreholes outside of the mine area were characterised by near-neutral to alkaline pH (7.2-8.7) from February 2014 to January 2015, and July 2015;
- The concentrations of trace elements was generally low in groundwater with the exceptions of As and Mo, which were occasionally elevated in some boreholes;
- The concentrations of SO_4^{2-} ranged from <5 to 745 mg/L in groundwater;
- Constituents of concern, which exceeded water quality standards for domestic use and DWAF water quality guidelines for livestock in groundwater on at least one occasion were:
  - EC, TDS, Cl^-, NO_3^-, Mo and As in borehole NT15, which is located to the east of the mine; and As and Mo in borehole NT8, which is located North West of the Mine;
  - EC, TDS, Cl^-, NO_3^-, Fe, Mn, Al and As in at least one of the boreholes that are located within the mine area, downstream of the mine;
- Mine water from the dams was characterised by alkaline pH (8.1-9.1) from February 2014 to January 2015, and July 2015;
- The concentration of SO_4^{2-} was generally low and ranged from <5 to 109 mg/L; and
- Constituents of concern, which exceeded water quality guidelines at least once in the mine water dams were EC, TDS, Cl^-, NO_3^-, Fe, Mn and Al.

The monitoring data classifies groundwater and mine water as neutral mine drainage (Figure 3), rarely bordering on saline.

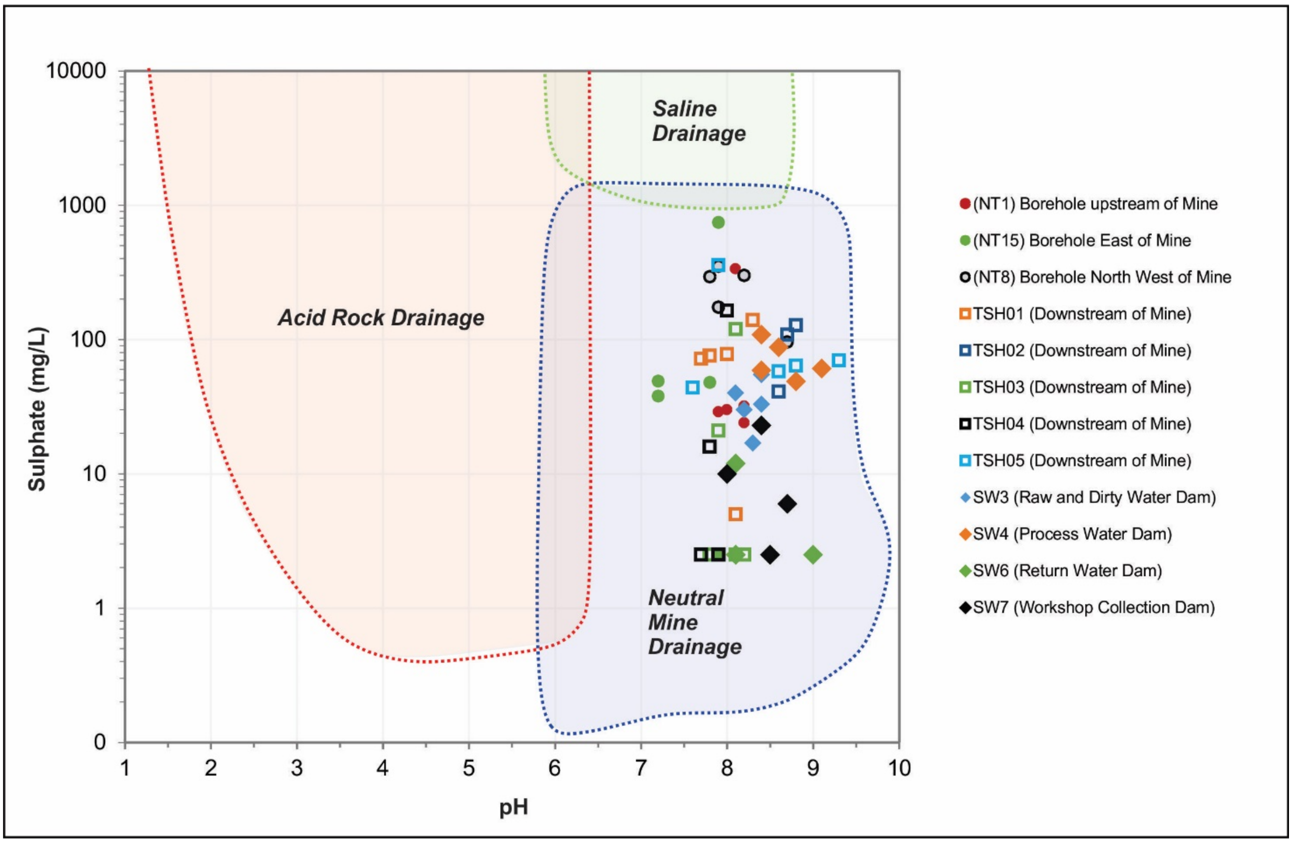

Figure 3: Classification of groundwater and mine water monitoring data based on sulphate and pH (after INAP, 2010)

3.2 Sampling Collection and Handling

The site familiarisation visit and fieldwork at Tshipi was conducted on 26th November 2015.

The sampling for each waste rock dump consisted of:

- Identifying and selecting areas to collect discrete samples;
- Use of a small hand spade by first removing the top 25 – 30 cm surface layers to obtain a discrete sample of the waste material below exposed layers of the targeted potential contaminant source areas/ waste streams;
- Geo-referencing sampling locations and taking photographs of the discrete samples and source area; and
- Compositing the discrete samples to create a composite sample for each waste rock dump. Plastic bags were filled with the composite samples and labelled appropriately.

The composite samples were transported to Johannesburg before shipment to UIS, a SANAS[2] accredited laboratory for analysis.

3.2.1 Sample location and Material types

The potential contamination source areas that were sampled and number of samples collected during the November 2015 sampling event are indicated in Table 1 and Figure 4. The field observations are provided in **Error! Reference source not found.**.

Table 1: Waste material sampled

Source Area	Material/ Rock Type	Number of Discrete Samples	Composite Sample ID
Northern Dump	Kalahari sands, calcrete, reddish brown clay and shale	9	TP_ND
Eastern Dump	Calcrete, reddish brown clay, conglomerate and shale	9	TP_ED
Western Dump	Dark reddish brown clay, black shale, conglomerate, red Kalahari sands and white calcrete	12	TP_WD

It should be noted that sampling was restricted to surface samples from areas near access roads on the top of the dump and around the base of the dumps. The slopes were not accessible due to safety reasons and no samples were collected below surface (>0.3 m) to assess the variation of the overburden materials with depth. Hence, the composite samples collected provide indicative waste characteristics, including ARD potential risk for the different materials on the overburden dumps.

3.3 Laboratory Analyses

The following laboratory analyses were carried out on the composite samples as per National Norms and Standards for the Assessment of Waste for Landfill Disposal No. R.635 gazetted (DEA GN 36784, August 2013):

- Determination of total elemental composition of all waste samples. This included analysis of major elements by XRF and multi-acid digestion followed by analysis of trace elements by ICP-MS; and
- ASLP (deionised 1:20 solid to liquid ratio) extraction, specified for non-putrescible mono disposed waste material, with the leachates analysed for pH, TDS, EC, major cations, major anions and trace elements.

Acid-base accounting (ABA) including paste pH, sulphur speciation (total sulphur, sulphide and sulphate), carbon speciation (total carbon, inorganic carbon and inorganic carbon) and neutralisation potential.

Figure 4: Location map of discrete samples from the waste rock dumps

3.4 Waste Classification and Assessment Methodology

3.4.1 SANS 10234 Classification

According to section 4(2) of GN R.634 of 2013, all waste generators must ensure that their waste is classified in accordance with SANS 10234 within 180 days of generation, except if it is listed in Annexure 1 of the GN R.634. Furthermore, waste must be re-classified every 5 years.

Waste classification according to SANS 10234 (based on the Global Harmonised System) indicates physical, health and environmental hazards. The SANS 10234 covers the harmonised criteria for classification of potentially hazardous substances and mixtures, including wastes, in terms of its intrinsic properties/hazards.

The chemical test results and based here on the 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.) (Table 2).

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

Table 2: 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
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

3.4.2 GN R.635 Waste Assessment

National Norms and Standards for the Assessment of Waste for Landfill Disposal No. R. 635 gazetted (DEA GN 36784, 23 August 2013) under the National Environmental Management Waste Act 59 of 2008 (NEMWA) have been used to determine the ZAC material classification type.

According to the Standards, the assessment methodology to determine the specific type of waste for disposal to landfill requirements is that the Total Concentrations (TC) and Leachable Concentration (LC) of the waste material be compared to threshold limits for Total Concentrations Threshold (TCT) and Leachable Concentration Thresholds (LCT) respectively. Exceedances of the threshold limits determine the type of waste (Type 0 to Type 4 Wastes).

The Norms and Standards require that the LC must be determined using Australian Standards (AS4439.1, AS4439.2 and 44396.3) or Toxicity Characteristic Leaching Procedure (TCLP at 1:20 solid: liquid ratio). However, for non-putrescible (non-decomposable) waste that is mono disposed, reagent water extract is required. For the purposes of the slimes, tailings and paste classification deionised water has been used at different solid to liquid ratios to leach the soluble chemical constituents and is hence suitable for use in the classification.

According to the Waste Standards the type of waste destined for disposal is determined as (Figure 5):

- Type 0 Waste: if concentrations above LCT3 or TCT2 limits (LC > LCT3 or TC > TCT2);
- Type 1 Waste: if concentrations are above the LCT2 but below or equal to LCT3 limits, or above the TCT1 but below or equal to TCT2 limits (LCT2 < LC ≤ LCT3 or TCT1 < TC ≤ TCT2);
- Type 2 Waste: if concentrations are above the LCT1 but below or equal to LCT2 and all concentrations below or equal to TCT1 limits (LCT1 < LC ≤ LCT2 and TC ≤ TCT1);
- Type 3 Waste: if concentrations are above the LCT0 but below or equal to LCT1 and all TC concentrations below or equal to TCT1 limits (LCT0 < LC ≤ LCT1 and TC ≤ TCT1); and
- Type 4 Waste: if all concentration levels for metal ions and inorganic anions below or equal to both LCT0 and TCT0 limits (LC ≤ LCT0 and TC ≤ TCT0) and with all chemical substance concentration levels also below the total concentration limits for organics and pesticides.

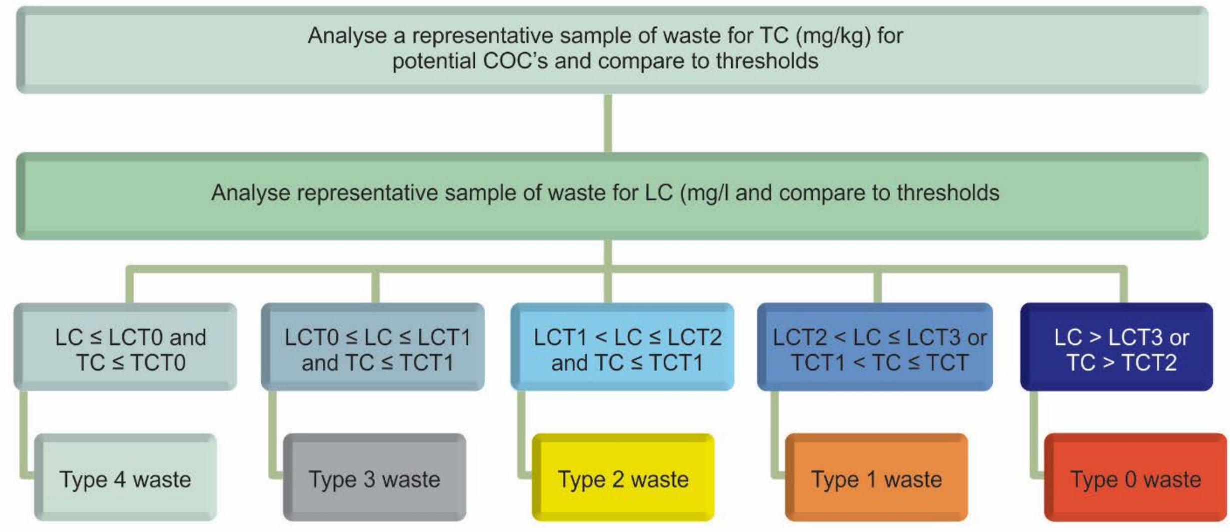

Figure 5: Waste classification based on GN R. 634 of 2013 Waste Standards

3.4.3 Barrier design requirements

The liner requirements/barrier design requirements, based on the type of waste, is detailed in GN R.636 are presented in Table 3.

Table 3: Landfill disposal requirements detailed in the GN R. 636 of 2013

Waste Type	Landfill Disposal Requirements
Type 0 Waste	The disposal of Type 0 waste to landfill is **not allowed**. The waste must be treated and re-assessed in terms of the *Standard for Assessment of Waste for Landfill Disposal*.
Type 1 Waste	Type 1 waste may only be disposed of at a **Class A** landfill designed in accordance with Section 3(1) and 3(2), or, subject to Section 3(4), may be disposed of at a landfill site designed and operated in accordance with the requirements for a **Hh / HH landfill** as specified in the Minimum Requirements for Waste Disposal by Landfill (2nd Ed., DWAF, 1998).
Type 2 Waste	Type 2 waste may only be disposed of at a **Class B** landfill designed in accordance with Section 3(1) and 3(2), or, subject to Section 3(4), may be disposed of at a landfill site designed and operated in accordance with the requirements for a **GLB+ landfill**

Waste Type	Landfill Disposal Requirements
	as specified in the Minimum Requirements for Waste Disposal by Landfill (2nd Ed., DWAF, 1998).
Type 3 Waste	Type 3 waste may only be disposed of at a **Class C** landfill designed in accordance with Section 3(1) and 3(2), or, subject to Section 3(4), may be disposed of at a landfill site designed and operated in accordance with the requirements for a **GLB+ landfill** as specified in the Minimum Requirements for Waste Disposal by Landfill (2nd Ed., DWAF, 1998).
Type 4 Waste	Disposal allowed at a landfill with a **Class D** landfill designed in accordance with Section 3(1) and 3(2), or, subject to Section 3(4), may be disposed of at a landfill site designed and operated in accordance with the requirements for a **GLB- landfill** as specified in the Minimum Requirements for Waste Disposal by Landfill (2nd Ed., DWAF, 1998).

3.4.4 Acid Rock Drainage Assessment

The screening criteria used in this study to assess the acid generation potential of the overburden materials is based on guidelines from Price et al.(1997) in conjunction with Soregaroli and Lawrence (1997), Morin and Hutt (2007) and MEND (2009). These guidelines are summarised in Table 4.

Table 4: Acid Generation Potential Assessment Criteria.

Guidelines from Price et al. (1997) and Soregaroli and Lawrence (1997).			
Sulphide sulphur	**NPR (Bulk NP /AP)**	**Potential for ARD**	**Comments**
<0.3%	----	None	No further ARD testing required provided there are no other metal leaching concerns. *Exceptions:* host rock with no basic minerals, sulphide minerals that are weakly acid soluble.
>0.3%	<1	Likely	Likely to be ARD generating.
	1-2	Possibly	Possibly ARD generating if NP is insufficiently reactive or is depleted at a rate faster than that of sulphides.
	2-4	Low	Not potentially ARD generating unless significant preferential exposure of sulphides occur along fractures or extremely reactive sulphides are present together with insufficiently reactive NP.
	>4	None	No further ARD testing required unless materials are to be used as a source of alkalinity.
Guidelines from Morin and Hutt (2007) and MEND (2009)			
Paste pH	**NPR**	**Potential for ARD**	**Comments**
<6	<1	Acid generating (AG)	Net acid generating, and already acidic.
>6		Potentially acid generating (PAG)	Potentially acid generating unless sulphide minerals are non-reactive. Thus samples are net acid generating, but not yet acidic.
<6 and >6	1 ≤ NPR ≤ 2	Uncertain	Possibly acid generating if NP is insufficiently reactive or is depleted at a rate faster than sulphides.

Guidelines from Price et al. (1997) and Soregaroli and Lawrence (1997).			
>6	>2	Not potentially acid generating (Non-PAG)	Not expected to generate acidity i.e samples are net acid neutralizing.
<6		Theoretically not possible	

4.0 RESULTS OF THE WASTE PROGRAMME

4.1 Waste Classification and Assessment Results

The analytical results on the composite overburden samples from Tshipi are summarised in this section – the full results are in **Error! Reference source not found.**.

4.1.1 Waste Assessment Results

Table 5 and Table 6 provides the comparisons of total elemental results and leachable concentration results to TCT and LCT guideline limits provided in the GN R.635 respectively. Shaded cells indicate exceedances of the respective guideline threshold limits.

The most important factors to note are that Mn exceeds TCT1 threshold (4 to 7.5 wt. % Mn) but all dissolved parameters are below the lowest leachability threshold (LCT0).

Table 5: Comparison of selected Total Concentrations (mg/kg) to TCT limits for Overburden samples

CoC	GNR.635 levels of thresholds for total concentrations			TP_ND	TP_ED	TP_WD
	TCT0	TCT1	TCT2			
As	5.8	500	2000	5.4	4.6	**7.2**
Ba	62.5	6250	25000	**466**	**276**	**560**
Cd	7.5	260	1040	0.38	0.26	0.31
Co	50	5000	20000	35	36	38
Cr	46000	800000	N/A	84.9	39.6	43.8
Cu	16	19500	78000	**25**	**23**	**24**
Hg	0.93	160	640	0.05	0.62	0.001
Mn	1000	25000	100000	70,244	46,407	74,955
Mo	40	1000	4000	5.0	1.5	2.1
Ni	91	10600	42400	27	31	27
Pb	20	1900	7600	9.7	8.2	9.4
Sb	10	75	300	1.6	0.81	0.79
Se	10	50	200	0.53	0.18	0.33
V	150	2680	10720	75	57	76
Zn	240	160000	640000	35	32	40

Notes

Grey: >TCT0; Yellow: >TCT1; Red: >TCT2

COC – Constituent of Concern

Table 6: Comparison of selected Leachable Concentrations (mg/L) to LCT limits for Overburden Material

Australian Standards Leach Procedure (1:20 Solid: Liquid Ratio)							
CoCs	**GN R.635 levels of thresholds for leachable concentrations**				**TP_ND**	**TP_ED**	**TP_WD**
	LCT0	**LCT1**	**LCT2**	**LCT3**	**Northern Dump**	**Eastern Dump**	**Western Dump**
pH	No guideline				7.9	8.3	7.8
TDS	1000	12500	25000	100000	76	80	80
As	0.01	0.5	1	4	0.002	0.001	0.001
B	0.5	25	50	200	0.041	0.043	0.16
Ba	0.7	35	70	280	0.079	0.082	0.17
Cd	0.003	0.15	0.3	1.2	<0.001	<0.001	<0.001
Co	0.5	25	50	200	0.001	<0.001	<0.001
Cr	0.1	5	10	40	0.004	0.000	0.002
Cu	2	100	200	800	0.004	<0.001	<0.001
Hg	0.006	0.3	0.6	2.4	0.0001	0.0002	0.0002
Mn	0.5	25	50	200	0.027	0.006	0.004
Mo	0.07	3.5	7	28	0.004	0.002	0.003
Ni	0.07	3.5	7	28	0.001	<0.001	<0.001
Pb	0.01	0.5	1	4	0.006	<0.001	<0.001
Sb	0.02	1	2	8	0.002	0.001	0.001
Se	0.01	0.5	1	4	0.001	<0.001	0.002
V	0.2	10	20	80	0.015	0.022	0.010
Zn	5	250	500	2000	0.034	0.002	0.006
Cl	300	15000	30000	120000	0.66	2.03	0.26
SO_4^{2-}	250	12500	25000	100000	4.2	4.14	7.10
NO_3^-	11	550	1100	4400	0.48	1.7	0.25
F^-	1.5	75	150	600	0.27	0.15	0.35
CN (Total)	0.07	3.5	7	28	<0.01	<0.01	<0.01

Notes

Grey: >LCT0; Yellow: >LCT1; Orange: >LCT2; Red: >LCT3

COC – Constituent of Concern

Units-mg/L for all COCs

4.1.1.1 North Dump materials

The total concentrations of barium and copper exceed the TCT0 levels and that of manganese exceeds the TCT1 level. The leachable concentrations of all constituents of concern were less than LCT0 levels in the composite sample. Subsequently the material at the Northern dump is assessed as **Type 1** (LCT2 < LC ≤ LCT3 **or** TCT1 < TC ≤ TCT2).

4.1.1.2 Eastern Dump Materials

The total concentrations of barium and copper exceed the TCT0 levels. Manganese exceeds the TCT1 level. The leachable concentrations of all constituents of concern were less than TCT0 and LCT0 levels in the composite sample. The material at the Eastern dump is therefore assessed as **Type 1** (LCT2 < LC ≤ LCT3 or TCT1 < TC ≤ TCT2).

4.1.1.3 Western Dump Materials

The total concentrations of arsenic, barium and copper exceed the TCT0 levels with manganese exceeding the TCT 1 level. The leachable concentrations of all constituents of concern were less than TCT0 and LCT0 levels in the composite sample. The material at the Western dump is therefore assessed as **Type 1** (LCT2 < LC ≤ LCT3 or TCT1 < TC ≤ TCT2).

4.1.1.4 Barrier Requirements

The material at all three dumps are **Type 1** materials due to total Mn concentrations exceeding the TCT1 level. According to the GN R.636, Type 1 material waste requires a Class A liner (Table 3).

4.1.2 Waste Classification Results

The materials from of the Northern, Eastern and Western dumps are classified as follows in terms of SANS 10234:

- Physical hazards: The materials are not combustible and do not enhance combustion of other substances. Therefore, they are classified as **non-hazardous in terms of physical hazards**;
- Health hazards:
  - The concentration of manganese in the composite samples of all dumps exceeds 1% (4 – 7 %). Chronic exposure to high levels of manganese by inhalation may lead to central nervous system effects (ATSDR, 1997). However, in its current form (solid phase contained in waste rock), the Mn is not considered to be hazardous to human health; and
  - Trace metals such as Cd, Ni, As and Cr (VI) have been recognized as human or animal carcinogens by International Agency for Research on Cancer (IARC). The carcinogenic capability of these metals depends mainly on factors such as oxidation states and chemical structures. The total concentrations of carcinogenic trace metals were <0.1% in all samples. Therefore none of these elements constitute a health risk and the North, Eastern and Western dump material.
  - The waste rock samples collected at Tshipi are considered n**on-hazardous in terms of human health**.

  Environmental hazard: The total Mn content of the waste materials composite samples exceeds the cut-off limit of 1%. The leachable Mn concentrations of these samples are low (< 0.0027 mg/L), as are the leachable concentrations of all other potential CoCs. Mn may be hazardous in the environment, particularly to aquatic organisms (Howe, Malcolm & Dobson, 2005). However, due to the extremely low solubility of the Mn in the waste rock, it is unlikely to impact negatively on the environment and is considered to be **non-hazardous to the environment.**

4.2 Acid Rock Drainage Assessment Results

The acid base results are discussed in this section and laboratory certificates are presented in Appendix D.

The sulphur analysis results indicate that total sulphur, sulphide and sulphate occurred at very low concentrations that were below detection limit (<0.01%). The acid potential (AP) was 0.31 kg CaCO3 eqv t-1 based on half the detection limit of sulphur concentration. This is expected since sulphide minerals are known to be rare in the manganese deposit (Turgis Mining Consulting, 2009).

Bulk neutralisation potential (Bulk NP) was very high in all overburden samples from all the dump (90-187 kg $CaCO_3$ eqv t^{-1}) (Table 7). The CaNP (94-224 kg CaCO3 eqv t-1) was higher than the Bulk NP suggesting that siderite and/or ankerite represented a significant proportion of total carbonates in the overburden samples. However, siderite and ankerite have limited neutralising capacity under oxidising field conditions as ferrous iron is an extra source of acidity due to the strong hydrolysis of the ferrous iron in solution (MEND, 2009).

Table 7: Acid base accounting results for overburden samples

Determinant	Units	Northern Dump	Eastern Dump	Western Dump
		TP-ND	TP-ED	TP-WD
Paste pH	s.u	7.8	8.1	8.2
Total Sulphur	%	<0.001	<0.001	<0.001
Sulphide Sulphur		<0.001	<0.001	<0.001
Sulphur in Sulphate		<0.001	<0.001	<0.001
Total Carbon		1.1	2.5	2.7
Organic Carbon		<0.003	<0.003	<0.003
Bulk NP	kg $CaCO_3$/T	90	187	186
Carbonate NP		94	206	224
Acid Potential		0.2	0.2	0.2
Net Neutralisation Potential		90	187	186
Neutralisation Potential Ratio	none	576	1197	1190
Classification based on NPR		**Non-PAG**	**Non-PAG**	**Non-PAG**

The generally high paste pH (7.8-8.2) indicates excess reactive NP to buffer acidity generated by the initial oxidation of sulphides during the testing procedure. Buffering is expected to be provided by calcite and dolomite which are known to occur in the deposit and in calcrete. There is excess buffering capacity in the overburden materials, with Bulk NP exceeding AP in all the samples.

Classification of acid rock drainage (ARD) potential show that all the samples of overburden materials are not potentially acid generating (Non-PAG) per the guidelines of Morin and Hutt (2007) and MEND (2009). Classification using the guidelines of Price et al. (1997) and Soregaloli and Lawrence (1997) also shows that all samples have no acid generating potential due to very low sulphur content.

Summary of Assessment and Classification Results

Table 8 provides a summary of the Tshipi waste classification and assessment results from this study.

Table 8: Tshipi assessment and classification results samples

Tshipi Potential Contaminant Sources	GN R.635	SANS 10234 R.634	Acid Rock Drainage Generation Potential
Northern Dump	Type 1	Hazardous waste	None
Eastern Dump	Type 1		
Western Dump	Type 1		

5.0 CONCLUSION

Based on the analytical data and information obtained during this investigation, the following are concluded:

- Waste materials: Classifies as non-hazardous waste due to the insolubility of the CoCs;
- Type 1 waste due to total Mn concentrations exceeding TCT1 levels and can be disposed on a facility with Class A liner / barrier. However, due to the insolubility of the CoCs (<LCT0 levels) it is expected to not have a negative impact on the environment; and

- The overburden material is not potentially acid generating.

On the basis of the above findings, it is recommended that whilst the material is Type 1 waste, one of the following ways forward be considered:

1) Given the high manganese content (4 to 7.5%), a resource assessment could be made of the dump with a view to potentially re-mining; or

2) Motivate for no liner requirement for the dumps on the basis that whilst the material is Type 1 waste,

   a. Class A liner is impractical for a waste rock dump on the basis of geotechnical properties: likely liner failure,

   b. The waste material is non-hazardous,

   c. The waste material is non-acid-generating,

   d. The concentration of all constituents of concern in leachate is below LCT0, indicating a low risk from seepage,

   e. The dumps do not contain waste water, so the only seepage through the dumps will be from recharge by the (low) rainfall in this area, and therefore,

   f. The dumps do not pose a significant risk to the water resource; or

3) Given that the assessment in this report is based upon three composite samples, a follow-up study could be commissioned to sample individual rock-types and

   a. Derive manganese content per rock-type with a view to considering economic value,

   b. Model the total and leachable concentrations of each whole dump based upon the rock-type specific results and the predicted tonnages of each rock type reporting to the dump, and

   c. This study to be done prior to motivation for no liner requirement.

Note that the barrier designs indicated by GN R. 636 will only apply should new cells or facilities be developed, subject to confirmation with the Department of Water and Sanitation. Current facilities remain legal in terms of transitional arrangements provided that the facilities have already been approved in terms of an EMPR authorised before 2 September 2014.

6.0 REFERENCES

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APPENDIX A

Sample Location maps, Field Notes and Photos (November 2015 sampling campaign)

Table B1: Sample locations

Location of composite	ID	Latitude	Longitude
Eastern Dump	TSHI-E1	-27.3844	22.97313
	TSHI-E2	-27.3822	22.97448
	TSHI-E3	-27.3838	22.97206
	TSHI-E4	-27.3817	22.97276
	TSHI-E5	-27.3817	22.97592
	TSHI-E6	-27.3844	22.97118
	TSHI-E7	-27.386	22.97218
	TSHI-E8	-27.386	22.97222
	TSHI-E9	-27.3842	22.97149
Northern Dump	TSHI-N1	-27.3682	22.95818
	TSHI-N2	-27.3674	22.95722
	TSHI-N3	-27.368	22.95594
	TSHI-N4	-27.3703	22.95586
	TSHI-N5	-27.3712	22.95667
	TSHI-N6	-27.3715	22.95673
	TSHI-N7	-27.3697	22.95549
	TSHI-N8	-27.3706	22.95536
	TSHI-N9	-27.3686	22.95555
Western Dump	TSHI-W1	-27.3841	22.96043
	TSHI-W2	-27.3841	22.96045
	TSHI-W3	-27.385	22.9591
	TSHI-W4	-27.3857	22.95748
	TSHI-W5	-27.3853	22.95701
	TSHI-W6	-27.3851	22.95683
	TSHI-W7	-27.3874	22.96142
	TSHI-W8	-27.388	22.95831
	TSHI-W9	-27.3829	22.95311
	TSHI-W10	-27.3868	22.95611
	TSHI-W11	-27.389	22.95882
	TSHI-W12	-27.3886	22.9604

Figure B1: Different material types on the Western dump. Dark reddish brown clay (left), (middle to right).

Figure B2: Dark reddish brown clay (right), conglomerate and black shale material (centre) and red Kalahari sands (left) on the Western dump

Figure B3: Multiple heaps of material on top of Western dump

Figure B4: Shale heaps on top of Western dump

Figure B5: Side slopes of Western dump, mixture of shale and calcrete

Figure B6: Landscape surrounding Western dump

Figure B7: Side slopes of Western dump, dark reddish brown clay, shale and calcrete, partially mixed, and partially separated along slopes.

Figure B8: Numerous heaps of calcrete, reddish brown clay and shale material at the top of Northern dump

Figure B9: Top of Northern dump

Figure B10: Calcrete heaps (right) at the top of Northern dump

Figure B11: Calcrete heaps at the top of Northern dump

Figure B12: Calcrete heaps mixed with Kalahari sand at the top of Northern dump

Figure B13: Side-slope of Northern dump with varying sections of calcrete (right), dark reddish clay (middle) and Kalahari sands (far left).

Figure B14: Heaps at the top of Eastern dump, calcrete on the left

Figure 15: Side-slope of Eastern dump, portions conglomerate, portions calcrete, and portions reddish brown clay.

Figure B16: Base of Eastern dump, mostly calcrete side slope with reddish brown clay heap also mixed with shale at the base of the dump.

APPENDIX B

Waste Assessment Results

Table B1: Classification of individual samples based on total concentrations (Solid sample chemistry data)

CoC	TCT0	TCT1	TCT2	TP_ND	TP_ED	TP_WD
Ag	ng			0.69	0.32	0.41
As	5.8	500	2000	5.42	4.64	7.22
Au	ng			0.01	0.02	0.01
B	ng			55.4	48.1	48.6
Ba	62.5	6250	25000	466	276	560
Be	ng			0.72	0.51	0.69
Bi	ng			0.38	0.23	0.24
Cd	7.5	260	1040	0.38	0.26	0.31
Ce	ng			8.04	7.54	9.66
Co	50.0	5000	20000	34.5	35.9	38.3
Cr	46000	800000	N/A	84.9	39.6	43.8
Cs	ng			1.17	0.88	1.00
Cu	16.0	19500	78000	25	23	24
Ga	ng			34.8	23.1	24.3
Ge	ng			14.5	8.99	13.0
Hf	ng			2.35	1.48	1.42
Hg	0.93	160	640	0.05	0.62	0.001
Ho	ng			0.41	0.13	0.18
Ir	ng			1.30	1.02	0.78
La	ng			10.8	3.27	4.27
Li	ng			8.51	7.47	7.81
Mn	1000	25000	100000	70244	46407	74955
Mo	40	1000	4000	4.97	1.45	2.12
Nb	ng			4.81	4.15	4.27
Nd	ng			10.0	3.48	4.66
Ni	91	10600	42400	26.9	30.6	27.2
Pb	20	1900	7600	9.71	8.23	9.41
Pt	ng			0.01	0.01	0.00
Rb	ng			35.1	32.7	27.4
Sb	10	75	300	1.55	0.81	0.79
Sc	ng			48.5	40.8	28.4
Se	10	50	200	0.53	0.18	0.33
Sn	ng			1.28	1.05	1.05
Sr	ng			300	75.5	197
Ta	ng			0.56	0.42	0.35
Te	ng			1.18	0.75	0.53

CoC	TCT0	TCT1	TCT2	TP_ND	TP_ED	TP_WD
Th		ng		3.01	0.33	0.37
Tl		ng		0.22	0.19	0.17
U		ng		1.32	0.89	1.12
V	150	2680	10720	75.1	56.5	76.1
W		ng		1.24	12.2	0.77
Y		ng		10.8	1.79	2.46
Zn	240	160000	640000	35.0	32.1	40.2
Zr		ng		109	67.9	68.5

Notes:

Grey: >TCT0; Yellow: >TCT1; Red: >TCT2

ng – no guideline

CoC – Constituent of Concern

Table B2: Classification of individual samples based on leachable concentrations (Solid sample leach test (1:20 solid: liquid ratio) chemistry data

CoC	Units	LCT0	LCT1	LCT2	LCT3	TP_ND	TP_ED	TP_WD
Ag	mg/l	ng				0.002	0.001	0.002
Al	mg/l	ng				0.253	0.124	0.016
As	mg/l	0.01	0.5	1	4	0.002	0.001	0.001
Au	mg/l	ng				<0.001	<0.001	<0.001
B	mg/l	0.5	25	50	200	0.041	0.043	0.158
Ba	mg/l	0.7	35	70	280	0.079	0.082	0.167
Be	mg/l	ng				<0.001	<0.001	<0.001
Bi	mg/l	ng				<0.001	<0.001	<0.001
Ca	mg/l	ng				8.114	8.923	8.339
Cd	mg/l	0.003	0.15	0.3	1.2	<0.001	<0.001	<0.001
Ce	mg/l	ng				<0.001	<0.001	<0.001
Co	mg/l	0.5	25	50	200	0.001	<0.001	<0.001
Cr	mg/l	0.1	5	10	40	0.004	0.000	0.002
Cs	mg/l	ng				<0.001	<0.001	<0.001
Cu	mg/l	2	100	200	800	0.004	<0.001	<0.001
Fe	mg/l	ng				0.243	0.140	0.055
Ga	mg/l	ng				<0.001	<0.001	<0.001
Ge	mg/l	ng				<0.001	<0.001	<0.001
Hf	mg/l	ng				<0.001	<0.001	<0.001
Hg	mg/l	0.006	0.3	0.6	2.4	0.0001	0.0002	0.0002
Ho	mg/l	ng				<0.001	<0.001	<0.001
Ir	mg/l	ng				<0.001	<0.001	<0.001
K	mg/l	ng				2.31	2.36	2.64
La	mg/l	ng				<0.001	<0.001	<0.001
Li	mg/l	ng				<0.001	<0.001	<0.001
Mg	mg/l	ng				4.03	4.51	4.45
Mn	mg/l	0.5	25	50	200	0.027	0.006	0.004
Mo	mg/l	0.07	3.5	7	28	0.004	0.002	0.003
Na	mg/l	ng				4.316	4.441	5.018
Nb	mg/l	ng				<0.001	<0.001	<0.001
Nd	mg/l	ng				<0.001	<0.001	<0.001
Ni	mg/l	ng						<0.001
Pb	mg/l	0.01	0.5	1	4	0.006	<0.001	<0.001
Rb	mg/l	ng				0.002	0.001	0.001

CoC	Units	LCT0	LCT1	LCT2	LCT3	TP_ND	TP_ED	TP_WD
Sb	**mg/l**	0.02	1	2	8	0.002	0.001	0.001
Se	**mg/l**	0.01	0.5	1	4	0.001	<0.001	0.002
Si	**mg/l**	ng				6.464	5.835	3.665
Sn	**mg/l**	ng				0.001	<0.001	<0.001
Sr	**mg/l**	ng				0.029	0.041	0.033
Ta	**mg/l**	ng				<0.001	<0.001	<0.001
Te	**mg/l**	ng				<0.001	<0.001	<0.001
Th	**mg/l**	ng				<0.0001	<0.0001	<0.0001
Ti	**mg/l**	ng				0.013	0.011	0.002
Tl	**mg/l**	ng				<0.001	<0.001	<0.001
U	**mg/l**	ng				0.0001	0.0001	0.0001
V	**mg/l**	0.2	10	20	80	0.015	0.022	0.010
W	**mg/l**	ng				0.002	0.001	0.001
Y	**mg/l**	ng				<0.001	<0.001	<0.001
Zn	**mg/l**	5	250	500	2000	0.034	0.002	0.006
Zr	**mg/l**	ng				<0.001	<0.001	<0.001
pH	**su**	ng				7.86	8.25	7.84
TDS	**mg/l**	ng				76	80	80
EC	**mS/m**	ng				8.10	8.99	8.88
TDS by Sum	**mg/l**	ng				66	70	62
TDS by EC	**mg/l**	ng				57	63	62
P Alk.	**mg/l CaCO3**	ng				<0.6	<0.6	<0.6
M Alk.	**mg/l CaCO3**	ng				35.5	33.5	37.8
F^-	**mg/l**	1.5	75	150	600	0.27	0.15	0.35
Cl^-	**mg/l**	300	15000	30000	120000	0.66	2.03	0.26
NO_2^-	**mg/l**	ng				<0.2	<0.2	<0.2
NO_3^-	**mg/l**	ng				2.14	7.33	1.08
NO_3 as N	**mg/l**	11	550	1100	4400	0.48	1.66	0.25
PO_4^{3-}	**mg/l**	ng				<0.8	<0.8	<0.8
SO_4^{2-}	**mg/l**	250	12500	25000	100000	4.23	4.14	7.10
NH_3	**mg/l**	ng				<0.01	<0.01	<0.01
Acidity to pH8.3	**mg/l $CaCO_3$**	ng				< 5	< 5	< 5
CN (Total)	**mg/l**	0.07	3.5	7	28	<0.01	<0.01	<0.01
Cr^{6+}	**mg/l**	ng				<5	<5	<5

Grey: >LCT0; Yellow: >LCT1; Orange: >LCT2; Red: >LCT3

ng – no guideline *CoC – Constituent of Concern*

ANALYTICAL REPORT: Major Oxides & Total Trace elements

To: **Golder Associates**
Attention: **Keretia Lupankwa**
Project ID: **1541973**
Site Location: TSHIPI
Order No: 12282 / 93114

Date of Request :07.12.2015

UIS Analytical Services
Analytical Chemistry
Laboratories 4, 6
Tel: (012) 665 4291
Fax: (012) 665 4294

Certificate of analysis: 13377

Note: all results in percentage (%) unless specified otherwise

Lims ID	Sample ID	SiO2	Al2O3	Fe(total)	Fe2O3	TiO2	CaO	MgO	Na2O	K2O	MnO	P	Ba	Sr	Cr	V	Zn
	Major Oxides	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
454396	**TP_ND**	58.4	4.18	4.14	5.93	0.388	4.62	1.825	0.156	0.612	8.993	0.014	0.047	0.031	0.010	0.008	0.002
454397	**TP_ED**	52.5	3.64	3.01	4.30	0.364	9.02	3.067	0.147	0.493	6.134	0.002	0.031	0.009	0.004	0.006	0.001
454398	**TP_WD**	40.3	4.31	7.83	11.2	0.370	9.94	3.098	0.234	0.491	9.657	0.028	0.076	0.025	0.004	0.008	0.002
454398 QC	**TP_WD Duplicate**	40.5	4.42	7.91	11.3	0.372	10.1	3.111	0.240	0.499	9.662	0.040	0.078	0.027	0.005	0.008	0.003

Lims ID	Sample ID	C (Total)	C (organic)	C (inorganic)	S (total)	S (pyritic)	S (sulphate)
	Total C & S, LOI	%	%	%	%	%	%
454396	**TP_ND**	1.13	<0.003	1.17	<0.003	<0.01	<0.01
454397	**TP_ED**	2.47	<0.003	2.56	<0.003	<0.01	<0.01
454398	**TP_WD**	2.69	<0.003	2.83	<0.003	<0.01	<0.01
454398 QC	**TP_WD Duplicate**	2.74	<0.003	2.83	<0.003	<0.01	<0.01

Lims ID	Sample ID	Ag	As	Au	B	Ba	Be	Bi	Cd	Ce	Co	Cr	Cs	Cu	Ga	Ge	Hf	Hg	Ho	Ir	La	Li	Mn
	Total trace elements	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
454396	**TP_ND**	0.69	5.42	0.01	55.4	466	0.72	0.38	0.38	8.04	34.5	84.9	1.17	24.9	34.8	14.5	2.35	0.05	0.41	1.30	10.8	8.51	70244
454397	**TP_ED**	0.32	4.64	0.02	48.1	276	0.51	0.23	0.26	7.54	35.9	39.6	0.88	23.2	23.1	8.99	1.48	0.62	0.13	1.02	3.27	7.47	46407
454398	**TP_WD**	0.41	7.22	0.01	48.6	560	0.69	0.24	0.31	9.66	38.3	43.8	1.00	24.1	24.3	13.0	1.42	0.001	0.18	0.78	4.27	7.81	74955
454398 QC	**TP_WD Duplicate**	0.41	7.89	0.01	50.1	570	0.70	0.21	0.32	8.79	41.0	41.4	0.99	25.8	25.4	13.8	1.46	<0.001	0.17	0.70	4.11	8.05	74849

Lims ID	Sample ID	Mo	Nb	Nd	Ni	Pb	Pt	Rb	Sb	Sc	Se	Sn	Sr	Ta	Te	Th	Tl	U	V	W	Y	Zn	Zr
	Total trace elements	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
454396	**TP_ND**	4.97	4.81	10.0	26.9	9.71	0.01	35.1	1.55	48.5	0.53	1.28	300	0.56	1.18	3.01	0.22	1.32	75.1	1.24	10.8	35.0	109
454397	**TP_ED**	1.45	4.15	3.48	30.6	8.23	0.01	32.7	0.81	40.8	0.18	1.05	75.5	0.42	0.75	0.33	0.19	0.89	56.5	12.2	1.79	32.1	67.9
454398	**TP_WD**	2.12	4.27	4.66	27.2	9.41	0.00	27.4	0.79	28.4	0.33	1.05	197	0.35	0.53	0.37	0.17	1.12	76.1	0.77	2.46	40.2	68.5
454398 QC	**TP_WD Duplicate**	2.13	4.30	4.42	27.9	9.45	0.00	27.8	0.73	29.4	0.37	1.14	204	0.31	0.62	0.36	0.19	1.07	76.6	0.72	2.45	44.3	66.8

Chemical elements: Ag, Al, As, Au, Ca, B, Ba, Be, Bi, Cd, Ce, Co, Cr, Cs, Cu, Ga, Ge, Hf, Hg, Ho, Ir, La, Li, Mn, Mo, Nb, Nd, Ni, Pb, Pt, Rb, Sb, Sc, Se, Sn, Sr, Ta, Te, Th, Tl, U, V, W, Y, Zn, Zr
Instrument: ICP-OES, ICP-MS, LECO CS 230
Method: Major oxides in soil by ICP-OES Trace elements in ore/soil by ICP-MS

Date: 26.05.2015
Analysed by: A. Motsepe / S. Nel

Date: 26.05.2015
Authorised : JJ Oberholzer

ANALYTICAL REPORT: Water Leach

To: Golder Associates
Attention: Keretia Lupankwa
Project ID: 1542613
Site Location: Tati
Order No: 93115

Date of Request : 07.12.2015

UIS Analytical Services
Analytical Chemistry
Laboratories 4, 6

Fax: (012) 665 4294

Certificate of analysis: 13377

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	Fe	Ga	Ge	Hf	Hg	Ho	Ir	K	La	Li	Mg	Mn
	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	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
454399	**TP_ND/WATER/LEACH**	0.002	0.253	0.002	<0.001	0.041	0.079	<0.001	<0.001	8.114	<0.001	<0.001	0.001	0.004	<0.001	0.004	0.243	<0.001	<0.001	<0.001	0.0001	<0.001	<0.001	2.31	<0.001	<0.001	4.03	0.027
454400	**TP_ED/WATER/LEACH**	0.001	0.124	0.001	<0.001	0.043	0.082	<0.001	<0.001	8.923	<0.001	<0.001	<0.001	0.000	<0.001	<0.001	0.140	<0.001	<0.001	<0.001	0.0002	<0.001	<0.001	2.36	<0.001	<0.001	4.51	0.006
454401	**TP_WD/WATER/LEACH**	0.002	0.016	0.001	<0.001	0.158	0.167	<0.001	<0.001	8.339	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	0.055	<0.001	<0.001	<0.001	0.0002	<0.001	<0.001	2.64	<0.001	<0.001	4.45	0.004
454401 QC	**Duplicate**	0.002	0.020	0.001	<0.001	0.165	0.165	<0.001	<0.001	8.178	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	0.034	<0.001	<0.001	<0.001	0.0001	<0.001	<0.001	2.59	<0.001	<0.001	4.36	0.007

Lims ID	Sample ID	pH	pH Temp	TDS	EC	TDS by Sum	TDS by EC	P Alk.	M Alk.	F	Cl	NO2	NO3	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		
	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	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		
454399	**TP_ND/WATER/LEACH**	7.86	24.3	76	8.10	66	57	<0.6	35.5	0.27	0.66	<0.2	2.14	0.48	<0.8	4.23	1.03	1.21	-7.97		<0.01	< 5		<0.01	<5			
454400	**TP_ED/WATER/LEACH**	8.25	24.7	80	8.99	70	63	<0.6	33.5	0.15	2.03	<0.2	7.33	1.66	<0.8	4.14	1.10	1.24	-6.30		<0.01	< 5		<0.01	<5			
454401	**TP_WD/WATER/LEACH**	7.84	24.1	80	8.88	62	62	<0.6	37.8	0.35	0.26	<0.2	1.08	0.25	<0.8	7.10	1.09	1.08	0.38		<0.01	< 5		<0.01	<5			
454401 QC	**Duplicate**	7.84	23.7	76	8.93	62	63	<0.6	37.8	0.29	0.23	<0.2	1.46	0.33	<0.8	7.88	1.06	1.09	-1.51		<0.01	< 5		<0.01	<5			

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: 26/01/2016
Analysed by: UIS Waterlab

Date: 26/01/2016
Authorised : JJ Oberholzer

To: Golder Associates
Attention: Keretia Lupankwa
Project ID: 1542613
Site Location: Tati
Order No: 93115

Lims ID	Sample ID	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
	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	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
454399	TP_ND/WATER/LEACH	0.004	4.316	<0.001	<0.001	0.001	0.006	<0.001	0.002	0.002	<0.001	0.001	6.464	0.001	0.029	<0.001	<0.001	<0.0001	0.013	<0.001	0.0001	0.015	0.002	<0.001	0.034	<0.001
454400	TP_ED/WATER/LEACH	0.002	4.441	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	<0.001	<0.001	5.835	<0.001	0.041	<0.001	<0.001	<0.0001	0.011	<0.001	0.0001	0.022	0.001	<0.001	0.002	<0.001
454401	TP_WD/WATER/LEACH	0.003	5.018	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	<0.001	0.002	3.665	<0.001	0.033	<0.001	<0.001	<0.0001	0.002	<0.001	0.0001	0.010	0.001	<0.001	0.006	<0.001
454401 QC	Duplicate	0.004	4.654	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	<0.001	0.004	3.534	<0.001	0.034	<0.001	<0.001	<0.0001	0.001	<0.001	0.0001	0.010	0.001	<0.001	0.005	<0.001
	WATER LEACH 1:20																									
454399	TP_ND/WATER/LEACH																									
454400	TP_ED/WATER/LEACH																									
454401	TP_WD/WATER/LEACH																									
454401 QC	Duplicate																									

Date: 26/01/2016
Analysed by: UIS Waterlab

APPENDIX C

Acid Base Accounting Results

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

Date received: 2015-12-14
Date completed: 2016-01-12
Project number: 184 **Report number: 56559** **Order number:** 13377

Client name: UIS Analytical Services
Contact person: Japie Oberholzer
Address: P.O. Box 8286, Centurion, 0046
Email: japieo@uis-as.co.za
Telephone: 012 665 4291
Cell: 072 488 1001

Acid – Base Accounting Modified Sobek (EPA-600)	Sample Identification			
	TP-ND	TP-ED	TP-WD	TP-WD
Sample Number	**24230**	**24231**	**24232**	**24232D**
Paste pH	7.8	8.1	8.2	8.2
Total Sulphur (%) (LECO)	<0.01	<0.01	<0.01	<0.01
Acid Potential (AP) (kg/t)	0.313	0.313	0.313	0.313
Neutralization Potential (NP)	90	187	186	186
Nett Neutralization Potential (NNP)	90	187	186	186
Neutralising Potential Ratio (NPR) (NP : AP)	288	598	597	595
Rock Type	III	III	III	III

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

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

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Client name: UIS Analytical Services **Contact person:** Japie Oberholzer
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APPENDIX: TERMINOLOGY AND ROCK CLASSIFICATION

TERMINOLOGY (SYNONYMS)

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

CLASSIFICATION ACCORDING TO NETT NEUTRALISING POTENTIAL (NNP)

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

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

ROCK CLASSIFICATION

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

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CLASSIFICATION ACCORDING TO NEUTRALISING POTENTIAL RATIO (NPR)

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

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

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

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

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

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APPENDIX D

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