Kalgold

Geochemical mineral waste characterisation & assessment

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List of Abbreviations

AMD	Acid Mine Drainage
LCT	Leach Concentration Threshold
NEMWA	National Environmental Management Waste Act
R635	Regulation 635
TCT	Total Concentration Threshold
XRD	X-Ray Diffraction

1 INTRODUCTION

Geochemical Dynamic Systems (GeoDyn) was requested by MvB Consulting (MvB) to conduct a waste classification and acid mine drainage (AMD) assessment for mineral waste material, i.e, low-grade ore, tailings and two types of waste rock from the Kalgold mining operations, Water Tank waste rock, Spanover Waste Rock, Spanover low-grade ore and the Kalgold tailings material (Figure 1).

1.1 Project objectives

The project has the following main objectives:

- Classification of the mineral waste material from the Kalgold mining operations.
- Assessment of the likelihood of the development of AMD conditions from the mineral waste material.
- Pollution source term identification and potential contaminant concentrations.
- Environmental geochemical risk assessment of the waste rock material

2 METHODOLOGY

2.1 Classification of mineral waste

The mineral waste classification was conducted according to the National Environmental Waste Management Act[1] Regulation 635 (R635). This classification has two components. The first is to compare the total chemical composition of the waste with the Total Concentration Threshold (TCT) values of R635. The second is to conduct a leach test and compare the results with the Leach Concentration Threshold (LCT) values in R635. The results of the combination of the two components mentioned above is used to derive an overall waste type according to the R635 criteria, as outlined in Table 1. The laboratory data, which was used for the classification, is shown in Appendix B.

Table 1 Waste classification criteria (R635) and corresponding required engineered barrier system (R636)

Waste class	Criteria (R635)	Description	Engineered Barrier System Requirement (R636)
Type 4	LC ≤ LCT0 and LC ≤ TCT 0	Inert	None (soil compaction)
Type 3	LCT0 < LC ≤ LCT1 **and** TC ≤ TCT 1 Wastes with all element or chemical substance leachable concentration levels for metal ions and inorganic anions ≤ LCT0, provided all chemical substance concentration levels below R635 concentration 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 landfill without any other waste	Low risk	Class C
Type 2	LCT1 <LC ≤ LCT2 **and** TC ≤ TCT1	High risk	Class B
Type 1	LCT2 < LC ≤ LCT3 **or** TCT1 < TC ≤ TCT2 If the TC of an element or chemical substance is > TCT2 and the concentration cannot be reduced below the TCT 2 limit but the LC for a particular element or chemical If a particular chemical substance in a waste is not listed with corresponding LCT and TCT limits Wastes that have not been assessed and to be determined to be otherwise		Class A
Type 0	LC > LCT3 **or** TC > TCT2	Hazardous	Hazardous waste disposal site

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[1] Act 59 of 2008

Figure 1 Sample locality map

2.2 Assessment of AMD potential and source term characterisation

A laboratory Acid-Base Accounting (ABA) analysis and numeric geochemical modelling, which is rooted in equilibrium thermodynamics and chemical kinetics, was used to assess the processes in the mineral waste, which could potentially cause pollution and contamination of the surrounding environment. These processes include those which could potentially cause AMD, which are outlined in Section 4**.**

The USGS geochemical modelling software package, PHREEQC, was used to develop the geochemical models. The model setup, uncertainties, assumptions and limitations are shown in Appendix A. Total chemical analyses (ICP-MS) as well as mineralogy (XRD) data were used as input to the geochemical models. The geochemical models were also used to determine the sources of potential pollutants and to calculate likely concentrations at which these pollutants leach into the environment.

3 WASTE CLASSIFICATION

The results of the comparison between the LCT and TCT class values of R635 is shown in Table 2 and Table 3.

3.1 Leach Concentration Threshold assessment

Table 2 indicates that the leach concentrations of all the LCT parameters fall below LCT0 values of R635.

3.2 Total Concentration Threshold assessment

Table 3 indicates that all the total analysis concentrations of the waste rock material fall below the lowest regulatory threshold value (TCT1), with the exception of boron, which exceeds the regulatory value of TCT1, but is below the regulatory value of TCT2.

3.3 Classification of waste rock material

According to the criteria set out in R635 (Table 1) the Kalgold Water Tank waste rock as well as the Spanover low-grade ore classifies as Type 3. This classification depends on the mobility of boron in the natural environment, i.e. the ability of boron to leach from the waste rock material under natural conditions. This leachability is assessed in the numeric geochemical modelling phase (Section 4 and Section 5).

4 CONCEPTUAL GEOCHEMICAL FRAMEWORK

The conceptual framework forms the basis of the geochemical modelling and is therefore discussed in this section for the Kalgold mineral waste material (Figure 2).

Table 2 Comparison of leach test data to R635 Leach Concentration Threshold (LCT) regulatory values

Inorganic Waste constituents	Abbreviation	R635 Leach Concentration Threshold Values				Water Tank Waste Rock Dump	Spanover Waste Rock dump	Spanover low-grade ore	Tailing
		LCT0	LCT1	LCT2	LCT3				
		mg/L	*mg/L*	*mg/L*	*mg/L*	mg/L			
					Metal Ions				
Arsenic	**As**	0.01	0.5	1	4	<0.001	<0.001	<0.001	<0.001
Boron	**B**	0.5	25	50	200	0.0	<0.025	<0.025	<0.025
Barium	**Ba**	0.7	35	70	280	0.0	<0.025	<0.025	<0.025
Cadmium	**Cd**	0.003	0.15	0.3	1.2	<0.001	<0.001	<0.001	<0.001
Cobalt	**Co**	0.5	25	50	200	0.0	<0.025	<0.025	<0.025
Chromium (Total)	**Cr(Total)**	0.1	5	10	40	<0.001	<0.025	<0.025	<0.025
Chromium (VI)	**Cr(VI)**	0.05	2.5	5	20	<0.010	<0.010	<0.010	<0.010
Copper	**Cu**	2.0	100	200	800	<0.001	<0.010	<0.010	<0.010
Mercury	**Hg**	0.006	0.3	0.6	2.4	<0.001	<0.001	<0.001	<0.001
Manganese	**Mn**	0.5	25	50	200	0.1	<0.025	0.068	0.025
Molybdenum	**Mo**	0.07	3.5	7	28	<0.001	<0.025	<0.025	<0.025
Nickel	**Ni**	0.07	3.5	7	28	0.00	<0.025	<0.025	<0.025
Lead	**Pb**	0.01	0.5	1	4	<0.001	<0.001	<0.001	<0.001
Antimony	**Sb**	0.02	1.0	2	8	<0.001	<0.001	<0.001	<0.001
Selenium	**Se**	0.01	0.5	1	4	<0.001	<0.001	<0.001	<0.001
Vanadium	**V**	0.2	10	20	80	<0.001	<0.025	<0.025	<0.025
Zinc	**Zn**	5.0	250	500	2 000	0.0	<0.025	<0.025	<0.025
					Inorganic Anions				
Total Dissolved Solids	**TDS**	1 000	12 500	25 000	100 000	40	34	128	226
Chloride	**Cl**	300	15 000	30 000	120 000	<2	2	7	18
Sulphate	**SO_4**	250	12 500	25 000	100 000	12	3	49	87
Nitrate as Nitrogen	**NO_3-N**	11	550	1 100	4 400	<0.1	<0.1	<0.1	<0.1
Fluoride	**F**	2	75	150	600	<0.2	<0.2	<0.2	<0.2
Cyanide (Total)	**CN^-(Total)**	0	4	7	28	<0.02	<0.02	<0.02	0.12

Table 3 Comparison of the total analysis data to R635 Total Concentration Threshold (TCT) regulatory values

Waste constituents	Abbreviation	R635 Total Concentration Threshold Values			Water Tank Waste Rock Dump	Spanover Waste Rock dump	Spanover low-grade ore	Tailings
		TCT0 *mg/kg*	TCT1 *mg/kg*	TCT2 *mg/kg*	*mg/kg*			
				Metal Ions				
Arsenic	**As**	5.8	500	2 000	1.2	1.6	6.0	0.8
Boron	**B**	150	15 000	60 000	227	90	33	90
Barium	**Ba**	62.5	6 250	25 000	60	195	79	74
Cadmium	**Cd**	7.5	260	1 040	<0.4	<0.4	<0.4	<0.4
Cobalt	**Co**	50	5 000	20 000	1.2	<10	<10	<10
Chromium (Total)	**Cr(Total)**	46 000	800 000	n.a	156	290	306	188
Chromium (VI)	**Cr(VI)**	6.5	500	2 000	<2	<5	<5	<5
Copper	**Cu**	16.0	19 500	78 000	<0.4	84	126	55
Mercury	**Hg**	0.93	160	640	0.4	<0.4	<0.4	<0.4
Manganese	**Mn**	1 000	25 000	100 000	60	1 680	1 828	2 300
Molybdenum	**Mo**	40	1 000	4 000	2.8	<10	<10	<10
Nickel	**Ni**	91	10 600	42 400	4	121	113	93
Lead	**Pb**	20	1 900	7 600	15	7.6	8	8.8
Antimony	**Sb**	10	75	300	<0.4	<0.4	<0.4	<0.4
Selenium	**Se**	10	50	200	<0.4	<0.4	<0.4	<0.4
Vanadium	**V**	150	2 680	10 720	43	244	85	72
Zinc	**Zn**	240.0	160 000	640 000	<0.400	103	101	115
				Inorganic Anions				
Fluoride	**F**	100	10 000	40 000	<0.5	239	174	183
Cyanide (Total)	**CN^-(Total)**	14	10 500	42 000	<0.5	<0.5	<0.5	54

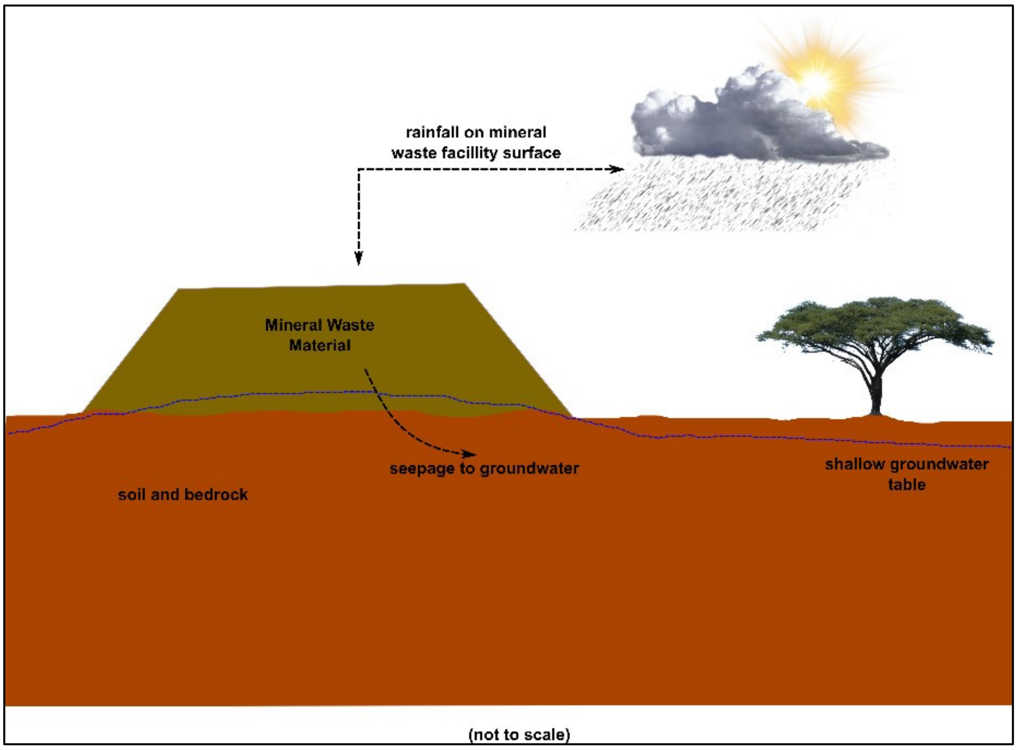

Figure 2 Conceptual model of the Kalgold waste rock material

4.1 Water tank waste rock material

The water tank waste rock dump (WTWRD) can be visualised as a dump or facility, open to the Earth's atmosphere in terms of oxygen, rainfall; and evaporation, from which contaminants can potentially leach into the soil groundwater systems (Figure 2). The WTWRD particles are coarse. Water and oxygen infiltration into the facility thus occurs more readily. However, due to the coarse particle size, the reactive surface area of this material is relatively low and geochemical processes, such as the breakdown of pyrite and other minerals of which the waste rock is composed, are relatively slow. However, if pollutants can escape the waste rock material, they will tend to leach vertically into the substrate below the waste rock facility and eventually into the groundwater. This will occur over a period of 2 - 5 years. It will be difficult to prevent the ingress of water, but after mining the waste rock dump can be rehabilitated by shaping it to enhance water runoff and possibly covering it with topsoil. The groundwater modelling has, however, showed that contaminant migration will be towards the pit, where it will settle as long as the pit remains open. Down-gradient receptors are not expected to be impacted.

The waste rock consists of the following minerals:

Quartz	[SiO_2]
Plagioclase	[$NaAlSi_3O_8$]
Muscovite	[$KAl_2(AlSi_3)O_{10}(OH)_2$]
Chlorite	[$Fe_2Al_2SiO_5(OH)_4$]

The waste rock in the Witwatersrand generally contains small amounts of pyrite [FeS_2], which was thus added to the Kalgold waste rock model. The minerals listed above, including pyrite, release silica, sodium, aluminium, iron and sulphate into the waste rock pore solutions. Boron is associated with muscovite and chlorite.

4.2 Waste rock, low-grade ore and tailings material

This material is analogous to the WTWRD material in terms of mineralogy. The major differences between these waste materials and the WTWRD material are the mineral compositions and the particle sizes of the material. The mineralogical compositions of the various materials, which were used in the numeric geochemical models, are shown in Table 4.

Table 4 Kalgold mineral waste material mineral composition

Mineral	Ideal formula	Waste Rock (Water Tank and Spanover) *wt%*	Spanover low-grade ore *wt%*	Tailings *wt%*
Quartz	SiO_2	56.2	67.7	67.7
Gypsum	$CaSO_4.2H_2O$	0.1	0.5	0.6
Chlorite	$Mg_5Al_2Si_3O_{10}(OH)_8$	18.4	10.7	6
Dolomite	$CaMg(CO_3)_2$	1.6	8.2	4.9
Pyrite	FeS_2	1.9	2.2	2.9
Sepiolite	$Mg_4Si_6O_{15}(OH)_2.6H_2O$	10.8	4.9	5.8
Calcite	$CaCO_3$	6.3	0.1	0.8
Siderite	$FeCO_3$	2	3.9	9.2
Ettringite	$Ca_6Al_2(SO_4)_3(OH)_{12}.26H_2O$	1.2	0.2	0.5
Bassanite	$CaSO_4.0.5H_2O$	0	0.6	0.9
Chloritoid	$FeAl_2(SiO_4)O(OH)_2$	1.3	1	0.6

Table 4 indicates that all three mineral waste types contain the mineral pyrite. Pyrite is unstable in the presence of oxygen in the Earth's atmosphere and breaks down to form acidity. This acidity can be balanced by the minerals calcite and dolomite, which also occur in the Kalgold mineral waste types, if it occurs in sufficient concentrations.

5 GEOCHEMICAL MODELLING

This section outlines the results of the numeric geochemical model for the mineral waste material. The potential contaminants flagged in the Waste Classification section are included in the numerical models to determine whether they are able to leach from the various materials in the long term. Appendix A contains a more detailed account of the setup of the numeric geochemical models.

5.1 Water Tank Waste Rock Material

A summary of the geochemical model results of the mineral waste rock is shown inTable 5. The values in Table 5 are compared to the LCT0 values in R635, not for the purposes of classification, as this regulatory process has been followed and is reported in Section 3, but only for comparative purposes. The SANS (2015) drinking water guideline values are used as comparative values for pH, TDS, sodium, potassium, aluminium and iron, as R635 does not contain values for these parameters. This is also done for comparative risk assessment purposes and should not be used out of this context.

Table 5 Numeric geochemical model results of the long-term WTWRD material leachate

Parameter	Abbreviation	*Units*	LCT0	SANS	Water Tank Waste Rock
pH	**pH**	*pH units*	n.g.v.	5 - 9.7	6.4
Total dissolved solids	**TDS**	*mg/L*	1 000	1 200	6.0
Sodium	Na^+	*mg/L*	n.g.v.	200	0
Potassium	K^+	*mg/L*	n.g.v.	300	2
Sulphate	SO_4^{2-}	*mg/L*	250	250	3
Bicarbonate	HCO_3^-	*mg/L*	n.g.v.	n.g.v.	1
Aluminium	Al^{3+}	*mg/L*	n.g.v.	0.3	<0.001
Iron (Total)	Fe_{total}	*mg/L*	n.g.v.	0.3	<0.001
Boron (total)	B_{total}	*mg/L*	0.7	2.4	0.003

The comparison between the numeric geochemical model results and the regulatory guideline values (Table 5) indicates that boron is not likely to leach from the waste rock material in concentrations, which are significantly lower than the regulatory values. This is because boron occurs in the silicate minerals muscovite and chlorite, which is stable at earth surface conditions. Boron is therefore not likely to leach from the waste rock in concentrations that may pose an environmental risk to any water source. Thus the WTWRD material can be classified as Type 4 waste.

5.2 Spanover Waste Rock Material

A summary of the geochemical model results of the mineral waste rock is shown in Table 5. The values in Table 5 are compared to the LCT0 values in R635, not for the purposes of classification, as this regulatory process has been followed and is reported in Section 3, but only for comparative purposes. The SANS (2015) drinking water guideline values are used as comparative values for pH, TDS, sodium, potassium, aluminium and iron, as R635 does not contain values for these parameters. This is also done for comparative risk assessment purposes and should not be used out of this context.

The comparison between the numeric geochemical model results and the regulatory guideline values (Table 6) indicates that the Spanover waste rock material has the potential to leach sulphate in concentrations exceeding the regulatory guideline values. None of the metals nor metalloid contaminants are shown to exceed regulatory guideline values. This is due to the fact that these constituents are locked up within the mineral structure of the mineral waste material. The rate of breakdown of these minerals is too slow for these constituents to leach in amounts exceeding regulatory guideline values.

Table 6 Numeric geochemical model results of the long-term Kalgold waste rock material leachate

Parameter	Abbreviation	*Units*	LCT0	SANS	Spanover Waste Rock
pH	**pH**	*pH units*	n.g.v.	5 - 9.7	5.0
Total dissolved solids	**TDS**	*mg/L*	1 000	1 200	1 033
Sulphate	SO_4^{2-}	*mg/L*	250	250	836
Bicarbonate	HCO_3^-	*mg/L*	n.g.v.	n.g.v.	197
Aluminium	Al^{3+}	*mg/L*	n.g.v.	0.3	<0.001
Barium	Ba^{2+}	*mg/L*	0.7	0.7	0.006
Boron (total)	B_{total}	*mg/L*	0.7	2.4	0.003
Copper (total)	Cu_{total}	*mg/L*	2.00	2.00	0.016
Fluoride	F^-	*mg/L*	1.5	1.5	0.001
Iron (total)	Fe_{total}	*mg/L*	n.g.v.	0.3	<0.001
Manganese (total)	Mn_{total}	*mg/L*	0.5	0.4	0.014
Nickel	Ni^{2+}	*mg/L*	0.07	0.07	0.015
Uranium (total)	U_{total}	*mg/L*	n.g.v.	0.03	0.010
Vanadium (total)	V_{total}	*mg/L*	0.2	0.2	0.013

5.3 Spanover Low-Grade Ore Material

A summary of the geochemical model results of the low-grade ore material is shown in Table 7. The values in Table 7 are compared to the LCT0 values in R635, not for the purposes of classification, as this regulatory process has been followed and is reported in Section 3, but only for comparative purposes. The SANS (2015) drinking water guideline values are used as comparative values for pH, TDS, sodium, potassium, aluminium and iron, as R635 does not contain values for these parameters. This is also done for comparative risk assessment purposes and should not be used out of this context.

The comparison between the numeric geochemical model results and the regulatory guideline values (Table 7) indicates that the low-grade ore material has the potential to leach sulphate in concentrations exceeding the regulatory guideline values. It also has the potential for a TDS load exceeding regulatory guideline values, but this is due to the presence of bicarbonate with the sulphate. Bicarbonate is not considered a pollutant. None of the metals nor metalloid contaminants are shown to exceed regulatory guideline values. This is due to the fact that these constituents are locked up within the mineral structure of the mineral waste material. The rate of breakdown of these minerals is too slow for these constituents to leach in amounts exceeding regulatory guideline values.

5.4 Kalgold Tailings Material

A summary of the geochemical model results of the low-grade ore material is shown in Table 8. The values in Table 8 are compared to the LCT0 values in R635, not for the purposes of classification, as this regulatory process has been followed and is reported in Section 3, but only for comparative purposes. The SANS (2015) drinking water guideline values are used as comparative values for pH, TDS, sodium, potassium, aluminium and iron, as R635 does not contain values for these parameters. This is also done for comparative risk assessment purposes and should not be used out of this context.

Table 7 Numeric geochemical model results of the long-term Kalgold low-grade ore material leachate

Parameter	Abbreviation	Units	LCT0	SANS	Low-Grade Ore
pH	**pH**	*pH units*	n.g.v.	5 - 9.7	5.5
Total dissolved solids	**TDS**	*mg/L*	1 000	1 200	1 690
Sulphate	**SO_4^{2-}**	*mg/L*	250	250	1 414
Bicarbonate	**HCO_3^-**	*mg/L*	n.g.v.	n.g.v.	276
Aluminium	**Al^{3+}**	*mg/L*	n.g.v.	0.3	0.002
Barium	**Ba^{2+}**	*mg/L*	0.7	0.7	0.007
Boron (total)	**B_{total}**	*mg/L*	0.7	2.4	0.003
Copper (total)	**Cu_{total}**	*mg/L*	2.00	2.00	0.009
Fluoride	**F^-**	*mg/L*	1.5	1.5	0.001
Iron (total)	**Fe_{total}**	*mg/L*	n.g.v.	0.3	<0.001
Manganese (total)	**Mn_{total}**	*mg/L*	0.5	0.4	0.007
Nickel	**Ni^{2+}**	*mg/L*	0.07	0.07	0.008
Uranium (total)	**U_{total}**	*mg/L*	n.g.v.	0.03	0.010
Vanadium (total)	**V_{total}**	*mg/L*	0.2	0.2	0.007

The comparison between the numeric geochemical model results and the regulatory guideline values (Table 8) indicates that the low-grade ore material has the potential to leach sulphate in concentrations exceeding the regulatory guideline values. It also has the potential for a TDS load exceeding regulatory guideline values, but this is due to the presence of bicarbonate with the sulphate. Bicarbonate is not considered a pollutant. None of the metals nor metalloid contaminants are shown to exceed regulatory guideline values.

Table 8 Numeric geochemical model results of the long-term Kalgold tailings material leachate

Parameter	Abbreviation	Units	LCT0	SANS	Tailings
pH	**pH**	*pH units*	n.g.v.	5 - 9.7	4.5
Total dissolved solids	**TDS**	*mg/L*	1 000	1 200	1 750
Sulphate	**SO_4^{2-}**	*mg/L*	250	250	1 550
Bicarbonate	**HCO_3^-**	*mg/L*	n.g.v.	n.g.v.	199
Aluminium	**Al^{3+}**	*mg/L*	n.g.v.	0.3	1.02
Barium	**Ba^{2+}**	*mg/L*	0.7	0.7	0.007
Boron (total)	**B_{total}**	*mg/L*	0.7	2.4	0.003
Copper (total)	**Cu_{total}**	*mg/L*	2.00	2.00	0.023
Fluoride	**F^-**	*mg/L*	1.5	1.5	0.001
Iron (total)	**Fe_{total}**	*mg/L*	n.g.v.	0.3	<0.001
Manganese (total)	**Mn_{total}**	*mg/L*	0.5	0.4	0.02
Nickel	**Ni^{2+}**	*mg/L*	0.07	0.07	0.02
Uranium (total)	**U_{total}**	*mg/L*	n.g.v.	0.03	0.020
Vanadium (total)	**V_{total}**	*mg/L*	0.2	0.2	0.018

This is due to the fact that these constituents are locked up within the mineral structure of the mineral waste material. The rate of breakdown of these minerals is too slow for these constituents to leach in amounts exceeding regulatory guideline values.

The pH of the tailings material is shown to by 4.5, which is below the regulatory drinking water guidelines. This shows that some acidity can be expected to leach from the tailings material, however, the amount of acidity projected to leach does not constitute acid mine drainage conditions, which typically has pH values of < 4.

6 ENVIRONMENTAL GEOCHEMICAL RISK ASSESSMENT

The environmental assessment methodology of Malan Scholes was used to assess the potential impact environmental impacts from the waste rock material assessed and discussed in this report. The methodology uses the following concepts in the assessment:

- **Nature of the impact**: A *brief description of the impact being assessed, in terms of the proposed activity or project, including the socio-economic or environmental aspect affected by this impact.*
- **Status of the impact:** *Whether the impact is of benefit or detriment to the environment or whether it is neutral.*
- **Magnitude of the impact: A** *brief description of the intensity or amplitude of the impact on socio-economic or environmental aspects.*
- **Extent of the project:** A *brief description of the spatial influence of the impact or the area that will be affected by the impact*.
- **Duration of the impact: A** *short description of the period of time the impact will have an effect on aspects*.
- **Probability of the impact occurring: T**he *estimated chance of the impact happening*.
- **Degree to which the impact can be reversed:** *The ability of an impact to be changed from a state of affecting aspects to a state of not affecting aspects*.
- **Degree to which impact may cause irreplaceable loss of resources: T***he amount of resources that can/can't be replaced.*
- **Degree to which the impact can be mitigated:** *The effect of mitigation measures on the impact and its degree of effectiveness.*
- **Confidence rating:** *Level of certainty of the impact occurring*.
- **Significance of the impacts:** *The combination of the duration and importance of the impact, in terms of physical and socio-economic extent, resulting in an indicative level of mitigation required*.
- **Cumulative impacts:** *The effect the combination of past, present and "reasonably foreseeable" future actions have on aspects.*

The potential environmental impacts assessed during this study for the operational and post-operational phases are:

1. The potential of the mineral waste material types to generate ***acid mine drainage*** conditions;
2. The potential of the mineral waste material types to ***leach metals and metalloids*** to the mineral waste substrate and groundwater;
3. The potential of the mineral waste material types to ***leach sulfate*** to the mineral waste substrate and groundwater;
4. The potential of the mineral waste material types to ***leach boron*** to the mineral waste substrate and groundwater;
5. The potential of the mineral waste material types to ***leach nitrate*** to the mineral waste substrate and groundwater;

The risk matrix is shown in Table 9 and discussed in the sections below.

6.1 Operational Phase

6.1.1 Acid mine drainage

The environmental risk matrix (Table 9) indicates that the risk of the development of acid mine drainage (AMD) conditions without implementing mitigation measures in the Water Tank waste rock, Spanover waste rock and low-grade ore material is “Very Low”. In the tailings, the risk rating is “Low”. Although the AMD risk of the tailings material can be decreased to “Very Low” by the implementation of mitigation measures, this is not required in the operational phase, as the pH, derived from numeric geochemical modelling, is ~4.5, which is higher than is typically regarded as AMD, i.e pH < ~3.

6.1.2 Leaching of metals and metalloids

The environmental risk matrix (Table 9) indicates that the risk of leaching of metals and metalloids from all waste types, i.e. Water Tank waste rock, Spanover waste rock, low-grade ore and tailings material is “Very Low”, without implementation of mitigation measures. The geochemical modelling has indicated that the risk of the leaching of metals and metalloids from all waste material types is negligible.

6.1.3 Leaching of sulfate

The environmental risk matrix (Table 9) indicates that the risk of leaching sulfate from the Water Tank waste rock material is “Very Low”. The geochemical modelling has shown that the amount of sulfate expected to leach from this material is negligible.

The environmental risk of leaching sulfate from the Spanover waste rock and low-grade ore material is “Low” without any mitigation measures. This is mostly due to the of sulfate leaching from these waste material types. The Low-grade ore material will be removed before the post-operational phase and will thus not be at risk of leaching sulfate in the long-term post-closure. The waste rock material will not be removed due to the “Low” risk rating for this activity.

The environmental risk of leaching sulfate from the tailings material is “Medium”.

Table 9 Environmental geochemical risk assessment impact matrix for the Kalgold waste rock

ENVIRONMENTAL ASPECT	NATURE OF THE IMPACT	IMPACT STATUS	MAGNITUDE	EXTENT	DURATION	REVERSIBILITY	IRREPLACEABILITY	PROBABILITY	SIGNIFICANCE	MITIGATION POTENTIAL	SIGNIFICANCE	CONFIDENCE RATING	CUMULATIVE IMPACTS
									PRE-MITIGATION		POST-MITIGATION		
Operational Phase													
GEOCHEMISTRY	Disposal of **Water Tank waste rock** onto the waste rock facility and the resultant formation of ***acid mine drainage conditions***	negative	5	3	5	2	15	1	15	High	15	Sure	Low
	Disposal of **waste rock** onto the waste rock facility and the resultant formation of ***acid mine drainage conditions***	negative	5	3	5	2	15	1	15	High	15	Sure	Low
	Disposal of **low-grade ore** onto the low-grade ore stockpile facility and the resultant formation of ***acid mine drainage conditions***	negative	5	3	5	2	15	1	15	High	15	Sure	Low
	Disposal of **tailings** onto the tailings facility and the resultant formation of ***acid mine drainage*** conditions	negative	5	3	5	2	15	2	30	High	15	Sure	Low
	Disposal of waste rock onto the **Water Tank waste rock** facility and resultant environmental pollution of Water Tank waste rock substrate and groundwater from the ***leaching of metal(loid)s***	negative	5	3	5	2	15	1	15	High	15	Sure	Low
	Disposal of **waste rock** onto the waste rock facility and resultant environmental pollution of waste rock substrate and groundwater from the ***leaching of metal(loid)s***	negative	5	3	5	2	15	1	15	High	15	Sure	Low
	Disposal of **low-grade ore** onto the low-frade ore facility and resultant environmental pollution of low-grade ore substrate and groundwater from the ***leaching of metal(loid)s***	negative	5	3	5	2	15	1	15	High	15	Sure	Low
	Disposal of **tailings** onto the tailings facility and resultant environmental pollution of tailings substrate and groundwater from the ***leaching of metal(loid)s***	negative	5	3	5	2	15	1	15	High	15	Sure	Low
	Disposal of waste rock onto the **Water Tank waste rock** facility and resultant environmental pollution of Water Tank waste rock substrate and groundwater from the ***leaching of sulfate***	negative	3	3	5	2	13	1	13	High	15	Sure	Low
	Disposal of **waste rock** onto the waste rock facility and resultant environmental pollution of waste rock substrate and groundwater from the ***leaching of sulfate***	negative	3	3	5	2	13	3	39	High	15	Sure	Low
	Disposal of **low-grade ore** onto the low-frade ore facility and resultant environmental pollution of low-grade ore substrate and groundwater from the ***leaching of sulfate***	negative	3	3	5	2	13	3	39	High	15	Sure	Low
	Disposal of **tailings** onto the tailings facility and resultant environmental pollution of tailings substrate and groundwater from the ***leaching of sulfate***	negative	3	3	5	2	13	4	52	High	15	Sure	Low
	Disposal of **Water tank waste rock** onto the Water Tanks waste rock facility and resultant environmental pollution of Water Tanks waste rock substrate and groundwater from the ***leaching of boron*** from the Water Tank waste rock material	neutral	2	3	5	1	11	1	11	High	11	Sure	Low
	Disposal of **waste rock** onto the waste rock facility and resultant environmental pollution of waste rock substrate and groundwater from the ***leaching of boron*** from the waste rock material	neutral	2	3	5	1	11	1	11	High	11	Sure	Low
	Disposal of **low-grade ore** onto the low-grade ore facility and resultant environmental pollution of low-grade ore substrate and groundwater from the ***leaching of boron*** from the low-grade ore material	neutral	2	3	5	1	11	1	11	High	11	Sure	Low
	Disposal of **tailings** onto the tailings facility and resultant environmental pollution of tailings substrate and groundwater from the ***leaching of boron*** from the tailings material	neutral	2	3	5	1	11	2	22	High	11	Sure	Low
	Disposal of **Water tank waste rock** onto the Water Tanks waste rock facility and resultant environmental pollution of Water Tanks waste rock substrate and groundwater from the ***leaching of nitrate*** from the Water Tank waste rock material	negative	5	3	3	2	13	4	52	High	11	Sure	Low
	Disposal of **waste rock** onto the waste rock facility and resultant environmental pollution of waste rock substrate and groundwater from the ***leaching of nitrate*** from the waste rock material	negative	5	3	3	2	13	4	52	High	11	Sure	Low
	Disposal of **low-grade ore** onto the low-grade ore facility and resultant environmental pollution of low-grade ore substrate and groundwater from the ***leaching of nitrate*** from the low-grade ore material	negative	5	3	3	2	13	4	52	High	11	Sure	Low
	Disposal of **tailings** onto the tailings facility and resultant environmental pollution of tailings substrate and groundwater from the ***leaching of nitrate*** from the tailings material	negative	5	3	3	2	13	4	52	High	11	Sure	Low
Post-Operational Phase													
GEOCHEMISTRY	Disposal of **Water Tank waste rock** onto the waste rock facility and the resultant formation of ***acid mine drainage conditions***	negative	5	3	5	2	15	1	15	High	15	Sure	Low
	Disposal of **waste rock** onto the waste rock facility and the resultant formation of ***acid mine drainage conditions***	negative	5	3	5	2	15	1	15	High	15	Sure	Low
	Disposal of **tailings** onto the tailings facility and the resultant formation of ***acid mine drainage conditions***	negative	5	3	5	2	15	2	30	High	15	Sure	Low
	Disposal of waste rock onto the **Water Tank waste rock** facility and resultant environmental pollution of Water Tank waste rock substrate and groundwater from the ***leaching of metal(loid)s***	negative	5	3	5	2	15	1	15	High	15	Sure	Low
	Disposal of **waste rock** onto the waste rock facility and resultant environmental pollution of waste rock substrate and groundwater from the ***leaching of metal(loid)s***	negative	5	3	5	2	15	1	15	High	15	Sure	Low
	Disposal of **tailings** onto the tailings facility and resultant environmental pollution of tailings substrate and groundwater from the ***leaching of metal(loid)s***	negative	5	3	5	2	15	1	15	High	15	Sure	Low
	Disposal of waste rock onto the **Water Tank waste rock** facility and resultant environmental pollution of Water Tank waste rock substrate and groundwater from the ***leaching of sulfate***	negative	3	3	5	2	13	3	39	High	15	Sure	Low
	Disposal of **waste rock** onto the waste rock facility and resultant environmental pollution of waste rock substrate and groundwater from the ***leaching of sulfate***	negative	3	3	5	2	13	3	39	High	15	Sure	Low
	Disposal of **tailings** onto the tailings facility and resultant environmental pollution of tailings substrate and groundwater from the ***leaching of sulfate***	negative	3	3	5	2	13	4	52	High	15	Sure	Low
	Disposal of **Water tank waste rock** onto the Water Tanks waste rock facility and resultant environmental pollution of Water Tanks waste rock substrate and groundwater from the ***leaching of boron*** from the Water Tank waste rock material	neutral	2	3	5	1	11	1	11	High	11	Sure	Low
	Disposal of **waste rock** onto the waste rock facility and resultant environmental pollution of waste rock substrate and groundwater from the ***leaching of boron*** from the waste rock material	neutral	2	3	5	1	11	1	11	High	11	Sure	Low
	Disposal of **tailings** onto the tailings facility and resultant environmental pollution of tailings substrate and groundwater from the ***leaching of boron*** from the tailings material	neutral	2	3	5	1	11	1	11	High	11	Sure	Low
	Disposal of **Water tank waste rock** onto the Water Tanks waste rock facility and resultant environmental pollution of Water Tanks waste rock substrate and groundwater from the ***leaching of nitrate*** from the Water Tank waste rock material	negative	5	3	3	2	13	1	13	High	11	Sure	Low
	Disposal of **waste rock** onto the waste rock facility and resultant environmental pollution of waste rock substrate and groundwater from the ***leaching of nitrate*** from the waste rock material	negative	5	3	3	2	13	1	13	High	11	Sure	Low
	Disposal of **tailings** onto the tailings facility and resultant environmental pollution of tailings substrate and groundwater from the ***leaching of nitrate*** from the tailings material	negative	5	3	3	2	13	1	13	High	11	Sure	Low

6.1.4 Leaching of boron

The environmental risk matrix (Table 9) indicates that the risk of boron leaching from the Water Tank waste rock, Spanover waste rock and low-grade ore material is "Very Low', without the implementation of any mitigation measures. This is predominantly due to the low risk of the release of boron in concentrations exceeding any regulatory leaching guideline values. This is due to the fact that boron is contained in silicate minerals, which break down very slowly over time by the process of chemical weathering.

The environmental risk of boron leaching from the tailings material is "Low", which is slightly higher than for the other waste materials. This is due to the lower pH in the tailings material and the slightly elevated probability of the leaching of boron from the silicate minerals. The severity of the eventuality of boron leaching from the tailings material is negligible and therefore mitigation measures are not required.

6.1.5 Leaching of nitrate

The environmental risk matrix (Table 9) indicates that the risk of nitrate is "Medium" for all mineral waste types without the implementation of mitigation measures. This is due to the co-deposition of the mineral waste material and process water. The process water contains the nitrate and not the mineral waste material. Therefore, this environmental risk is only likely in the operational phase and the nitrate leaching will cease completely when mining operations cease.

6.2 Post-Operational Phase

6.2.1 Acid mine drainage

The environmental risk matrix (Table 9) indicates that the risk of the development of acid mine drainage (AMD) conditions without implementing mitigation measures in the Water Tank waste rock, Spanover waste rock and low-grade ore material is "Very Low". In the tailings, the risk rating is "Low". The AMD risk of the tailings material can be decreased to "Very Low" by the implementation of mitigation and rehabilitation measures may be considered to further reduce this impact. This will also have beneficial effects for other environmental risks, as described in the sections below.

6.2.2 Leaching of metals and metalloids

The environmental risk matrix (Table 9) indicates that the risk of leaching of metals and metalloids from all waste types, i.e. Water Tank waste rock, Spanover waste rock, low-grade ore and tailings material is "Very Low", without implementation of mitigation measures. The geochemical modelling has indicated that the risk of the leaching of metals and metalloids from all waste material types is negligible.

6.2.3 Leaching of sulfate

The environmental risk matrix (Table 9) indicates that the risk of leaching sulfate from the Water Tank waste rock material is "Very Low". The geochemical modelling has shown that the amount of sulfate expected to leach from this material is negligible.

The environmental risk of leaching sulfate from the waste rock and low-grade ore material is "Low" without any mitigation measures. This is mostly due to the of sulfate leaching from these waste material types. The Low-grade ore material will be removed before the post-operational phase and will thus not be at risk of leaching sulfate in the long-term post-closure. The waste rock and tailings material will not be removed, but due to the “Low” risk rating for this activity, mitigation and rehabilitation measures may be considered to further reduce this impact.

The environmental risk of leaching sulfate from the tailings material is “Medium”. This risk rating can be decreased by applying simple mitigation and rehabilitation measures may be considered to further reduce this impact.

6.2.4 Leaching of nitrate

The environmental risk matrix (Table 9) indicates that the risk of nitrate is “Medium” for all mineral waste types without the implementation of mitigation measures. This is due to the co-deposition of the mineral waste material and process water. The process water contains the nitrate and not the mineral waste material. Therefore, this environmental risk is only likely in the operational phase and the nitrate leaching will cease completely when mining operations cease. Mitigation in the post-operational phase is therefore not required.

7 CONCLUSIONS

The following conclusions follow from this study:

7.1 Kalgold Water Tank waste rock

- The Kalgold Water Tank waste rock material classifies as Type 3 according to the criteria set out in R635. However, the Type 3 class is reached by the exceedance of only boron and only in the total analysis (TCT). Long-term, numeric geochemical modelling confirms the leach test that the boron is located within the silicate mineral structures and are thus unlikely to leach from the waste rock in concentrations excluding any regulatory guideline values. The waste should therefore classify as Type 4 based on the geochemical assessment.
- The Kalgold Water Tank waste rock material is unlikely to produce acid mine drainage conditions.
- The risk rating of the cumulative impacts from the Kalgold Water Tank waste rock is “Low”.

7.2 Spanover waste rock

- The Kalgold Spanover waste rock material classifies as Type 3 according to the criteria set out in R635. However, the Type 3 class is reached by the exceedance of only boron and only in the total analysis (TCT). Long-term, numeric geochemical modelling confirms the leach test that the boron is located within the silicate mineral structures and are thus unlikely to leach from the waste rock in concentrations excluding any regulatory guideline values. The waste should therefore classify as Type 4 based on the geochemical assessment.
- The Kalgold waste rock material is unlikely to produce acid mine drainage conditions.
- The risk rating of the cumulative impacts from the Kalgold waste rock material is “Low”.

7.3 Kalgold Spanover low-grade ore material

- The geochemical assessment indicates that only sulfate is likely to exceed regulatory guidelines in the Operational Phase of the project. The low-grade ore material will be removed before closure of the mine, implying no long-term post-closure impacts. This material should therefore be classified as Type 4 as defined in R635.
- The low-grade ore material is unlikely to develop acid mine drainage conditions.
- The risk rating of the cumulative impacts from the Kalgold low-grade ore material is “Low”.

7.4 Kalgold tailings material

- The geochemical assessment indicates that only sulfate is likely to exceed regulatory guidelines in the Operational Phase of the project. In the post-operational phase a cap can be placed on the tailings facility to reduce oxygen infiltration into the facility and reduce sulfate leaching to acceptable levels in the Post-Operational phase. Therefore this material should be classified as Type 4 as defined in R635.
- Although the leachate from the tailings is expected to be slightly acidic (pH ~4.5), it is unlikely to develop acid mine drainage conditions, which generally has pH values of less than 3.

  The risk rating of the cumulative impacts from the Kalgold tailings material is “Low”

8 RECOMMENDATIONS

The following recommendations follow from the study:

1. Based on the geochemical assessment all the mineral waste types, i.e. the Water Tank waste rock, the Spanover waste rock, the low-grade ore material and the tailings material can be classified as Type 4.

9 REFERENCES

OMI Solutions (2020) Kalgold waste classification. *Technical Report*

APPENDIX A: MODEL SENSITIVITY, UNCERTAINTY AND LIMITATIONS

The sensitivities, uncertainties and limitations of the various geochemical models are presented in this section.

The Kalgold waste material is exposed to the Earth's atmosphere, which is aerobic and contains 21% oxygen. The minerals from the XRD analysis (Section 4) were used as kinetic inputs to the model to account for time in the geochemical processes. The WRD material consists of relatively large particle sizes, which imply low reaction rates of the geochemical processes The rates at which reactions, e.g. breakdown of pyrite, occurs, is correlated to the reactive surface area of the particles. The finer the particles, the larger the reactive surface area of the material as a whole and the more rapid reactions occur. The reactions for the mineral waste material therefore occur significantly slower than for the tailings material. Slower reaction rates and larger pore spaces between particles prevent the mineral waste facility to develop well-developed geochemical zones. Therefore the whole mineral waste facility can be treated as a single entity in the geochemical modelling. The permeability of Witwatersrand gold mineral waste is relatively large, due to the coarse particles. The contact-time between the waste-rock and the percolating water solution is therefore also significantly less in the mineral waste material. This an important consideration in modelling water quality from of these facilities. A conservative approach was followed in that the same ratio of water to rock of 1:1 is used in the mineral waste, thereby allowing geochemical reactions to take place, even though the exact ratio is uncertain.

The limitation of this model is that it simulates the geochemical processes, e.g. the breakdown of minerals, and cannot be used to calculate the rate at which water percolates through the tailings system.

APPENDIX B: LABORATORY CERTIFICATES

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

Date received: 2020-07-03
Project number: 1000
Report number: 92749
Date completed: 2020-07-24
Order number: MVB_20_02

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Acid – Base Accounting Modified Sobek (EPA-600)	Sample Identification	
	Water Tank Waste Rock Dump	Water Tank Waste Rock Dump
Sample Number	98538	98538 D
Paste pH	6.8	6.8
Total Sulphur (%) (LECO)	0.02	0.02
Acid Potential (AP) (kg/t)	0.763	0.778
Neutralization Potential (NP)	-1.48	-1.74
Nett Neutralization Potential (NNP)	-2.24	-2.52
Neutralising Potential Ratio (NPR) (NP : AP)	1.94	2.24
Rock Type	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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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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CERTIFICATE OF ANALYSES

EXTRACTIONS AS 4439.3

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Analyses	Sample Identification Water Tank Waste Rock Dump				
Sample Number	98538				
TCLP / Borax / Distilled Water	Distilled Water				
Ratio*	1:20				
Units	mg/ℓ	LCT0 mg/l	LCT1 mg/l	LCT2 mg/l	LCT3 mg/l
As, Arsenic	<0.001	0.01	0.5	1	4
B, Boron	0.004	0.5	25	50	200
Ba, Barium	0.013	0.7	35	70	280
Cd, Cadmium	<0.001	0.003	0.15	0.3	1.2
Co, Cobalt	0.001	0.5	25	50	200
Cr_{Total}, Chromium Total	<0.001	0.1	5	10	40
Cr(VI), Chromium (VI)	<0.010	0.05	2.5	5	20
Cu, Copper	<0.001	2.0	100	200	800
Hg, Mercury	<0.001	0.006	0.3	0.6	2.4
Mn, Manganese	0.139	0.5	25	50	200
Mo, Molybdenum	<0.001	0.07	3.5	7	28
Ni, Nickel	0.001	0.07	3.5	7	28
Pb, Lead	<0.001	0.01	0.5	1	4
Sb, Antimony	<0.001	0.02	1.0	2	8
Se, Selenium	<0.001	0.01	0.5	1	4
U, Uranium	<0.001				
V, Vanadium	<0.001	0.2	10	20	80
Zn, Zinc	0.002	5.0	250	500	2000
Inorganic Anions	mg/ℓ				
Total Dissolved Solids*	40	1000	12 500	25 000	100 000
Chloride as Cl	<2	300	15 000	30 000	120 000
Sulphate as SO4	12	250	12 500	25 000	100 000
Nitrate as N	<0.1	11	550	1100	4400
Fluoride as F	<0.2	1.5	75	150	600
Total Cyanide as CN [o]	<0.02	0.07	3.5	7	28
Paste pH	6.8				
Acid Base Accounting	See attached report 92749 ABA				
X-ray Diffraction [o]	See attached report 92749 XRD				

[o] = Outsourced

***Please note:**
1. The samples were used as received.
2. A moisture content were determined for wet or moist samples.
3. In cases where the sample were a slurry, a solid to liquid ratio were done (reported).
   Moisture content were determined after filtration
4. The results are reported as received. The moisture content were not taken into account.

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Assistant Geochemistry Project Manager

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CERTIFICATE OF ANALYSES

Digestion AS 4439.3

Date received: 2020/07/03
Project number: 1000
Report number: 92749
Date completed: 2020/07/24
Order number: MVB_20_02

Client name: MvB Consulting
Address: P.O. Box 2166, Rant en Dal, 1751
Telephone: ---
Contact person: Marius van Biljon
Email: marius@mvbconsult.co.za
Cell: 079 741 9595

Analyses	Sample Identification				
	Water Tank Waste Rock Dump				
Sample Number	98538		TCT0 mg/kg	TCT1 mg/kg	TCT2 mg/kg
Digestion	HNO3 : HF				
Dry Mass Used (g)	0.25				
Volume Used (mℓ)	100				
Units	mg/ℓ	mg/kg			
As, Arsenic	0.003	1.20	5.8	500	2000
B, Boron	0.567	227	150	15000	6000
Ba, Barium	0.150	60	62.5	6250	25000
Cd, Cadmium	<0.001	<0.400	7.5	260	1040
Co, Cobalt	0.003	1.20	50	5000	20000
Cr$_{Total}$, Chromium Total	0.391	156	46000	800000	N/A
Cu, Copper	<0.001	<0.400	16	19500	78000
Hg, Mercury	0.001	0.400	0.93	160	640
Mn, Manganese	0.151	60	1000	25000	100000
Mo, Molybdenum	0.007	2.80	40	1000	4000
Ni, Nickel	0.010	4.00	91	10600	42400
Pb, Lead	0.037	15	20	1900	7600
Sb, Antimony	<0.001	<0.400	10	75	300
Se, Selenium	<0.001	<0.400	10	50	200
U, Uranium	0.003	1.20			
V, Vanadium	0.108	43	150	2680	10720
Zn, Zinc	<0.001	<0.400	240	160000	640000
Inorganic Anions	mg/ℓ	mg/kg			
Cr(VI), Chromium (VI) Total [o]	---	<2	6.5	500	2000
Total Fluoride [o]	---	<0.5	100	10000	40000
Total Cyanide as CN [o]	---	<0.5	14	10500	42000

[o] = Outsourced

UTD = Unable to determine

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CERTIFICATE OF ANALYSES
X-RAY DIFFRACTION

Date received: 2020-07-03
Project number: 1000

Report number: 92749

Date completed: 2020-07-14
Order number: MVB_20_02

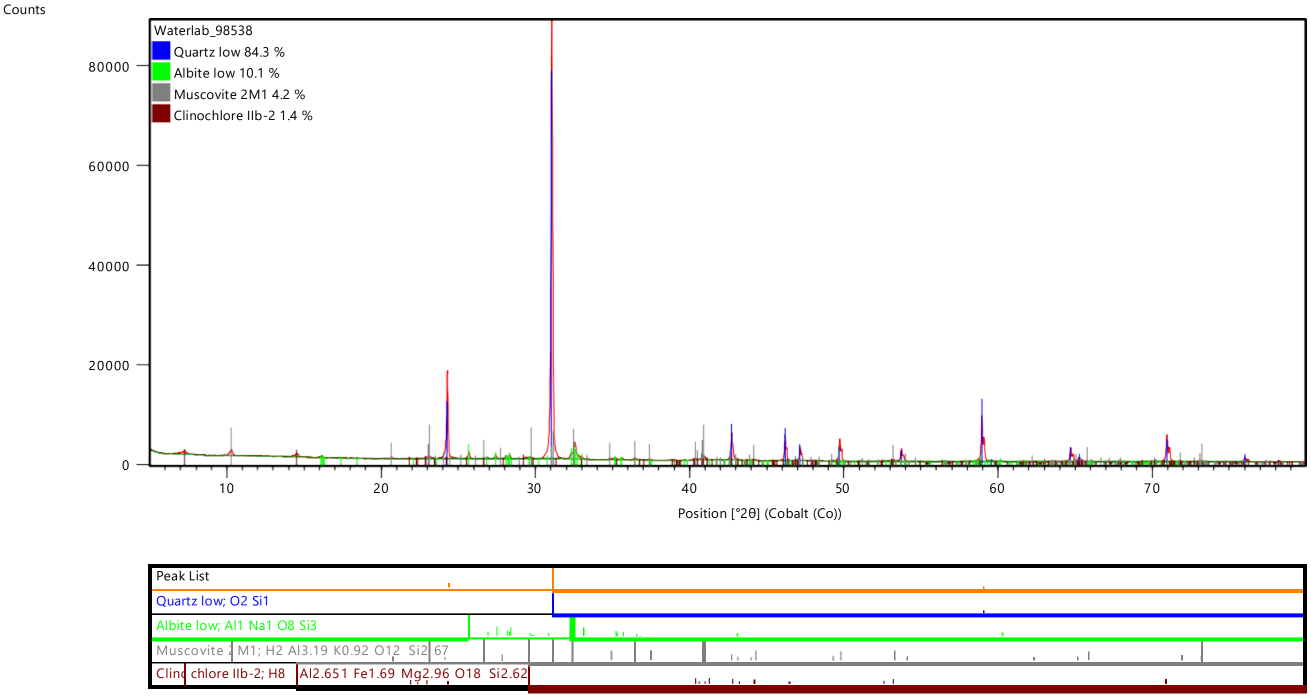
Client name: MvB Consulting
Address: P.O. Box 2166, Rant en Dal, 1751
Telephone: ---

Facsimile: ---

Contact person: Marius van Biljon
Email: marius@mvbconsult.co.za
Cell: 079 741 9595

Composition (%) [o]	
Water Tank Waste Rock Dump	
98538	
Mineral	Amount (weight %)
Quartz	84.3
Plagioclase	10.1
Muscovite	4.2
Chlorite	1.4

[o] = Outsourced



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CERTIFICATE OF ANALYSES
X-RAY DIFFRACTION

Date received: 2020-07-03
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Note:

The material was prepared for XRD analysis using a back loading preparation method.
Diffractograms were obtained using a Malvern Panalytical Aeris diffractometer with PIXcel detector and fixed slits with Fe filtered Co-Kα radiation. The phases were identified using X'Pert Highscore plus software.
The relative phase amounts (weight %) were estimated using the Rietveld method.

Comment:

- In case the results do not correspond to results of other analytical techniques, please let me know for further fine tuning of XRD results.
- Mineral names may not reflect the actual compositions of minerals identified, but rather the mineral group. Smectite, lizardite (serpentine), vermiculite, chlorite and kaolinite peaks overlap, and further test would be necessary to distinguish. Identification is largely based on peak shapes and positions.
- Due to preferred orientation and crystallite size effects, results may not be as accurate as shown.
- Traces of additional phases such as kaolinite and smectite may be present.
- Amorphous phases, if present, were not taken into consideration during quantification.

Ideal Mineral compositions:

Compound Name	Ideal Chemical Formula
Quartz	SiO2
Plagioclase	(Na,Ca)(Si,Al)4O8
Chlorite	(Mg,Fe)5Al(AlSi3O10)(OH)8
Muscovite/Mica	K Al2 ((OH)2 Al Si3 O10)

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