GROUNDWATER BASELINE STUDY FOR MATAI

MATAI MINING (PTY) LTD

NORTH WEST

MARCH 2019

PRJ_R_1/Rev01

kimopax

your future in safe hands

Directors: ST Netshiozwi | C Monokofala | MS Masoga | ME Madisha

Email: info@kimopax.com | Website: www.kimopax.com

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MATAI MINING (PTY) LTD

NORTH WEST PROVINCE

MARCH 2018

Conducted on behalf of:

Matai Mining (Pty) Ltd
P.O Box 786163
Sandton
2146

Compiled by:

____

Karabo Lenkoe-Magagula

Reviewed by:

____

Collen Monokofala

Project team:

Reborn Musie

Mapoti Mahlangu

Document History and Distribution List

Project Number	Date	Revision Number
KIM-2017-GEO-128	September	01

Name	Institution
Matai Mining (Pty) Ltd	Matai Mining (Pty) Ltd
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List of Abbreviations

ABA	Acid Base Accounting
AG	Acid Generating
AP	Acid Potential
ARD	Acid Rock Drainage
BDL	Below Detection limit
BIC	Bushveld igneous Complex
DEA	Department of Environmental Affairs
DMR	Department of Mineral Resources
DW	Distilled/Reagent Water
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EMP	Environmental Management Program
EMPR	Environmental Management Program Report
GQS	Groundwater Quality Specifications
ICP	Inductively Coupled Plasma Spectrometry
LC	Leachable Concentration
LCT	Leachable Concentration Threshold
LOM	Life of Mine
mbgl	Meters below ground level
mg/kg	milligrams per kilogram

mg/L	milligrams per litre
mamsl	meters above mean sea level
NAG	Net Acid Generation
NEM: WA	National Environmental Management Waste Act
NEMA	National Environmental Management Act
NNP	Nett Neutralising Potential
non-PAG	Non-Potentially Acid Generating
NP	Neutralising Potential
NPR	Neutralising Potential Ratio
PAG	Potentially Acid Generating
SANS	South African National Standards
SPLP	Synthetic Precipitation Leachate Procedure
TC	Total Concentration
TCLP	Toxicity Characteristic Leachate Procedure
TCT	Total Concentration Threshold
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
WHO	World Health Organisation
XRD	X-Ray Diffraction
XRF	X-Ray Fluorescence

EXECUTIVE SUMMARY

Matai Mining (Pty) Ltd is applying for a mining right on the farms, certain portion of farm Magazynskraal 3 JQ, certain portion of farm Haakdoorn 6 JQ, the farm Wildebeeskuil 7 JQ, certain portion of the remaining extent of portion 1, certain portion of the remaining extent of portion 2, certain portion of the remaining extent of portion 5, certain portion of 6, portions 11, 12 and 13 (portion of portion 2) and certain portion of the remaining extent of the farm Syferkuil 9 JQ, the remaining extent of portion 1, portion 2, portion 3 (a portion of portion 1), the remaining extent of the farm Middelkuil 8 JQ.

The proposed project is in the Moses Kotane Municipality, Bojanala Platinum District Municipality, North West Province, South Africa. The project is approximately centred on Geographic coordinates (Latitude 25° 00′ 00” S, Longitude 27° 10′ 00” E).

Regional climate at the area is typically hot summers and cool, dry winters that falls within the Highveld Climatic Zone. Temperatures ranged between 0.4 °C and 34.1 °C, where the maximum temperatures have been recorded to occurred in December and the minimum occurring in June and July. The average annual evaporation is approximately 1329mm.

The geology of the area is characterised by the Bierkraal Magnetite Gabbro from the Rustenburg Layered Suite of the Bushveld Complex. The Bierkraal Magnetite Gabbro is classified as a ferrogabbroic Upper Zone according to the Standard zonal subdivision. The BMG of the Rustenburg Layered Suite consists of magnetite gabbro, diorite and a magnetite layer. The Matai area is classified as having a moderate potential for groundwater occurrence with typical borehole yields between 0.5 and 2.0 l/s being reported.

Proposed project area falls within A24E quaternary catchment, which forms part of the catchment of the Crocodile River which ultimately feeds into the Limpopo.

Three dominants hydro-stratigraphic units (Alluvial deposits; Shallow weathered aquifer system; and Shallow and Deeper Localized fracture aquifer system) are found in the catchments. The water levels measured during the hydrocensus ranges between 14.31mbgl and 44.9 mbgl. A comparison of the water level elevation with topography shows a good correlation of 99.9%.

Geochemistry and Waste Classification

Four core samples representative of the material to be stockpiled were collected and submitted to Aquatico Laboratories for analysis. The samples were analysed for XRF, XRD, ABA, Sulphur Speciation and leaching.

Based on the results of ABA and sulphur speciation, none of the samples have potential to generate acid.

Four of the collected samples were analysed in order to classify the waste rock material in accordance with the NEM: WA Regulations (2013) by comparison with Total Concentration Threshold (TCT) and Leachable Concentration Thresholds (LCT). Total Concentration values were determined by *aqua regia* digestion while the leachable concentrations were prepared by a leachate of 25% aqueous extraction.

The results to classify the waste yielded a Type 4 waste based on Leachable Concentration and Type 3 based on Total concentration. For the study, a Class C landfill will be needed for disposal of the material based on the TC and LC results. The leach test results show that no chemicals of concern leached out. Based on the risk-based approach model, the current mitigation (separation of dirty and clean water, containing of all runoff from storage facilities and installation of stockpile berms), Kimopax proposes that the residue stockpiles be classed as Type 4 waste that needs to be deposited on Class D disposal area

Numerical Modelling

As the potential pollution sources are located close to water divided, and open pit, groundwater flow during active mining will be toward the open pit, but also toward main natural surface drainage. The contamination plume that will emanate from the plant area is anticipated to move into western direction toward the mine pit (Figure 21 to Figure 32). But the contamination plume that will emanate from the waste dump area is anticipated to move into eastern direction toward the north-north-east down-gradient of the waste dump. The toe of the plume (with a concentration of less 1 mg/l) is estimated to extend 700 m away from waste dump, 20 years after contamination commences.

The open pit area will be kept dry for mine safety and polluted water should be pumped to dirty water dams.

Any pollution plumes emanating from mining activities (Waste dump, plant, dirty water dams, etc.) is expected to be restricted to the mine property. Neighbouring boreholes will not be affected during active mining

The development of proposed Matai Mine project poses risks to groundwater as assessed. The proper design, construction and operation, and maintenance of the appropriate respective liner system below dirty water dams, waste dump, should be implemented as well as the rehabilitation of the open mine, are part of the key focus areas to mitigate groundwater impacts. The following precautions must be taken into consideration to reduce possible groundwater risks posed by the development of proposed Mine:

a) Groundwater management strategies must be implemented to prevent risk of water pollution;
b) Groundwater monitoring network should be installed before the starting of any construction activities on site;
c) The monitoring network can be updated according to the DWA minimum requirements, if required;
a) Monitoring of groundwater must be done once quarterly;
    - Any waste and spills (especially during construction, operation and closure) need to be cleaned up immediately according to the DWA minimum requirements;
    - Authorities need to be notified in the event of a spill or leachate during construction, operation and closure;
    - Clean and dirty water is to be separated, and any containment of dirty water should be lined.
    - Vehicle storage and maintenance areas to be hard-surfaced; Regular maintenance of vehicles must be implemented;
    - The reusing dirty water from mine activities must be assessed and implemented as much as possible.
    - Application for WULA amendment as per DWA requirements

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1 INTRODUCTION

Kimopax (Pty) Ltd (hereafter Kimopax) has being appointed by Matai Mining (Pty) Ltd (hereafter Matai) to conduct a groundwater baseline study as part of specialist study that will form part of mining rights application in terms of the Section 23 (a), (b) and (c) read together with regulation 11(1) (g) of the MPRDA (ACT 28 of 2002). This document constitutes the baseline groundwater study, which forms part of the EIA.

Matai Mining (Pty) Ltd is applying for a mining right on the farms, certain portion of farm Magazynskraal 3 JQ, certain portion of farm Haakdoorn 6 JQ, the farm Wildebeeskuil 7 JQ, certain portion of the remaining extent of portion 1, certain portion of the remaining extent of portion 2, certain portion of the remaining extent of portion 5, certain portion of 6, portions 11, 12 and 13 (portion of portion 2) and certain portion of the remaining extent of the farm Syferkuil 9 JQ, the remaining extent of portion 1, portion 2, portion 3 (a portion of portion 1), the remaining extent of the farm Middelkuil 8 JQ.

1.1 Locality

Matai Project is in the Moses Kotane Municipality, Bojanala Platinum District Municipality, North West Province, South Africa. It lies about 10km south from the closest town Northam, approximately, 80km north east of Rustenburg and 220km north west of Johannesburg, between the Pilanesberg Nature Reserve in the south (approx. 8km from the project), Pilanesberg Mines in the west (approx. 8km from the project) and Siyanda Resources Union Mine in the north (approx. 5km from the project). The project is approximately centred on Geographic coordinates (Latitude 25° 00′ 00" S, Longitude 27° 10′ 00" E). Figure 1 shows the proposed project site location. The elevation at the site is approximately 1075 m amsl to 1015 m amsl, and the area slopes gently in a north-easterly direction.

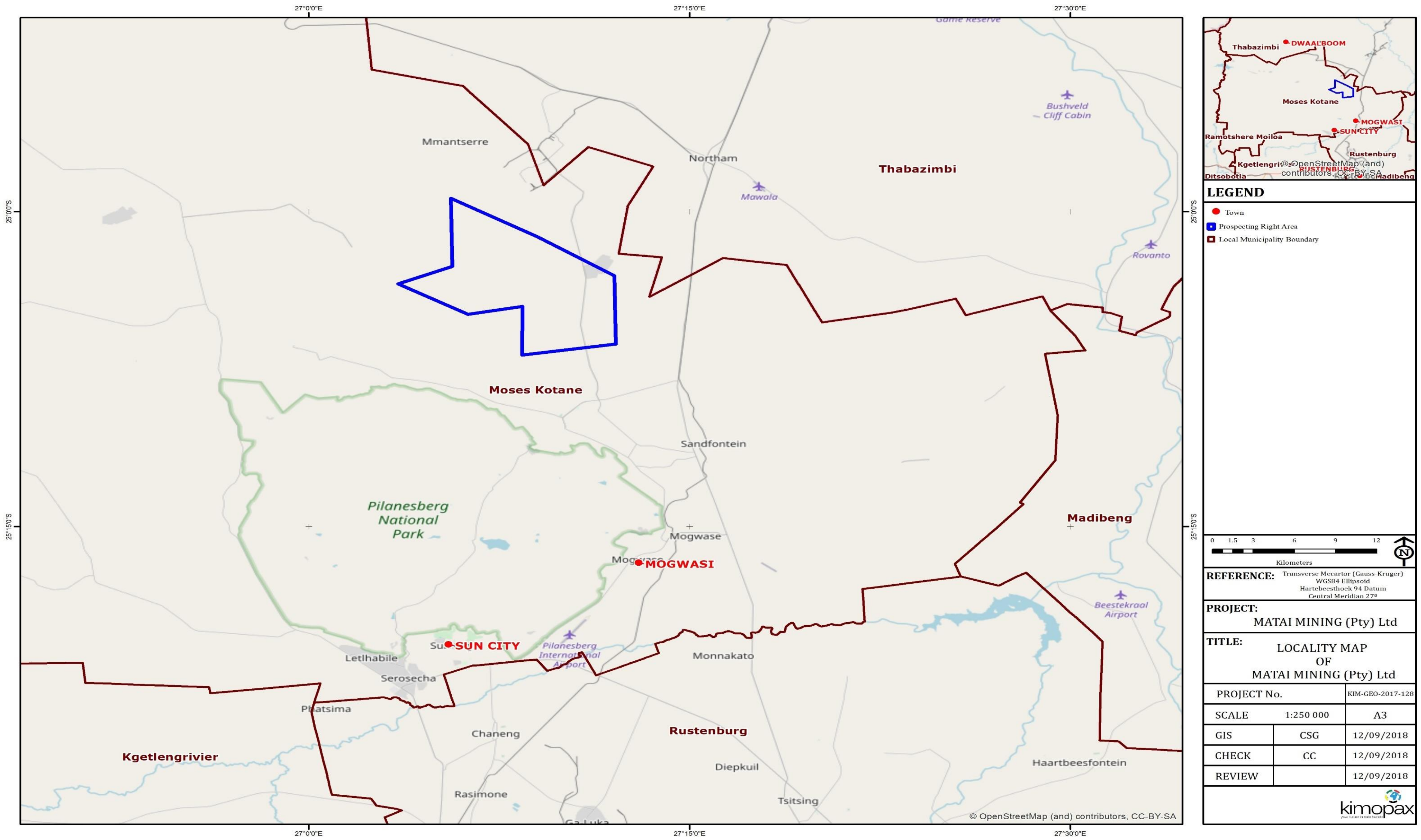

Figure 1: Locality Map

2 BASELINE ANALYSI

2.1 Climate

The regional climate is typically hot summers and cool, dry winters. Matai project site falls within the Highveld Climatic Zone where the mean annual precipitation, 85% falls during summer season thunderstorms. Report by SLR indicate that thunderstorms generally occur every 3 to 4 days in summer and are of short duration and high intensity. Temperatures in this climatic zone are generally mild, but low minima can be experienced in winter due to clear night skies. Frost characteristically occurs in the winter months. Generally, winds are light, but south-westerly winds associated with thunderstorms are typically strong and gusty (SLR, 2013).

2.2 Temperature

Monthly mean and hourly maximum and minimum temperatures are given in Table 1 as sourced from SRL (2015) report. Temperatures ranged between 0.4 °C and 34.1 °C, where the maximum temperatures have been recorded to occurred in December and the minimum occurring in June and July. During the day, temperatures increase to reach maximum at around 14:00 in the afternoon. Ambient air temperatures decrease to reach a minimum at around 06:00 i.e. just before sunrise.

Table 1: average monthly minimum and maximum temperature

Average temperatures												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
minimum	16,4	15,1	12,6	6	5	0,4	0,9	3,1	6,4	11,1	13,1	15,4
Maximum	32,8	33,6	32,4	28	24,8	22,4	21,1	26	30,3	32,5	32,6	34,1
Average	24,7	24,1	22,6	18,9	16	12,4	10,9	14,9	19,4	22	23,9	24,9

2.3 Rainfall and evaporation

Rainfall data are selected to be representative of the site is DWS station A2E021 (Zwartklip). Zwartklip weather station has rainfall record for a period of 15 years. The same station evaporation data was used for consistency purposes.

Table 2 presents a summary of the monthly rainfall and evaporation at Station A2E021. Evaporation figures recorded for the area are high. The average annual evaporation is approximately 1329mm. The highest evaporation occurs in December (more than 160mm) and the lowest evaporation in June (less than 60mm).

Table 2: Monthly rainfall and evaporation distribution

Month	Rainfall (mm)	Evaporation (mm)
Jan	151	150
Feb	62	125
Mar	78	114
Apr	39	85
May	6.0	70
Jun	3.0	55
Jul	1.0	61
Aug	4.o	82
Sep	16	115
Oct	51	150
Nov	67	158
Dec	82	163
Total	560	1328

2.4 Topography

The project site is relatively flat, at an average elevation of 1040 metres above mean sea level (mamsl), with various non-perennial drainage lines crossing the site. The topographic relief can be described as relatively gently sloping towards the north-east, while the topographic elevation varies between 1075mamsl in the north east of the project site to 1015 mamsl in the north. To the south of the project site is the Pilanesberg Mountain Range and the associated hills that vary between 1 330 and 1 534 mamsl.

2.5 Hydrology

The Water Resources of South Africa Manual WR2012 (WRC, 2012) shows that the project area falls within the Limpopo Water management area (WMA) 1 (Figure 2). Most of the project site falls within quaternary catchment A24E, lesser extent of the project site is located within the quaternary catchment A24D both of which form upstream of Bierspruit Dam at the outlet of the catchment. The catchments are within the catchment of the Crocodile River which ultimately feeds into the Limpopo.

The quaternary catchment climatic and runoff parameters such as mean annual; runoff (MAR), mean annual precipitation (MAP) a mean annual evaporation (MAE), have been extracted from the WR2012 study are indicated in Table 3 (WRC, 2012)

Table 3 MAR, MAP and MAE of the A24E and A24D Quaternary

Quaternary Catchment	Total Area (km^2)	MAR (* 10^6 m^3)	MAP (mm)	MAE (mm)	Rainfall Zone	Evaporation Zone	MRA in Catchment %/ km^2
A24D	1328	19.72	600	1850	A2N	3A	1% (13.8 km^2)
A24E	688	10.39	592	1800	A2N	3A	12% (85.2 km^2)

*million cubic meters (mcm).

Both quaternary catchments are bound to the south by the Pilanesberg, which comprises an area of elevated topography and hills. The watercourses in the area are all non-perennial with the headwaters emanating from the Pilanesberg. The watercourses have a relatively flat grade except for the watercourses originating at the catchment divide in the Pilanesberg mountain range, which are extremely steep through the mountainous area before flattening at the foot of the range.

The tributaries of the Brakspruit within the catchment A24E which drain through the MRA area east of the infrastructure footprint include:

b) The Sefathlane (also known as the Moruleng in upstream reaches) flows north from the Pilanesberg to a confluence with the Lesobeng.

The Lesobeng (also known as the Lesele in upstream reaches) flows north from the Pilanesberg to a confluence with the Sefathlane, approximately 0.5 km south of the project area;

On the west of the site within quaternary catchment A24D, is the Bofule river draining northwards. The potential runoff from the study area drains, either to the west into the Bofule (only the pit footprint) or to the east into the Lesobeng - Sefahlane river system.

Both the Bofule and Sefathlane river systems eventually ends in the into the Bierspruit River after they converge at the outflow from the quaternary catchment A24E approximately 19km northeast and downstream off the Matai project boundary. The Bierspruit then flows onwards to a confluence with the Crocodile River approximately 45km north of the project area.

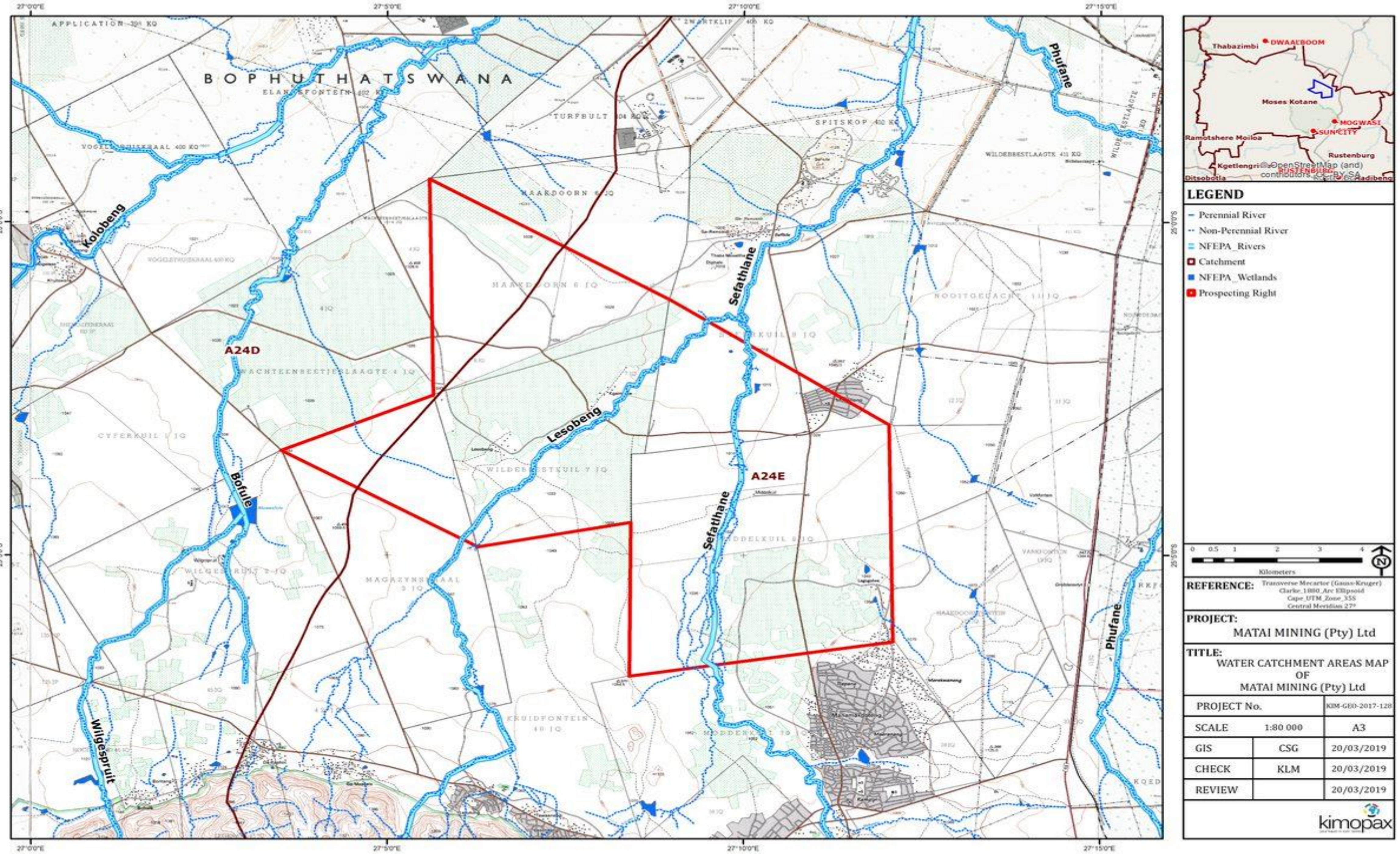

Figure 2: Drainage map

3 GEOLOGY

3.1 Regional geology

According to available geological maps the proposed Matai project is located on the Bushveld Igneous Complex (BIC) that is estimated to have developed approximately 2,060 million years ago. The mafic rock sequence of the BIC, the Rustenburg Layered Suite (RLS), is the world's largest known mafic igneous layered intrusion containing approximately 90% of the world's known platinum group metals (PGMs) reserves. In addition to the PGM's, extensive deposits of iron, tin, chromium, titanium, vanadium, copper, nickel and cobalt also occur.

The Bushveld Complex extends approximately 450 km east to west and approximately 250 km north to south. It underlies an area of some 65 000 km^2, spanning parts of the Limpopo, North West, Gauteng and Mpumalanga Provinces. The Bushveld Complex consists of four distinct igneous suites, namely, in age order, early mafic sills, the Rooiberg Group felsites, multiple mafic and ultramafic layers of the Rustenburg Layered Series which host platinum group element mineralisation and the latest Lebowa Granite Suite which cross-cuts the 110 km thick Rustenburg Series. Covering of the Bushveld by younger sediments and intrusion of later magmas means that the outcrop of the Rustenburg? Layered Series is limited to two basin-like lobes to the west and east and a linear lobe to the north.

3.2 Local geology

The study area is underlain by the Bierkraal Magnetite Gabbro (BMG) from the Rustenburg Layered Suite of the Bushveld Complex (geological map 2526 Rustenburg 1:250 000). The Bierkraal Magnetite Gabbro (BMG) is classified as a ferrogabbroic Upper Zone according to the Standard zonal subdivision (Johnson, et al. 2006). The BMG of the Rustenburg Layered Suite consists of magnetite gabbro, diorite and a magnetite layer. The surface geology is shown in Figure 3.

3.3 Geohydrological setting

The 1:500 000 Geohydrological Map of Johannesburg (2526), developed by the Department of Water and Sanitation (DWS), characterise the underlying aquifers present on site as "Inter-granular" and "Fractured Type" aquifer (Figure 4).

The Matai area is classified as having a moderate potential for groundwater occurrence with typical borehole yields between 0.5 and 2.0 l/s being reported. Higher yielding boreholes are usually related to regional linear geological features like lineaments, fractures or faults.

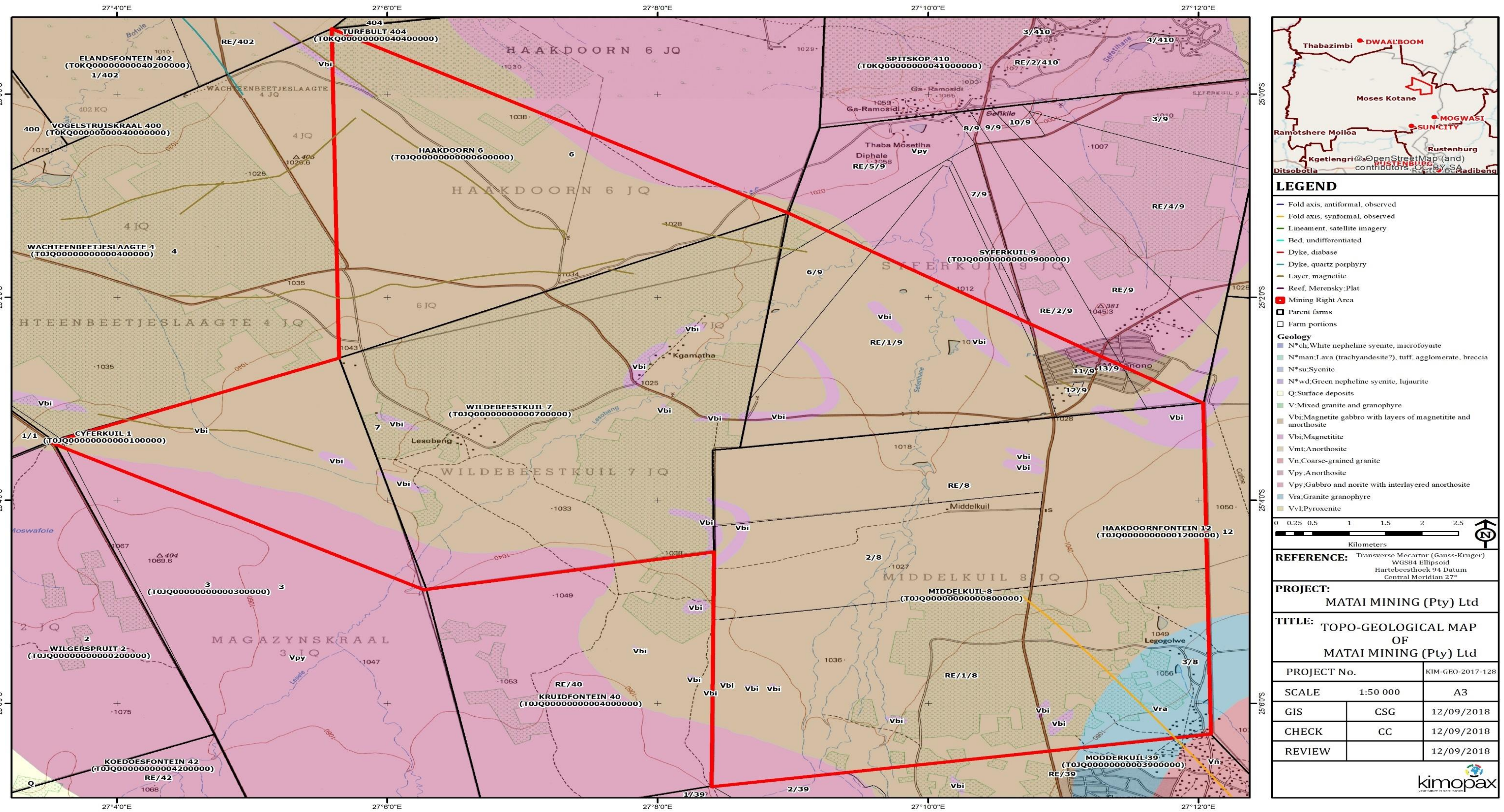

Figure 3: Geological map of the area

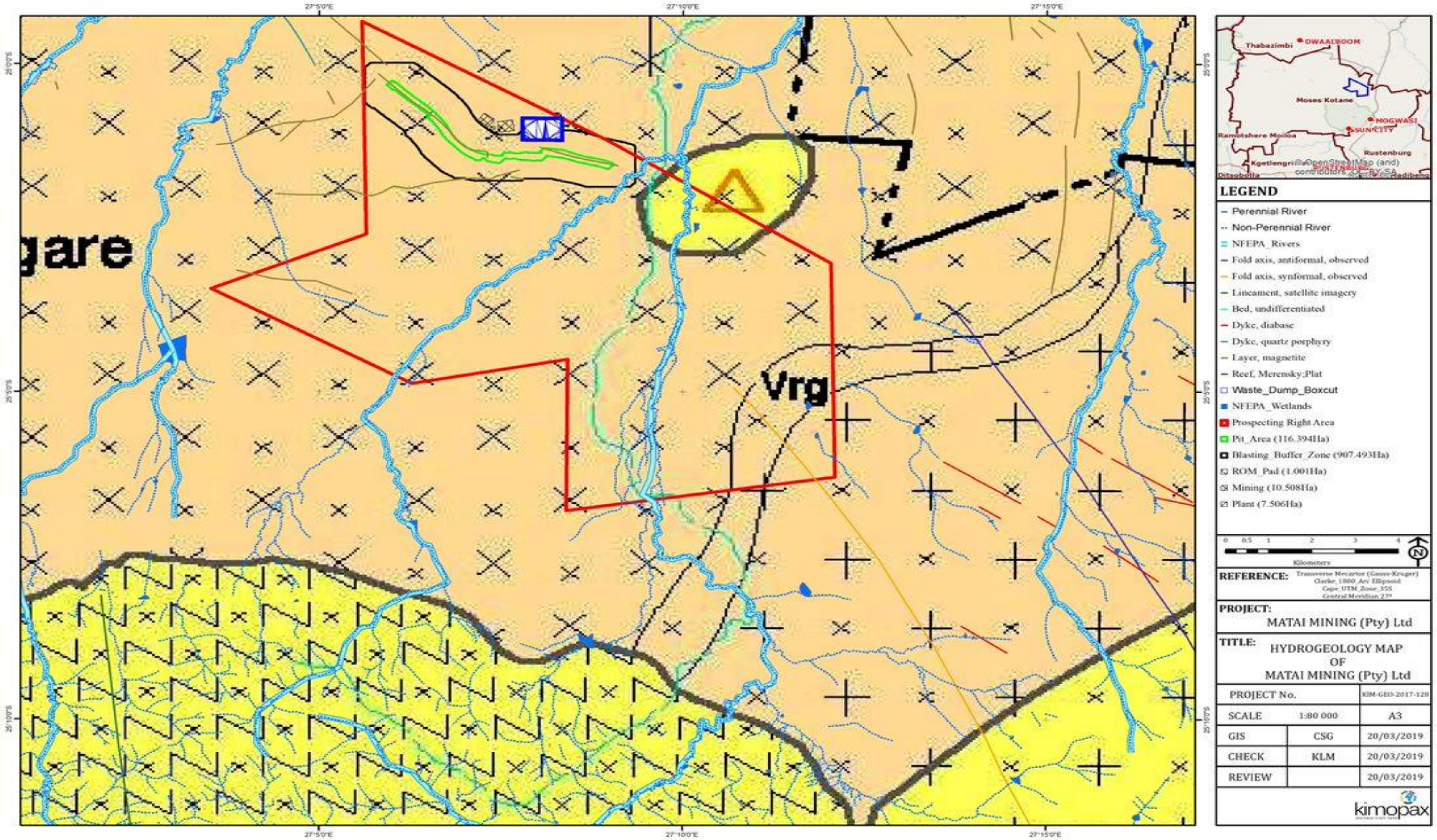

Figure 4: Geohydrological map

4 FIELD INVESTIGATION

4.1 Hydrocensus

Kimopax conducted a hydrocensus (December 2018) within and around the project area to obtain recent water level and water quality data. 17 existing boreholes were verified, and coordinates were updated using a handheld GPS, usage and status update and a water sample taken, see Table 5 for summary of hydrocensus results and location shown in Figure 5. During the hydrocensus period, some of the boreholes were locked for safety reason, and no access to the water level could be obtained.

The results of the hydrocensus are shown in Table 4.

Table 4: Chemistry Results: Hydrocensus

Sample ID	Units	BH09	BH13	BH11	BH04	BH06	SW01	BH12	BH03
Electrical Conductivity at 25°C	mS/m	54,1	112,5	79,2	51,2	58,7	25,9	45,5	69,2
pH at 25°C	pH	7,33	7,2	7,42	8,32	7,35	7,64	8,55	7,92
Alkalinity ($CaCO_3$)	mg/l	264,5	439,1	123,3	247,7	264,7	95,7	120,9	168
Turbidity	NTU	0,72	4,33	0,36	53,2	80,2	318	0,24	25,1
Nitrite (NO_2)	mg/l	0,07	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Nitrate (NO_3)	mg/l	1,6	2,5	1,1	9,2	1,3	1	5	1,4
Ammonium (NH_4)	mg/l	0,3	0,2	0,3	0,5	0,3	0,3	0,2	0,3
Free and Saline Ammonia (NH_3)	mg/l	0,2	0,2	0,2	0,4	0,2	0,2	0,2	0,2
Orthophosphate (PO4)	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Chloride (Cl)	mg/l	12	75	119	13	29	8	34	66
Dissolved Cadmium (Cd)	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Chemical Oxygen Demand (O_2)	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Mercury and its components	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Suspended Solids @ 105°C	mg/l	3,3	14,4	1,1	8510	52	100	3,3	84

Sample ID	Units	BH09	BH13	BH11	BH04	BH06	SW01	BH12	BH03
Total Dissolved Solids @ 180°C	mg/l	342	868	486	336	358	174	342	452
Total hardness ($CaCO_3$)	mg/l	240	470	202	42	254	58	171	310
Chromium 6+ (Cr)	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Potassium (K)	mg/l	6,89	2,88	10,37	2,7	2,86	4,78	3,39	1,88
Calcium (Ca)	mg/l	54,36	109,26	35,04	6,39	54,85	18,48	17,98	56,33
Sodium (Na)	mg/l	18,72	65,02	69,09	102,72	27,49	32,46	22,72	20,72
Magnesium (Mg)	mg/l	20,46	63,5	26,64	5,63	27,04	6,07	27,77	38,87
Iron (Fe)	mg/l	0,003	0,03	0,018	0,523	0,93	2,883	0,004	0,044
Fluoride (F)	mg/l	0,2	2,1	0,3	4,9	BDL	5	BDL	BDL
Sulphate (SO_4)	mg/l	3	67	102	34	9	13	44	101
Aluminium (Al)	mg/l	BDL	BDL	BDL	0,649	BDL	4,244	BDL	BDL
Manganese (Mn)	mg/l	0,005	0,029	0,006	0,021	0,117	0,087	BDL	BDL
Copper (Cu)	mg/l	0,004	0,007	0,012	0,012	0,002	0,008	BDL	0,005
Boron (B)	mg/l	0,016	0,028	0,06	0,043	0,014	0,02	0,006	BDL
Lead (Pb)	mg/l	0,01	0,017	0,011	0,003	0,013	0,007	0,008	0,012
Total Chromium (Cr)	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Zinc (Zn)	mg/l	0,007	0,02	0,705	0,006	BDL	0,014	0,018	0,005
Total Cyanide (CN)	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Silica (SiO_2)	mg/l	52	56	7,9	10,2	57	16,4	84	57

Note: BDL: below detection limit

Table 5: Summary of Hydrocensus

BHID	Longitude	Latitude	Elevation	Date	Borehole Depth 9m)	Water level (mbgl)	Usage	Pump type
BH01	27,169793	-25,009311	1001,19	2018/12/11	30	15,62	Not Used	None
BH02	27,144933	-25,016408	1016,68	2018/12/11	25	dry	Not Used	Mono
BH03	27,122020	-25,024152	1024,76	2018/12/11	60	49,44	Not Used	Mono
BH04	27,135147	-25,049779	1021,37	2018/12/11	50	14,61	Not Used	None
BH05	27,179756	-25,043121	1023,46	2018/12/11	4,46	blocked	Not Used	None
BH06	27,178333	-25,044330	1018,87	2018/12/11	30	23,3	Not Used	None
BH07	27,169178	-25,068645	1018,84	2018/12/11	blocked	blocked	Not Used	None
BH08	27,168972	-25,068806	1017,84	2018/12/12	33	dry	Not Used	None
BH09	27,179128	-25,077642	1034,49	2018/12/11	35	31,36	Not Used	submersible
BH10	27,185429	-25,048480	1026,15	2018/12/12		equipped	yes	Mono
BH11	27,185899	-25,045635	1024,79	2018/12/12	Unknown	equipped	Not Used	None
BH12	27,206420	-24,998535	997,38	2018/12/12	Unknown	equipped	yes	submersible
BH13	27,195203	-24,985956	992,76	2018/12/12	18	14,31	yes	None
BH14	27,195676	-24,995818	1002,35	2018/12/12		equipped	Not Used	None
BH15	27,077351	-24,952776	1021,08	2018/12/13	Unknown	locked	Not Used	Mono

BHID	Longitude	Latitude	Elevation	Date	Borehole Depth 9m)	Water level (mbgl)	Usage	Pump type
BH16	27,099265	-24,952128	990,53	2018/12/13	Unknown	blocked	Not Used	Mono
BH17	27,078768	-24,985673	1005,97	2018/12/13	Unknown	blocked	Not Used	Mono

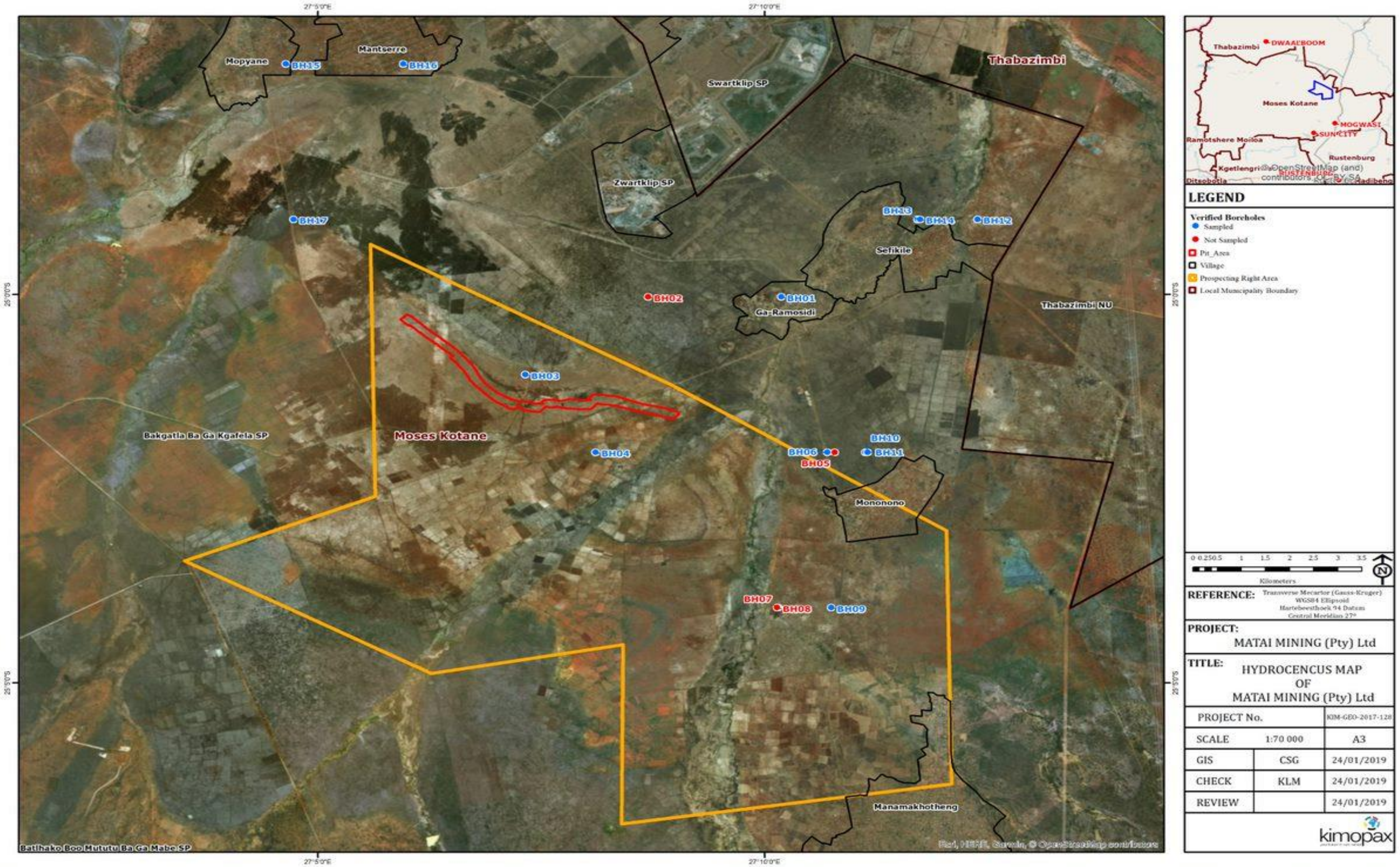

Figure 5: Hydrocensus map

4.2 Geophysical Survey

4.2.1 Magnetic Surveys

The aim of magnetic surveys is to investigate sub surface geology based on anomalies in the earth's magnetic field resulting from the varying magnetic properties of underlying rocks. Different rock types have different magnetic susceptibilities, which may have remnant magnetism. The contrast in magnetic susceptibility and/or remnant magnetism gives rise to anomalies related to structures like intrusive dykes, faults, lithologic contacts and weathered/ fractured bedrock.

In hydrogeological investigations the total magnetic field is usually measured at 5 meters intervals to delineate detailed weathered, fractured and anomalous zones.

4.2.2 Electromagnetic Surveys

The EM-34 is used for rapid measurements of terrain conductivity with a maximum effective penetration depth of 60 meters. The transmitter coil is energized with an alternating current. The time-varying primary magnetic field arising from the alternating current induces very small currents in the earth. These currents generate a secondary magnetic field, which is measured by the receiver coil, together with the primary magnetic field.

The EM-34 system utilizes a transmitter coil and a receiver coil at specific designed operating frequencies, coil separations and orientations to directly measure apparent terrain conductivity in mS/m. The EM-34, which is two-man portable, has the two coils flexibly connected. The coil spacing is measured electronically, which can be 10, 20 or 40 meters to directly vary the effective exploration depths as follows:

For Matai surveys, both the 20m and 40m coil separation employed to investigate sub-surface conductive zones at a maximum depth of 60m. Results of the geophysical surveys undertaken is discussed below.

4.2.3 Geophysical Survey Results

Three traverses (MAT-4_1, MAT-2_1 and MAT-3_1) at various lengths from 900 m to 1000 m were successfully surveyed using both magnetic and electromagnetic techniques. Location of surveyed traverse is shown in Figure 9 and results of the geophysical profiles are discussed in the following sections (Figure 7, 8 and 9).

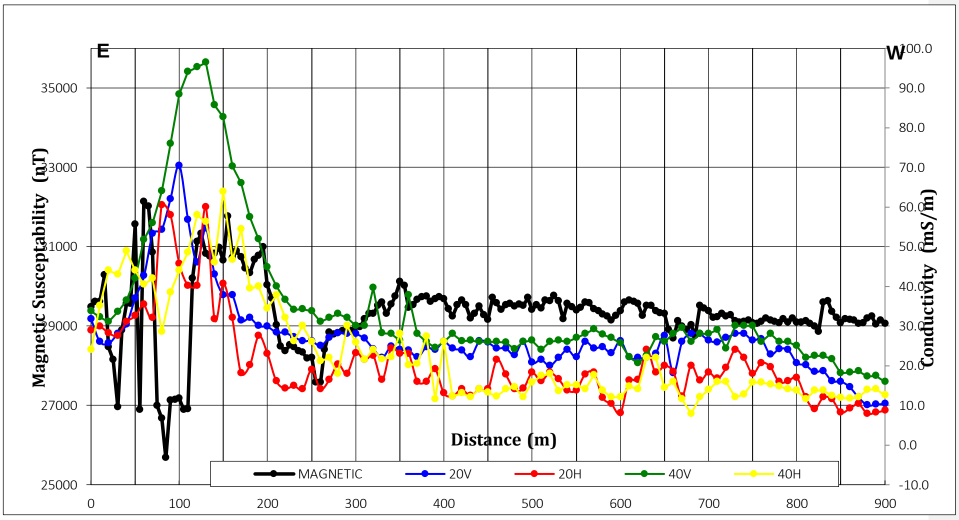

Figure 6: Traverse MAT-4_1

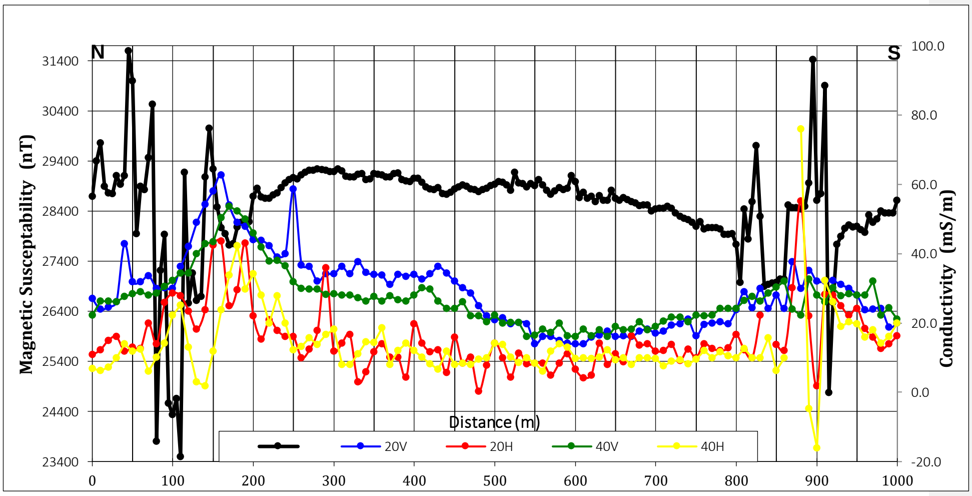

Figure 7: Traverse MAT-3_1

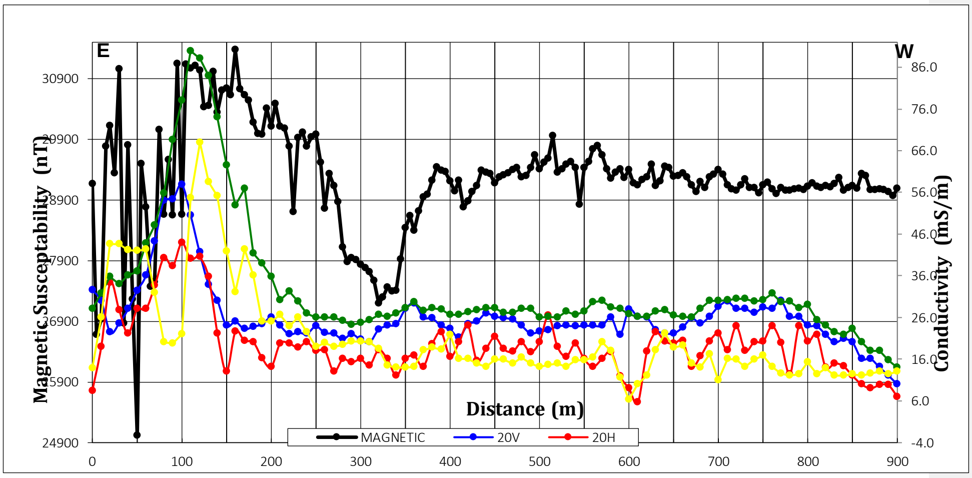

Figure 8: Traverse MAT-2_1

A total of three (3) geophysical traverses were conducted. A station spacing of 10 m was used during electromagnetic method survey and 5m spacing used during proton precision magnetometer survey. Data from the geophysical surveys was processed and presented as profiles using spread sheets (MS Office Excel). According to the geophysical data, geological features such as a dyke intrusion, fracturing and geological contact were identified as drilling targets.

Table 6: Summarised list of sites selected for exploration drilling

Traverse No.	Station No.	Latitude	Longitude	Proposed Drill Depth (m)
MAT-4_1	80	-25,021024	27,122480	50
MAT-4_1	680	-25,024876	27,118558	60
MAT-3_1	190	-25,021190	27,130887	60
MAT-2_1	540	-25,024301	27,130710	110
Totals	**4**			**280**

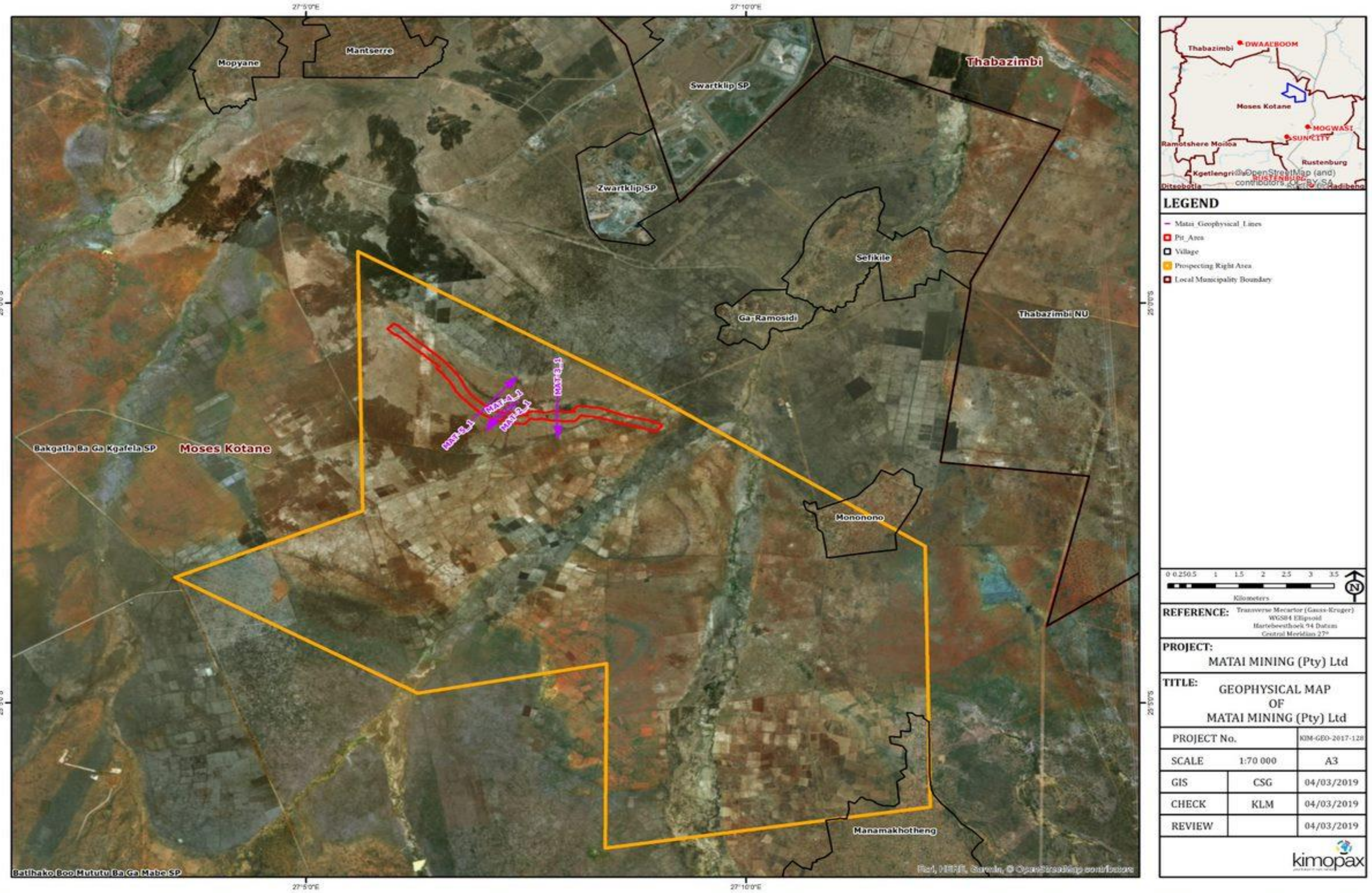

Figure 9: Location of Surveyed Traverses

4.3 Drilling

Drilling of boreholes was conducted by S&S Drilling under Kimopax controlled supervision. The drilling programme was carried as in accordance with "Minimum Standards and Guidelines for Groundwater Resource Development for the Community Water Supply and Sanitation Programme" (DWAF, 1997).

Rotary air percussion drilling employing a down-the-hole hammer is used for the sinking of boreholes. This drilling technique is ideally suited for hard rock formations. Material cuttings brought to the surface by air returned from the borehole are collected and described for each metre drilled. The following information is recorded during drilling:

a) Static groundwater level;
b) Rock penetration rates;
c) Depth of groundwater strikes;
d) Borehole yield (cumulative with each water strike) based on airlifted deliveries, and
e) Borehole construction details.

A total of four (4) boreholes were drilled at Matai project area. Out of the four (4) drilled boreholes, one borehole had a static water level of 44, 68 mbgl. Results of the drilling programme are summarized in Table 7. Successful drilled boreholes will be incorporated into the monitoring network of Matai.

4.3.1 Summary of Drilling

The borehole construction and geological logs are attached as Appendix A. Photos of successfully drilled boreholes are attached as Appendix B.

The Summary of drilling is as follows:

a) Borehole MAT-01 was successfully drilled to the depth of 50m. As indicated in the table below, two water strike encountered at a depth of 19m and 25m. The construction of the borehole was as follows:
    - 0-9m - Plain casing
b) Borehole MAT-02 was successfully drilled to the depth of 60m. No water strike was encountered.
   The construction of the borehole was as follows:

- 0-2m – Plain casing.

c) Borehole MAT-03 was successfully drilled to the depth of 60m. No water strike was encountered.

   The construction of the borehole was as follows:

   - 0-1m – Plain casing.

d) Borehole MAT-04 was successfully drilled to the depth of 110m. No water strike was encountered.

   The construction of the borehole was as follows:

   - 0-4m – Plain casing

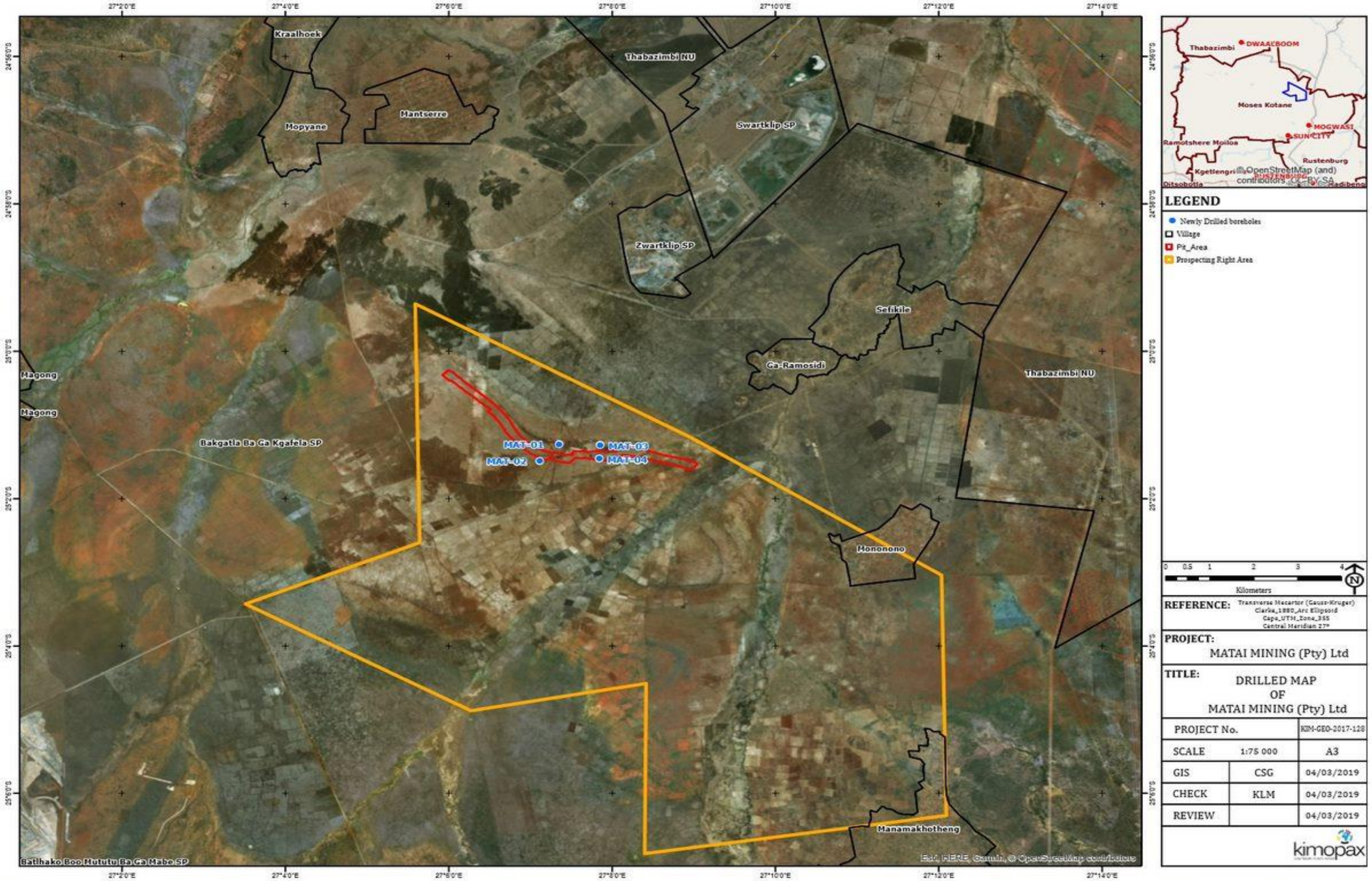

Figure 10: Drilled boreholes

Table 7: Summary of boreholes drilled

Borehole Number	Co-ordinates (WGS'84)		Depth (mbgl)	Plain casing	Water strike (mbgl)	Final blow yield	Water Level (mbgl)	Casing type	Lithologies intersected	Drilled date
	Latitude	Longitude								
MAT-01	-25,0210240	27,1224800	50	0-9	19 & 25	-	44,68	Steel	Oxidized Magnetite, Magnetite, and Melanorite	19/02/2019
MAT-02	-25,0248760	27,1185580	60	0-2	-	-	-		Oxidized Magnetite, Magnetite, Gabbro and Melanorite	20/02/2019
MAT-03	-25,0211900	27,1308870	60	0-1	-	-	-		Residual norite, Magnetite, Melanorite, Magnetite	20/02/2019
MAT-04	-25,0243010	27,1307100	110	0-4	-	-	-		Overburden, Residual norite, Olivine Melanorite.	21/02/2019

4.4 Testing

Refameetse Testing company were contracted by Kimopax to conducted aquifer test (field work) at existing boreholes identified during the hydrocensus phase.

Prior to all aquifer tests, static groundwater levels were measured in the boreholes to be tested to enable drawdown calculation during the aquifer test. The static water level of each boreholes is indicated in the table below.

Since the yield of the boreholes are unknown, calibration test was performed. All the boreholes could not be tested as the boreholes could not maintain the calibration test.

Table 8: Aquifer Testing Summary

Borehole Number	Latitude (S)	Longitude. (E)	BH-Information						Borehole -Testing		
	WGS84	WGS84	Depth	WL	Depth of pump	Datum Level	Casing Height	Diam Pump Inlet	Date	Test Type	Yield
	Decimal degree	Decimal degree	m	mbgl	m	m	magl	mm	Completed	CT (Calibration Test)	l/s
BH3	25,02418	-27,12196	59,62	49,47	58,57	0,13	0,22	165	28/02/2019	10CT	-
BH4	25,04978	-27,13514	40,93	33,22	39,5	0,12	0,28	165	27/02/2019	07CT	-

5 CONCEPTUAL MODEL

The conceptual model is a simplified representation of the essential hydrological features and behaviour of the physical hydrogeological system, to an adequate degree of detail. A set of assumptions are considered to reduce the real problem and the real domain to simplified versions that are acceptable in view of the objectives of the modelling.

This is the first groundwater model and should be considered as a baseline model. The information of site characteristics provided by the client is adopted to simplify the accounting of the most prevailing flow and mass transport processes by the geohydrological numerical software to be used. The following is included:

c) The known geological and geohydrological features and characteristics of the area;
d) The static water levels heads (hydrocensus of 12.2018) in the study area; A description of the processes and interactions taking place within the study area that will influence the movement of groundwater; and
e) Any simplifying assumptions necessary for the development of a numerical model and the selection of a suitable numerical code.

5.1 Aquifers

The mining activities and associated infrastructures are located on a well-developed (up to 100 mbgl) felsic, mafic and ultra-mafic rocks (gabbro, norite, nelanorite, olivine-magnetite), laterally bounded in the south east by the acid rocks of the Pilanesberg outcrop.

Three dominants hydro-stratigraphic units (alluvial deposits; Sshallow weathered aquifer system; and shallow and deeper Localized fracture aquifer system) are found in the catchments.

5.1.1 Alluvial aquifers

The alluvial deposits occur along the main surface water drainage. The water flowing down this river will recharge the shallow alluvial aquifers, which in turn will drain downwards to the weathered and fractured aquifers due to their inter-connectivity.

5.1.2 Shallow weathered aquifers

The top soil (overburden) forms the roof of the weathered/fractured igneous and sedimentary rocks. Current drilling information (boreholes drilling logs analysis) in the mining area, suggests an average thickness of 15 m and occurred up to 30 mbgl. To account for the transition to the competent rock, it is assumed that the shallow weathered aquifer extends to 50 mbgl.

The depths to static groundwater level are up to 0.57 m below ground level. Such measured water levels are a function of the product of the combined saturated aquifers (weathered and fractured) thickness, the hydraulic conductivity (transmissivity) and effective aquifer recharge. This aquifer is unconfined to semi-confined and is recharged by rainfall. Literature review suggests that rock materials of the shallow weathered aquifer are of low permeability (0.05 to 5 m/d). The regional groundwater gradient is predominantly toward the Diphiri River (A24E) in the east, and the Bofule River in the west (A24D).

5.1.3 Deeper fractured aquifer

A deeper fractured rock aquifer formed by competent rocks. Fracturing associated with tectonic movements may occurred at places during intrusions. The deeper fractured aquifer is expected to be unconfined to semi-confined, as available geological logs in the area did not show any impermeable layer between the two aquifer systems.

There is insufficient information available to confirm the exact thickness of the deeper aquifer fractured, but general information from existing literature suggests we limit the deeper fractured aquifer at 50 m below the bottom of the shallow weathered aquifer.

5.2 Groundwater Level

For the purpose of the study, water level measured during the hydrocensus are used. The water levels measured during the hydrocensus ranges between 14.31mbgl and 44.9 mbgl. A comparison of the water level elevation with topography shows a good correlation of 99.9% (Figure 11). This confirms that groundwater elevation mimics the topography.

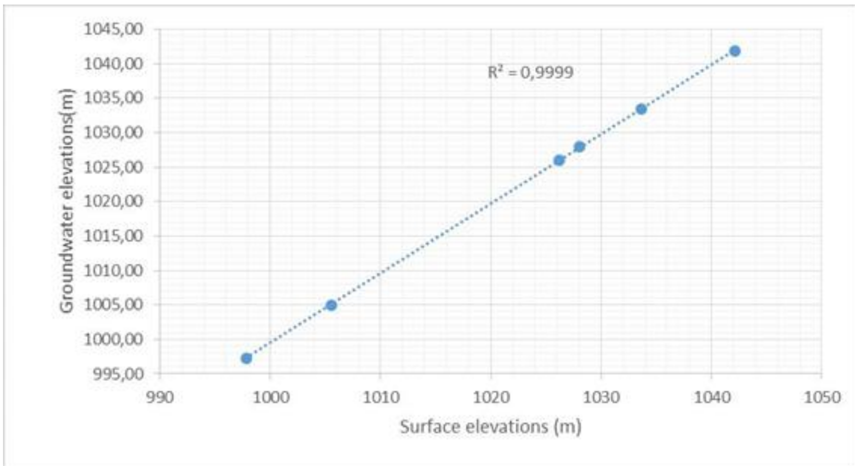

Figure 11: Correlation between surface and groundwater elevations

5.3 Recharge Estimation

The quantity of rainfall and intensity of rainfall (monthly rainfall) are the major drivers of aquifer recharge in the study area. Groundwater recharge is sustained by direct rainfall on the surface area. For the recharge estimation, the chloride method will be used.

According to Cook (2003), the Chloride Mass Balance is the most reliable technique for determine the recharge rates to fractured rock aquifers. The percentage rainfall, representing average annual recharge, can be derived from the ratio of the chloride concentration in rainfall relative to that of groundwater, (Bredenkamp et al, 1995). The CMB-method can be applied to the saturated zone to estimate a 'true' total recharge originating from both diffuse and preferential flow components through the unsaturated zone. The CMB-method in the saturated zone has been used in basement aquifers throughout southern Africa to estimate recharge (Xu and Beekman, 2003; Adams et al., 2004). This method entails determining the recharge over an entire drainage area by integrating the ratio of average chloride content in rainfall (wet and dry deposition) to that of groundwater over the whole area.

The Chloride Mass Balance can be represented by this equation:

$$Rt= \frac{P * Clp + D}{Clgw}$$

P= Precipitation (mm per time)

Rt= total recharge (mm per time)

D=Dry deposition

Clp: Chloride concentration in precipitation

Clgw: Chloride Concentration in groundwater

Recharge estimate was obtained by using the chloride concentration in the rainwater and groundwater, together with annual rainfall. The average concentration of chloride (44 mg/L) in groundwater of the boreholes within the mine were used for the calculation.

$$\text{RE\%}= \frac{Clp}{Clgw} X100$$

Clp: Chloride concentration in precipitation

Clgw: Chloride Concentration in groundwater

The mean annual precipitation of the project area is 937 mm. The chloride rainfall concentration is assumed to be 0,5 mg/L for a semi-arid area. Based on the calculation, the recharge rate is 1,14% of MAP, with 6,82 Mm/year.

5.4 Groundwater Quality

Water quality data was presented by means of tables, a stiff diagram and a piper diagram. The Piper diagram was generated using the WISH software. A Piper diagram is utilised to characterise water types in a graphical manner and to distinguish between specific water types in an area.

The Piper diagram was quartered to simplify this process and can be grouped into a left, bottom, right and upper quarter. The position of the water sample on the plot is based on the ratio of the various constituents (measured in equivalence) and is not an indication of the absolute water quality or the suitability thereof for domestic consumption.

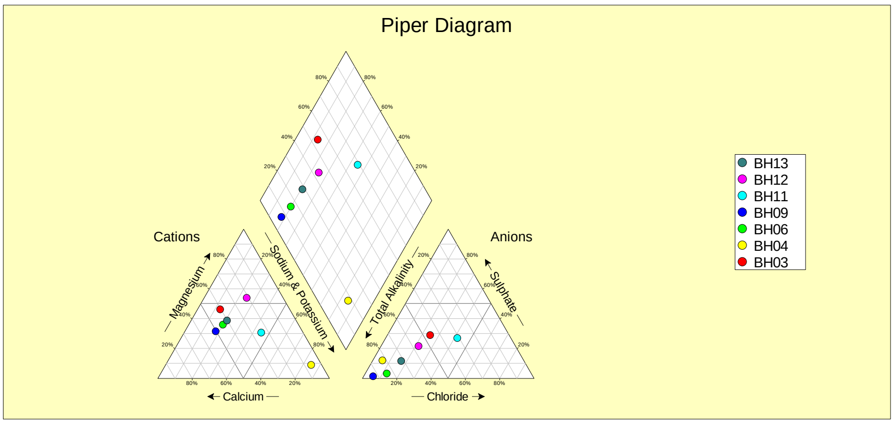

Figure 12: Piper Diagram

The following could be deduced from the piper diagram

Cations

a) BH13, BH06, BH03, BH11 and BH09 are no dominant type water
b) BH12 magnesium
c) BH04 sodium and potassium

Anions

a) BH13, BH06, BH09, BH12 and BH04 are Bicarbonate type
b) BH11 and BH03 No dominant type
c) BH13, BH06, BH09, BH12 and BH03 is magnesium bicarbonate type water
d) BH04 is sodium bicarbonate type water
e) BH11 is mixed type water

Stiff diagrams are used to understand the interactions of water samples with anthropogenic pollutants (McKenzie *et al.*, 2001)

The samples can be classified as follows:

a) BH03: Mg-HCO_3
b) BH04: Na-HCO_3

c) BH06: CaMg-HCO3
d) BH09: CaMg-HCO3
e) BH11: Na-Cl
f) BH12: Mg-HCO_3
g) BH13: CaMg-HCO3

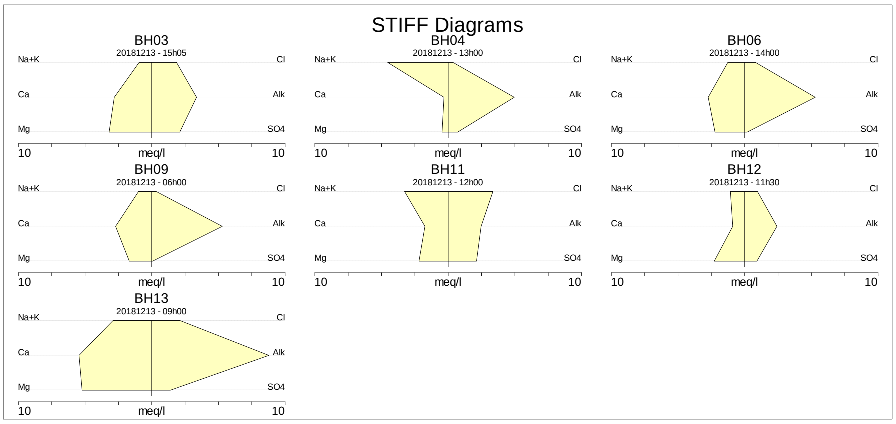

Figure 13: Stiff Diagram: Chemistry Results

5.5 Aquifer Domain and Boundaries

There is a good correlation between the groundwater level elevations and the surface topography. No evidence of subsurface no-flow boundaries has been clearly identified.

The Mine is projected on the water divided of 02 quaternary catchments (A24D, and A24E), and groundwater drainage is confirmed to follow main topography, it is logical therefore to include large areas of the surface water sub-catchments of the principal (perennial) surface drainage (The Phufane river, and the Bofule River), into the modelling domain. We consider that the groundwater system extents over the geometry of the surface water system within the catchments. The Phufane river (far east of the project area), the Bofule River (west of project area) and the water divided (North, and South of the project are) of the quaternary catchments boundary, form the limit of the groundwater systems to be modelled. The Diphiri river (east of the mining area), which feed into the Phufane river may also receive groundwater from the study area and is considered as internal model boundary. Most of the groundwater recharges occurring within the study area are expected to discharge into these water courses.

According to Vegter (1995) the regional recharge is 32 mm/a. Groundwater recharge (R) for the area was also calculated using the chloride method (Bredenkamp et al., 1995) and is expressed as a percentage of the Mean Annual Precipitation (MAP). This estimation suggests that local recharge to the shallow aquifer may reach 10.90% of the Mean Annual Precipitation:

This dynamic recharge from rainfall results in fresh and good groundwater quality in undisturbed areas. This aquifer is, however, more likely to be affected by contaminant sources situated on surface.

5.6 Potential Contamination Sites

Impacts of mining activities should be limited to the shallow aquifer(s) and surface water bodies in the near vicinity of the lease area. Such impacts are expected to be probably contaminations from plan's area, and waste dump, will be located north of the projected pits.

6 NUMERICAL MODEL

The numerical model solves both complex and simple problems and can be used to simulate various scenarios without undue effort. The basic steps involved in modelling can be summarised as:

a) Collecting and interpreting field data, to understand the natural system and to specify the investigated groundwater problem. The assignment of real field parameters makes the numerical model a site-specific groundwater model. The quality of the simulations depends largely on the quality of the input data.
b) Calibration & validation; which require to overcome the lack of input data. The calibration and validation also accommodate the simplification of the natural system in the model. The model input data are altered within ranges, until the simulated and observed values are fitted within an acceptable tolerance.
c) Modelling scenarios: Alternative scenarios for a given area may be assessed efficiently. When applying numerical models in a predictive sense, limits exist in model application. Predictions of a relative nature are often more useful than those of an absolute nature.

6.1 Numerical Software Code and Geometry Model

The base line model is built with Feflow, which is developed since 1979 by the WASY Institute for Water Resources Planning and Systems Research Ltd (Germany), and is has been continuously improved. It is an interactive groundwater modelling system for three and two-dimensional, areal and cross-sectional, fluid density-coupled, thermohaline or uncoupled, variably saturated, transient or steady state flow, mass and heat transport in subsurface water resources with or without one or multiple free surfaces.

Finite elements divide the aquifer into a mesh of node points that form polygonal (triangular) cells, which can be adapted to different types of boundaries conditions. A finite element network was designed to provide a high resolution of the numerical solution, and to accommodate the model area. A grid consisting of 3 layers, 81315 elements, 50058 nodes, and 220603 faces, 189345 edges. The topographic elevations from SRTM DEM were used with available geological information to for the elevations of the slices. 3D-views of the modelling area are given in Figure 14; Figure 15 and Figure 16.

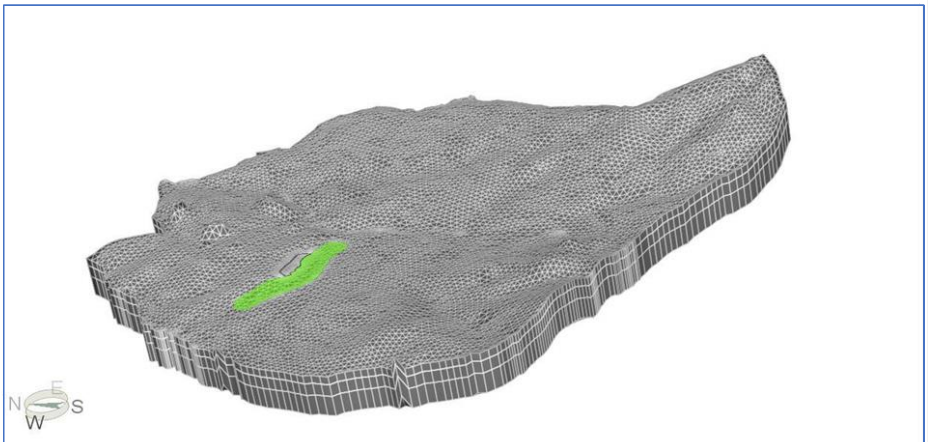

Figure 14: Baseline numerical model geometry

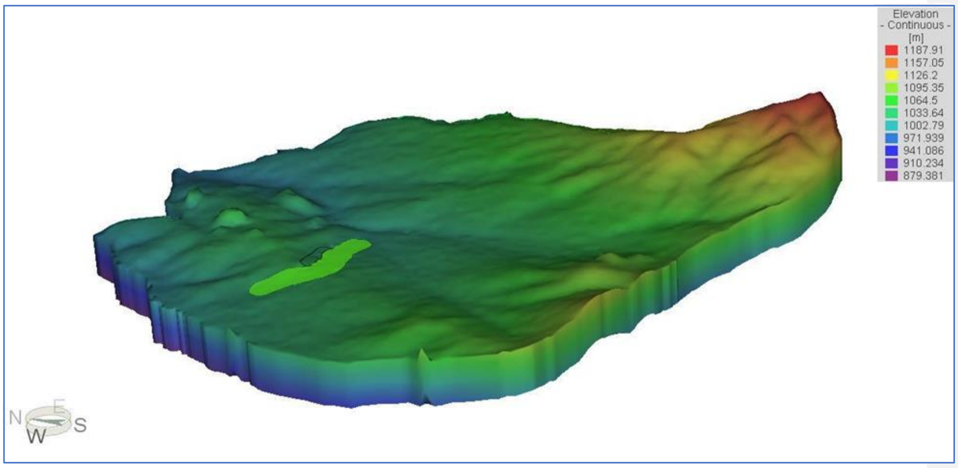

Figure 15: Baseline Numerical Model Elevations

Table 9: Details of model layers and simplified flow characteristics

Layer Number	Hydro-stratigraphic unit	Thickness	Transmissivity	Vertical hydraulic conductivity	Storativity	Type of Aquifer
		m	m²/day	m/day		
Layer 1	Moderate to high weathering	20	14	0,07	0,001	Unconfined
Layer 2	Low weathering	30	10	0,01	0,001	Confined/ Unconfined
Layer 3	Fresh rocks with minor fractures	50	1,5	0,001	0,0005	Confined/ Unconfined

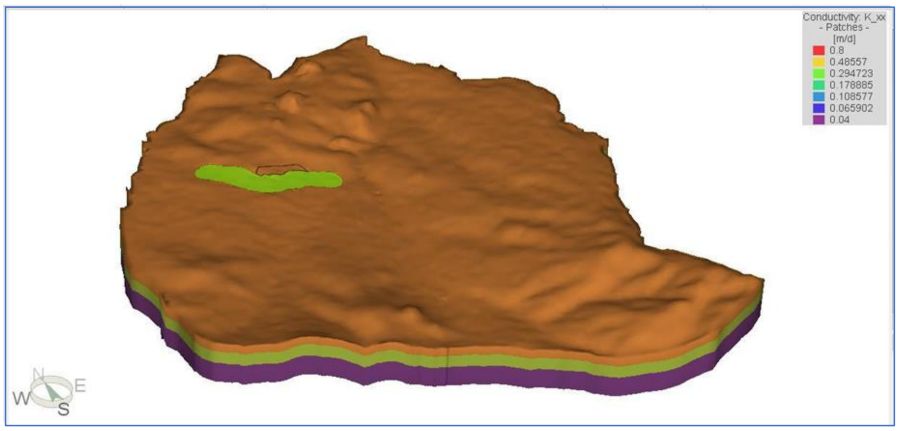

Figure 16: Baseline Numerical Model Input Hydraulic conductivity

6.2 General Assumptions and Model Limitations

A numerical model solves both complex and simple problems and serves as basis for the simulation of various scenarios. However, it should be reiterated that, as a simplified representation (approximation) of the real system a numerical groundwater model, the level of accuracy is sensitive to the quality of the data that is available. Errors due to uncertainty in the data and the capability of numerical methods to describe natural physical processes are always associated with groundwater numerical models. The building of a numerical model requires some assumptions to make an easier representation of the real aquifer systems. Such assumptions involve mainly:

a) Geological and hydrogeological features;
b) Boundary conditions of the study area;
c) Initial water levels of the study area;
d) The processes governing groundwater flow; and
e) The selection of the most appropriate numerical code.

The following assumptions have been made behind the above developed conceptual model:

a) The top of the aquifer is represented by the generated groundwater heads;

- Where specific aquifer parameters have not been determined for some reason, text book values have been used where applicable considering typical hydrogeological environment, with reasonable estimates of similar hydrogeological environments;
- The system is initially in equilibrium and therefore in steady state, even though natural conditions have been disturbed.

b) The boundary conditions assigned to the model are considered correct;

- The impacts of other activities (agriculture, etc...) have not been considered.
- The complexities associated with flow and transport in aquifer systems have not been considered.
- Any interpretation and decision from the model results should be based on these assumptions.

6.3 Model Boundaries Conditions

Boundaries occur at the edges of the model area and at locations in the model area where external influences are represented, such as rivers, wells, and leaky impoundments. Criteria for selecting hydraulic boundary conditions are primarily catchments topography, hydrology and geology. The topography, hydrology, and groundwater drainage were used mainly in the definition of the lateral boundary, whereas available geology and hydrogeology information were used for the aquifer layer thickness.

The Phufane river, the Bofule river, and the South water divided are set to Dirichlet (constant head) boundary condition. The Non perennial Diphiri river, a tributary of the Phufane river is set in the model to Cauchy conditions

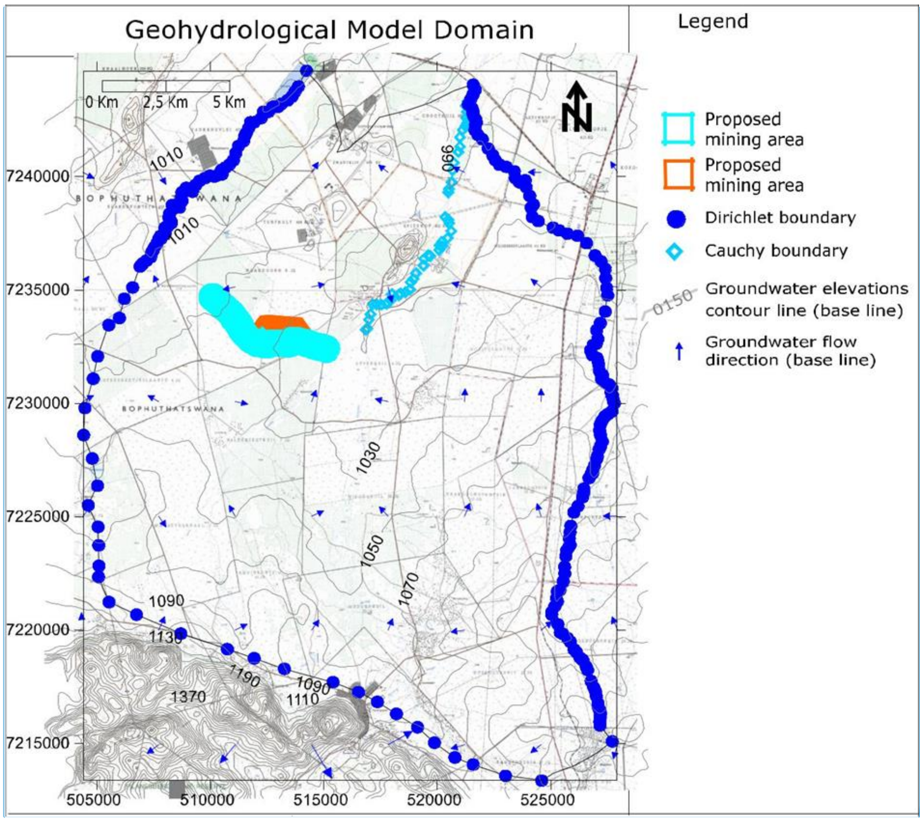

Figure 17: Groundwater drainage and model boundary conditions

Commented [m1]: Legend please split Light blue and Brown and label Proposed mining area pit and proposed mining area infrastructure and rock pile?

6.4 Calibration of groundwater flow model and initial conditions

Boundary conditions, and hydrological parameters (recharge and conductivity/transmissivity), is selected by a combination of trial and error, to generate the result that most strongly matches observed hydraulics heads (hydrocensus of 12.2018). A correlation of 94.59 % is observed between measured and calculated groundwater elevations. Also, the main groundwater drainage (flow direction) observed from the Bayesian interpolation results is reproduced. It is important to note that only performed and this is not ideal. The confidence in the model would be increased if the model was calibrated with time series data.

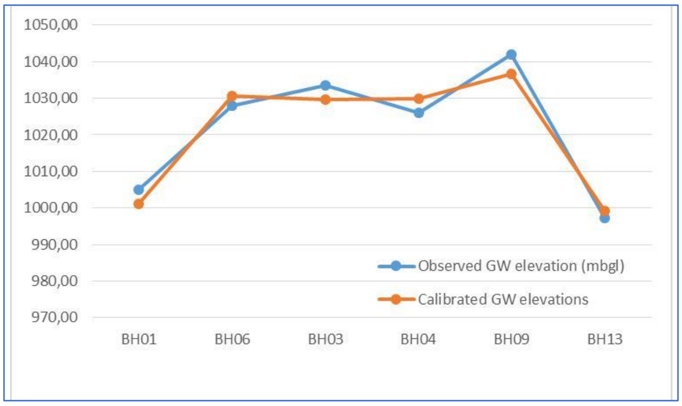

Figure 18: Correlation between observed and calibrated groundwater elevations

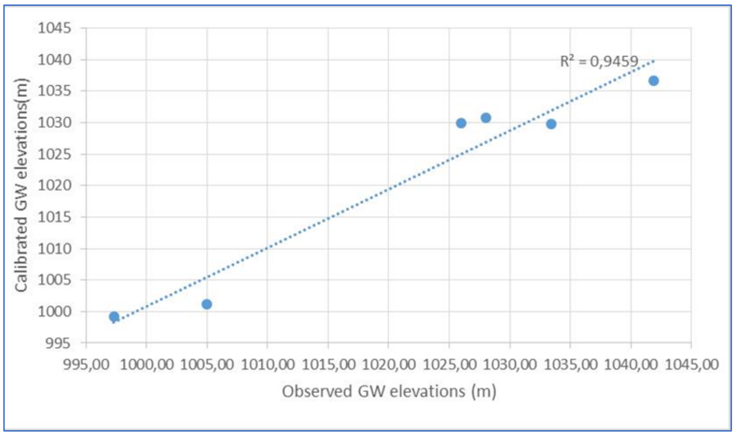

Figure 19: Correlation between observed and calibrated groundwater elevations

6.5 Mass Transport model

The most important processes that involved in the transport through a medium are Advection, and the Hydrodynamic dispersion (Mechanical dispersion and Molecular diffusion). Other phenomena (sorption, adsorption, deposition, ion exchange, etc...) may affect the concentrations distribution of a contaminant as it moves through a medium. The effective porosity is required to calculate the average linear velocity of groundwater flow, which in turn is needed to track water particles and to calculate contaminant concentrations in the groundwater (Figure 20 and Figure 21).

Table 10: Details of model layers and simplified flow characteristics

Layer Number	Porosity	Longitudinal dispersivity	Transversal dispersivity
Layer 1	0,3	70	7
Layer 2	0,15	30	3
Layer 3	0,08	0,07	0,007

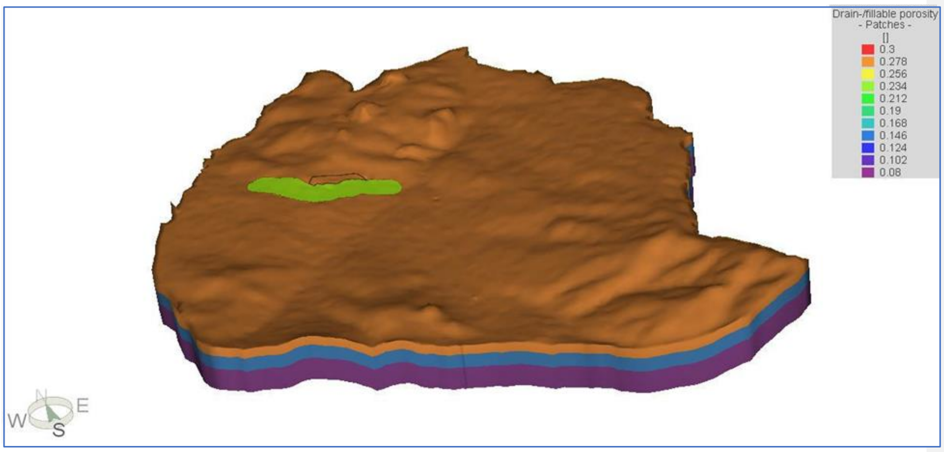

Figure 20: Model Input Porosity

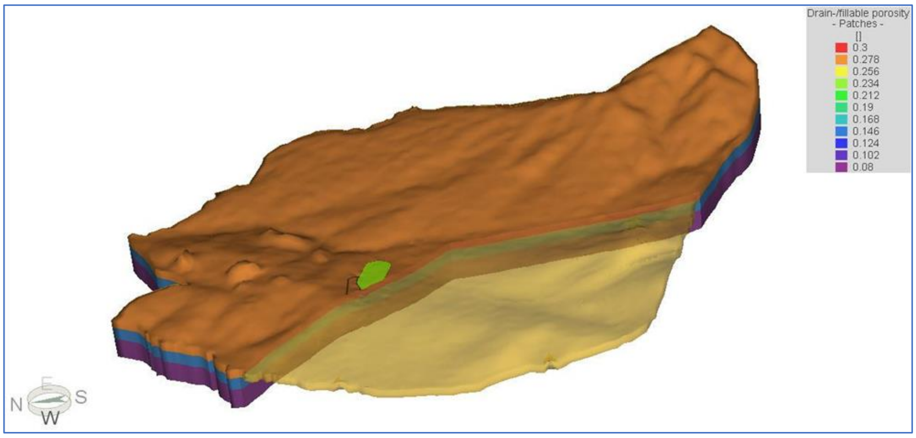

Figure 21: Model Input Porosity (Pane view)

The mass balance equation (Bear and Verruijt, 1992) (equation of hydrodynamic dispersion or the advection-dispersion equation) of a pollutant (contaminant) is expressed as:

$$\frac{nc}{t} = -q_{c,total} - f + n - P_c + R_c$$

where: nc = mass of pollutant per unit volume of porous medium; n = porosity of saturated zone; c = concentration of pollutant (mass of pollutant per unit volume of liquid (water)); Δq = excess of inflow of a considered pollutant over outflow, per unit volume of porous medium, per unit time; f = quantity of pollutant leaving the water (through adsorption, ion exchange etc.); = mass of pollutant added to the water (or leaving it) as a result of chemical interactions among species inside the water, or by various decay phenomena; = rate at which the mass of a pollutant is added to the water per unit mass of fluid; ρ = density of pollutant; Pc = total quantity of pollutant withdrawn (pumped) per unit volume of porous medium per unit time; Rc = total quantity of pollutant added (artificial recharge) per unit volume of porous medium per unit time.

Contaminant migration is attributable only to advection and hydrodynamic dispersion. It is assumed that no decay or retardation of contaminants is taking place in the aquifer. The effect of retardation will be reduced due to the fractured flow characteristics of the hard rock formations. This assumption will provide a worst-case scenario in terms of travel distance of contaminants.

No mass transport was possible, because this is a base line numerical model and there is insufficient monitoring data.

By default, initial concentration of 0 mg/l is assigned to fresh water in the aquifer system. The contamination sources are represented by a higher initial concentration at the top aquifer. The mass flux (source term) of the contaminant (Sulphate) was assigned accordingly. Assuming a maximum contaminant concentration of 600 mg/l, and a minimum mitigation measure under pollution source, a mass flux of 52.2 x 10-3 $g/m^2/day$ was used in the contamination area.

6.6 Simulation of Predictive Scenarios

The simulation of scenarios of potential impacts of the proposed mining of the Matai mine project, to groundwater is conducted, with focus on the contamination migration scenarios (Pollution plume).

6.6.1 Seepage into Open Pit

Opencast mining will result in groundwater inflows into the pits, which needs to be dewatered. Subsequent to such dewatering, a cone of depression will be formed radially around the open pit, and the groundwater flow gradient will be toward the open pit. The shape and extent of the cone of depression is determined by many factors including:

a) The Transmissivity of the surrounding aquifer systems,
b) The presence of geological structures such as dykes and faults that could act, as preferred flow paths for groundwater,
c) Depth of mining below the static groundwater level,
d) The recharge rate, and
e) Rate of mining, and the size of the opencast pit.

No concurrent rehabilitation has been included in this scenario and therefore it be the 'worst-case' scenario.

The cone of depression will mostly extend in the western direction toward the Bofule River (Catchment A24D) and become deeper as pit floor is lowered. The expected inflow into the pit is 730 m^3/d when mining floor will reach 20 mbgl. It will increase to a maximum of 2800 m^3/d when mining floor reaches 60 mbgl, and it will stabilize to 1150 m^3/d when mining floor will reach 90 mbgl. The simulated cone of depressions for different depths of pit floor, are shown from Figure 22 to Figure 24.

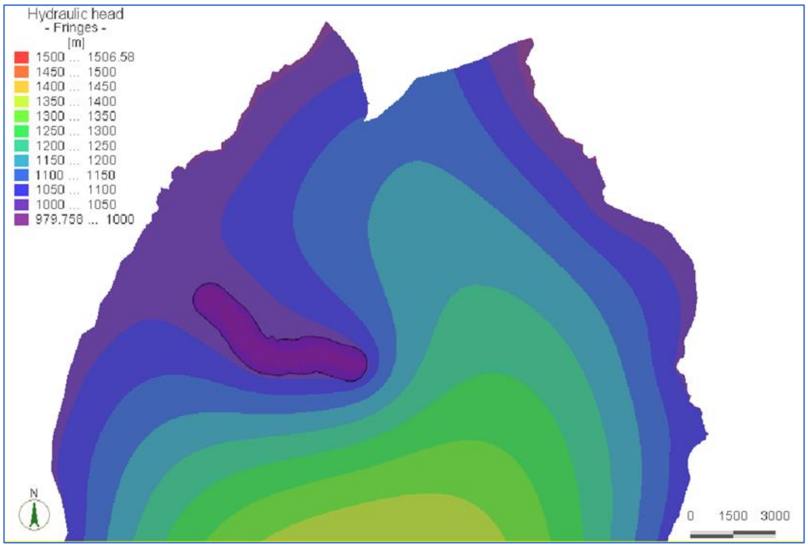

Figure 22: Cone of depression when open pit floor reaches 20 mbgl

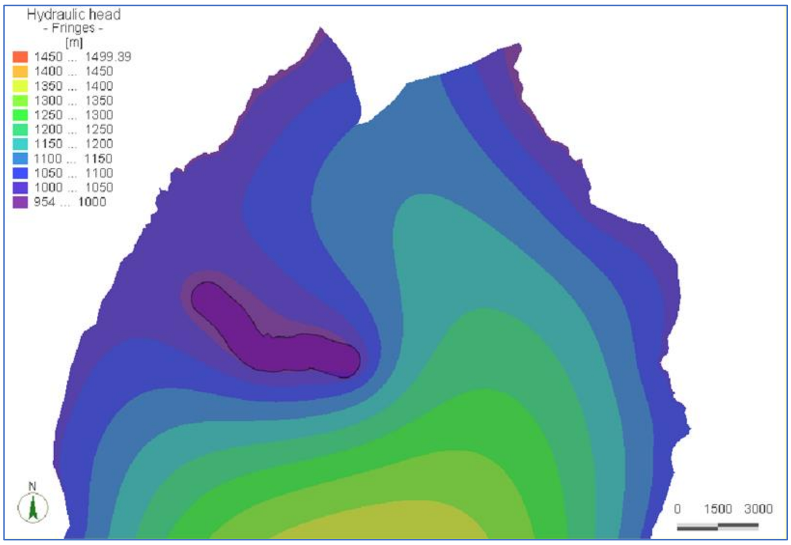

Figure 23: Cone of depression when open pit floor reaches 60 mbgl

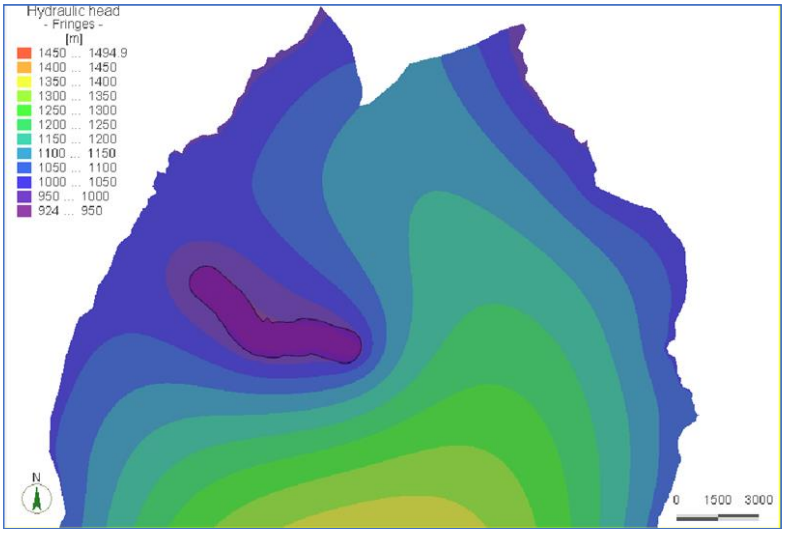

Figure 24: Cone of depression when open pit floor reaches 90 mbgl

6.7 Pollutions

As the potential pollution sources are located close to water divided, and open pit, groundwater flow during active mining will be toward the open pit, but also toward main natural surface drainage. The contamination plume that will emanate from the plant area is anticipated to move into western direction toward the mine pit (Figure 25 to Figure 33). But the contamination plume that will emanate from the waste dump area is anticipated to move into eastern direction toward the north-north-east down-gradient of the waste dump. The toe of the plume (with a concentration of less 1 mg/l) is estimated to extend 700 m away from waste dump, 20 years after contamination commences.

The open pit area will be kept dry for mine safety and polluted water should be pumped to dirty water dams.

Any pollution plumes emanating from mining activities (Waste dump, plant, dirty water dams, etc.) is expected to be restricted to the mine property. Neighbouring boreholes will not be affected during active mining

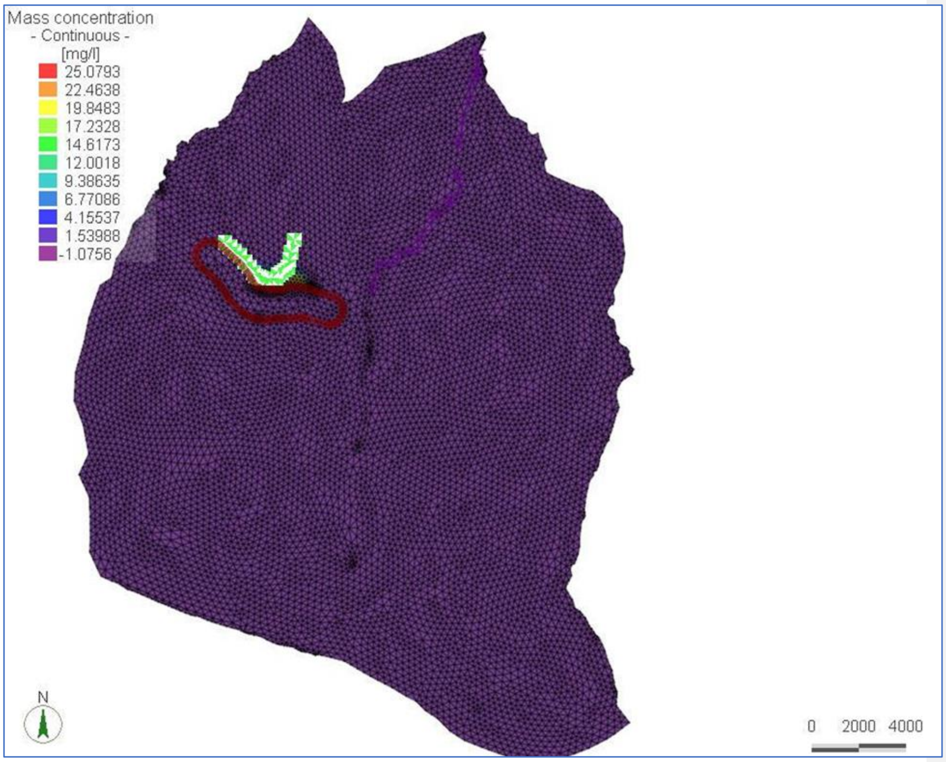

Figure 25: Contamination plume after _ global 3D view

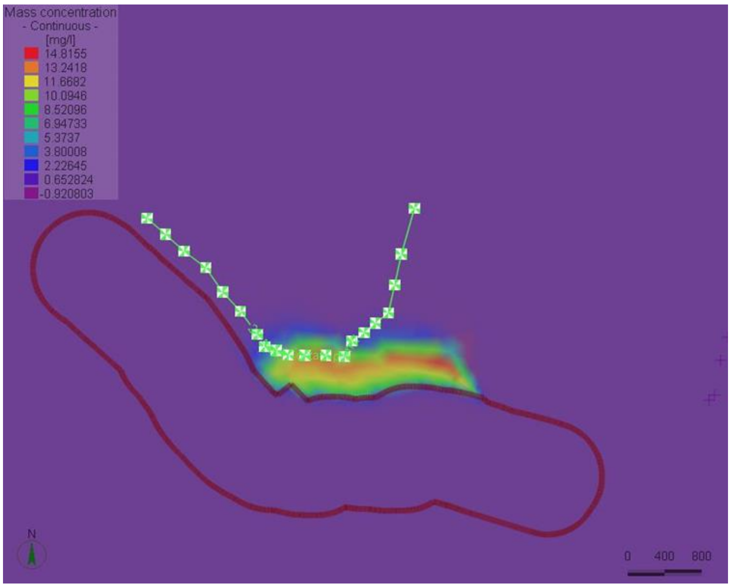

Figure 26:Contamination plume after 5 years _ zoom

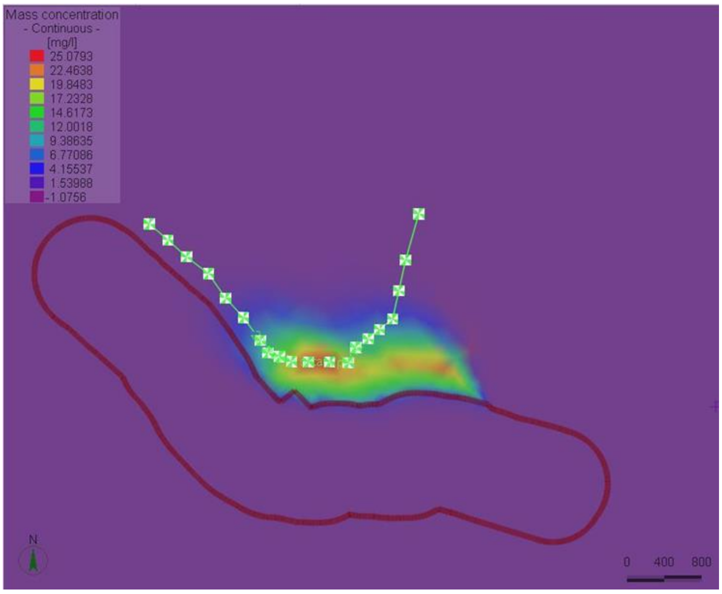

Figure 27: Contamination plume after 20 years _ zoom

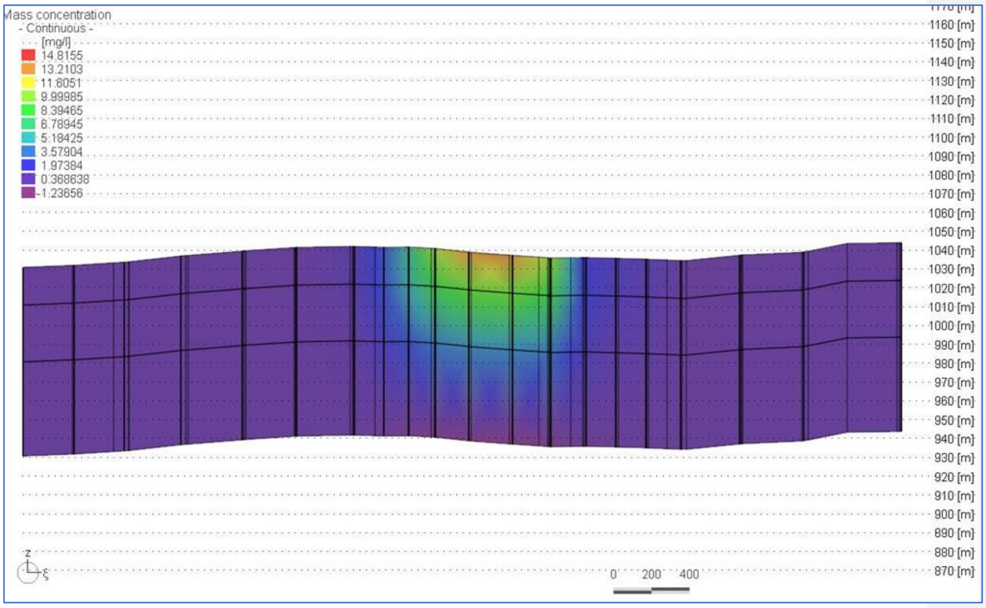

Figure 28:Contamination plume after 5 years _ Cross section view

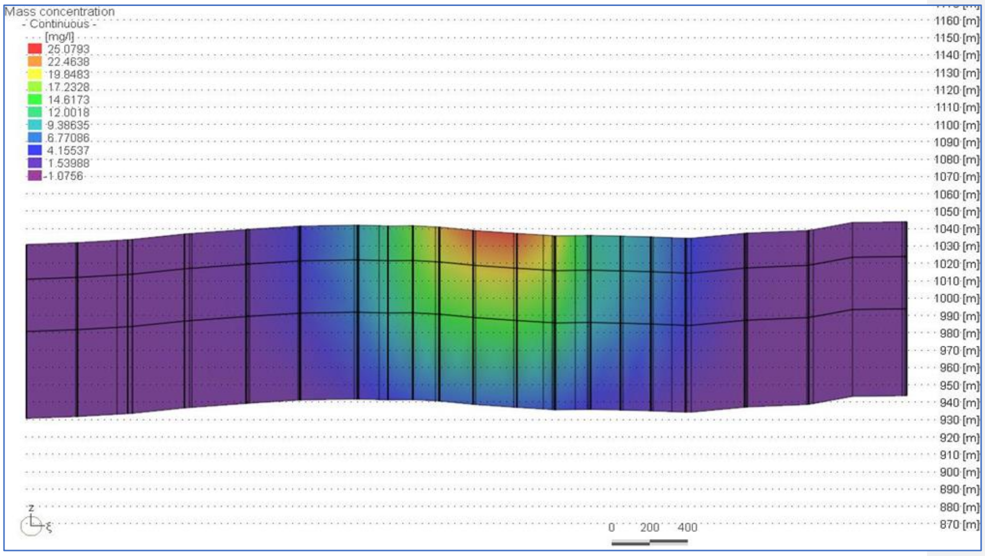

Figure 29: Contamination plume after 20 years _ Cross section view

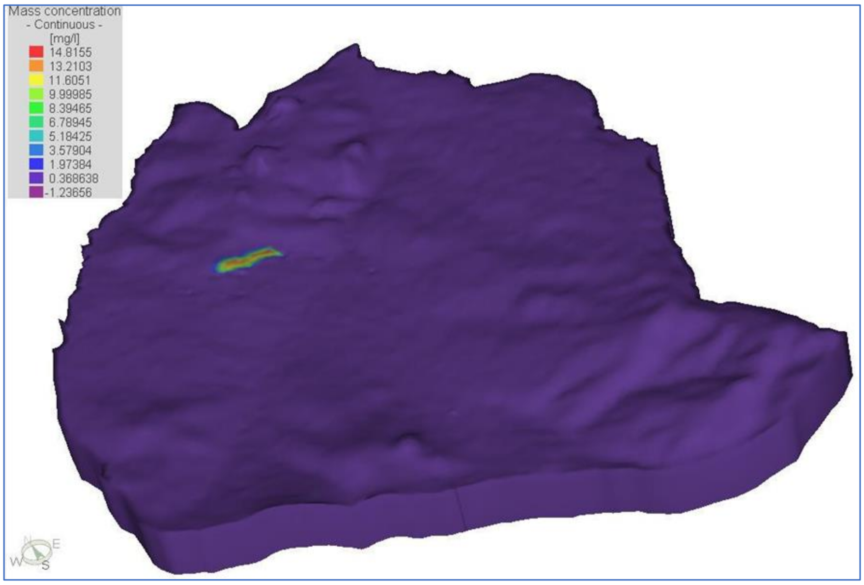

Figure 30: Contamination plume after 5 years _ global 3D view

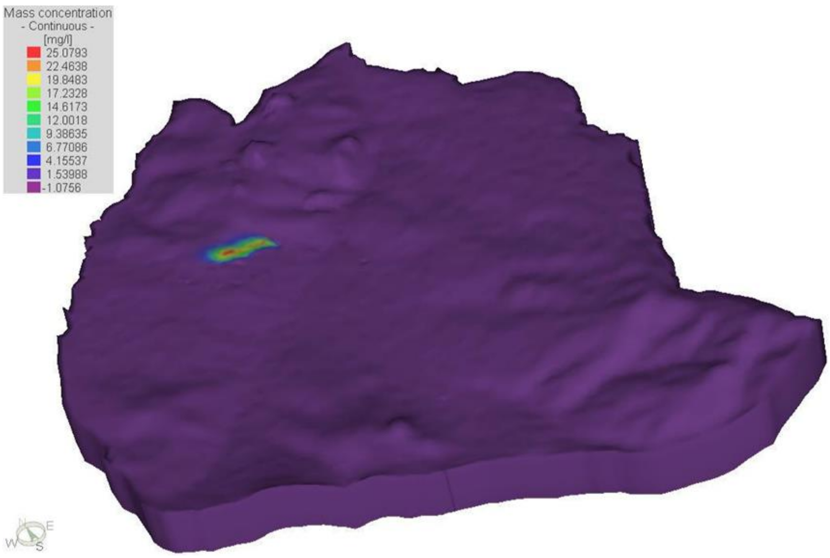

Figure 31:Contamination plume after 20 years _ global 3D view

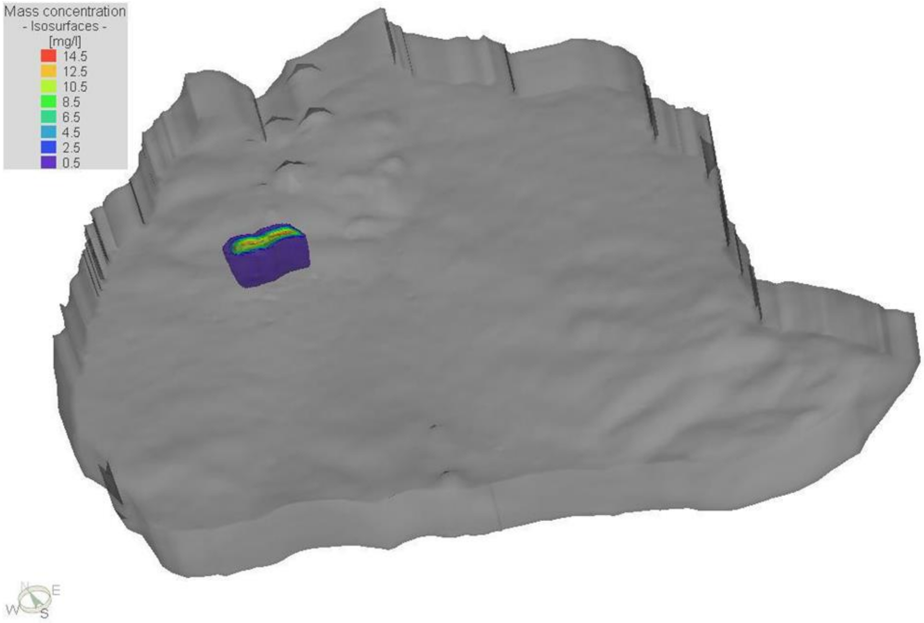

Figure 32:Contamination plume after 5 years _ global 3D view2

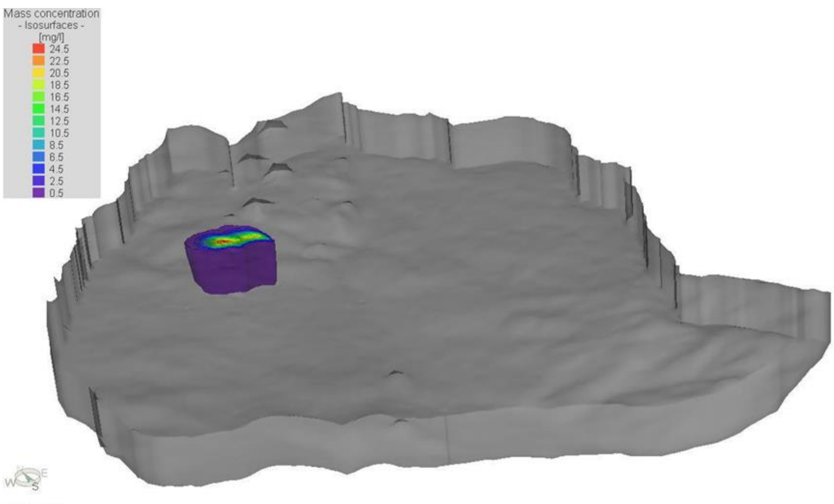

Figure 33: Contamination plume after 20 years _ global 3D view2

7 GEOCHEMSITRY

7.1 Scope of Work and Methodology

Samples were collected from the material that represents the material to be stockpiled as waste material. These samples were collected from core material that represents the hanging wall, footwall, the sulphides and the partings.

The samples were collected according to the information provided by the client (see Table 11)

Table 11: Summary of the samples

Sample Number	Description	Sampling Depth (From)	Sampling Depth (To)
MDD004-KIM-01	Representative of the Hanging Wall	49.58	50.80
MDD004-KIM-02	Representative of the Partings	68.97	69.94
MDD004-KIM-03	Representative of the Foot Wall	85.00	91.29
MDD004-KIM-04	Representative of the Sulphide sample	91.46	92.00

7.2 Laboratory Test

All samples were sent to Aquatico (Pty) Ltd (Pty) where accredited methods were used to prepare and analyse the samples. Samples were analysed for the following:

a) Acid-Base Accounting (ABA);
b) Nett Acid Generation (NAG);
c) X-ray diffraction (XRD);
d) X-ray florescence (XRF);
e) Deionised Water (DW) leachate tests and
f) Aqua *Regia* Digestion.

7.3 Laboratory Test Descriptions and Purpose

The laboratory tests to determine the potential for waste rock dump material samples to produce acid mine drainage (AMD) are generally grouped into two categories: static and kinetic tests. Static tests are relatively simple, inexpensive and rapid and enable initial screening of waste material in terms of the potential to produce AMD.

Static testing provides an indication of whether a sample has the potential to generate AMD and the elements that may leach from sample, whereas kinetic testing provides more confidence in the static test findings, as well as providing an indication of the time scale of the AMD and metal leaching.

7.3.1 XRD and XRF

XRF is an X-ray method used to determine the elemental composition of a material that allows for the evaluation of a material's chemical compound distribution, as well as the various trace element concentrations. XRD allows for the measurement of the crystal structures within a sample to determine the mineralogical composition of the material that allows determining whether any reactive solids will lead to environmental risks through the study of the various minerals.

7.3.2 ABA and NAG

Acid-Base Accounting (ABA) is a first order classification procedure whereby the acid-neutralising potential and acid-generating potential of rock samples are determined, and the difference (Net Neutralising Potential) is calculated. This procedure includes Nett Acid Generation tests that evaluate the Net Acid Generation and neutralising potential of the material to evaluate the potential of the material to counter acid production. The Net Neutralising Potential (NPR), and/or the ratio of neutralising potential to acid-generation potential, is compared with predetermined values listed in Table 12, to divide samples into categories based on their potential to generate or neutralise acid.

Table 12: Criteria for interpreting ABA results (Price, 1997)

Potential for AMD	Criterion	Comments
Likely	NPR<1	Potentially acid generating, unless sulphide minerals are non-reactive

Potential for AMD	Criterion	Comments
Possible	1<NPR<2	Possibly acid generating if NP is insufficiently reactive or is depleted at a rate faster than sulphides
Low	2<NPR<4	Not potentially acid generating unless significant preferential exposure of sulphide
None	NPR>4	Non-acid generating

7.3.3 Leachate Tests and Total Element Analysis

Reagent water leachate tests are done to simulate the heavy metal and ions leachate potential of soils, waste material left in-situ under normal conditions. These analyses will be used to characterise the mobile phase of a stockpiled material and simulate the potential of any heavy metal or ion contamination from the material.

7.4 Lab Results Interpretation

The results for the whole rock analyses, ABA and Leach tests are reported below. All laboratory results and certificates are shown in Appendix C.

7.4.1 Rock Mineralogy

Four samples were collected and submitted to Aquatico Laboratories for analysis. The samples were milled, and the material was prepared for XRD analysis. The mineralogy of the samples is shown in Table 13. Major minerals in the mineral component of the waste rock include Fosterite, Plagioclase and Clino-pyroxene.

Table 13: XRD results

Composition (%) [s]					
Sample Number		MDD004-KIM-01	MDD004-KIM-02	MDD004-KIM-03	MDD004-KIM-04
Mineral	Formula	Amount	Amount	Amount	Amount
		(weight %)			
Forsterite	Mg_2SiO_4	46,04	1,31	0,63	0,4
Plagioclase	$CaAl_2Si_2O_8$ - $NaAl_2Si_2O_8$	34,25	0	90,51	85,45
Ilmenite	$FeTiO_3$	4,07	8,52	2,07	1,72

Composition (%) [s]					
Sample Number		MDD004-KIM-01	MDD004-KIM-02	MDD004-KIM-03	MDD004-KIM-04
Mineral	Formula	Amount	Amount	Amount	Amount
		(weight %)			
Fayalite	Fe_2SiO_4	2,26	0,96	0	0
Biotite	$K(Mg,Fe)_3AlSi_3O_{10}(OH)_2$	1,46	25,47	0	1,82
Clinopyroxene	$(Mg,Fe)SiO_3$	3,35	38,65	1,24	3,58
Ortho Pyroxene	$CaMgSi_2O_6 – CaFeSi_2O_6$	0	3,17	2,65	2,19
Magnetite	Fe_3O_4	4,01	8,29	2,71	2,2
Ulvospinel	Fe_2TiO_4	0,15	0	0,16	0
Hornblende	$(Ca,Na)_2–3(Mg,Fe,Al)5(Al,Si)8O_{22}(OH,F)_2$	4,4	13,62	0,04	2,64

7.4.2 Rock Composition

Table 14 represents the major element composition of the samples as determined by XRF and expressed as metal oxides for comparative purposes (wt.%).

The silica and magnesium in the samples reflects the presence of pyroxenes and forsterite. The amount of iron in the residue stockpile material corresponds well with the amount of ilmenite and magnetite detected by XRD.

Table 14:Major Element Composition of samples determined by XRF analysis (wt %)

Sample Number	Major Element Concentration (wt %) [s]			
	MDD004-KIM-01	MDD004-KIM-02	MDD004-KIM-03	MDD004-KIM-04
Fe_2O_3	48,00	24,24	21,09	19,64
SiO_2	30,87	33,23	41,03	43,81
Al_2O_3	7,24	3,46	19,45	18,84
K_2O	0,14	0,52	0,33	0,43
P_2O_5	0,08	0,51	0,13	0,06
Mn_3O_4	0,53	0,28	0,14	0,17
CaO	3,01	8,60	8,06	8,84
MgO	7,87	17,88	0,75	1,39
TiO_2	5,45	6,70	4,22	3,61
Na_2O	1,05	0,41	3,03	3,04
V_2O_5	0,03	0,07	0,11	0,07
BaO	0,02	0,03	0,02	0,03

Sample Number	Major Element Concentration (wt %) [s]			
	MDD004-KIM-01	MDD004-KIM-02	MDD004-KIM-03	MDD004-KIM-04
Cr_2O_3	0,03	0,12	0,02	0,03
SrO	0,01	0,06	0,04	0,04
ZrO_2	0,01	0,08	0,01	0,01
MnO	0,50	0,26	0,13	0,16
LOI	-3,30	4,54	1,32	0,10
Total (XRF)	101,04	100,72	99,74	100,09

7.4.3 Sulphur Speciation

The objective of sulphur analysis is to identify and measure the concentration of different sulphur species present in the sample. Sulphide minerals are the primary sources of acidity and leaching of trace metals and their measurement is a critical requirement for acid drainage chemistry prediction.

A set of rules, which has been derived based on several of the factors calculated in ABA, was reported by Soregaroli and Lawrence (1998). It has been shown that for sustainable long-term acid generation, at least 0,3% Sulphide–S (total sulphur minus weak acid soluble sulphur) is needed. Values below this can yield acidity, but this is likely to be only of short-term significance. Soregaroli and Lawrence (1998) further states that samples with less than 0.3% sulphide sulphur are regarded as having insufficient oxidizable sulphides to sustain long-term acid generation

The sulphur content of the partings, footwall and the "sulphide" sample are below the 0.3% benchmark and is unlikely to generate acid (Table 15). This comparison is made in the section below. The hanging wall samples have Total S (%) > 0.3 %, and this will be investigated further below.

Table 15: Sulphur Speciation

Sample Number	Description	Total Sulphur	Sulphide Sulphur	Sulphate Sulphur
MDD004-KIM-01	Representative of the Hanging Wall	0,708	**0,325**	0,383
MDD004-KIM-02	Representative of the Partings	0,269	0,002	0,267
MDD004-KIM-03	Representative of the Foot Wall	0,355	0,291	0,064

Sample Number	Description	Total Sulphur	Sulphide Sulphur	Sulphate Sulphur
MDD004-KIM-04	Representative of the Sulphide sample	0,218	0,166	0,052

7.4.4 Acid Generating Potential

The acid generation potential of the hard rock and stockpile materials were estimated by using ABA on the samples collected from waste representing the WRD. The NAG test provides a direct assessment of the potential for a material to produce acid after a period of exposure (to a strong oxidant) and weathering. The test can be used to refine the results of the ABA predictions. In the Net-acid Generating (NAG) test hydrogen peroxide (H_2O_2) is used to oxidize sulphide minerals in order to predict the acid generation potential of the sample.

For the material to be classified in terms of their acid-mine drainage (AMD) potential, the ABA results could be screened in terms of its NNP, %S and NP:AP ratio.

Research and experience across the world have shown that there is a range from – 20 to 20 kg/t $CaCO_3$ where the system or sample can either become acidic or remain neutral. Some authorities state that any sample with a negative NNP value (NNP < -20) is potentially acid-generating, and any sample with positive NNP value (NNP > 20) might not generate acid since there will be enough alkalinity to buffer any acid that could be generated.

The analysed samples show a positive NNP value indicating the potential to neutralise the acid or predict a positive net drainage water quality from a rock sample (Table 18 and Table 19). All the samples representing the stockpile material have a positive NNP, and this illustrate the buffering capacity of the material.

Based on the NAG pH, none of the sample have high risk to generate acid (see Table 16)

Table 16: NAG pH Classification

Sample number	NAGpH	NAG pH Rating	Verdict
MDD004-KIM-01	5,24	>5,5	Non-acid generating
MDD004-KIM-02	6,84	>5,5	Non-acid generating
MDD004-KIM-03	4,02	Between 3,5 and 5,5	Low risk acid generating
MDD004-KIM-04	4,07	Between 3,5 and 5,5	Low risk acid generating

7.4.5 Leach Test

The potential leachate quality emanating from the residue stockpile is characterised by using deionised water as a reagent.

Although the leach test can determine the leachability of determinants, the liquid-to-solid ratio may not represent actual field conditions depending on the waste saturation; therefore, resultant concentrations should not be considered to exactly represent run-off that could emanate from the site. It is important to note that the degree of dilution of a short-term leaching test in the laboratory could be different to the degree of dilution expected at the site. The results of the leach tests should therefore be used as indicators of actual field conditions, considering that the rock samples are crushed in the lab to increase the surface area for reaction and enhanced leaching. The results from short-term leach tests generally cannot be applied to develop reaction rates and predict long-term mine water quality but should instead be used to get an initial indication of parameters of constituents of interest.

Based on the leach test results, most of the elements were measured below detection limit (Table 17).

Table 17: Leach Test Results

Elements	Units	MDD004-KIM-01	MDD004-KIM-02	MDD004-KIM-03	MDD004-KIM-04
pH	pH	8,71	9,12	8,79	9,09
EC	mS/m	7,8	22,8	7,2	8,5
Alk	mg $CaCO_3$/l	21,5	78,1	33,3	41,2
Cl	mg/l	9,07	15	9,26	6,62
SO_4	mg/l	5,0	8,04	2,0	1,55
PO_4	mg/l	0,016	BDL	0,065	0,037
NH_4	mg/l	BDL	BDL	BDL	BDL
NO_3	mg/l	BDL	BDL	BDL	BDL
F	mg/l	BDL	0,598	BDL	BDL
Ca	mg/l	0,756	2,67	0,725	1,7
Mg	mg/l	2,49	3,98	0,145	0,351
K	mg/l	3,74	30,7	1,13	3,97
Al	mg/l	0,227	0,043	2,45	2,62
Fe	mg/l	0,149	0,008	1,26	0,984
Mn	mg/l	0,001	BDL	0,008	0,008
Cd	mg/l	BDL	BDL	BDL	BDL
Co	mg/l	BDL	BDL	BDL	BDL
Cr	mg/l	BDL	BDL	BDL	BDL

Elements	Units	MDD004-KIM-01	MDD004-KIM-02	MDD004-KIM-03	MDD004-KIM-04
Cu	mg/l	BDL	BDL	BDL	BDL
Ni	mg/l	BDL	BDL	BDL	BDL
Pb	mg/l	BDL	BDL	BDL	BDL
Zn	mg/l	BDL	BDL	BDL	BDL
B	mg/l	BDL	BDL	BDL	BDL
Ba	mg/l	BDL	0,003	BDL	0,002
Be	mg/l	BDL	BDL	BDL	BDL
V	mg/l	BDL	0,038	0,037	0,035
Bi	mg/l	BDL	BDL	BDL	BDL
Ag	mg/l	BDL	BDL	BDL	BDL
Ga	mg/l	BDL	0,001	0,012	0,013
Li	mg/l	BDL	0,001	BDL	BDL
Mo	mg/l	BDL	0,017	BDL	BDL
Rb	mg/l	BDL	0,013	0,003	0,006
Sr	mg/l	BDL	0,058	BDL	BDL
Te	mg/l	BDL	BDL	BDL	0,003
Tl	mg/l	BDL	BDL	BDL	BDL
Cr^{6+}	mg/l	BDL	BDL	BDL	BDL

Table 18: ABA Results for Waste Material to be stockpiled

Sample number	pH paste	NAG	NAG pH	Total Sulphur	Sulphide Sulphur	Sulphate Sulphur	Acid Potential AP (TS)	Acid Potential AP (SS)	Neutralization Potential NP	Net Neutralization Potential NNP	NP / AP
units	pH	$CaCO_3$ kg/t	pH	%	%	%	$CaCO_3$ kg/t	$CaCO_3$ kg/t	$CaCO_3$ kg/t	$CaCO_3$ kg/t	-
MDD004-KIM-01	9,23	0,55	5,24	0,708	0,325	0,383	22,1	10,2	41,7	31,5	4,11
MDD004-KIM-02	8,95	0	6,84	0,269	0,002	0,267	8,41	-0,313	74,6	74,5	1203
MDD004-KIM-03	9,88	1,01	4,02	0,355	0,291	0,064	11,1	9,09	9,5	0,41	1,05
MDD004-KIM-04	9,54	1,15	4,07	0,218	0,166	0,052	6,81	5,19	7,0	1,81	1,35

Note: The AP highlighted was measure below detection limit of 0,062

Table 19: Classification of Acid Generating Potential

Site Number	pH values	Net Neutralising Potential	NPR (Open System)	NPR (Closed System)	%S and NPR Method (Soregali and Lawrence,1997)
MDD004-KIM-01	Lower Acid Risk	Probably Excess Neutralising Minerals	No Acid Potential	Acid under certain conditions	confirm with other testing
MDD004-KIM-02	Lower Acid Risk	Probably Excess Neutralising Minerals	No Acid Potential	No Acid Potential	Too little S to create sustained acidity
MDD004-KIM-03	Lower Acid Risk	Verify with other tests	Acid under certain conditions	Likely Acid Generator	Too little S to create sustained acidity
MDD004-KIM-04	Lower Acid Risk	Verify with other tests	Acid under certain conditions	Likely Acid Generator	Too little S to create sustained acidity

8 WASTE ASSESSMENT FOR DISPOSAL INTO WASTE ROCK DUMP

8.1 Introduction

Four of the collected samples were analysed in order to classify the waste rock material in accordance with the NEM: WA Regulations (2013) by comparison with Total Concentration Threshold (TCT) and Leachable Concentration Thresholds (LCT). Total Concentration values were determined by *aqua regia* digestion while the leachable concentrations were prepared by a leachate of 25% aqueous extraction.

8.2 Legislative Guidelines

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

As residue deposits and residue stockpiles are waste, they are regulated by the following regulations, both promulgated on 23 August 2013:

a) R635 – National norms and standards for assessment of waste for landfill disposal; and
b) R636 – National norms and standards for disposal of waste to landfill.

According to these regulations, waste that is generated must be classified in accordance with SANS 10234 within 180 days of generation, Waste that has already been generated, but not previously classified must be classified within 18 months of the date of commencement of the regulations, The norms and standards specify the waste classification methodologies for determining the waste category, and the specifications for pollution control barrier systems (liners) for each of the waste categories.

The Department of Environmental Affairs (DEA) has published the following draft regulations:

a) The Regulations Regarding the Planning and Management of Residue Stockpiles and Residue Deposits from a Prospecting, Mining, Exploration or Production Operation (the Regulations) which were published under GNR R 632 on 24 July 2015.
b) In terms of waste classification, these regulations state that residue stockpiles and residue deposits must be characterised to identify any potential risk to health or safety and environmental impact in terms of physical characteristics, chemical characteristics (toxicity, propensity to oxidise and decompose, propensity to undergo spontaneous combustion, pH and chemical composition of the water separated from the solids, stability and reactivity and the rate thereof, neutralising potential and concentration of volatile organic compounds), and mineral content.

In addition, the quality of seepage from residue facilities needs to be predicted:

a) Notice 1006 of 2014 (14 November 2014): Proposed regulations to exclude a waste stream or a portion of a waste stream from the definition of waste.

These regulations state that waste generated from a source listed in Category A of Schedule 3 of NEM: WA may be excluded from being defined as hazardous on demonstration that the waste is non-hazardous in accordance with the Waste Management and Classification regulations. Exclusion of a waste stream from the definition of waste may be considered if it can be demonstrated that any contaminant of concern originating from the waste reaching the receptor will not exceed the acceptable environmental limits for any contaminant of concern for such a receptor. The acceptable environmental limits have not been defined.,

8.3 Waste Assessment Methodology

Six of the collected samples were analysed in order to classify the WRD and TSF material in accordance with the NEM: WA Regulations (2013) and NEM: WA, 2014 (Act No, 26 of 2014, by comparison with total and leachable concentration thresholds,

Total Concentration values were determined by *aqua regia* digestion and analysis with ICP methods by Aquatico Laboratory in Gauteng Province.

Total Concentration Threshold limits are subdivided into three categories as follows:

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

b) TCT1 limits derived from land remediation values for commercial/industrial land (DEA, March 2010); and
c) TCT2 limits derived by multiplying the TCT1 values by a factor of 4, as used by the Environmental Protection Agency, Australian State of Victoria.

Leachable concentration was determined by following the Australian Standard Leaching Procedure for Wastes, Sediments and Contaminated Soils (AS 4439.3-1997), as specified in the NEM: WA Regulations (2013). The procedure recommends the use of reagent water for leaching of non-putrescible material that will be mono-filled. A leachate of 1:20 solids per reagent water was prepared and analysed by Aquatico Laboratory.

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

a) LCT0 limits derived from human health effect values for drinking water, as published by the Department of Water and Sanitation (DWS) and South African National Standards (SANS);
b) LCT1 limits derived by multiplying LCT0 values by a Dilution Attenuation Factor (DAF) of 50, as proposed by the Australian State of Victoria;
c) LCT2 limits derived by multiplying LCT1 values by a factor of 2; and
d) LCT3 limits derived by multiplying the LCT2 values by a factor of 4.

Waste is classified by comparison of the total and leachable concentration of elements and chemical substances in the waste material to TCT and LCT limits as specified in the National Norms and Standards for Waste Classification and the National Norms and Standards for Disposal to Landfill as per Table 20.

Table 20: Waste Classification Criteria

Waste Type	Element or chemical substance concentration	Disposal
0	LC > LCT3 **OR** TC > TCT2	Not allowed
1	LCT2 < LC ≤ LCT3 **OR** TCT1 < TC ≤ TCT2	Class A or Hh:HH landfill
2	LCT1 < LC ≤ LCT2 **AND** TC ≤ TCT1	Class B or GLB+ landfill
3	LCT0 < LC ≤ LCT1 **AND** TC ≤ TCT1	Class C or GLB- landfill

Waste Type	Element or chemical substance concentration	Disposal
4	LC ≤ LCT0 **AND** TC ≤ TCT0 for metal ions and inorganic anions **AND** all chemical substances are below the total concentration limits provided for organics and pesticides listed	Class D or GLB- landfill

8.4 Results

Based on the results from the analysis, none of the samples were measured to be above LCT0 (Table 21). Based on the LCT results only, the residue is classified as type 4

Based on the results from the analysis of the total concentration of the samples:

d) TCT0 threshold values for barium and nickel is exceeded in MDD004-KIM-02;
e) TCT0 threshold value for cobalt is exceeded in MDD004-KIM-01 and MDD004-KIM-02,
f) TCT0 threshold values for copper is exceeded in all samples;
g) TCT0 threshold values for manganese is exceeded in MDD004-KIM-01 and
h) TCT0 threshold values for vanadium is exceeded in MDD004-KIM-03 and MDD004-KIM-04.

Based on the TC results only, the residue is classified as type 3 (Table 22). Based on R 635, Section 7, paragraph 6, waste with all elements or chemical substances leachable concentration levels for metal ions and inorganic anions below or equal to the LCT0 limits are Type 3 waste. This will apply irrespective of the total concentration of elements or chemical substances in the waste, provided that the inherent physical and chemical character of the waste is stable and will not change over time. For the study, a Class C landfill will be needed for disposal of the material based on the TC and LC results.

8.5 Risk Based Approach Model

The Department of Environmental Affairs (DEA) has published the following notification:

a) No 1440: Proposed Amendments to The Regulations Regarding the Planning and Management of Residue Stockpiles and Residue Deposits, 2015

The main aim of the amendments is to allow for the pollution control barrier system required for residue stockpiles and residue deposits to be determined on a case by case basis, based on a risk analysis approach.

The leach test results show that no chemicals of concern leached out. Based on the risk-based approach model, the current mitigation (separation of dirty and clean water, containing of all runoff from storage facilities and installation of stockpile berms), Kimopax proposes that the residue stockpiles be classed as Type 4 waste that needs to be deposited on Class D disposal area.

Kimopax advises that monitoring boreholes be established near the waste rock dumps. The Class D liner setup is depicted in figure below. According to GNR 636: "Type 4 waste may only be disposed of at a Class D landfill designed in accordance with section 3(1) and (2) of these Norms and Standards, or, subject to section 3(4) of these Norms and Standards, may be disposed of at a landfill site designed in accordance with the requirements for a G:L:B+ landfill as specified in the Minimum Requirements for Waste Disposal by Landfill (2nd Ed., DWAF, 1998

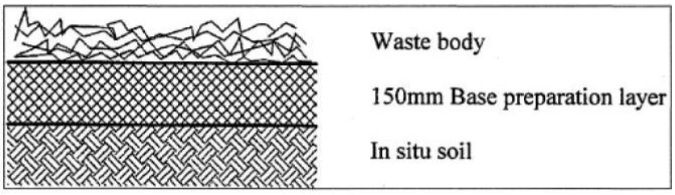

Figure 34:Class D landfill (GNR 636)

Table 21: LCT Classification

Elements & Chemical Substances in Waste	LCT0	LCT1	LCT2	LCT3	MDD004-KIM-01	MDD004-KIM-02	MDD004-KIM-03	MDD004-KIM-04
				mg/l				
As, Arsenic	0.01	0.5	1	4	<0,010	<0,010	<0,010	<0,010
B, Boron	0.5	25	50	200	<0,500	<0,500	<0,500	<0,500
Ba, Barium	0.7	35	70	280	<0,700	<0,700	<0,700	<0,700
Cd, Cadmium	0.003	0.15	0.3	1.2	<0,003	<0,003	<0,003	<0,003
Co, Cobalt	0.5	25	50	200	<0,400	<0,400	<0,400	<0,400
Cr Total, Chromium	0.05	2.5	5	20	<0,100	<0,100	<0,100	<0,100
Cr (VI), Chromium (VI)	0.05	2.5	5	20	<0,020	<0,020	<0,020	<0,020
Cu, Copper	2.0	100	200	800	<1,00	<1,00	<1,00	<1,00
Hg, Mercury	0.006	0.3	0.6	2.4	<0,006	<0,006	<0,006	<0,006
Mn, Manganese	0.5	25	50	200	<0,500	<0,500	<0,500	<0,500
Mo, Molybdenum	0.07	3.5	7	28	<0,070	<0,070	<0,070	<0,070
Ni, Nickel	0.07	3.5	7	28	<0,070	<0,070	<0,070	<0,070
Pb, Lead	0.01	0.5	1	4	<0,010	<0,010	<0,010	<0,010
Sb, Antimony	0.2	10	20	8	<0,020	<0,20	<0,20	<0,020
Se, Selenium	0.01	0.5	1	4	<0,010	<0,010	<0,010	<0,010
V, Vanadium	0.2	10	20	80	<0,200	<0,200	<0,200	<0,200
Zn, Zinc	5.0	250	500	2000	<2,00	<2,00	<2,00	<2,00
TDS	1000	12500	25000	100000	<100	<100	<100	<100
Chloride	300	1500	30000	120000	<50,0	<50,0	<50,0	<50,0
Sulphate	250	12500	25000	100000	<50,0	<50,0	<50,0	<50,0
NO_3 as N, Nitrate-N	11	550	1100	4400	<10,0	<10,0	<10,0	<10,0
F, Fluoride	1.5	75	150	600	<1,00	1,06	<1,00	<1,00

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Elements & Chemical Substances in Waste	LCT0	LCT1	LCT2	LCT3	MDD004-KIM-01	MDD004-KIM-02	MDD004-KIM-03	MDD004-KIM-04
mg/l								
CN-(total), Cyanide Total	0.07	3.5	7	28	<0,05	<0,05	<0,05	<0,05

Table 22: TCT Classification

Elements & Chemical Substances in Waste	TCT0	TCT1	TCT2	MDD004-KIM-01	MDD004-KIM-02	MDD004-KIM-03	MDD004-KIM-04
mg/kg							
As, Arsenic	5,8	500	2000	<5,80	<5,80	<5,80	<5,80
B, Boron	150	15000	60000	<150	<150	<150	<150
Ba, Barium	62,5	6250	25000	<62,5	**124**	<62,5	<62,5
Cd, Cadmium	7,5	260	1040	<7,50	<7,50	<7,50	<7,50
Co, Cobalt	50	5000	20000	**110**	**77,6**	<50,0	<50,0
Cr Total, Chromium Total	46000	800000	N/A	<1000	<1000	<1000	<1000
Cr (VI), Chromium (VI)	6,5	500	2000	<5,00	<5,00	<5,00	<5,00
Cu, Copper	16	19500	78000	**68,1**	**156**	**81,4**	**47,8**
Hg, Mercury	0,93	160	640	<0,900	<0,900	<0,900	<0,900
Mn, Manganese	1000	25000	100000	**2200**	<1000	<1000	<1000
Mo, Molybdenum	40	1000	4000	<10,0	<10,0	<10,0	<10,0
Ni, Nickel	91	10600	42400	<50,0	**539**	76,5	51
Pb, Lead	20	1900	7600	<20,0	<20,0	<20,0	<20,0
Sb, Antimony	10	75	300	<10,0	<10,0	<10,0	<10,0
Se, Selenium	10	50	200	<10,0	<10,0	<10,0	<10,0

Elements & Chemical Substances in Waste	TCT0	TCT1	TCT2	MDD004-KIM-01	MDD004-KIM-02	MDD004-KIM-03	MDD004-KIM-04
mg/kg							
V, Vanadium	150	2680	10720	<100	140	**302**	**172**
Zn, Zinc	240	160000	640000	<220	<220	<220	<220

9 IMPACT ASSESSMENT

The model outputs were used to assess the potential impact of the mine on the groundwater environment. In this task, the environmental impacts are rated based on their significance scoring before and after mitigation methods are implemented. Details of the impact assessment methodology used to determine the significance of physical, bio-physical and socio-economic impacts are provided below.

The significance rating process follows the established impact/risk assessment formula:

Significance = Consequence x Probability x Nature

Where

Consequence = Intensity + Extent + Duration

And

Probability = Likelihood of an impact occurring

And

Nature = Positive (+1) or negative (-1) impact

Note: In the formula for calculating consequence, the type of impact is multiplied by +1 for positive impacts and -1 for negative impacts.

The matrix calculates the rating out of 147, whereby Intensity, Extent, Duration and Probability are each rated out of seven as indicated in Table 23. The weight assigned to the various parameters is then multiplied by +1 for positive and -1 for negative impacts.

Impacts are rated prior to mitigation and again after consideration of the mitigation measure proposed in this EIA/EMP Report. The significance of an impact is then determined and categorised into one of eight categories, as indicated in Table 24, which is extracted from **Error! Reference source not found.**. The description of the significance ratings is discussed in Table 25.

It is important to note that the pre-mitigation rating takes into consideration the activity as proposed, i.e. there may already be certain types of mitigation measures included in the design (for example due to legal requirements). If the potential impact is still considered too high, additional mitigation measures are proposed.

Table 23: Impact Assessment Parameter Ratings

Rating	Intensity/ Replaceability		Extent	Duration/Reversibility	Probability
	Negative Impacts (Nature = -1)	**Positive Impacts (Nature = +1)**			
7	Irreplaceable loss or damage to biological or physical resources or highly sensitive environments. Irreplaceable damage to highly sensitive cultural/social resources.	Noticeable, on-going natural and / or social benefits which have improved the overall conditions of the baseline.	International The effect will occur across international borders.	Permanent: The impact is irreversible, even with management, and will remain after the life of the project.	Definite: There are sound scientific reasons to expect that the impact will occur. >80% probability.
6	Irreplaceable loss or damage to biological or physical resources or moderate to highly sensitive environments. Irreplaceable damage to cultural/social resources of moderate to highly sensitivity.	Great improvement to the overall conditions of a large percentage of the baseline.	National Will affect the entire country.	Beyond project life: The impact will remain for some time after the life of the project and is potentially irreversible even with management.	Almost certain / Highly probable: It is most likely that the impact will occur. <80% probability.

Rating	Intensity/ Replaceability		Extent	Duration/Reversibility	Probability
	Negative Impacts (Nature = -1)	**Positive Impacts (Nature = +1)**			
5	Serious loss and/or damage to physical or biological resources or highly sensitive environments, limiting ecosystem function. Very serious widespread social impacts. Irreparable damage to highly valued items.	On-going and widespread benefits to local communities and natural features of the landscape.	Province/ Region Will affect the entire province or region.	Project Life (>15 years): The impact will cease after the operational life span of the project and can be reversed with sufficient management.	Likely: The impact may occur. <65% probability.
4	Serious loss and/or damage to physical or biological resources or moderately sensitive environments, limiting ecosystem function. On-going serious social issues. Significant damage to structures / items of cultural significance.	Average to intense natural and / or social benefits to some elements of the baseline.	Municipal Area Will affect the whole municipal area.	Long term: 6-15 years and impact can be reversed with management.	Probable: Has occurred here or elsewhere and could therefore occur. <50% probability.

Rating	Intensity/ Replaceability		Extent	Duration/Reversibility	Probability
	Negative Impacts (Nature = -1)	Positive Impacts (Nature = +1)			
3	Moderate loss and/or damage to biological or physical resources of low to moderately sensitive environments and, limiting ecosystem function. On-going social issues. Damage to items of cultural significance.	Average, on-going positive benefits, not widespread but felt by some elements of the baseline.	Local Local extending only as far as the development site area.	Medium term: 1-5 years and impact can be reversed with minimal management.	Unlikely: Has not happened yet but could happen once in the lifetime of the project, therefore there is a possibility that the impact will occur. <25% probability.
2	Minor loss and/or effects to biological or physical resources or low sensitive environments, not affecting ecosystem functioning. Minor medium-term social impacts on local population. Mostly repairable. Cultural functions and processes not affected.	Low positive impacts experience by a small percentage of the baseline.	Limited Limited to the site and its immediate surroundings.	Short term: Less than 1 year and is reversible.	Rare / improbable: Conceivable, but only in extreme circumstances. The possibility of the impact materialising is very low as a result of design, historic experience or implementation of adequate mitigation measures. <10% probability.

Rating	Intensity/ Replaceability		Extent	Duration/Reversibility	Probability
	Negative Impacts (Nature = -1)	**Positive Impacts (Nature = +1)**			
1	Minimal to no loss and/or effect to biological or physical resources, not affecting ecosystem functioning. Minimal social impacts, low-level repairable damage to commonplace structures.	Some low-level natural and / or social benefits felt by a very small percentage of the baseline.	Very limited/Isolated Limited to specific isolated parts of the site.	Immediate: Less than 1 month and is completely reversible without management.	Highly unlikely / None: Expected never to happen. <1% probability.

Table 24: Probability/Consequence Matrix

		Significance																																					
Probability	7	-147	-140	-133	-126	-119	-112	-105	-98	-91	-84	-77	-70	-63	-56	-49	-42	-35	-28	-21	21	28	35	42	49	56	63	70	77	84	91	98	105	112	119	126	133	140	147
	6	-126	-120	-114	-108	-102	-96	-90	-84	-78	-72	-66	-60	-54	-48	-42	-36	-30	-24	-18	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126
	5	-105	-100	-95	-90	-85	-80	-75	-70	-65	-60	-55	-50	-45	-40	-35	-30	-25	-20	-15	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105
	4	-84	-80	-76	-72	-68	-64	-60	-56	-52	-48	-44	-40	-36	-32	-28	-24	-20	-16	-12	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84
	3	-63	-60	-57	-54	-51	-48	-45	-42	-39	-36	-33	-30	-27	-24	-21	-18	-15	-12	-9	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63
	2	-42	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42
	1	-21	-20	-19	-18	-17	-16	-15	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
		-21	-20	-19	-18	-17	-16	-15	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21

		Consequence

Table 25: Significance Rating Description

Score	Description	Rating
109 to 147	A very beneficial impact that may be enough by itself to justify implementation of the project. The impact may result in permanent positive change	Major (positive) (+)
73 to 108	A beneficial impact which may help to justify the implementation of the project. These impacts would be considered by society as constituting a major and usually a long-term positive change to the (natural and / or social) environment	Moderate (positive) (+)
36 to 72	A positive impact. These impacts will usually result in positive medium to long-term effect on the natural and / or social environment	Minor (positive) (+)
3 to 35	A small positive impact. The impact will result in medium to short term effects on the natural and / or social environment	Negligible (positive) (+)
-3 to -35	An acceptable negative impact for which mitigation is desirable. The impact by itself is insufficient even in combination with other low impacts to prevent the development being approved. These impacts will result in negative medium to short term effects on the natural and / or social environment	Negligible (negative) (-)
-36 to -72	A minor negative impact requires mitigation. The impact is insufficient by itself to prevent the implementation of the project but which in conjunction with other impacts may prevent its implementation. These impacts will usually result in negative medium to long-term effect on the natural and / or social environment	Minor (negative) (-)
-73 to -108	A moderate negative impact may prevent the implementation of the project. These impacts would be considered as constituting a major and usually a long-term change to the (natural and / or social) environment and result in severe changes.	Moderate (negative) (-)
-109 to -147	A major negative impact may be sufficient by itself to prevent implementation of the project. The impact may result in permanent change. Very often these impacts are immitigable and usually result in very severe effects. The impacts are likely to be irreversible and/or irreplaceable.	Major (negative) (-)

9.1 *Construction Phase and Operational Phases*

Table 26: Impact assessment of mine dewatering

Dimension	Rating	Motivation	Significance
Impact: mining – lowering of the water table			
Pre-Mitigation			
Duration	5 (project life)	Opencast mining of will result in groundwater inflows into the pits, which needs to be pumped out for mine safety. The expected inflow into the pit is 730 m^3/d when mining floor will reach 20 mbgl. It will stabilise to 1150 m^3/d when mining floor will reach 90 mbgl	60 (Minor Negative)
Extent	2 (limited)	Considering the rock permeability, the radius of influence is expected to be limited to about 800 m away.	
Intensity	3 (moderate)	Mine dewatering will result in lowering of the water table within the site	
Probability	6 (definite)	The dewatering of the groundwater system in the immediate vicinity of the pits will results in wider cone of depression as depth to pit floor will increase.	
Mitigation/ Management Actions			
a) Store the dewatered water in PCDs and ensure that the dams will have enough storage volume; b) If that is not possible, re-introduce treated water into the streams after ensuring that they meet the required standards as per the WUL or river quality objectives; c) Supply equal volumes and better-quality water to affected user if proven that there is an impact on specific users; d) Monitoring of groundwater water levels and groundwater inflow rates; and e) Update numerical model annually.			
Post-Mitigation			
Duration	5 (project life)	The water level will remain below its natural level throughout the life of mine to keep the pits dry	24 (Minor Negative)

Dimension	Rating	Motivation	Significance
Extent	2 (limited)	With the above stated mitigation methods, the extent is expected to remain limited.	
Intensity	1 (minimal)	If the abstracted water is stored in PCDs or treated and re-introduced to the streams, or placed on evaporation ponds, the environmental significance is rated as minimal.	
Probability	3 (unlikely)	With the application of the proposed mitigation plans, the probability of the impact will be unlikely.	

Table 27: Impact assessment of mine water contamination

Dimension	Rating	Motivation	Significance
Impact: Deposition waste rock on WRDs can result in the contamination of groundwater as a result of seepage			
Pre-Mitigation			
Duration	7 (Project Life)	The impact of the WRDs on water quality will continue for the project life.	60 (Minor Negative)
Extent	2 (limited)	Any contamination that will seep from the WRDs is expected to move eastern direction toward the north-north-east down-gradient of the waste dump. The toe of the plume estimated to extend 700 m away from waste dump, 20 years after contamination commences.	
Intensity	3 (moderate)	The contamination will be moderate as the extent will be limited	
Probability	5 (Likely)	Seepage from WRDs is likely	
Mitigation/ Management Actions			
a) Implement compacted clay or synthetic liner underneath the WRDs to minimizes seepage following the waste classification result; b) Re-use water collected in the WRDs berms. Any excess should be treated to acceptable quality before it is discharged to the environment;			

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Dimension	Rating	Motivation	Significance
c) Monthly and quarterly monitoring of the surface water and groundwater respectively			
Post-Mitigation			
Duration	7 (Permanent)	The impact of the WRDs on groundwater quality will continue in perpetuity, even after mine closure.	27 (Negligible Negative)
Extent	1 (very limited)	The size of the contamination plume will be reduced if a liner is implemented. It will also be localized as it will be intercepted by the deep-cutting rivers.	
Intensity	1 (minimal)	With the above mitigation plans, impact is expected to be minimal within the WRD.	
Probability	3 (unlikely)	Impact on the groundwater outside the WRDs is unlikely.	

9.2 Closure and Post Closure

Table 28: Impact assessment for decant annd mine water contamination

Dimension	Rating	Motivation	Significance
Impact: decanting and groundwater contamination			
Pre-Mitigation			
Duration	7 (permanent)	After mine closure and ceasing of dewatering, pit is likely to decant. Once the mine starts to decant, it is not expected to stop naturally. Pollution from WRDs on groundwater quality will continue in perpetuity, even after mine closure.	72 (Moderate Negative)
Extent	4 (municipal)	A steady increase in groundwater discharge (decant) to the Diphiri river (Catchment A24E) will take place, as the direct result of increased recharge and transmissivity of the backfilled pit. It will take 15 years for the pit to flood, thereafter, decanting will commence. The position of the expected decant	

Dimension	Rating	Motivation	Significance
		point is shown in Figure 24. The decant volume is estimated to stabilise at 95 m3/d	
Intensity	4 (serious)	Seepage and decant is expected to have a serious impact and require management and rehabilitation measures to prevent irreplaceable impacts. If the pH is acidic, dissolved metals and sulphates will remain is solution	
Probability	5 (Likely)	Based on the current studies, decant and seepage are likely to occur	
Mitigation/ Management Actions			
a) Identify decant areas and raise topography to increase time to decant; b) Plan open cast mining so that the perimeters follow the surface contours along the lowest side of the pit and not cut directly across streams; c) Implement mitigation measures for WRDs stated in **Error! Reference source not found.**; d) Monitoring groundwater levels, decant rates and qualities; e) Revegetated WRD as quickly as possible to minimize recharge rates; f) Divert all clean runoff away from, the pit through a series of berms; g) Re-evaluate impact of decant after end of life, once monitoring information is available; and h) Treat seepage and decanted water using passive or active means to meet the recommended standards.			
Post-Mitigation			
Duration	7 (permanent)	The decant is expected to continue for the foreseeable future	30 (Negligible Negative)
Extent	2 (limited)	With the implementation of the mitigation measures above the extent of impact will be limited	
Intensity	1 (minor)	With the implementation of the mitigation measures above, the environmental significance is rated as minimal to no loss	
Probability	3 (unlikely)	If the decant and seepage is treated to the SANS or river quality objectives, its impact is unlikely	

10 GROUNDWATER MONITORING PROGRAME

Groundwater monitoring should continue during all phases of the mine operation to identify impacts over time, and that effective measures can be undertaken at the early stage before negative impacts to the environment takes place. The main objectives in positioning the monitoring boreholes are to

a) Monitor the movement of polluted groundwater migrating away from the mine area; and
b) Monitor the lowering of the water table and the radius of influence

The positions of the recommended monitoring points are displayed Figure 35 and their coordinates given in Table 29**.** Considering the project size and closeness of the receiving environment, a total of four additional monitoring points is recommended for the purpose of groundwater monitoring.

Table 29: Proposed Monitoring Boreholes

Proposed Boreholes	UTM_WGS84		Location
	longitude	Latitude	
MMBH1	514073.748	7233837.984	Down gradient of waste dump
MMBH2	513156.501	7233864.191	Down gradient of waste dump
MMBH3	512211.405	7233971.793	Down gradient of waste plant
MMSW1	516765.551	7234383.810	surface water point, down gradient of dump

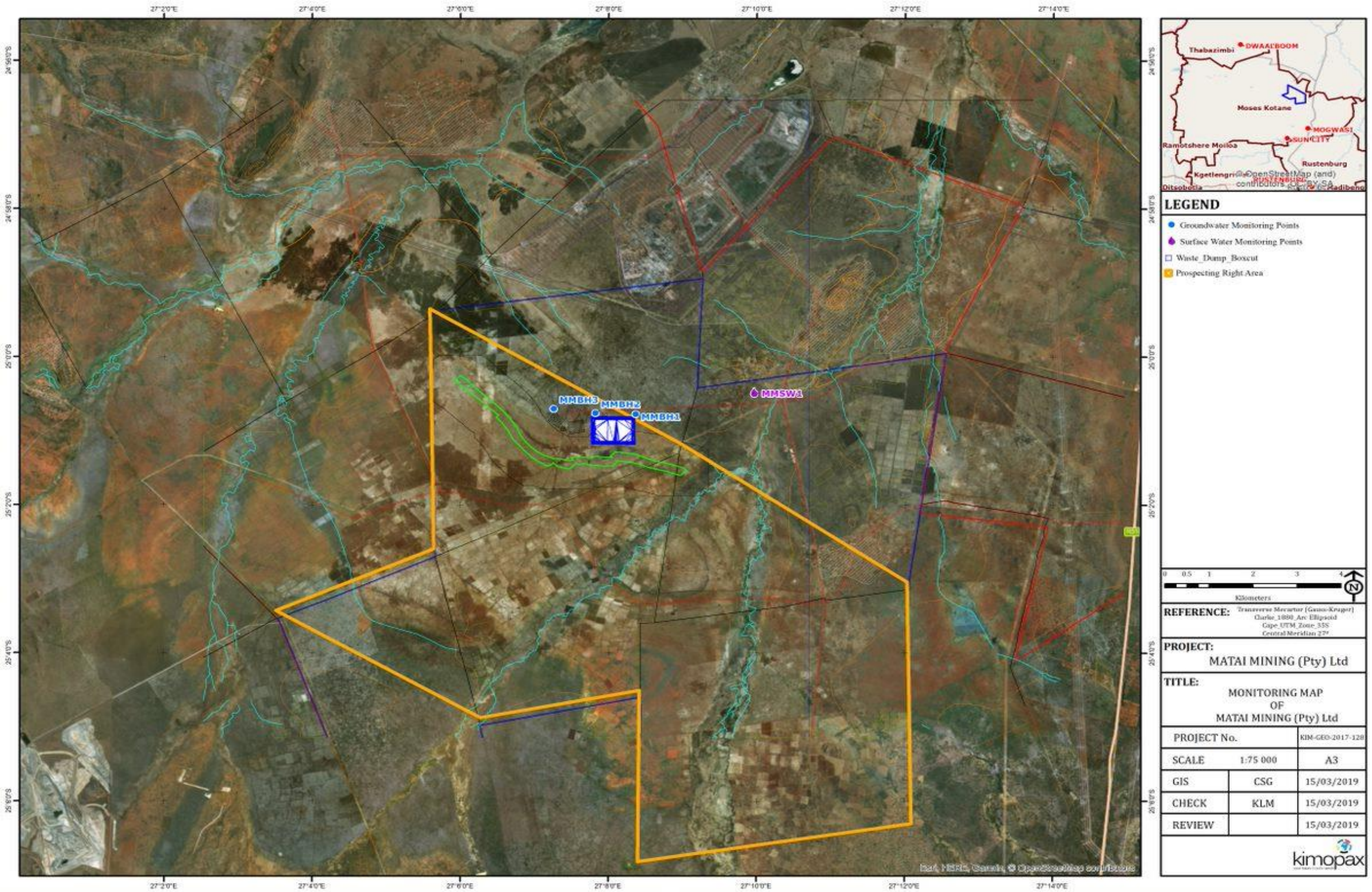

Figure 35: Proposed Monitoring Programme

10.1 Groundwater level

Groundwater levels must be recorded at least monthly using an electrical contact tape or pressure transducer, to detect any changes or trends in groundwater elevation and flow direction.

10.2 Groundwater sampling

Groundwater is a slow-moving medium and drastic changes in the groundwater composition are not normally encountered within days. Considering the proximity streams to the proposed mine, monitoring should be conducted at least quarterly to reflect influences of wet and dry seasons. The sampling frequency could be adjusted following the trend analysis.

Samples should be collected by using clean one litre plastic bottles with a cap. The sampling bottles should be marked clearly with the borehole name, date of sampling, sampling depth and the sampler's name and submitted to a SANAS accredited laboratory. It is suggested that quarterly samples be collected, extending up to 10 years post closure or until a sustainable situation is reached and has been signed off by the authorities.

It is recommended that a full analysis of all the variables be undertaken at least once a year to determine and confirm the variables of concern. Analyses of the following constituents are recommended:

a) Macro Analysis i.e. Ca, Mg, Na, K, SO_4, NO_3, F, Cl;
b) Al, Fe, Mn, As;
c) pH and Alkalinity; and
d) TDS and EC.

10.3 Data storage

During any project, good hydrogeological decisions require good information developed from raw data. The production of good, relevant and timely information is the key to achieve qualified long-term and short-term plans. For the minimisation of groundwater contamination, it is necessary to utilize all relevant groundwater data.

The generation and collection of this data is very expensive as it requires intensive hydrogeological investigations and therefore the data has to be managed in a centralised database if funds are to be used in the most efficient way. Kimopax has compiled a WISH-based database during this investigation and it is highly recommended that the applicant utilises this database and continuously update and manage it as new data becomes available

11 CONCLUSIONS

The following are the main conclusion:

f) Three dominants hydro-stratigraphic units (Alluvial deposits; Shallow weathered aquifer system; and Shallow and Deeper Localized fracture aquifer system) are found in the catchments;
g) The regional groundwater gradient is predominantly toward the Diphiri River (A24E) in the east, and the Bofule River in the west (A24D),
h) The water levels measured during the hydrocensus ranges between 14.31mbgl and 44.9 mbgl;
i) The recharge rate for the project area is estimated as 1,14% of MAP, with 6,82 Mm/year;
j) As the potential pollution sources are located close to water divided, and open pit, groundwater flow during active mining will be toward the open pit, but also toward main natural surface drainage;
k) Any pollution plumes emanating from mining activities (Waste dump, plant, dirty water dams, etc.) is expected to be restricted to the mine property;
l) During mining activity, the neighbouring boreholes will not be affected;
m) The WRD samples, representative of the material to be stockpiled were found to be non-acid generating based on the ABA and sulphur speciation test;
a) The potential impacts (quality, quantity) have been identified and assessed accordingly;
b) The overall project impacts (construction, operation) significance is expected to be from very low to high without any appropriate mitigation;
c) Thorough planning, design, suitable investment, management measures, workplace procedures and good housekeeping will generally mitigate the potential impacts rising from proposed mine development will be reduced to low;
d) Monitoring will be necessary to ensure that any impacts on water quality and quantity that do arise are dealt with rapidly.

12 RECOMMNDATIONS

Kimopax recommends the following:

a) At any mine, geochemical assessments shouldn't be considered as once-off investigations, further geochemical analysis of residue stockpile in future with a larger amount of samples for basic ABA and NAG tests to add greater statistical value to the evaluation of AMD potential;
b) The geochemical assessment conducted is static and provides the total amount of acid generation and/or neutralising potential. Static tests do not provide information on when the acid generation or neutralisation will occur. Long term (20 to 45 weeks) kinetic tests are often required to assess the long-term geochemical behaviour of the residue stockpiles;
c) Kimopax proposes that the residue stockpile be classed as Type 4 waste that needs to be deposited on Class D "what" based on the Risk Based Approach Model; and
d) Additional monitoring boreholes are proposed to monitor the movement of polluted groundwater migrating away from the mine area and the lowering of the groundwater table due to mine dewatering. This will include water level and water quality monitoring monthly in the first year and quarterly from year two onwards; and
n) Groundwater numerical modelling should be updated every two years until the end of the mining activities

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Appendix A: Hydrocensus Lab Results

Appendix B: Borehole Logs

Appendix C: Geochemistry Lab Results

Head Office: 546 16th Road, Constantia Park, Midrand, 1685

Tel: +27 11 312 9765 Fax: +27 11 312 9768/ +27 86 219 8717

Eastern Cape: 62 Bonza Bay Road, Beacon Bay, East London, 5247

Tel: +27 43 721 0178 Fax: +27 86 558 7022

Limpopo: 17 A Plein Street, Polokwane, 0700

Tel: +27 15 295 4849 Fax: +27 86 218 2757

Mpumalanga: 40 John Magagula Street, Middelburg, 1050

Tel: +27 13 243 0680 Fax: +27 86 219 8717