



Consulting Environmental Scientists

ISO 9001:2015 | B-BBEE Level Two
www.gptglobal.com

Hydrogeological Study and Numerical Model
for

MMSEZ, Mopane

Compiled for:

**Kinetic Development Group And South African
Energy Metallurgical Base (Pty) Ltd**

Project No.: GUKSM-25-13083

Version: Draft

Date: April 2025

Offices in: Gauteng, Western Cape,
KwaZulu-Natal & Mozambique

Report Type: Hydrogeological Study and Numerical Model
Site Name: MMSEZ, Mopane
Site Location: Mopane, Limpopo
Compiled For: Kinetic Development Group And South African Energy Metallurgical Base (Pty) Ltd
Compiled By: H.C. Dreyer, B.Sc. Hons; Pr. Sci. Nat (138930)
GPT Reference: GUKSM-25-13083

Version: Draft
Date: April 2025
Distribution List (Current Version): Gudani Consulting (Pty) Ltd, Mr S Nkopane

Reviewed by: M. Terblanche; B. Sc. Hons.; Pr. Sci. Nat (400081/17)

Disclaimer:

The results and conclusions of this report are limited to the Scope of Work agreed between GEM-GPT and the Client for whom this investigation has been conducted. All assumptions made and all information contained within this report and its attachments depend on the accessibility to and reliability of relevant information, including maps, previous reports and word-of-mouth, from the Client and Contractors.

Copyright:

The copyright in all text and other matter (including the manner of presentation) is the exclusive property of Groundwater Environmental Management - GPT (Pty) Ltd, unless where referenced to external parties. It is a criminal offence to reproduce and/or use, without written consent, any matter, technical procedure and/or technique contained in this document. This document must be referenced if any information contained in it is used in any other document or presentation.

Declaration:

I hereby declare:

- I have no vested interest (present or prospective) in the project that is the subject of this report as well as its attachments. I have no personal interest with respect to the parties involved in this project.
- I have no bias with regard to this project or towards the various stakeholders involved in this project.
- I have not received, nor have I been offered, any significant form of inappropriate reward for compiling this report.



(electronic signature)

H.C. Dreyer, B.Sc. Hons; Pr. Sci. Nat (138930)



(electronic signature)

M. Terblanche; B. Sc. Hons.; Pr. Sci. Nat (400081/17)

Customer Satisfaction:

Feedback regarding the technical quality of this report (i.e. methodology used, results discussed and recommendations made), as well as other aspects, such as timeous completion of project and value of services rendered, can be posted onto GPT's website at www.gptglobal.com.

EXECUTIVE SUMMARY

Geo Pollution Technologies (Pty) Ltd (GPT) was appointed by Gudani Consulting (Pty) Ltd to conduct a geohydrological study with a Numerical Flow Model for the Musina-Makhado Special Economic Zone (MMSEZ) site near Mopane. The area is situated in quaternary catchment A71K and A80F.

The MMSEZ site area is located adjacent to the South and East of Mopane in the Limpopo Province. The site area is characterised by a relatively flat topography that is gently sloping upwards to the south of the site. Small hills with moderate relief are present at both the northern and southern borders of the site. The average slope across the site is in the order of 1.3 :100 (0.013) with a maximum of 15.5: 100 at the Southern hills.

The average annual rainfall (1970-2024) for the general site location is 325.8 mm per year, with the high rainfall months between November and March.

The investigated area falls within the 2228 Alldays 1:250 000 geology series maps. The site is predominantly underlain by Quaternary sandy soils, which form the main surface cover. Bedrock geology comprises outcrops of the Beit Bridge Complex (Gambu Group) in the central, northern, and southern areas, characterized by calc-silicate rocks, marble, leucogneisses, hornblende granitoid gneiss, metaquartzite, and amphibolite. South of the northern Gambu outcrop and beneath a fault line, the Karoo Supergroup is present, consisting of undifferentiated Mikambeni and Madzaringwe Formations with mudstone, shale, carbonaceous shale, sandstone, coal seams, and basal diamictite.

According to the 1:500 000 General Hydrogeological Map the rocks underlying the site typically act as secondary aquifers (intergranular and fractured rock aquifers). However, the multi-layered weathering system present on these rocks could prove to have up to two aquifer systems present in the form of a shallow, saprolitic aquifer with a weathered, intergranular soft rock base associated with the contact of fresh bedrock and the weathering zone; and an intergranular & fractured bedrock aquifer.

The GDT calculated a aquifer vulnerability value of 34%, which is medium.

A hydrocensus was conducted on the 27th March 2025. A total of 14 locations were visited based on the gathered information. Out of these, only 11 locations had boreholes where water level measurements could be taken. Three boreholes were found to be either dry or blocked. The water levels ranged between 17.34 mbgl and 33.42 mbgl with an average of 25.95 mbgl. The general groundwater flow direction is to the north of the site.

Based on information collected during the hydrocensus it can be concluded that the aquifer system in the study area can be classified as a Sole Aquifer System.

Most boreholes show exceedances in several water quality parameters based on drinking, domestic, and industrial use standards:

SANS Drinking Water

- TDS and EC exceed the aesthetic limits for KB03, 06, 07, 08 and 09.
- Sulphate exceeds the acute health limit in KB07
- Fluoride exceeds the chronic health limit in KB03, 06, 08 and 09.
- Sodium and Chloride both exceed aesthetic limits in KB03, 06, 07, 08 and 09.

- E coli is detected in both KB08 and KB11
- Aluminium exceeds the operational limit in KB11.
- Total coliforms exceed the operational limits in all analysed boreholes.

DWAF Domestic Use

- Aluminium exceed the TWQR in KB11
- Calcium exceeds the TWQR in KN06, 07, 08 and 09.
- Chloride exceed the TWQR in KB06 and 07.
- Fluoride exceed the TWQR in KB03, 06, 08 and 09.
- Magnesium exceed the TWQR in KB03, 06, 07, 08 and 09.
- Sodium exceed the TWQR in KB03, 06, 07, 08 and 09.
- Sulphate exceed the TWQR in KB07
- TDS exceed the TWQR in KB03, 06, 07, 08 and 09

DWAF Industrial Use

- Total Alkalinity exceed the TWQR in KB006, 07, 08, 09 and 11.
- Chloride exceed the TWQR in all analysed boreholes.
- Sulphate exceed the TWQR in KB06, 07, 08 and 09.
- TDS exceed the TWQR in all analysed boreholes.

Based on the numerical flow and transport modelling performed, the following hydrogeological impacts were identified:

1. Groundwater Quantity:

Production-related groundwater abstraction during both construction and operational phases are modelled to lower the water table in the vicinity of the production boreholes. In a worst-case scenario, modelled drawdowns exceed 9 metres within the site boundaries. However, a broader zone of influence is anticipated to extend northward, with water level declines of approximately 4 to 9 metres. Several boreholes used for domestic and livestock watering purposes are likely to be impacted.

Predicted drawdown at affected boreholes:

BH	Drawdown (m)
Mopane Game Safaris	6.4
ERA-1	4
KB04	4.4
ERA-7	7
KB03	10.6
KB07	6
KB09	8.4
7	8.6
P13	9.3

BH	Drawdown (m)
P02	12.6
P01	9.5
P12	9.4
P03	6
KB01	5
KB02	5.9
KB14	6.1
KB13	6.9
P04	4.9
P05	5.5
KB10	4.8

2. Groundwater Quality:

The risk of contamination to the aquifer at this site is considered negligible due to the presence of a thick vadose zone, low recharge potential, and engineered control measures such as hardstanding areas and wastewater management systems. As such, no significant impact on the underlying aquifer is anticipated under normal operating conditions.

3. Decommission

When abstraction activities from the boreholes cease, the estimated recovery period for groundwater levels to return to baseline conditions is approximately 34 years, based on a worst-case scenario. This recovery timeframe is influenced by several factors, with rainfall and natural recharge being the most significant

Recommendations

- Conduct a detailed assessment to identify potential contaminant sources. The study must include determining the types of chemical substances used during operations and performing a waste classification study on industrial materials and waste generated at the site. This should be done once the planned industries become operational. The assessment should incorporate the identification of potential contamination locations and improve understanding of the nature, extent, and environmental impact of waste production.
- Conduct bi-annual water level monitoring at the abstraction boreholes and additional selected boreholes within the anticipated cone of depression. (Once abstraction begins)
- After construction and the start of industrial activities, install a limited number of monitoring boreholes downstream of likely contamination sources. Coordinate the selection of these downstream monitoring locations with the waste classification assessment. These boreholes should be monitored on a bi-annual basis according to the report recommendations for analysis.

TABLE OF CONTENTS

	Page
1. INTRODUCTION	1
2. SCOPE OF WORK	1
3. METHODOLOGY.....	1
3.1. DESKTOP REVIEW	1
3.2. HYDROCENSUS & SITE VISIT	1
3.3. GROUNDWATER MODELLING.....	1
3.4. NUMERICAL MODELLING.....	2
3.5. POTENTIAL IMPACTS ASSESSMENT	2
3.6. REPORTING	2
4. GEOGRAPHICAL SETTING	2
4.1. SITE LOCATION, TOPOGRAPHY AND DRAINAGE.....	2
4.2. CLIMATE.....	5
5. GROUNDWATER SETTING	6
5.1. GEOLOGY	6
5.2. HYDROGEOLOGY	8
5.2.1. UNSATURATED ZONE - SHALLOW, AQUIFER	8
5.2.2. SATURATED ZONE - INTERGRANULAR & FRACTURED, BEDROCK AQUIFER	8
5.3. GROUNDWATER AVAILABILITY ASSESSMENT	8
5.4. GROUNDWATER RECHARGE CALCULATIONS.....	8
6. AQUIFER CHARACTERISATION	9
6.1. AQUIFER VULNERABILITY	9
6.2. AQUIFER CLASSIFICATION.....	10

6.3.	AQUIFER PROTECTION CLASSIFICATION.....	12
7.	HYDROCENSUS.....	13
8.	GROUNDWATER LEVELS	16
9.	POTENTIAL GROUNDWATER CONTAMINANTS	19
10.	GROUNDWATER QUALITY.....	21
10.1.1.	GROUNDWATER QUALITY	21
10.1.1.1.	SANS DRINKING WATER.....	21
10.1.1.2.	DWAF DOMESTIC USE	21
10.1.1.3.	DWAF INDUSTRIAL USE	22
10.1.2.	GROUNDWATER QUALITY DISCUSSION.	22
10.1.3.	SPATIAL ANALYSIS OF GROUNDWATER QUALITY.....	22
10.1.3.1.	PIE DIAGRAMS	22
10.1.3.2.	CLASSED CONCENTRATION MAPS	22
11.	CONCEPTUAL SITE MODEL.....	30
12.	GROUNDWATER FLOW AND TRANSPORT MODELLING	31
12.1.	MODEL SET-UP AND BOUNDARIES.....	32
12.2.	GROUNDWATER ELEVATION AND GRADIENT.....	35
12.3.	GROUNDWATER SOURCE AND SINKS.....	35
12.4.	CONCEPTUAL MODEL INPUT	37
12.5.	CALIBRATION OF THE NUMERICAL MODEL	37
13.	HYDROGEOLOGICAL IMPACTS.....	40
13.1.	OPERATIONAL PHASE IMPACTS ON GROUNDWATER QUALITY.....	40
13.2.	CONSTRUCTION & OPERATIONAL PHASE IMPACTS ON GROUNDWATER QUANTITY	40
13.3.	DECOMMISSIONING PHASE.	42

14.	IMPACTS QUANTIFICATION	43
14.1.	ASSESSMENT CRITERIA	43
14.2.	MITIGATION	44
14.2.1.	DETERMINATION OF SIGNIFICANCE WITHOUT MITIGATION	44
14.2.2.	DETERMINATION OF SIGNIFICANCE WITH MITIGATION	45
14.3.	ASSESSMENT WEIGHTING	45
14.3.1.	RANKING, WEIGHTING AND SCALING	45
14.3.1.1.	IDENTIFYING THE POTENTIAL IMPACTS WITHOUT MITIGATION MEASURES (WOM)	46
14.3.1.2.	IDENTIFYING THE POTENTIAL IMPACTS WITH MITIGATION MEASURES (WM)	46
14.3.1.2.1.	MITIGATION EFFICIENCY (ME)	46
14.3.1.2.2.	SIGNIFICANCE FOLLOWING MITIGATION (SFM)	46
14.4.	ENVIRONMENTAL IMPACT ASSESSMENT (EIA) REGULATIONS, 2017	47
15.	GROUNDWATER MONITORING NETWORK	49
15.1.	DESIGN CONSIDERATIONS	49
15.2.	MONITORING NETWORK RECOMMENDATIONS	49
15.3.	MONITORING FREQUENCY	50
15.4.	MONITORING NETWORK PARAMETERS.....	50
15.5.	GROUNDWATER LEVELS	50
15.6.	MONITORING CONSTITUENTS.....	50
15.6.1.	ABBREVIATED ANALYSIS (POLLUTION INDICATORS)	50
15.6.2.	FULL ANALYSIS	51
16.	CONCLUSIONS AND RECOMMENDATIONS.....	52

LIST OF FIGURES

	Page
FIGURE 1: SITE LOCATION AND QUATERNARY CATCHMENT BOUNDARIES	3
FIGURE 2: SITE TOPOGRAPHY	4
FIGURE 3: CLIMATIC DATA REPRESENTATION	5
FIGURE 4: REGIONAL GEOLOGY MAP (1:250 000 GEOLOGY SERIES MAP).....	7
FIGURE 5: HYDROCENSUS MAP.	15
FIGURE 6: CORRELATION GRAPH OF TOPOGRAPHY VS AVAILABLE GROUNDWATER LEVELS	17
FIGURE 7: GROUNDWATER FLOW MAP	18
FIGURE 8: GROUNDWATER AND SURFACE WATER PIE DIAGRAM	26
FIGURE 9: CHLORIDE CLASSED CONCENTRATION MAP	27
FIGURE 10: SODIUM CLASSED CONCENTRATION MAP.....	28
FIGURE 11: SULPHATE CLASSED CONCENTRATION MAP.....	29
FIGURE 12: LATERAL DELINEATION OF THE REGIONAL MODEL	33
FIGURE 13: MODEL BOUNDARY AND BOUNDARY CONDITIONS	34
FIGURE 14: GROUNDWATER CALIBRATION RESULTS.....	36
FIGURE 15: WATER LEVEL CALIBRATION GRAPH	38
FIGURE 16: MODELLED GROUNDWATER CONTOURS	39
FIGURE 17: MODELLED DRAWDOWN	41
FIGURE 18: LATERAL DELINEATION OF THE REGIONAL MODEL	66
FIGURE 19: LATERAL DELINEATION IN THE SITE AREA	67
FIGURE 20: VERTICAL DELINEATION OF THE MODELLED AREA	68

LIST OF TABLES

	Page
TABLE 1: CLIMATIC DATA	5
TABLE 2: RECHARGE CALCULATION FOR THE SHALLOW UNCONFINED AQUIFER.....	8
TABLE 3: RATINGS - AQUIFER SYSTEM MANAGEMENT AND SECOND VARIABLE CLASSIFICATIONS .	11
TABLE 4: RATINGS - GROUNDWATER QUALITY MANAGEMENT (GQM) CLASSIFICATION SYSTEM...	11
TABLE 5: GQM INDEX FOR THE STUDY AREA	12
TABLE 6: HYDROCENSUS DATA SUMMERY	14
TABLE 7: MINE MONITORING GROUNDWATER LEVELS.	16
TABLE 8: WATER QUALITIES COMPARED TO SANS 241-1:2015 GUIDELINES FOR DRINKING WATER. ..	23
TABLE 9: WATER QUALITIES COMPARED TO DWAF DOMESTIC USE GUIDELINES	24
TABLE 10: WATER QUALITIES COMPARED TO DWAF INDUSTRIAL USE	25
TABLE 11: INPUT PARAMETERS TO THE NUMERICAL FLOW MODEL.....	35
TABLE 12: OPTIMAL CALIBRATED AQUIFER PARAMETERS	37
TABLE 13: CALIBRATION STATISTICS	37
TABLE 14: PREDICTED DRAWDOWN AT AFFECTED BOREHOLES	42
TABLE 15: IMPACT ASSESSMENT CRITERIA	43
TABLE 16: SIGNIFICANCE WITHOUT MITIGATION.....	44
TABLE 17: SIGNIFICANCE WITH MITIGATION MEASURES.....	45
TABLE 18: DESCRIPTION OF ASSESSMENT PARAMETERS WITH ITS RESPECTIVE WEIGHTING	45
TABLE 19: SIGNIFICANCE RATING OF IMPACT(S)	48
TABLE 20: PROPOSED WATER LEVEL MONITORING BOREHOLES	49

LIST OF APPENDICES

	Page
APPENDIX I: LABORATORY CERTIFICATE OF ANALYSIS	55
APPENDIX II: NUMERICAL MODEL METHODOLOGY AND SETUP	65

LIST OF ABBREVIATIONS

Abbreviation	Explanation
ARD	Acid Rock Drainage
BPG	Best Practice Guidelines
CMS	Catchment Management Strategy
CSM	Conceptual Site Model
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
IWRMP	Integrated Water Resources Management Plan
IWRM	Integrated Water Resources Management
km ²	Square kilometre
L/s	Litres per second
mamsl	Metres above mean sea level
ML/d	Megalitres per day
m	metre
mm	Millimetre
mm/a	Millimetres per annum
mS/m	Millisiemens per metre
m ³	Cubic metre
MAP	Mean Annual Precipitation
MPRDA	Mining and Petroleum Resources Development Act (Act No. 73 of 2002) 1989)
NEMA	National Environmental Management Act (Act No. 107 of 1998)
NWA	National Water Act (Act No. 36 of 1998)
ppm	Parts per million
RDM	Resource Directed Measures
RQO	Resource Quality Objective
RWQO	Resource Water Quality Objective
TDS	Total Dissolved Solids
WMA	Water Management Area
WMP	Water Management Plan

DEFINITIONS

Definition	Explanation
Aquiclude	A geologic formation, group of formations, or part of formation through which virtually no water moves
Aquifer	A geological formation which has structures or textures that hold water or permit appreciable water movement through them. Source: National Water Act (Act No. 36 of 1998).
Borehole	Includes a well, excavation, or any other artificially constructed or improved underground cavity which can be used for the purpose of intercepting, collecting or storing water in or removing water from an aquifer; observing and collecting data and information on water in an aquifer; or recharging an aquifer. Source: National Water Act (Act No. 36 of 1998).
Boundary	An aquifer-system boundary represented by a rock mass (e.g. an intruding dolerite dyke) that is not a source of water, and resulting in the formation of compartments in aquifers.
Cone of Depression	The depression of hydraulic head around a pumping borehole caused by the withdrawal of water.
Confining Layer	A body of material of low hydraulic conductivity that is stratigraphically adjacent to one or more aquifers; it may lie above or below the aquifer.
Dolomite Aquifer	See “Karst” Aquifer
Drawdown	The distance between the static water level and the surface of the cone of depression.
Fractured Aquifer	An aquifer that owes its water-bearing properties to fracturing.
Groundwater	Water found in the subsurface in the saturated zone below the water table.
Groundwater Divide or Groundwater Watershed	The boundary between two groundwater basins which is represented by a high point in the water table or piezometric surface.
Groundwater Flow	The movement of water through openings in sediment and rock; occurs in the zone of saturation in the direction of the hydraulic gradient.
Hydraulic Conductivity	Measure of the ease with which water will pass through the earth's material; defined as the rate of flow through a cross-section of one square metre under a unit hydraulic gradient at right angles to the direction of flow (m/d).
Hydraulic Gradient	The rate of change in the total hydraulic head per unit distance of flow in a given direction.
Infiltration	The downward movement of water from the atmosphere into the ground.
Intergranular Aquifer	A term used in the South African map series referring to aquifers in which groundwater flows in openings and void spaces between grains and weathered rock.
Karst (Karstic)	The type of geomorphological terrain underlain by carbonate rocks where significant solution of the rock has occurred due to flowing groundwater.

Definition	Explanation
Karst (Karstic) Aquifer	A body of soluble rock that conducts water principally via enhanced (conduit or tertiary) porosity formed by the dissolution of the rock. The aquifers are commonly structured as a branching network of tributary conduits, which connect together to drain a groundwater basin and discharge to a perennial spring.
Monitoring	The regular or routine collection of groundwater data (e.g. water levels, water quality and water use) to provide a record of the aquifer response over time.
Observation Borehole	A borehole used to measure the response of the groundwater system to an aquifer test.
Phreatic Surface	The surface at which the water level is in contact with the atmosphere: the water table.
Piezometric Surface	An imaginary or hypothetical surface of the piezometric pressure or hydraulic head throughout all or part of a confined or semi-confined aquifer; analogous to the water table of an unconfined aquifer.
Porosity	Porosity is the ratio of the volume of void space to the total volume of the rock or earth material.
Production Borehole	A borehole specifically designed to be pumped as a source of water supply.
Recharge	The addition of water to the saturated zone, either by the downward percolation of precipitation or surface water and/or the lateral migration of groundwater from adjacent aquifers.
Recharge Borehole	A borehole specifically designed so that water can be pumped into an aquifer in order to recharge the ground-water reservoir.
Saturated Zone	The subsurface zone below the water table where interstices are filled with water under pressure greater than that of the atmosphere.
Specific Capacity	The rate of discharge from a borehole per unit of drawdown, usually expressed as $m^3/d \cdot m$.
Specific Yield	The ratio of the volume of water that drains by gravity to that of the total volume of the saturated porous medium.
Storativity	The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.
Transmissivity	Transmissivity is the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. It is expressed as the product of the average hydraulic conductivity and thickness of the saturated portion of an aquifer.
Unsaturated Zone (Also Termed Vadose Zone)	That part of the geological stratum above the water table where interstices and voids contain a combination of air and water.
Watershed (Also Termed Catchment)	Catchment in relation to watercourse or watercourses or part of a watercourse means the area from which any rainfall will drain into the watercourses or part of a watercourse through surface flow to a common point or points. Source: National Water Act (Act No. 36 of 1998).
Water Table	The upper surface of the saturated zone of an unconfined aquifer at which pore pressure is equal to that of the atmosphere.

HYDROGEOLOGICAL STUDY AND NUMERICAL MODEL

MMSEZ, MOPANE

1. INTRODUCTION

Geo Pollution Technologies (Pty) Ltd (GPT) was appointed by Gudani Consulting (Pty) Ltd to conduct a geohydrological study with a Numerical Flow Model for the MMSEZ site near Mopane.

2. SCOPE OF WORK

- Desktop study
- Site Walk Over
- Fieldwork
- Conceptual and Numerical Model
- Reporting

3. METHODOLOGY

3.1. Desktop Review

Existing data and previous reports (both geological, geotechnical and hydrogeological, if any) were gathered, collated, and assessed to provide input for the numerical flow and transport model.

This comprehensive review ensured that relevant historical and current information was integrated into the model for accuracy and reliability.

3.2. Hydrocensus & Site Visit

A hydrocensus & site visit investigation was conducted to collect data from the study area and surrounding environments and to facilitate site familiarization. This investigation included a comprehensive census of boreholes, with water level measurements and the sampling of six boreholes. Samples were submitted to a SANAS accredited laboratory for full SANS241:2015 analysis excluding certain microbiological analysis. Additionally, other groundwater-related information was investigated to provide a thorough understanding of the local hydrogeological conditions.

3.3. Groundwater Modelling

Modelling was performed as a representation of a groundwater flow system and/or geochemical system that attempts to mimic the natural processes. It is therefore a simplified version of the natural system, compiled with geological, hydrogeological, hydrological and meteorological data, which utilises governing equations to incorporate all this data and simulates the hydraulic properties or geochemical properties of the system.

These models were utilised to provide a quantitative understanding of a groundwater system in terms of existing conditions as well as induced stresses, which inherently aids in the identification of cost-effective and efficient solutions to groundwater contamination and management challenges.

3.4. Numerical modelling

Numerical groundwater modelling is the most reliable method of anticipating and quantifying the potential impacts on the groundwater regime. The finite difference numerical model was created using the Groundwater Modelling System (GMS) Version 10.8 graphical user interface for the well-established Modflow and MT3DMS numerical codes.

MODFLOW is a 3D, cell-centred, finite difference, saturated flow model developed by the United States Geological Survey. MODFLOW can perform both steady state and transient analyses and has a wide variety of boundary conditions and input options. It was developed by McDonald and Harbaugh of the US Geological Survey in 1984 and underwent eight overall updates since. The latest update (MODFLOW NWT) incorporates several improvements extending its capabilities considerably, the most important being the introduction of the new Newton formulation and solver, vastly improving the handling of dry cells which has proven to be problematic in the past.

3.5. Potential impacts assessment

The Project impact assessment is presented in [Section 11](#) and details to the methodology for the impact assessment are attached in [Appendix IV](#). The groundwater impact assessment provided includes recommended mitigation measures that are necessary to manage and mitigate groundwater impacts.

3.6. Reporting

A comprehensive report detailing the findings of the study was compiled. This report includes an analysis of the data, the outcomes of the numerical flow model, the assessment of potential impacts, proposed mitigation measures and recommendations, providing a thorough overview of the study's conclusions.

4. GEOGRAPHICAL SETTING

4.1. Site Location, Topography and Drainage

The MMSEZ site area is located adjacent to the South and East of Mopane in the Limpopo Province. (Figure 1).

The site area is characterised by a relatively flat topography that is gently sloping upwards to the south of the site. Small hills with moderate relief are present at both the norther and southern borders of the site. The average slope across the site is in the order of 1.3 :100 (0.013) with a maximum of 15.5: 100 at the Sothern hills. The topography (shown in Figure 2) can normally be used as a good first approximation of the hydraulic gradient in the unconfined aquifer.

The area is situated in quaternary catchment A71K and A80F. Locally drainage is to the North and Northwest direction draining into the Sand River to the north of the site.

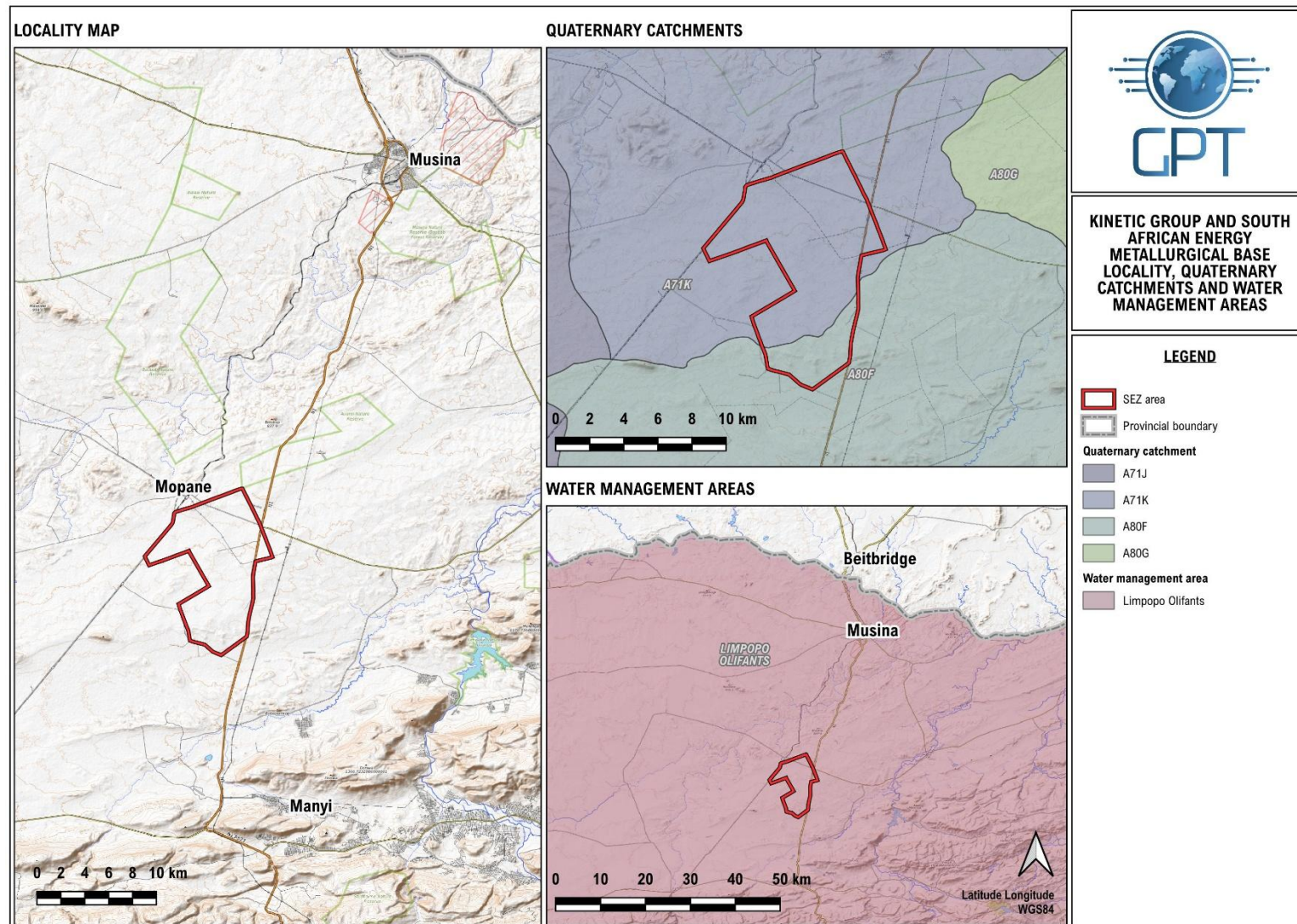


Figure 1: Site Location and Quaternary Catchment Boundaries

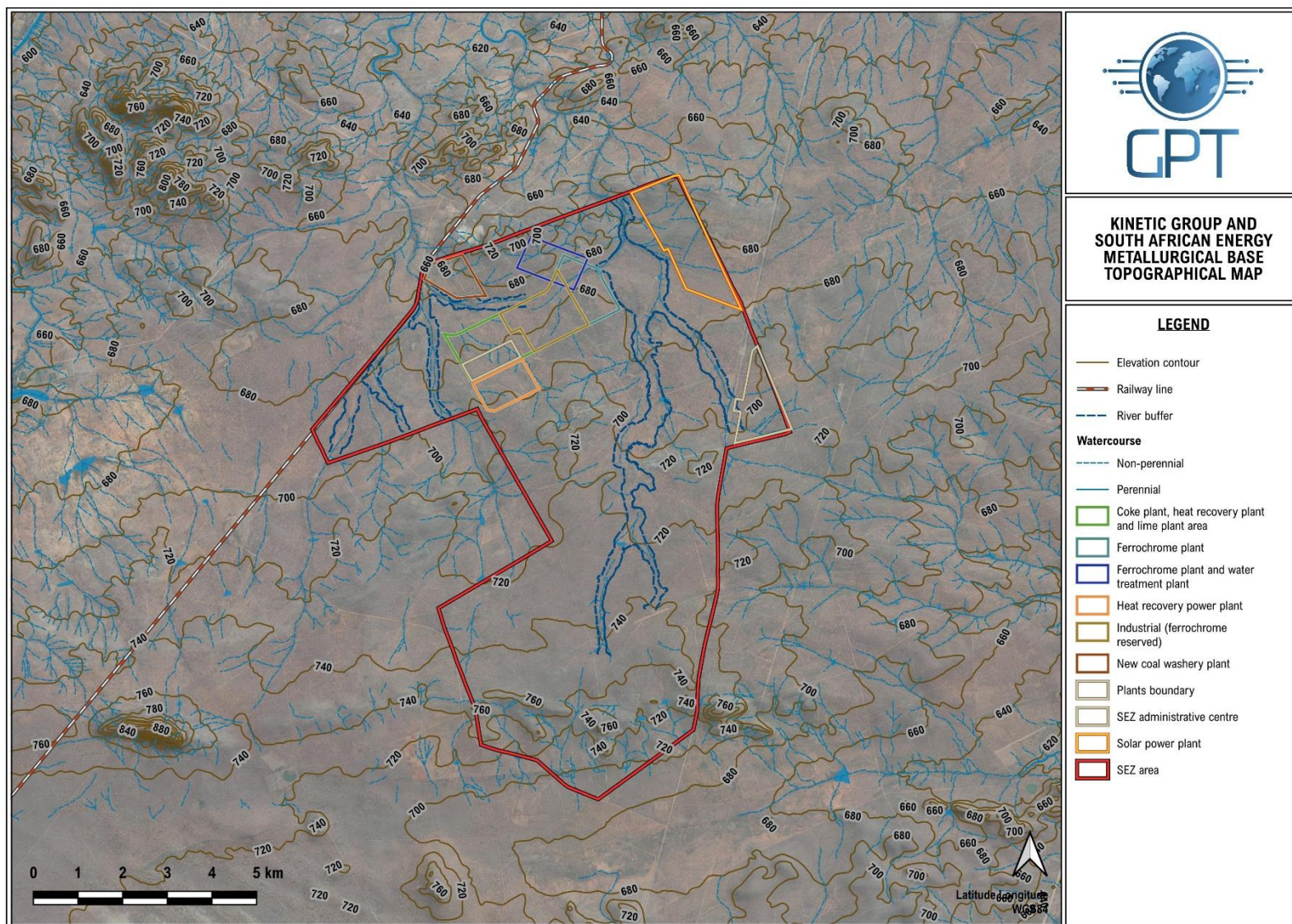


Figure 2: Site Topography

4.2. Climate

Climatic data was obtained from DWS station A8E001, Nairobi at Nzhelele Dam. The average annual rainfall (1970-2024) for the general site location is 325.8 mm per year, with the high rainfall months between November and March. The site is located in the summer rainfall region of Southern Africa¹.

Table 1: Climatic Data

Month	Average Monthly Rainfall (mm)	Mean Monthly Evaporation (mm)
January	58	243
February	53	207
March	42.3	202
April	18.1	169.8
May	6.5	144
June	3	118.1
July	2.4	126.1
August	3.5	159.7
September	7.3	199.8
October	20.7	239.4
November	50.8	232.2
December	60.2	251
Annual	325.8	2292.1

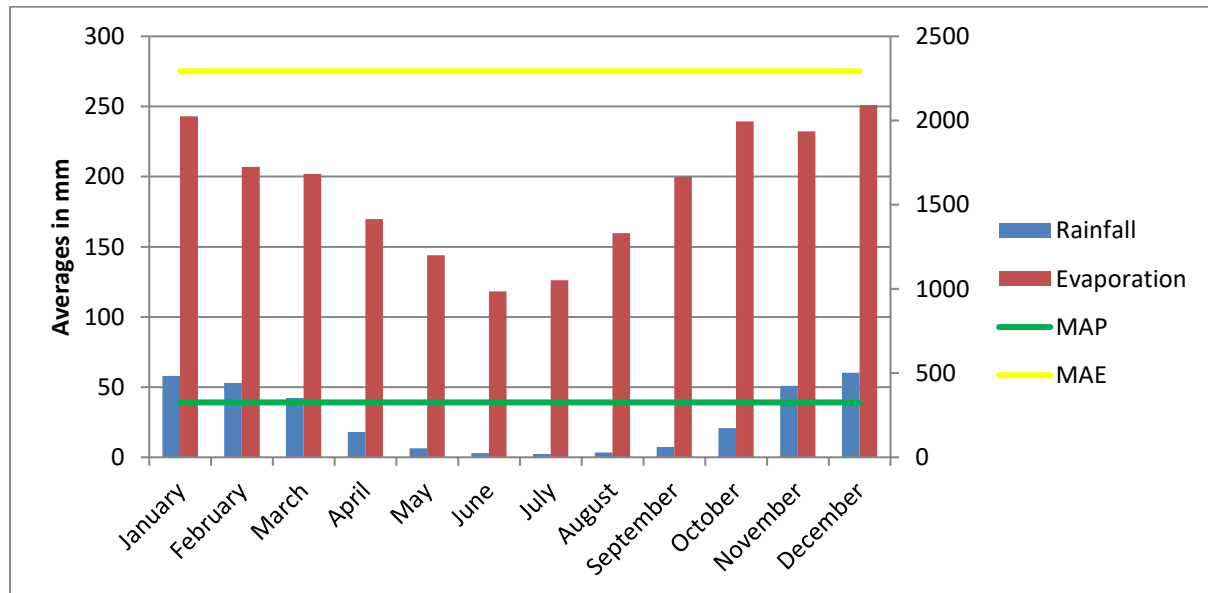


Figure 3: Climatic data representation

¹ <https://www.samsamwater.com/climate/>

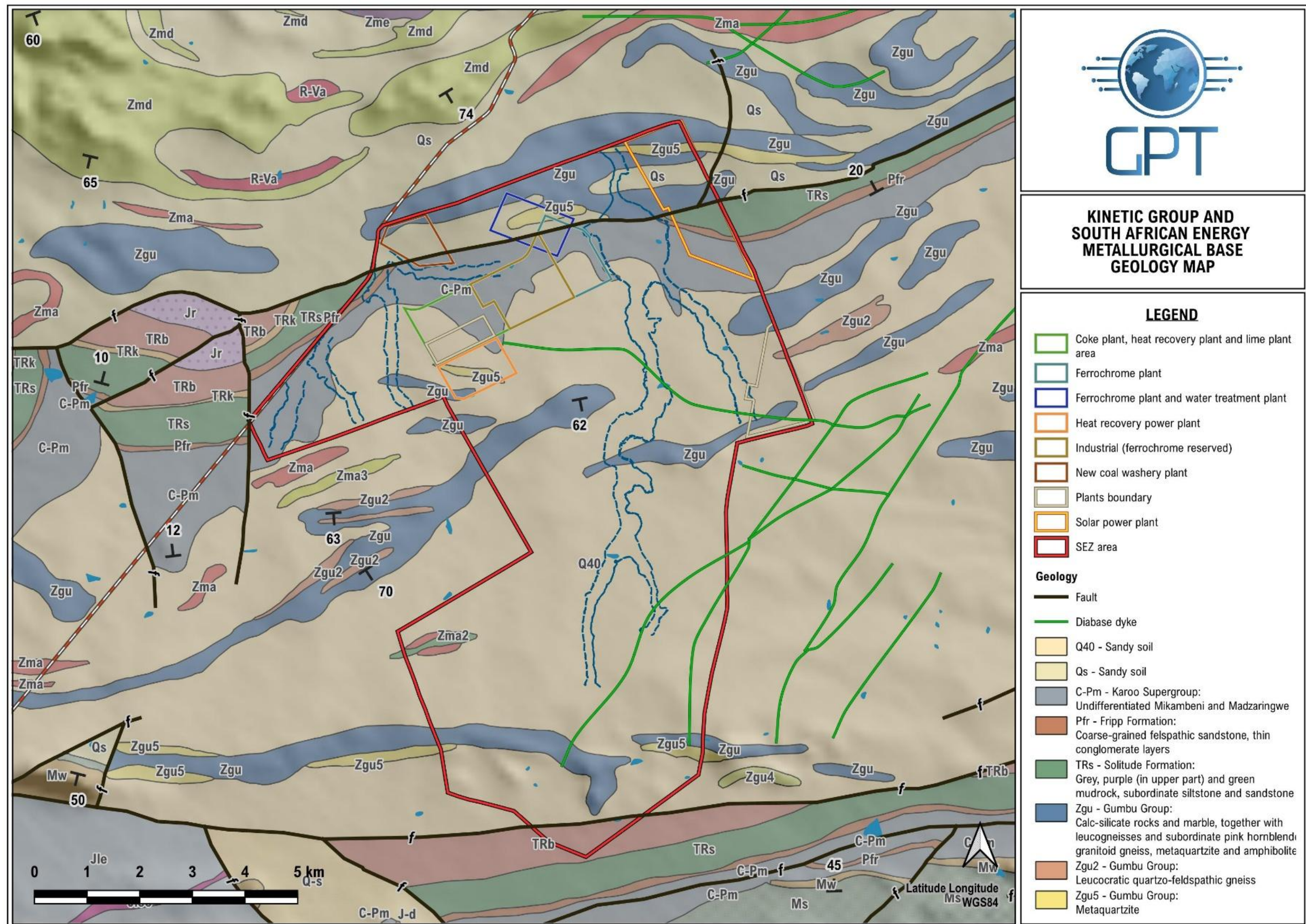
5. GROUNDWATER SETTING

5.1. Geology

The investigated area falls within the 2228 Alldays 1:250 000 geology series maps. The area is underlain predominantly by three geological groups:

- Quaternary sands consisting of predominantly sandy soils. This group covers the largest surface area at the site.
- Beit bridge complex geological units consisting of the Gambu Group. These outcroppings in the centre of the site and at both the southern and northern borders of the site, consist mainly of calc-silicate rocks and marble; together with leucogneisses and subordinate pink hornblende granitoid gneiss, metaquartzite and amphibolite.
- The Karoo Supergroup is situated just south of the northern Gambu outcropping, below a fault line, is mainly from the undifferentiated Mikambeni and Madzaringwe formations consisting of mudstone, shale, carbonaceous shale, sandstone, conglomerate, coal seams; locally diamictite or conglomerate at base.
- Additionally, some diabase dykes exist within the site boundary and small sections of the Fripp and solitude formations near the Karoo supergroup layers dipping northward. The Fripp formation consists of coarse -grained felspathic sandstones and the Solitude formation of grey - purple mudrock with subordinate siltstone and sandstone.

These geological units can be seen in Figure 4.



5.2. Hydrogeology

According to the 1:500 000 General Hydrogeological Map the rocks underlying the site typically act as secondary aquifers (intergranular and fractured rock aquifers). However, the multi-layered weathering system present on these rocks could prove to have up to two aquifer systems present in the form of a shallow, saprolitic aquifer with a weathered, intergranular soft rock base associated with the contact of fresh bedrock and the weathering zone; and an intergranular & fractured bedrock aquifer. These aquifer systems are discussed below.

5.2.1. Unsaturated Zone - Shallow, aquifer

The main source of recharge into the shallow aquifer is rainfall that infiltrates the aquifer through the unsaturated (vadose) zone. Vertical movement of water is faster than lateral movement in this system as water moves predominantly under the influence of gravity.

5.2.2. Saturated Zone - Intergranular & Fractured, bedrock aquifer

The undifferentiated Mikambeni and Madzaringwe geological layers act as fractured aquifers. The Gumbu geological group act as an intergranular and fractured aquifer. Groundwater occurs mainly in faults and associated shear zones as well as fractured contact zones between mafic and acidic rocks and dyke contacts.

5.3. Groundwater Availability Assessment

The analysis of 79 borehole records within the Mikambeni and Madzaringwe geological layers indicates that 32% of the yields are between 0.5 and 2l/s, 29% are less than 0.5l/s and 40% are more than 2l/s. However, the Gumbu geological group yield analysis shows that 75% of the successful boreholes yield less than 2l/s. Due to the low and erratic rainfall in this area, together with periodical droughts and the dense vegetation in places, recharge events are very irregular. These factors, together with abstraction contributed significantly to the generally deep-water levels (30-60m) occurring in the area. The Gumbi Geological Unit is the dominant underlying formation in the area, which generally exhibits low groundwater potential. The overall area in general, therefore has a low groundwater potential.

5.4. Groundwater Recharge Calculations

Recharge to the shallow, unconfined aquifer was calculated using the RECHARGE program developed by the Institute for Groundwater Studies at the University of the Free State, South Africa.

Table 2: Recharge calculation for the shallow unconfined aquifer

Recharge Estimation			
Method	mm/a	% of rainfall	Certainty (Very High = 5; Low = 1)
Chloride	1	0.4	3
Various schematic maps			
Soil	19.2	5.9	2
Geology	13.0	4.0	3
Vegter	3.0	0.9	3
Acru	10.0	3.1	3

Harvest Potential	6.0	1.8	3
-------------------	-----	-----	---

Recharge to the shallow, unconfined aquifer was calculated using the RECHARGE program developed by the Institute for Groundwater Studies at the University of the Free State, South Africa. The calculated recharge percentage using a certainty of 3 and higher equates to approximately 2% of annual precipitation.

6. AQUIFER CHARACTERISATION

The term aquifer refers to a strata or group of interconnected strata comprising of saturated earth material capable of conducting groundwater and of yielding usable quantities of groundwater to boreholes and /or springs (Vegter, 1994). In the light of South Africa's limited water resources it is important to discuss the aquifer sensitivity in terms of the boundaries of the aquifer, its vulnerability, classification and finally protection classification, as this will help to provide a framework in the groundwater management process.

6.1. Aquifer Vulnerability

Aquifer vulnerability assessment indicates the tendency or likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer. Stated in another way, it is a measure of the degree of insulation that the natural and manmade factors provide to keep contamination away from groundwater.

- Vulnerability is high if natural factors provide little protection to shield groundwater from contaminating activities at the land surface.
- Vulnerability is low if natural factors provide relatively good protection and if there is little likelihood that contaminating activities will result in groundwater degradation.

The following factors have an effect on groundwater vulnerability:

- Depth to groundwater: Indicates the distance and time required for pollutants to move through the unsaturated zone to the aquifer.
- Recharge: The primary source of groundwater is precipitation, which aids the movement of a pollutant to the aquifer.
- Aquifer media: The rock matrices and fractures which serve as water bearing units.
- Soil media: The soil media (consisting of the upper portion of the vadose zone) affects the rate at which the pollutants migrate to groundwater.
- Topography: Indicates whether pollutants will run off or remain on the surface allowing for infiltration to groundwater to occur.
- Impact of the vadose zone: The part of the geological profile beneath the earth's surface and above the first principal water-bearing aquifer. The vadose zone can retard the progress of the contaminants.

The Groundwater Decision Tool (GDT) was used to quantify the vulnerability of the aquifer underlying the site using the below assumptions.

- Depth to groundwater below the site was estimated from water levels measured during the hydrocensus inferred to be at mean of -25.95 mbgl.
- Groundwater recharge of 6.19 mm/a (1.9% recharge).
- Northern Karoo vadose zone.

- Gradient of 1.3% were assumed and used in the estimation.

The aquifer vulnerability for a contaminant released from surface to a specified position in the groundwater system after introduction at some location above the uppermost aquifer was determined using the criteria described below and assuming a worst-case scenario:

- Highly vulnerable (> 60), the natural factors provide little protection to shield groundwater from contaminating activities at the land surface.
- Medium Vulnerable = 30 to 60%, the natural factors provide some protection to shield groundwater from contaminating activities at the land surface, however based on the contaminant toxicity mitigation measures will be required to prevent any surface contamination from reaching the groundwater table.
- Low Vulnerability ($< 30\%$), natural factors provide relatively good protection and there is little likelihood that contaminating activities will result in groundwater degradation
- The GDT calculated a vulnerability value of 34%, which is **medium**.

6.2. Aquifer Classification

The aquifer(s) underlying the subject area were classified in accordance with “A South African Aquifer System Management Classification, December 1995.”

The main aquifers underlying the area were classified in accordance with the Aquifer System Management Classification document². The aquifers were classified by using the following definitions:

- Sole Aquifer System: An aquifer which is used to supply 50% or more of domestic water for a given area, and for which there is no reasonably available alternative sources should the aquifer be impacted upon or depleted. Aquifer yields and natural water quality are immaterial.
- Major Aquifer System: Highly permeable formations, usually with a known or probable presence of significant fracturing. They may be highly productive and able to support large abstractions for public supply and other purposes. Water quality is generally very good (Electrical Conductivity of less than 150 mS/m).
- Minor Aquifer System: These can be fractured or potentially fractured rocks which do not have a high primary permeability, or other formations of variable permeability. Aquifer extent may be limited and water quality variable. Although these aquifers seldom produce large quantities of water, they are important for local supplies and in supplying base flow for rivers.
- Non-Aquifer System: These are formations with negligible permeability that are regarded as not containing groundwater in exploitable quantities. Water quality may also be such that it renders the aquifer unusable. However, groundwater flow through such rocks, although imperceptible, does take place, and needs to be considered when assessing the risk associated with persistent pollutants.

Based on information collected during the hydrocensus (see section 7) it can be concluded that the aquifer system in the study area can be classified as a “Sole Aquifer System”, based on the fact that the local population is dependent on groundwater.

² Department of Water Affairs and Forestry & Water Research Commission (1995). A South African Aquifer System Management Classification. WRC Report No. KV77/95.

In order to achieve the Aquifer System Management and Second Variable Classifications, as well as the Groundwater Quality Management Index, a points scoring system as presented in Table 3 and Table 4 was used.

Table 3: Ratings - Aquifer System Management and Second Variable Classifications

Aquifer System Management Classification		
Class	Points	Study area
Sole Source Aquifer System:	6	6
Major Aquifer System:	4	
Minor Aquifer System:	2	
Non-Aquifer System:	0	
Special Aquifer System:	0 - 6	
Second Variable Classification (Weathering/Fracturing)		
Class	Points	Study area
High:	3	
Medium:	2	2
Low:	1	

Table 4: Ratings - Groundwater Quality Management (GQM) Classification System

Aquifer System Management Classification		
Class	Points	Study area
Sole Source Aquifer System:	6	6
Major Aquifer System:	4	
Minor Aquifer System:	2	
Non-Aquifer System:	0	
Special Aquifer System:	0 - 6	
Aquifer Vulnerability Classification		
Class	Points	Study area
High:	3	
Medium:	2	2
Low:	1	

As part of the aquifer classification, a Groundwater Quality Management (GQM) Index is used to define the level of groundwater protection required. The GQM Index is obtained by multiplying the rating of the aquifer system management and the aquifer vulnerability. The GQM index for the study area is presented in Table 5.

The vulnerability, or the tendency or likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer, in terms of the above, is classified as **medium**.

The level of groundwater protection based on the Groundwater Quality Management Classification:

$$\begin{aligned}\text{GQM Index} &= \text{Aquifer System Management} \times \text{Aquifer Vulnerability} \\ &= 6 \times 2 = 12\end{aligned}$$

Table 5: GQM Index for the Study Area

GQM Index	Level of Protection	Study Area
<1	Limited	
1 - 3	Low Level	
3 - 6	Medium Level	
6 - 10	High Level	
>10	Strictly Non-Degradation	12

6.3. Aquifer Protection Classification

A Groundwater Quality Management Index of 12 was estimated for the study area from the ratings for the Aquifer System Management Classification. According to this estimate a Strictly Non-Degradation **protection** is required for the aquifer. Reasonable and sound groundwater protection measures based on the modelling will therefore be recommended to ensure that no cumulative pollution affects the aquifer, even in the long term.

DWS's water quality management objectives are to protect human health, carrying capacity of the environment and the environment. Therefore, the significance of this aquifer classification is that measures must be taken to limit the risk to the following environments.

- The protection of the underlying aquifer.

7. HYDROCENSUS

A hydrocensus was conducted on the 27th March 2025. The national groundwater archive was utilized to identify the locations of existing boreholes within the surrounding area of the site. Locals and residents were questioned for any additional boreholes that might not be reported in the groundwater archive. A total of 14 locations were visited based on the gathered information.

Out of these, only 11 locations had boreholes where water level measurements could be taken. Three boreholes were found to be either dry or blocked. An electrical contact water level meter (dipmeter) was used to determine water level in the boreholes and the depth of the boreholes. The depth of boreholes with installed pumps could not be measured. A summary of the collected hydrocensus data is presented in Table 6 and a hydrocensus map in Figure 5.

Table 6: Hydrocensus Data Summery

Borehole ID	Longitude	Latitude	Elevation	WL (mbgl)	WL mamsl (mamsl)	Coller Height (m)	Water Use	Pump Installed	Owner	Comment
KB01	29.92162	-22.628882	681.7993	25.6	656.1993	0	Domestic & Livestock	Submersible	Hennie Erwee	Borehole at guesthouse, several more boreholes on property with only one surveyed.
KB02	29.919056	-22.64075	692.2986	26.14	667.0386	-0.44	Domestic	Submersible	Ashttron Energies	Water is of poor quality, not used for drinking.
KB03	29.882789	-22.624	681.0763	29.74	651.0763	0.13	Domestic & Livestock	Submersible	Thomas Sthagathaga	Water is of poor quality, not used for drinking.
KB04	29.863774	-22.615368	675.074	30.99	642.284	0.9	Sample Only	None	Public	Green Monitoring well next to the R525 near Mopane
KB05	29.846882	-22.622381	658.5936	NM	NM	NM	Domestic	Submersible	Mopane Intermediate School	Borehole Buried
KB06 (H18-0579)	29.854299	-22.61567	662.8	17.34	645.04	0.21	Domestic	Submersible	Mopane Intermediate School	BH used by school as drinking water supply.
KB07	29.871034	-22.631684	682.4738	28.97	653.0838	0.21	Not in use	None	Mulambwane CPA	Borehole not in use
KB08 (BH08)	29.85305	-22.636207	670.8857	19.35	651.2357	0.15	Domestic & Livestock	Submersible	Mulambwane CPA	
KB09	29.882203	-22.630405	674.3868	20.1	653.1268	0.58	Domestic & Livestock	Submersible	Mulambwane CPA	
KB10	29.889789	-22.667204	706.2468	33.42	672.4068	0.21	Not in use	None	Mulambwane CPA	Borehole not in use
KB11 (BH09)	29.899544	-22.656575	694.215	21.36	672.035	0.41	Domestic & Livestock	Submersible	Mulambwane CPA	Borehole used for drinking water
KB12	29.876626	-22.687902	720.8456	32.49	688.2356	0.06	Not in use	None	Mulambwane CPA	Borehole not in use
KB13	29.913014	-22.652005	695.5615	NM	NM	NM	Domestic	Submersible	Ashttron Energies	Borehole locked, could not access.
KB14	29.917632	-22.646846	700.1092	NM	NM	NM	Domestic	Submersible	Boabab Toll Plaza	Dipmeter stuck/stopped at 39mbgl
NM: Not Measured										

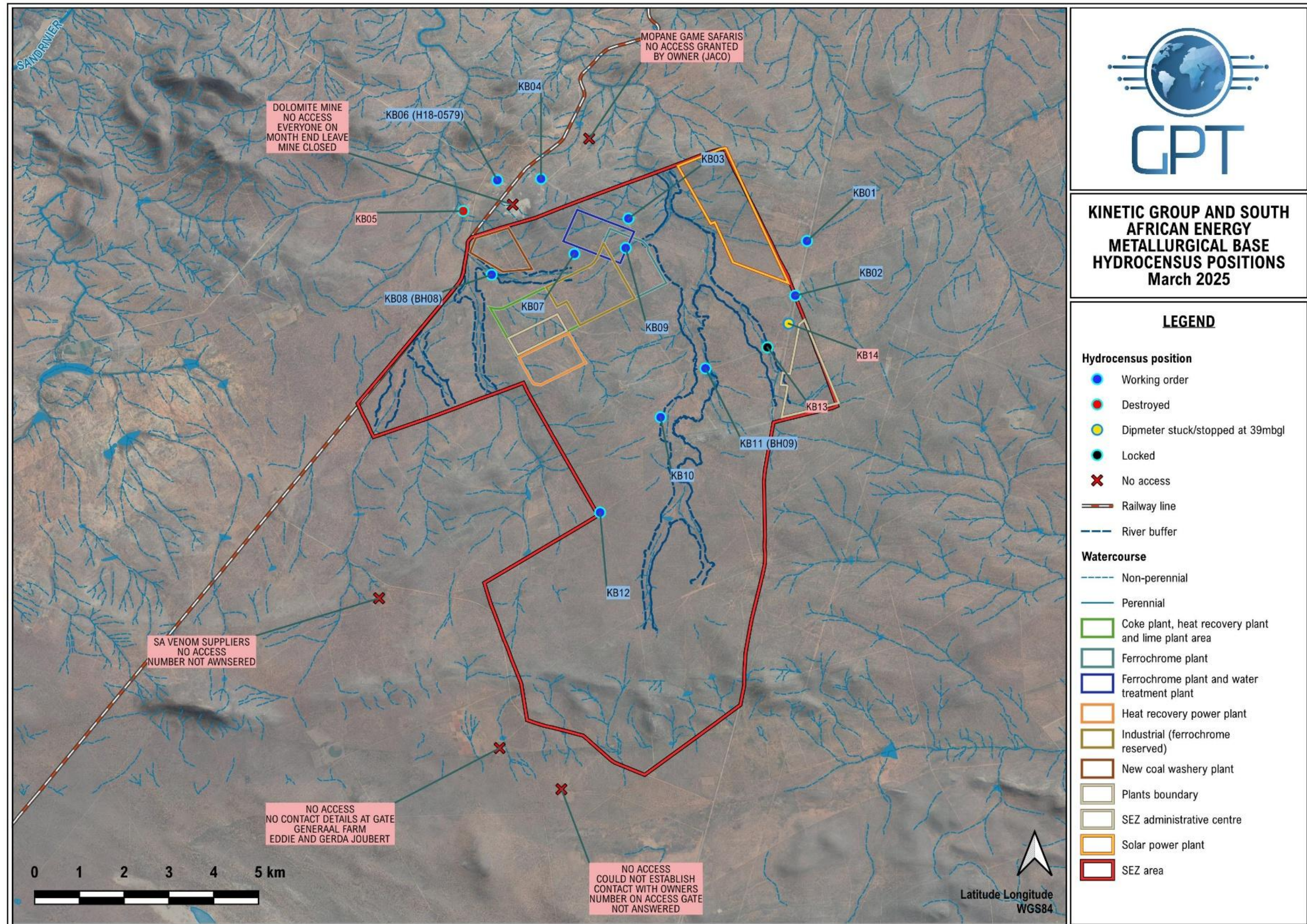


Figure 5: Hydrocensus Map.

8. GROUNDWATER LEVELS

Groundwater levels could be taken at eleven (11) boreholes during the hydrocensus (Table 7). The water levels ranged between 17.34 mbgl and 33.42 mbgl with an average of 25.95 mbgl.

Table 7: Mine monitoring groundwater levels.

Borehole ID	WL (mbgl)
KB01	25.6
KB02	26.14
KB03	29.74
KB04	30.99
KB06 (H18-0579)	17.34
KB07	28.97
KB08 (BH08)	19.35
KB09	20.1
KB10	33.42
KB11 (BH09)	21.36
KB12	32.49

A correlation coefficient was calculated from the hydrocensus points with available water level data. This relationship helps distinguish between boreholes with static water levels and those with anomalous levels due to disturbances like pumping or local hydrogeological heterogeneities. Generally, a good correlation should exist between topography and static groundwater level.

A correlation of 0.898 was calculated using the boreholes, indicating a strong correlation (Figure 6). This correlation between groundwater levels and elevation can be used for quick estimations of expected groundwater levels at various elevations within the vicinity of the site.

A groundwater flow map was created using the available groundwater levels during the hydrocensus, the map is depicted in **Figure 7**, and displays that the general groundwater flow direction is to the north of the site.

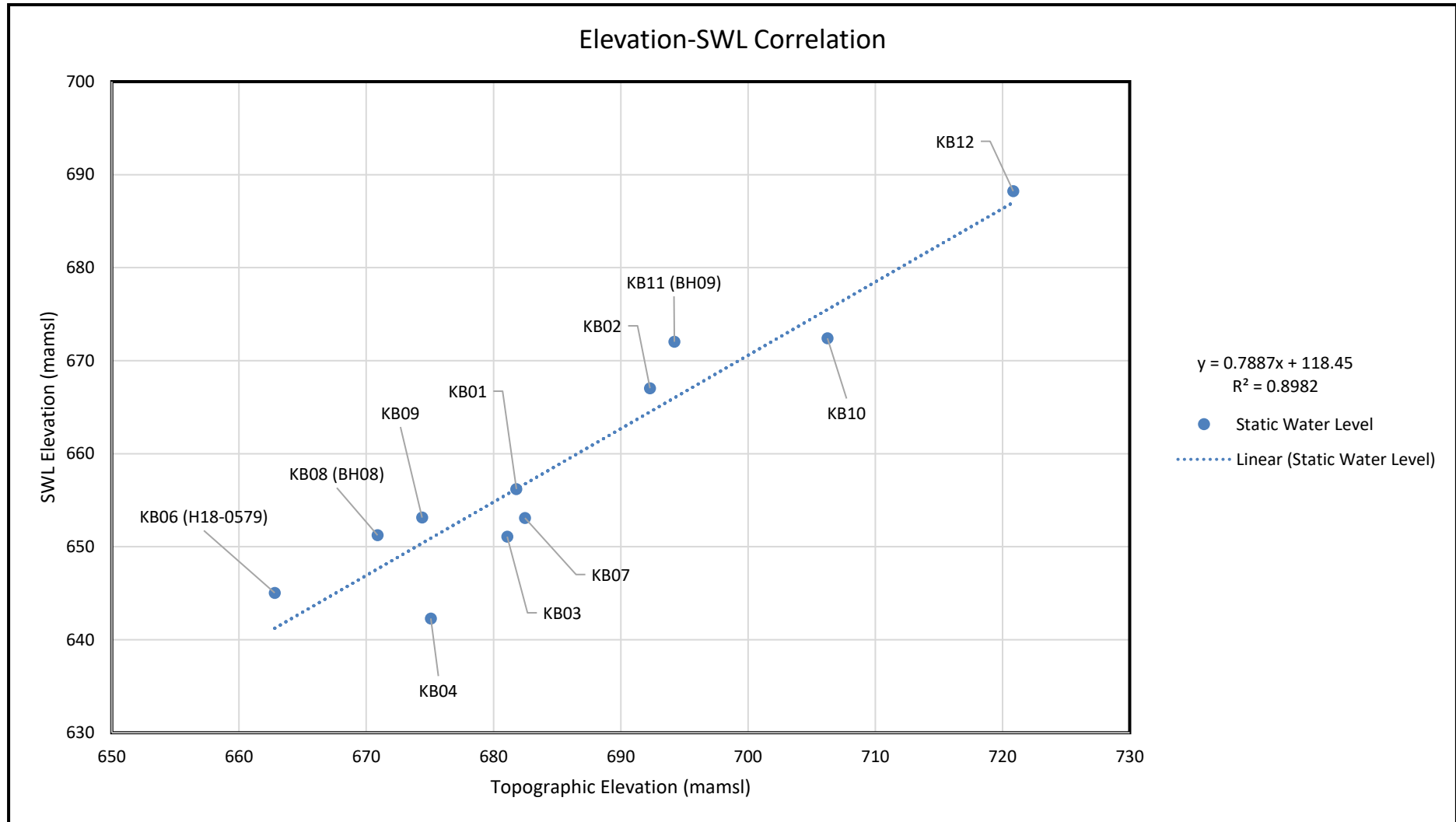


Figure 6: Correlation Graph of topography vs available groundwater levels

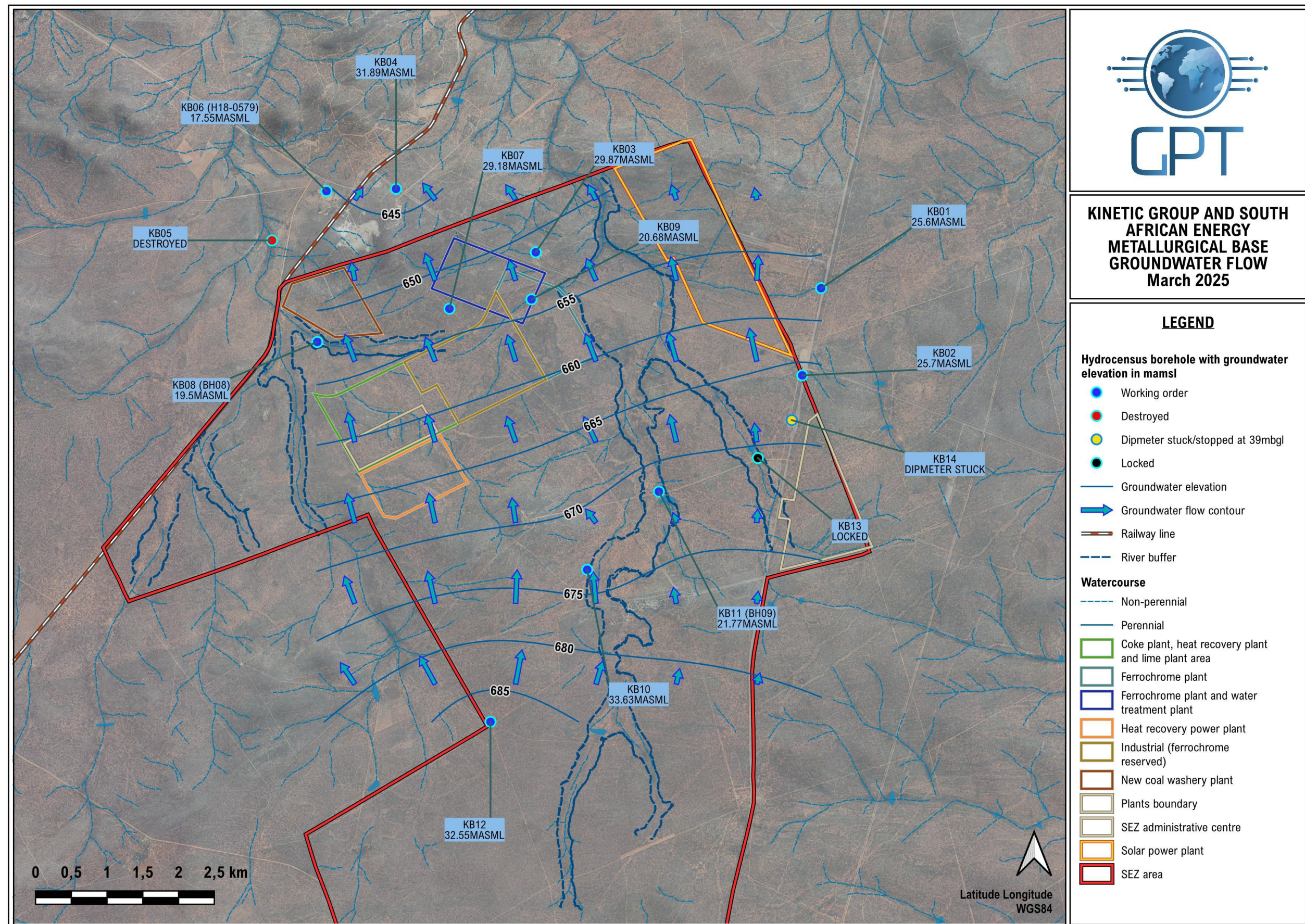


Figure 7: Groundwater Flow Map

9. POTENTIAL GROUNDWATER CONTAMINANTS

The type and quantity of potential groundwater contaminants will be influenced by, and directly associated with, the industrial activities planned for the MMEZ area. These include the ferrochrome smelter, coal washing plant, coking plant, lime plant and other anthropogenic sources. As no industrial operations have commenced to date, potential contamination sources have not yet been studied or analysed on-site. The types of contamination described below are based on literature and professional experience, and may include:

Ferrochrome Plant Contaminants:

A ferrochrome plant is a facility that produces ferrochrome, an alloy of iron and chromium primarily used in the steel industry. The production process typically involves smelting chromite ore with coke or coal at high temperatures in a submerged arc furnace. This process results in the generation of various waste products, including slag, dust, and effluent, which pose potential environmental risks, particularly to groundwater resources.

At a ferrochrome smelter, potential sources of groundwater contamination are primarily associated with the storage, handling, and disposal of raw materials, process residues, and waste products. However, the most significant source of contaminants is the slag produced during the smelting process. Slag is the stony waste matter separated from metals during smelting or refining, and its disposal is a key concern due to its chemical composition and potential to leach hazardous substances.

There is a tendency for metal industry leachates to include elevated concentrations of the following constituents:

- Heavy metals, particularly hexavalent chromium
- Fluoride
- Ammonia
- Sulphate
- Sodium

There exists the potential for heavy metals—especially Cr(VI)—to be progressively released through the weathering of slag materials. These elements may then be transported by acidic leachates. Potentially harmful leachates from the ferrochrome slag facility are characterised by hexavalent chromium [Cr(VI)].

Chromium is commonly used in the production of alloys and corrosion-resistant steel and iron. This metal is particularly dangerous since it accumulates in many organisms (Duffus, 1980)³. It is said that chromium is involved in fatty acid metabolism in humans. It is also an essential element needed for the proper functioning of insulin (Kempster and Smith, 1985)⁴. Chromium (III) is less readily absorbed via the gastrointestinal tract than chromium (VI). Consequently, the toxic effects of chromium are usually caused by the hexavalent form. Acute effects from oral exposure include the corrosion of the gastrointestinal tract and kidney necrosis (Rudd, 1987)⁵. Furthermore, the hexavalent form of

³ Duffus, J.H. (1980). *Environmental Toxicology. Resource and Environmental Science Series*, Edward Arnold Publishing, London, 164p.

⁴ Kempster, P.L. and Smith, R. (1985). *Proposed Aesthetic/Physical and Inorganic Drinking-Water Criteria for the Republic of South Africa*. CSIR Research Report 628, 50p

⁵ Rudd, T. (1987). *Scope of the Problem*. In: Lester, J.N. (ed.). *Heavy Metals in Wastewater and Sludge Treatment Processes*, 1, pp 1-30.

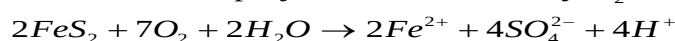
chromium is recognised as a mammalian carcinogen. It should be noted that chromium (III) compounds are more toxic to fish than the hexavalent compounds.

Chromium is normally present in the environment as poorly soluble trivalent salts of low toxicity (Rudd, 1987). Since chromium (III) may be oxidised to the more toxic hexavalent form, it is suggested that the standards for drinking water should be expressed in terms of the total chromium concentration (Schroeder and Lee, 1975). The rate at which chromium (III) is oxidised under normal conditions is uncertain. However, oxidation of this element is likely to be accelerated during the chlorination of drinking water.

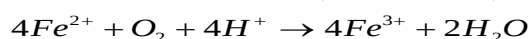
Coke Plant & Coal Washery Contaminants:

The coal washing and coking plants are coal handling facilities, and the main source of potential contamination will occur in the form of Acid Mine Drainage (AMD). AMD occurs when sulphides in the form of pyrite contained in coal are exposed to oxygen and water during processing. The chemical process for the formation of AMD is as follows:

1. Oxidation of polysulfide to sulfate by O_2 :

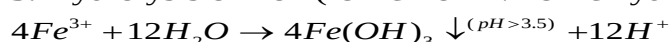


2. Oxidation of Fe^{2+} (ferrous iron) to Fe^{3+} (ferric iron) by O_2 :

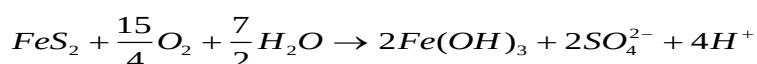
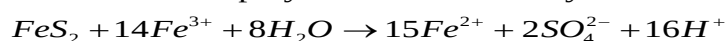


Rate determining step (slow at pH 2-3, fast at pH 5)

3. Hydrolysis of iron (ferric iron $\rightarrow$ ferric hydroxide)



4. Oxidation of polysulfide to sulfate by Fe^{3+} at low pH:



The resulting drainage has a very low pH, which promotes the dissolution of various metals. These acidic conditions can lead to the mobilization of contaminants, with potential sources of contamination including runoff from coal stockpiles as well as handling and sorting facilities.

Lime Plant Area Contaminants:

A lime plant typically processes limestone. Potential sources of contamination at such a facility are mainly associated with the handling, storage, and disposal of lime and related by-products. The highly alkaline nature of lime means that any leachate or runoff can significantly increase the pH of surrounding soils and groundwater. Elevated pH levels may mobilize otherwise immobile contaminants such as heavy metals from surrounding materials.

Operational (anthropogenic) contaminants may include:

- Organic contaminants such as fuels and oils from machinery and workshops.
- Anthropogenic contaminants such as solid waste and sewage.

The potential contaminants listed above may or may not be present at the site, and their presence can only be confirmed through chemical analysis and investigation. To more accurately assess potential contaminant types, it's essential to identify potential chemical contaminants used during operations as well as conducting a waste classification study on the industrial materials and waste generated at the site once the various planned industries are operational. This will aid in determining the nature and extent of waste production, as well as its potential environmental impact.

10. GROUNDWATER QUALITY

Six water samples were selected from boreholes found during the hydrocensus. The locations were selected based on their spatial relevance to the potential development area. The analysis mainly serves as a baseline reference for current constituent levels present within the aquifer at the site.

The chemical results of these samples were compared to the maximum recommended concentrations for drinking water, as outlined in SANS 241-1:2015 target water quality limits, as well as the Department of Water Affairs and Forestry (DWAF) guidelines for domestic use and industrial use. The drinking water limits, and domestic use limits provide an indication of suitability of water use for domestic purposes. The industrial use limits help assess the suitability of the water available for various industrial processes. Any exceedances do not imply that the aquifer or groundwater has been contaminated, it provides a baseline of the current groundwater status quo before any developments took place.

The results of the screening for groundwater are presented in Table 8, Table 9, Table 10 and discussed in the sections below:

10.1.1. Groundwater quality

10.1.1.1. SANS Drinking Water

The following observations were made:

- TDS and EC exceed the aesthetic limits for KB03, 06, 07, 08 and 09.
- Sulphate exceeds the acute health limit in KB07
- Fluoride exceeds the chronic health limit in KB03, 06, 08 and 09.
- Sodium and Chloride both exceed aesthetic limits in KB03, 06, 07, 08 and 09.
- E coli is detected in both KB08 and KB11
- Aluminium exceeds the operational limit in KB11.
- Total coliforms exceed the operational limits in all analysed boreholes.

10.1.1.2. DWAF Domestic Use

The following observations were made:

- Aluminium exceed the TWQR in KB11
- Calcium exceeds the TWQR in KB06, 07, 08 and 09.
- Chloride exceed the TWQR in KB06 and 07.
- Fluoride exceed the TWQR in KB03, 06, 08 and 09.
- Magnesium exceed the TWQR in KB03, 06, 07, 08 and 09.

- Sodium exceed the TWQR in KB03, 06, 07, 08 and 09.
- Sulphate exceed the TWQR in KB07
- TDS exceed the TWQR in KB03, 06, 07, 08 and 09

10.1.1.3. DWAF Industrial Use

The following observations were made:

- Total Alkalinity exceed the TWQR in KB006, 07, 08, 09 and 11.
- Chloride exceed the TWQR in all analysed boreholes.
- Sulphate exceed the TWQR in KB06, 07, 08 and 09.
- TDS exceed the TWQR in all analysed boreholes.

10.1.2. Groundwater quality discussion.

The groundwater quality at the site exceeds several guideline limits for drinking, domestic and industrial applications. The water is can therefore generally be classified as having poor-quality and can be considered brackish, with elevated concentrations of dissolved salts.

10.1.3. Spatial analysis of groundwater quality

10.1.3.1. Pie Diagrams

The pie diagrams (Figure 8) show both the individual ions present in a water sample and the total ion concentrations in meq/l or mg/l. The scale for the radius of the circle represents the total ion concentrations, while the subdivisions represent the individual ions. It is very useful in making quick comparisons between waters from different sources and presents the data in a convenient manner for visual inspection. From the tables and figures the following can be deduced:

Borehole KB07, located to the north of the site, exhibits the comparatively highest total ion concentration and is characterized by a Sodium/Magnesium-Chloride-type water. Similarly, boreholes KB06 and KB09 also display a Sodium/Magnesium signature; however, their anionic composition reflects a more balanced ratio between chloride and bicarbonate. KB03, while also showing a large chloride presence, is predominantly influenced by a bicarbonate anion signature. In contrast, KB11, located to the south of the site, has the lowest total ion concentration and is dominated by a Bicarbonate-Sodium water type.

10.1.3.2. Classed Concentration Maps

The concentrations of three constituents; chloride, sodium, and sulphate were mapped across the analysed boreholes. These concentrations were compared against the target water quality ranges for domestic use, and the results were classified accordingly on the maps. The maps are used to spatially illustrate the distribution of some constituents that exceed the limits specified in the domestic water use guidelines is several boreholes. The maps are shown in Figure 9, Figure 10 and Figure 11.

The maps indicate that KB07, followed by KB06, are the boreholes with the most frequent exceedances of the Target Water Quality Range (TWQR) limits. It is also evident that constituent concentrations generally increase toward the north of the site, while the borehole to the south exhibit overall better water quality in comparison to the domestic TWQR thresholds.

Table 8: Water qualities compared to SANS 241-1:2015 guidelines for drinking water.

Determinant	Risk	Unit	Standard limits	KB03	KB06	KB07	KB08	KB09	KB11
Physical and aesthetic determinants									
Total dissolved solids	Aesthetic	mg/L	1 200	2233	2345	7665	1785	1983	1023
Conductivity at 25 °C	Aesthetic	mS/m	170	319	335	1095	255	283.3	146.1
pH at 25 °C ^b	Operational	pH units	5 to 9.7	7.61	8.11	7.17	7.63	7.56	7.81
Chemical determinants – macro-determinants									
Nitrate as N (NO ₃ - N)	Acute health	mg/L	11	BDL	BDL	BDL	BDL	BDL	BDL
Nitrite as N (NO ₂ - N)	Acute health	mg/L	0.9	BDL	BDL	BDL	BDL	BDL	BDL
Combined nitrate plus nitrite (NO ₃ +NO ₂)	Acute health		1	BDL	BDL	BDL	BDL	BDL	BDL
Sulfate as SO ₄ ²⁻	Acute health	mg/L	500	186	280.8	986.8	170.3	187.7	37.49
	Aesthetic	mg/L	250	186	280.8	986.8	170.3	187.7	37.49
Fluoride as F ⁻	Chronic health	mg/L	1.5	1.51	2.12	1.21	1.64	1.61	1.44
Ammonia as N	Aesthetic	mg/L	1.5	0.34	0.08	0.31	0.08	0.32	0.06
Chloride as Cl ⁻	Aesthetic	mg/L	300	489.2	622.1	2849	359.6	491.4	92.03
Sodium as Na	Aesthetic	mg/L	200	309.1	225.2	837.5	223.1	238.8	169
Zinc as Zn	Aesthetic	mg/L	5	0.07	BDL	BDL	0.06	BDL	0.07
Chemical determinants – micro-determinants									
Arsenic as As	Chronic health	mg/L	0.01	BDL	BDL	BDL	BDL	BDL	BDL
Boron as B	Chronic health	mg/L	2.4	0.95	0.86	BDL	0.71	0.73	BDL
Copper as Cu	Chronic health	mg/L	2	0.23	0.05	BDL	BDL	BDL	0.05
Iron as Fe	Aesthetic	mg/L	0.3	0.08	BDL	BDL	BDL	BDL	BDL
Lead as Pb	Chronic health	mg/L	0.01	BDL	BDL	BDL	BDL	BDL	BDL
Manganese as Mn	Aesthetic	mg/L	0.1	0.05	BDL	BDL	BDL	BDL	BDL
Nickel as Ni	Chronic health	mg/L	0.07	BDL	BDL	BDL	BDL	BDL	BDL
Aluminium as Al	Operational	mg/L	0.3	0.13	0.16	BDL	0.07	0.13	0.53
Microbiological determinants									
<i>E. coli</i> ^a or faecal coliforms ^b	Acute health	cfu/100 mL	0	0	0	0	46	0	72
Total coliforms ^d	Operational	cfu/100 mL	10	150	1720	41700	280000	300	510000
BDL = Below Detection Limit									
Exceed Risk Limit									

Table 9: Water qualities compared to DWAF Domestic Use guidelines

Water Quality Constituents		KB03	KB06	KB07	KB08	KB09	KB11	TWQR	Tolerable	Exceeding TWQR
Total Alkalinity	M Alk. [mg/l CaCO ₃]	782.50	515.00	745.00	565.00	510.00	577.50	Not available		
Aluminium	Al [mg/l]	0.13	0.16	BDL	0.07	0.13	0.53	0 - 0.15	0.15 - 0.5	> 0.5
Ammonia	NH ₃ [mg/l]	0.34	0.08	0.31	0.08	0.32	0.06	0 - 1.0	1.0 - 10	> 10.0
Arsenic	As [mg/l]	BDL	BDL	BDL	BDL	BDL	BDL	0 - 10	10 - 200	> 200
Boron	B [mg/l]	0.95	0.86	BDL	0.71	0.73	<0.5	Not available		
Calcium	Ca [mg/l]	64.16	156.90	393.60	84.66	83.52	43.58	0 - 32	32 - 80	> 80
Chloride	Cl [mg/l]	489.20	622.10	2849.00	359.60	491.40	92.03	0 - 100	100 - 600	> 600
Chromium	Cr [mg/l]	BDL	BDL	BDL	BDL	BDL	BDL	0 - 0.050		> 0.050
Copper	Cu [mg/l]	0.23	0.05	BDL	BDL	BDL	0.05	0 - 1	1 - 30	> 30
Electrical Conductivity	EC [mS/m]	319.00	335.00	1095.00	255.00	283.30	146.10	Not available		
Fluoride	F [mg/l]	1.51	2.12	1.21	1.64	1.61	1.44	0 - 1.0	1.0 - 1.5	> 1.5
Iron	Total Fe [mg/l]	0.08	BDL	BDL	BDL	BDL	BDL	0 - 0.1	0.1 - 1.0	> 1.0
Lead	Pb [mg/l]	BDL	BDL	BDL	BDL	BDL	BDL	0 - 10	10 - 50	> 50
Magnesium	Mg [mg/l]	168.20	197.30	758.90	128.40	145.50	64.29	0 - 30	30 - 70	> 70
Manganese	Mn [mg/l]	0.05	BDL	BDL	BDL	BDL	BDL	0 - 0.05	0.05 - 1.0	> 1.0
Nickel	Ni [mg/l]	BDL	BDL	BDL	BDL	BDL	BDL	Not available		
Nitrate	NO ₃ as N [mg/l]	BDL	BDL	BDL	BDL	BDL	BDL	0 - 6		> 6
pH	pH units	7.61	8.11	7.17	7.63	7.56	7.81	6.0 - 9.0		9
Potassium	K [mg/l]	22.49	16.12	55.27	19.57	16.68	9.25	0 - 50	50 - 100	> 100
Sodium	Na [mg/l]	309.10	225.20	837.50	223.10	238.80	169.00	0 - 100	100 - 200	> 200
Sulphate	SO ₄ [mg/l]	186.00	280.80	986.80	170.30	187.70	37.49	0 - 200	200 - 400	> 400
Total Dissolved Solids	TDS [mg/l]	2233.00	2345.00	7665.00	1785.00	1983.00	1023.00	0 - 450	450 - 1 000	> 1000
Zinc	Zn [mg/l]	0.07	BDL	BDL	0.06	BDL	0.07	0 - 3	3 - 10	> 10
BDL: Below Detection Limit										
TWQR- Target water quality range										
Tolerable - Suitable for short-term intake, in some instances health problems can occur during extensive long-term intake in sensitive individuals such as infants										
Exceeding TWQR- Exceedance of target water quality range may lead to adverse affects										

Table 10: Water qualities compared to DWAF Industrial Use

Water Quality Constituents		KB03	KB06	KB07	KB08	KB09	KB11	TWQR	Moderate	Exceeding TWQR
Total Alkalinity	M Alk. [mg/l CaCO3]	0.00	515.00	745.00	565.00	510.00	577.50	0 - 50	50 - 120	> 120
Aluminium	Al [mg/l]	0.13	0.16	BDL	0.07	0.13	0.53	Not available		
Ammonia	NH ₃ [mg/l]	0.34	0.08	0.31	0.08	0.32	0.06	Not available		
Arsenic	As [mg/l]	BDL	BDL	BDL	BDL	BDL	BDL	Not available		
Boron	B [mg/l]	0.95	0.86	BDL	0.71	0.73	<0.5	Not available		
Calcium	Ca [mg/l]	64.16	156.90	393.60	84.66	83.52	43.58	Not available		
Chloride	Cl [mg/l]	489.20	622.10	2849.00	359.60	491.40	92.03	0 - 20	20 - 50	> 50
Chromium	Cr ⁶⁺ [mg/l]	BDL	BDL	BDL	BDL	BDL	BDL	Not available		
Copper	Cu [mg/l]	0.23	0.05	BDL	BDL	BDL	0.05	Not available		
Electrical Conductivity	EC [mS/m]	319.00	335.00	1095.00	255.00	283.30	146.10	Not available		
Fluoride	F [mg/l]	1.51	2.12	1.21	1.64	1.61	1.44	Not available		
Iron	Total Fe [mg/l]	0.08	BDL	BDL	BDL	BDL	BDL	Not available		
Lead	Pb [mg/l]	BDL	BDL	BDL	BDL	BDL	BDL	Not available		
Magnesium	Mg [mg/l]	168.20	197.30	758.90	128.40	145.50	64.29	Not available		
Manganese	Mn [mg/l]	0.05	BDL	BDL	BDL	BDL	BDL	Not available		
Nickel	Ni [mg/l]	BDL	BDL	BDL	BDL	BDL	BDL	Not available		
Nitrate	NO ₃ as N [mg/l]	BDL	BDL	BDL	BDL	BDL	BDL	Not available		
pH	pH units	7.61	8.11	7.17	7.63	7.56	7.81	7.0 - 8.0	6.0-7, 8.0-9.0	<6, >9
Potassium	K [mg/l]	22.49	16.12	55.27	19.57	16.68	9.25	Not available		
Sodium	Na [mg/l]	309.10	225.20	837.50	223.10	238.80	169.00	Not available		
Sulphate	SO ₄ [mg/l]	0.00	280.80	986.80	170.30	187.70	37.49	0 - 30	30 -150	> 150
Total Dissolved Solids	TDS [mg/l]	2233.00	2345.00	7665.00	1785.00	1983.00	1023.00	0 - 100	100 - 450	> 450
Zinc	Zn [mg/l]	0.07	BDL	BDL	0.06	BDL	0.07	Not available		
BDL: Below Detection Limit										
TWQR- Target water quality range										
Moderate damage or interference with processes or impairment of product quality										
Exceeding TWQR- Significant damage or interference with processes or impairment of product quality										

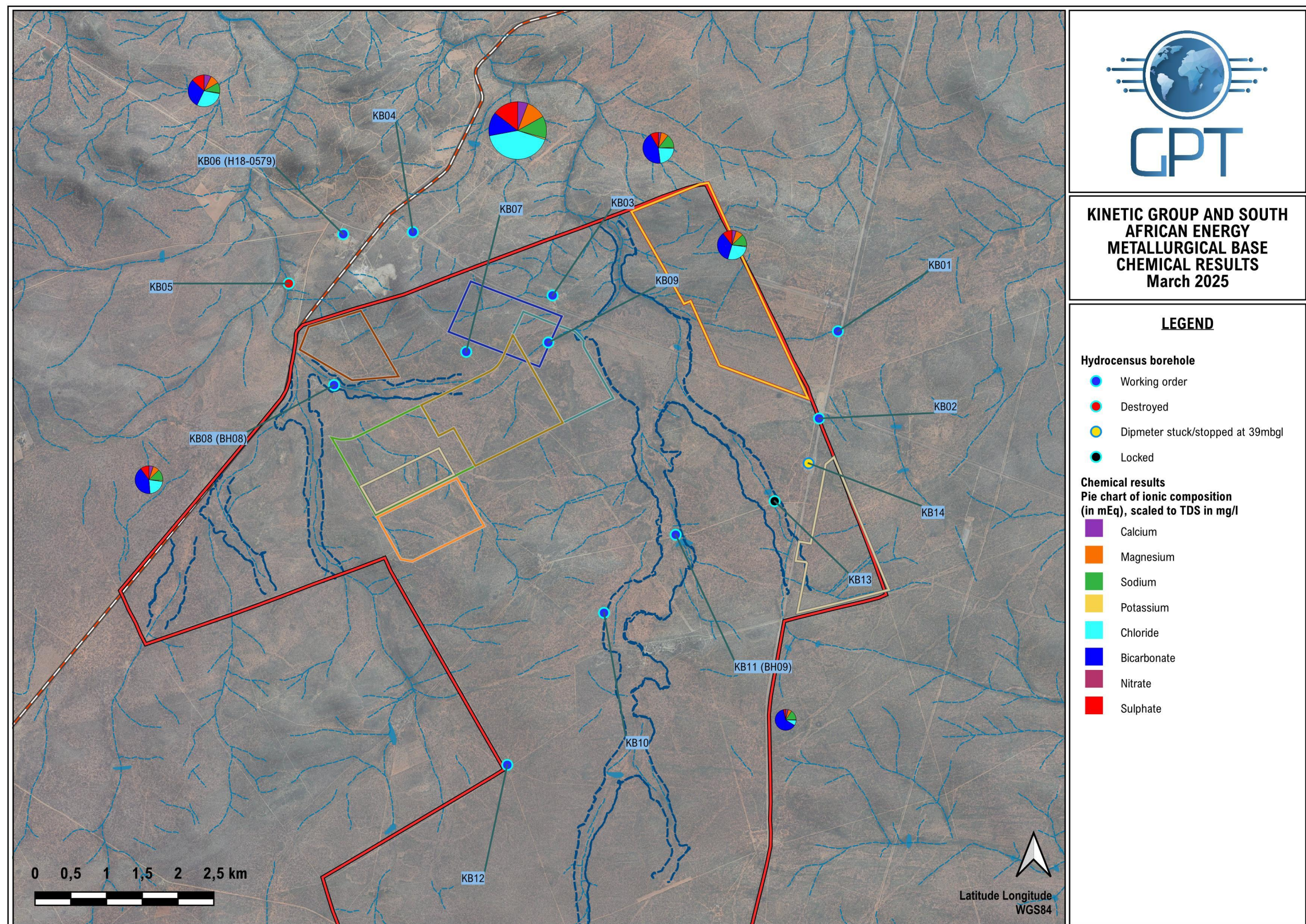


Figure 8: Groundwater and surface water pie diagram

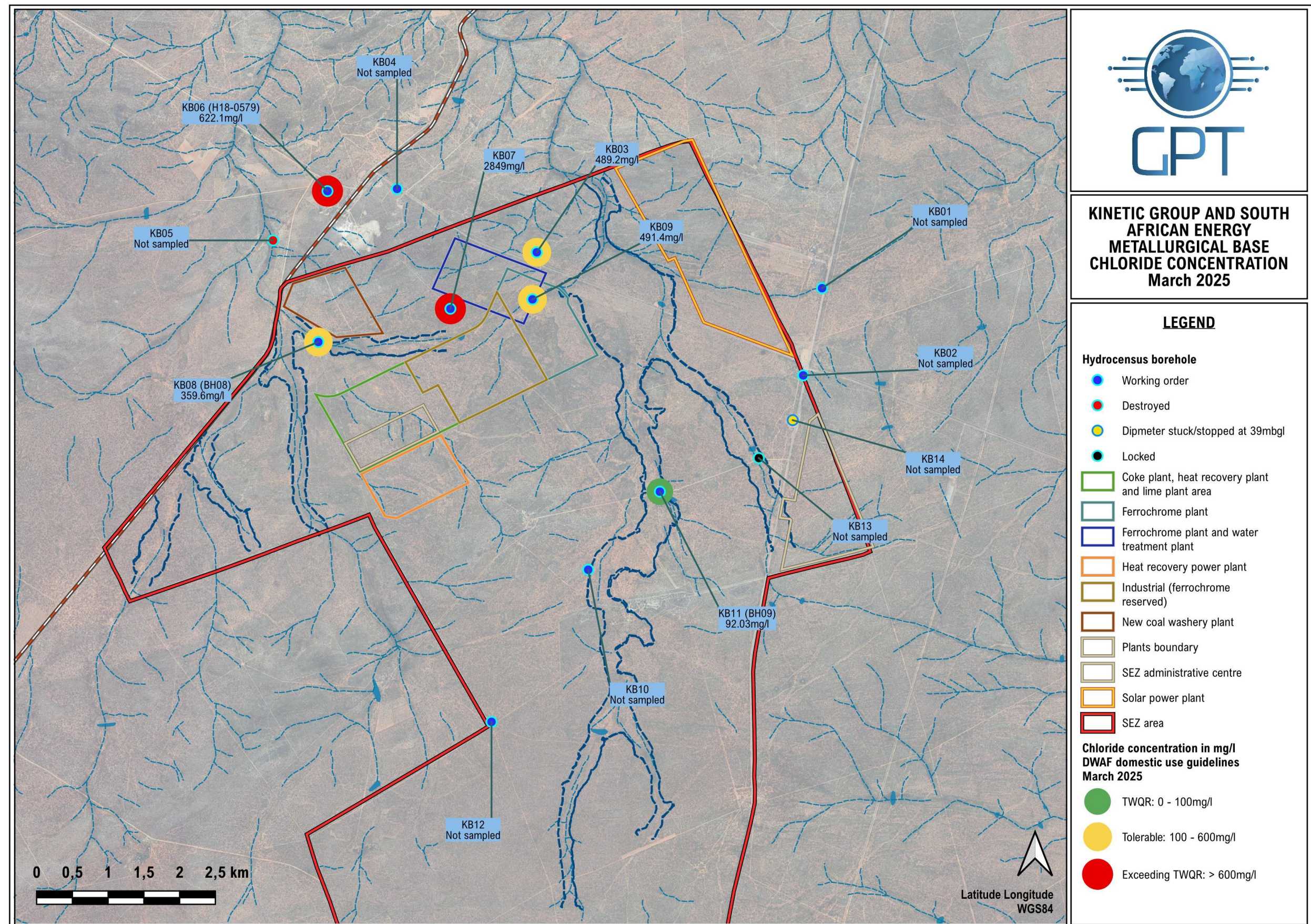


Figure 9: Chloride Classed Concentration Map

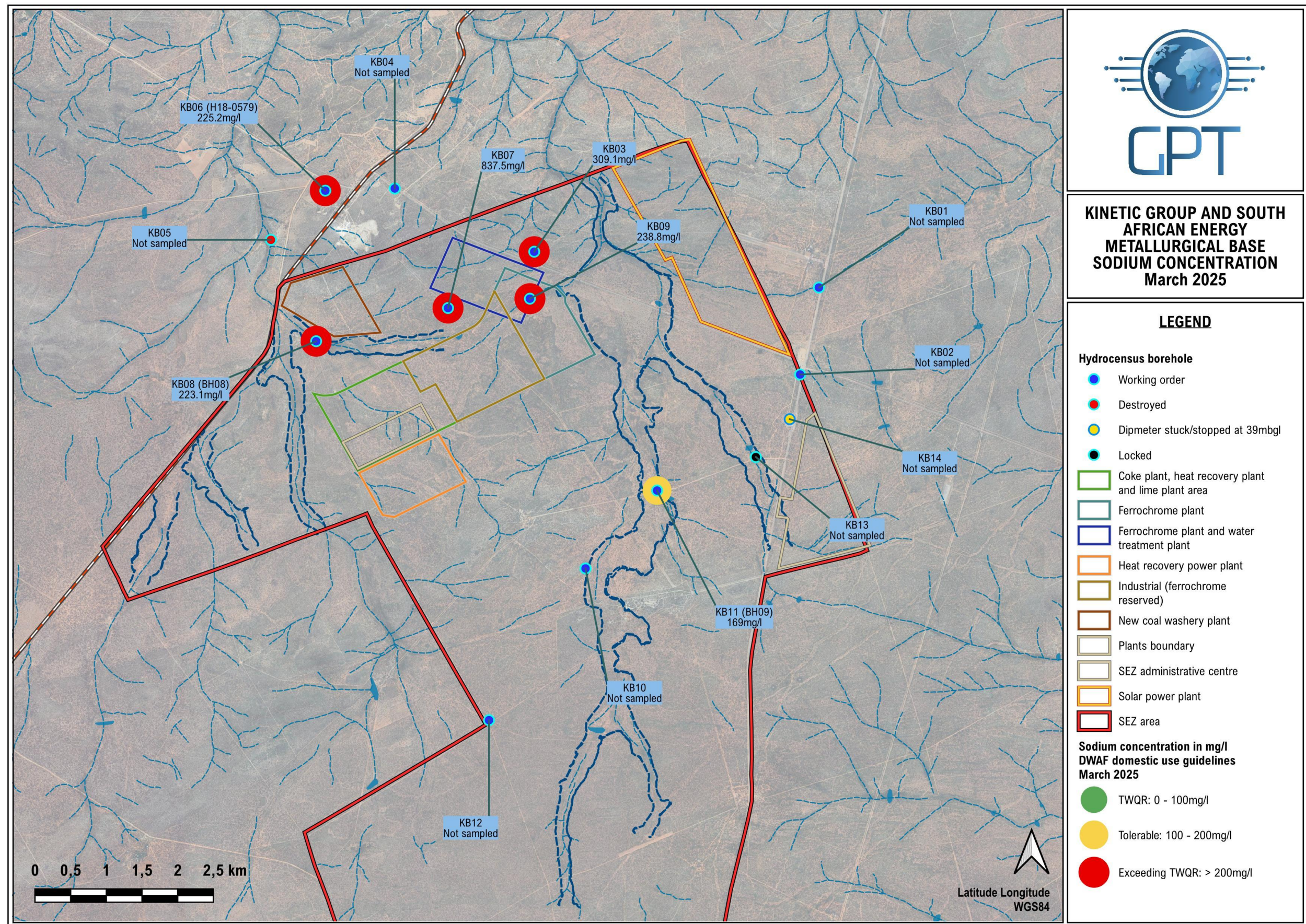


Figure 10: Sodium Classed Concentration Map

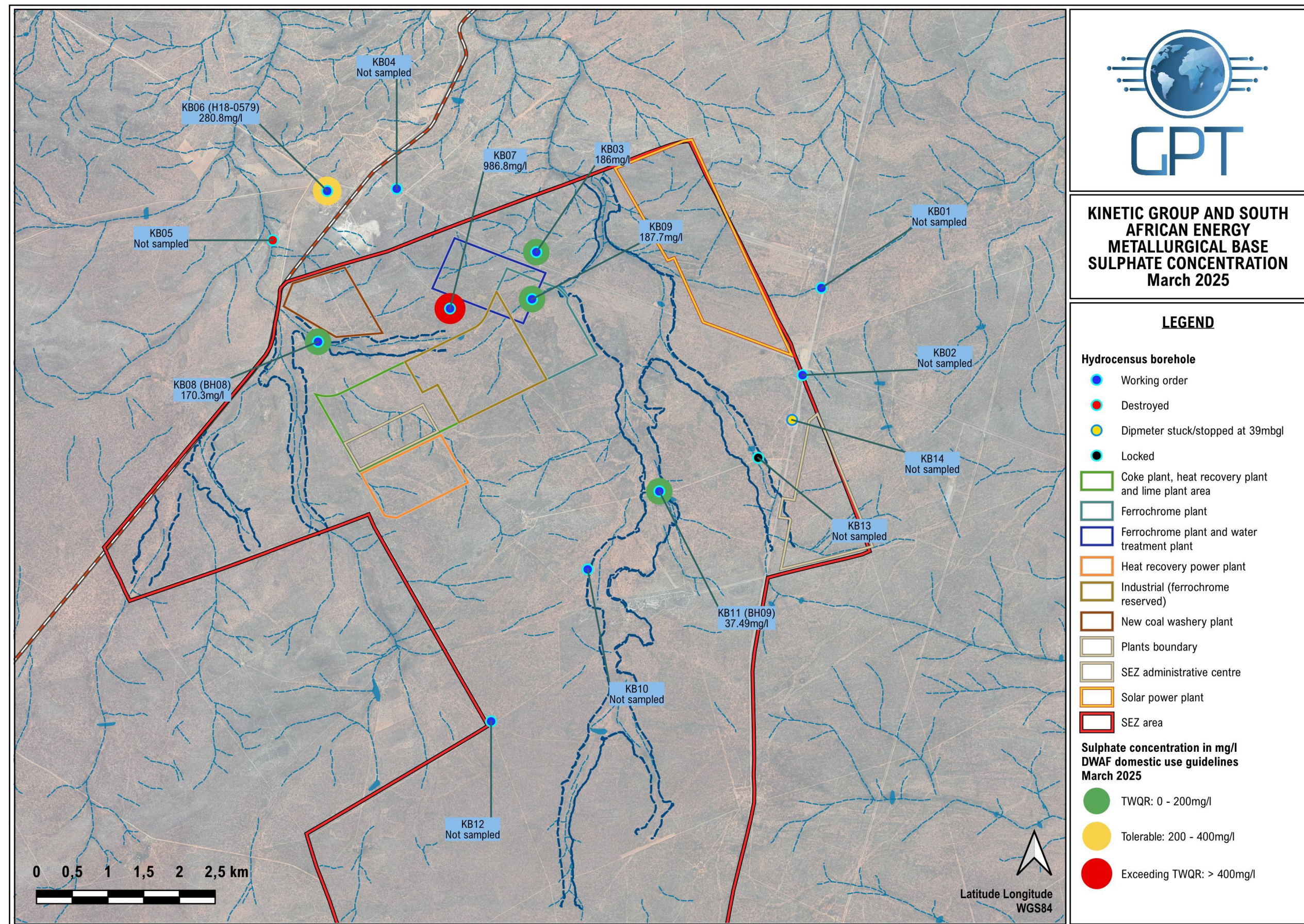


Figure 11: Sulphate Classed Concentration Map

11. CONCEPTUAL SITE MODEL

In principle, the CSM is one of the primary planning tools that can be used to support the decision-making process and managing groundwater on a large scale. The CSM organises available information about a site in a clear and transparent structure and facilitates the identification of data and information gaps. Once the CSM is established, additional required data can be gathered and integrated in the CSM, followed by a revision of the CSM and a refinement of decision goals over time. Thus, the CSM matures and enables an improved understanding of the site characteristics, such as contamination status, receptor profiles, etc., and the re-adjustment of decision criteria.

The site-specific details regarding the CSM for **MMSEZ, Mopane** include:

- **Geology:** The site is predominantly underlain by Quaternary sandy soils, which form the main surface cover. Bedrock geology comprises outcrops of the Beit Bridge Complex (Gambu Group) in the central, northern, and southern areas, characterized by calc-silicate rocks, marble, leucogneisses, hornblende granitoid gneiss, metaquartzite, and amphibolite. South of the northern Gambu outcrop and beneath a fault line, the Karoo Supergroup is present, consisting of undifferentiated Mikambeni and Madzaringwe Formations with mudstone, shale, carbonaceous shale, sandstone, coal seams, and basal diamictite or conglomerate.
- **Aquifer Description:** The multi-layered weathering system present on the geology could prove to have up to two aquifer systems present in the form of a shallow, saprolitic aquifer with a weathered, intergranular soft rock base associated with the contact of fresh bedrock and the weathering zone; and an intergranular & fractured bedrock aquifer.
- **The calculated recharge percentage** equates to approximately 2% of annual precipitation. Which is very low.
- **Static water level:** The water levels ranged between 17.34 mbgl and 33.42 mbgl with an average of 25.95 mbgl.
- **Rainfall:** The average annual rainfall (1970-2024) for the general site location is 325.8 mm per year.
- **Groundwater flow direction:** The groundwater flow direction is in a general northern direction.
- **Water Quality:** Groundwater quality at the site exceeds several guideline limits for drinking, domestic and industrial applications. The water is generally classified as poor-quality and brackish, with elevated concentrations of dissolved salts.
- **Receptors:** Possible receptors are on-site water users.

CSM Discussion: Contamination Risk

A notably thick vadose zone, conservatively estimated at a minimum of 15 m and potentially exceeding 30 m in certain areas, underlies the site. This unsaturated zone, coupled with the region's low effective recharge rates and relatively low annual rainfall (by South African standards), significantly limits the vertical migration potential of contaminants. Under typical conditions, and in the absence of significant contaminant volumes or continuous pollutant sources, contaminants are expected to undergo attenuation, dispersion, and degradation within the vadose zone. This provides

a natural protective barrier to the underlying aquifer, reducing the likelihood of groundwater contamination from surface-based activities.

The Groundwater Decision Tool (GDT) calculated an aquifer vulnerability value of 34%, categorised as medium. This value is slightly above the 30% threshold, which indicates that the aquifer's natural characteristics are generally effective in limiting contamination risk. A previous study conducted by WSM-Leshika in June 2021, using the DRASTIC method, also concluded that the aquifer vulnerability ranges from low to very low. However, it is important to note that this conclusion was based on the assumption of dry deposition, which may not be applicable in scenarios involving liquid waste, where the potential for contaminant mobility and infiltration is higher.

In support of the above, the client has confirmed that all waste and raw material stockpiles will be stored on hardstand surfaces with integrated wastewater management systems. These engineered controls significantly reduce the likelihood of contaminant infiltration by disrupting the pathway to the vadose zone. The combination of impermeable surfaces and controlled stormwater management systems serves to further minimise the risk of percolation and subsurface transport.

Based on these factors, it is both scientifically and reasonably concluded that the risk of groundwater contamination is minimal under the proposed operational conditions. Any leachate that might be generated is expected to dissipate or degrade within the vadose zone, without reaching the water table.

Due to the protective nature of the vadose zone and the low likelihood of contaminants breaching this barrier, it was not feasible to accurately simulate groundwater contamination using numerical transport modelling. Introducing contaminants directly into the saturated zone during modelling would not reflect the realistic site conditions and would overlook the critical attenuation capacity of the thick unsaturated layer. Therefore, modelling efforts were focused on simulating drawdown impacts associated with groundwater abstraction, not contaminant transport.

12. GROUNDWATER FLOW AND TRANSPORT MODELLING

The numerical groundwater flow model is constructed and simulated to aid in decision making processes and environmental management. The purpose of the numerical model is to develop a tool that can be used to assess the impact, as a result of the abstraction from the water supply boreholes.

The following limitations and assumptions apply to the numerical model:

- The groundwater regime of the study area is highly heterogeneous due to intrusions, which ultimately influence the groundwater flow patterns. Constructing a groundwater flow model with all the detail is close to impossible; however, assumptions are made based on data gathered in the field and used to simulate different scenarios.
- The numerical model is based on limited available data on aquifer parameters such as hydraulic conductivity and storage. Aquifer hydraulic parameters are based on previous investigations⁶ and literature (as referenced in Table 11).
- Numerous exploration and existing boreholes were drilled and tested for potential water supply to the MMSEZ southern industrial zone in a previous study done by Matukane and Associates in 2021. Four production boreholes were recommended in the A71K catchment yielding 427.68 m³/day. The long-term demand of the MMSEZ cannot be met by local groundwater

⁶ WSM Leshika Consulting (2021). Specialist Groundwater Report, Musina Makhado SEZ, Modelling of Groundwater Impacts, Southern Industrial Zone. Project Number: wh21023

resources and alternative sources will be required. These four abstraction boreholes are included in the numerical flow model and the abstraction rates are sourced from the utilisation recommendations made by Matukane & Associates (PTY) Ltd⁷. These recommended production boreholes are recommended to supply water for the construction phase of the project.

- As indicated by the client, the footprint of raw material stockpiles and slag stockpiles will be on hardstanding and the slag will be temporarily sorted.
- The results must be viewed with caution as a homogeneous aquifer has been assumed. Heterogeneities in the aquifer are unknown and the effect of this cannot be predicted.

12.1. Model Set-Up and Boundaries

The model domain is irregularly shaped with dimensions of ~62 km by ~28 km in the horizontal direction. The modelling area was discretised by a 224 x 227 grid in the x and y direction, respectively, resulting in 179 624 active cells for the model grid. A grid refinement of 50 m x 50 m was applied with gradually coarser grid cell sizes to a maximum size of 2 000 m x 2 000 m away from the site to reduce model run time. The active cells within the model grid and grid refinement is shown in Figure 17. Along the vertical direction the model consists of four (4) layers.

Boundaries were chosen far enough removed from site boundaries not to be affected by boundary conditions. These boundaries are described in Table 11 and shown in Figure 13.

⁷ Matukane & Associates (PTY) Ltd (2021). Geohydrological Investigation for Groundwater Development MM-SEZ, Southern Area, Limpopo

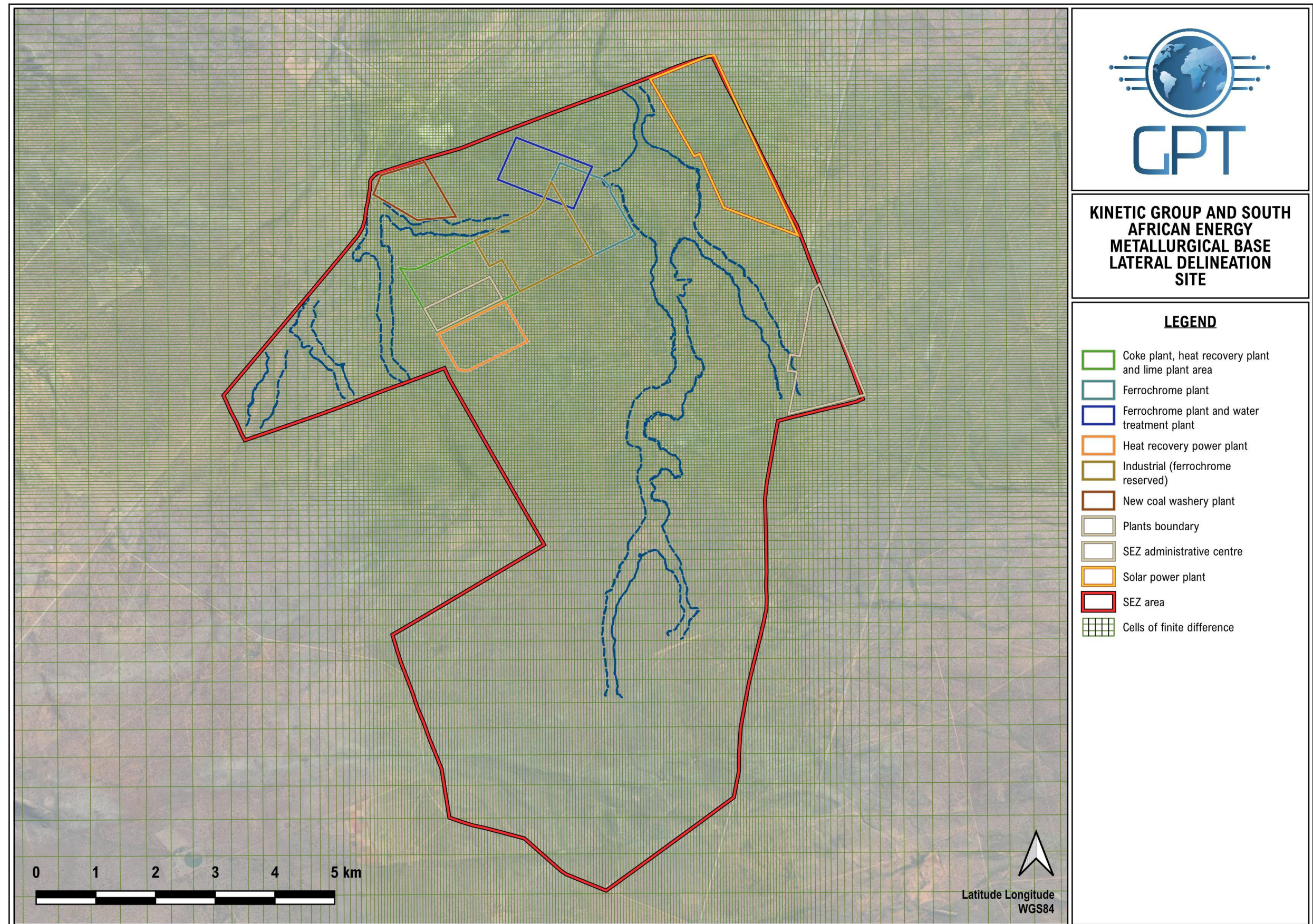


Figure 12:Lateral Delineation of The Regional Model

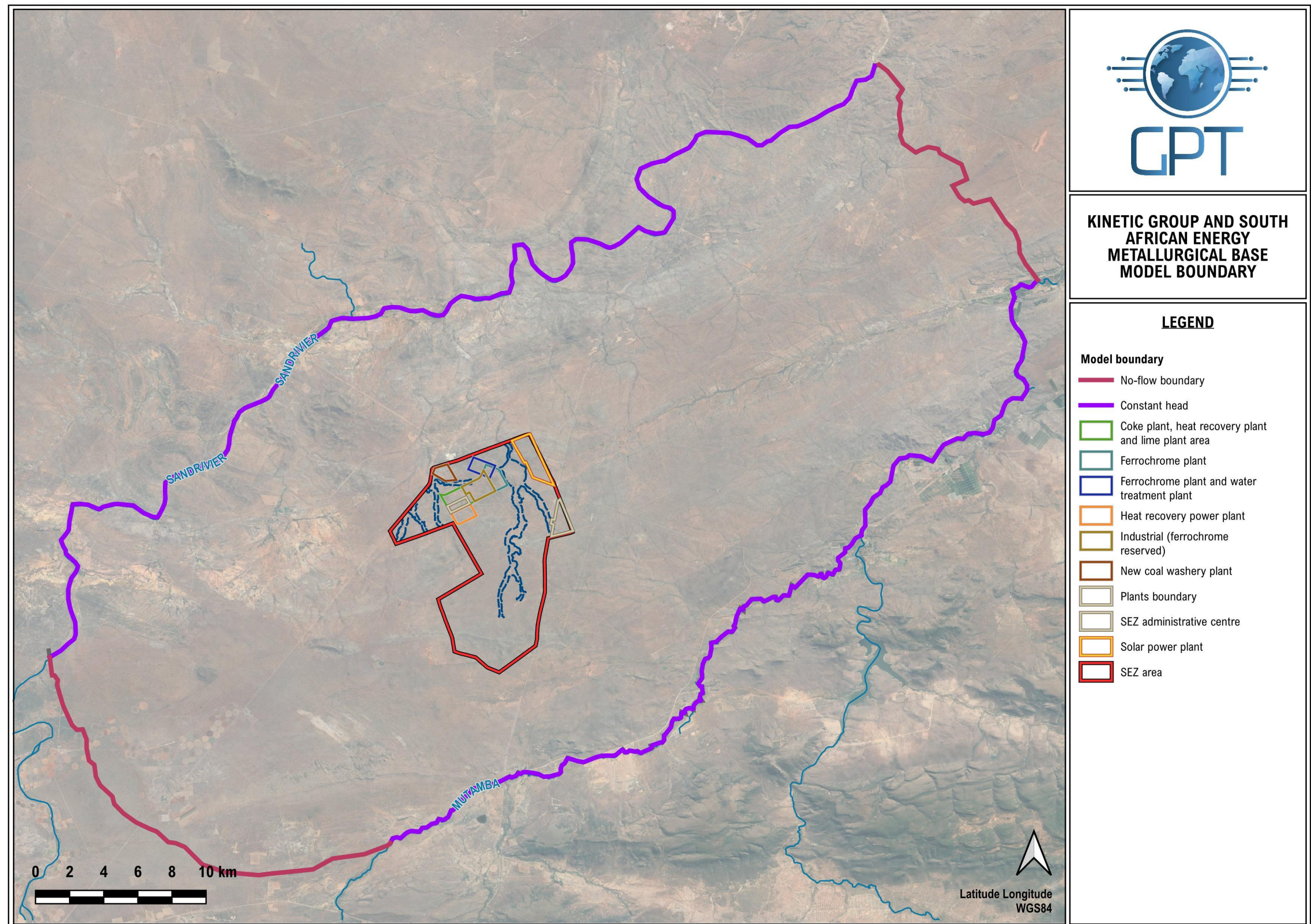


Figure 13: Model Boundary and Boundary Conditions

12.2. Groundwater Elevation and Gradient

The calibrated static water levels as modelled have been contoured (Figure 19). Groundwater flow direction should be perpendicular to these contours and inversely proportional to the distance between contours. As can be expected, the groundwater flow is mainly from topographical high to low areas, eventually draining to the local streams.

12.3. Groundwater Source and Sinks

Although the most relevant aquifer parameters are optimised by the calibration of the model, many parameters are calculated and/or judged by conventional means. The fixed assumptions and input parameters were used for the numerical model of this area.

Table 11: Input parameters to the numerical flow model

Model Parameter	Value	Unit	Reason
Recharge to the aquifer	0.00000893	m/d	Calculated
Evapotranspiration	0.00628	m/d	Calculated
Boundaries	Topographic water divides	-	Natural boundaries at the site that would potentially include modelled impacts.
Refinement	50	m	Based on the scale of the project area and limiting the cells per layer to less than 100k
Grid dimensions	224 x 227	Number	Product of the grid refinement
Hydraulic anisotropy (vertical)	10	-	Anderson et al. (2015)
Effective porosity	15 declining to 2 with depth in each layer	%	Wang et al. (2009)
Layers	4	Number	Depth of proposed abstraction boreholes ranges from 42 to 66 mbgl.
Longitudinal dispersion	50	m	Schulze-Makuch (2005)
Head error range	13	m	Calculated as 10% of the difference between the maximum and minimum calculated head elevations

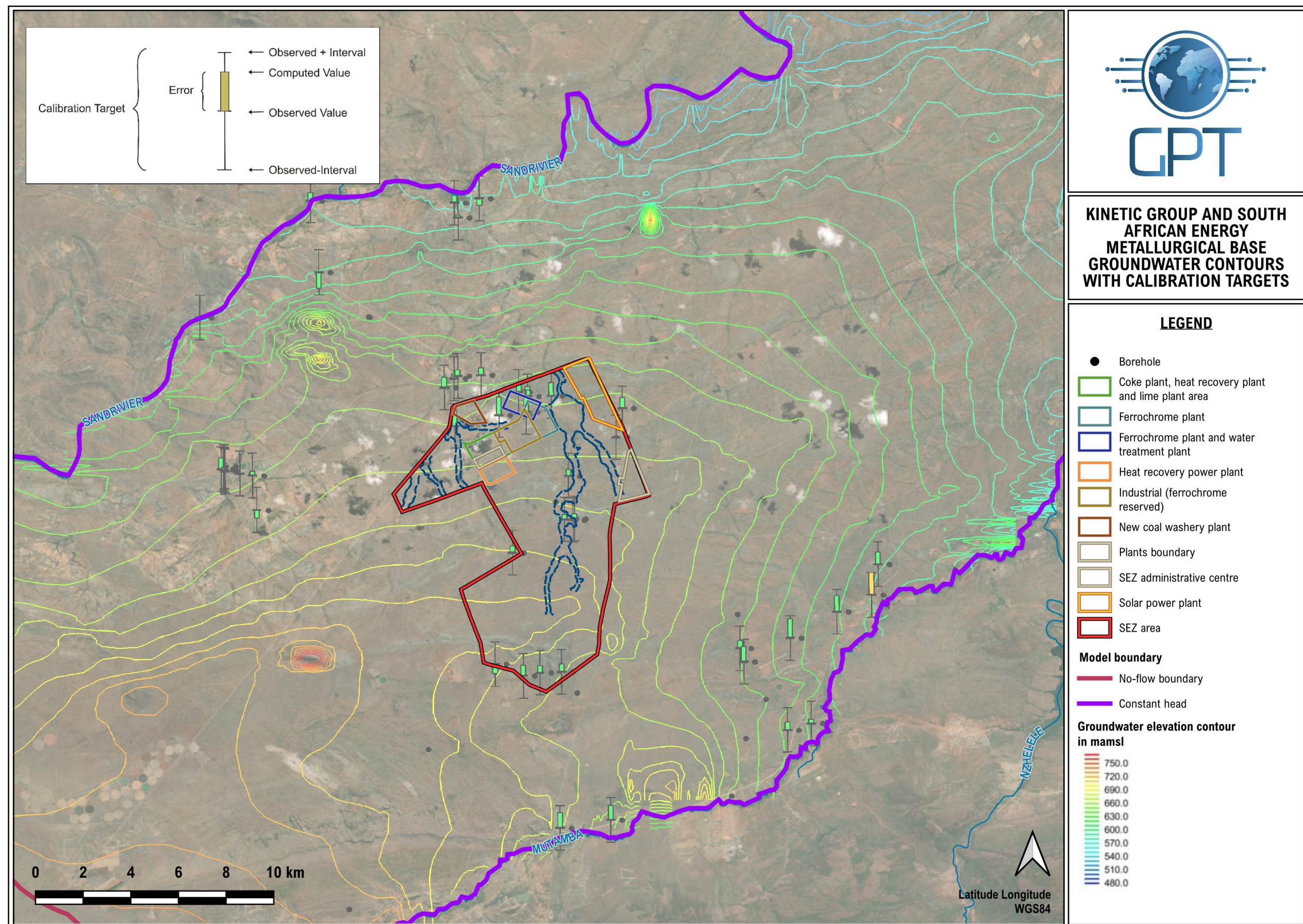


Figure 14: Groundwater Calibration Results

12.4. Conceptual Model Input

For this study, the subsurface was envisaged to consist of the following hydrogeological units.

- The upper few metres below surface consist of completely weathered material also referred to as regolith. This layer is anticipated to have a reasonable high hydraulic conductivity, but in general unsaturated.
- The next few tens of meters can be subdivided into two aquifer systems comprising of highly to moderately fractured lithologies with a lower hydraulic conductivity compared to the overlying weathered material. The permanent groundwater level resides in this unit and is about 20 to 30 meters below ground level. The groundwater flow direction in this unit is influenced by regional topography. The hydraulic conductivity of this aquifer was estimated to range from 0.45 to 0.8 m/d.
- Below a few tens of meters, the fracturing of the aquifer is less frequent and fractures less significant due to increased pressure. This results in an aquifer of lower hydraulic conductivity and very slow groundwater flow velocities.

12.5. Calibration of the Numerical Model

Water level data obtained during both the desktop review and hydrocensus was used to calibrate the numerical groundwater flow model. The results obtained during the calibrated model were used as initial conditions to simulate drawdown impacts. A fit was obtained for the measured groundwater levels (Figure 15).

All other parameters were unchanged, with values as listed in the paragraphs above. The calibration error statistics can be seen in Table 13. The head error was below 5 meters, which can be regarded as sufficient.

Table 12: Optimal Calibrated Aquifer Parameters

Aquifer	Model layer	Layer thickness (m)	Porosity (%)	Hydraulic conductivity (m/d)
Regolith	Layer 1	15	0.15	0.8
Highly Fractured Aquifer	Layer 2	30	0.1	0.45
Moderately Fractured Aquifer	Layer 3	35	0.05	0.009
Slightly Fractured Aquifer	Layer 4	20	0.02	0.0009

Table 13: Calibration Statistics

Description	Value
Mean Residual (Head)	-4.59
Mean Absolute Residual (Head)	5.80
Root Mean Squared Residual (Head)	6.90

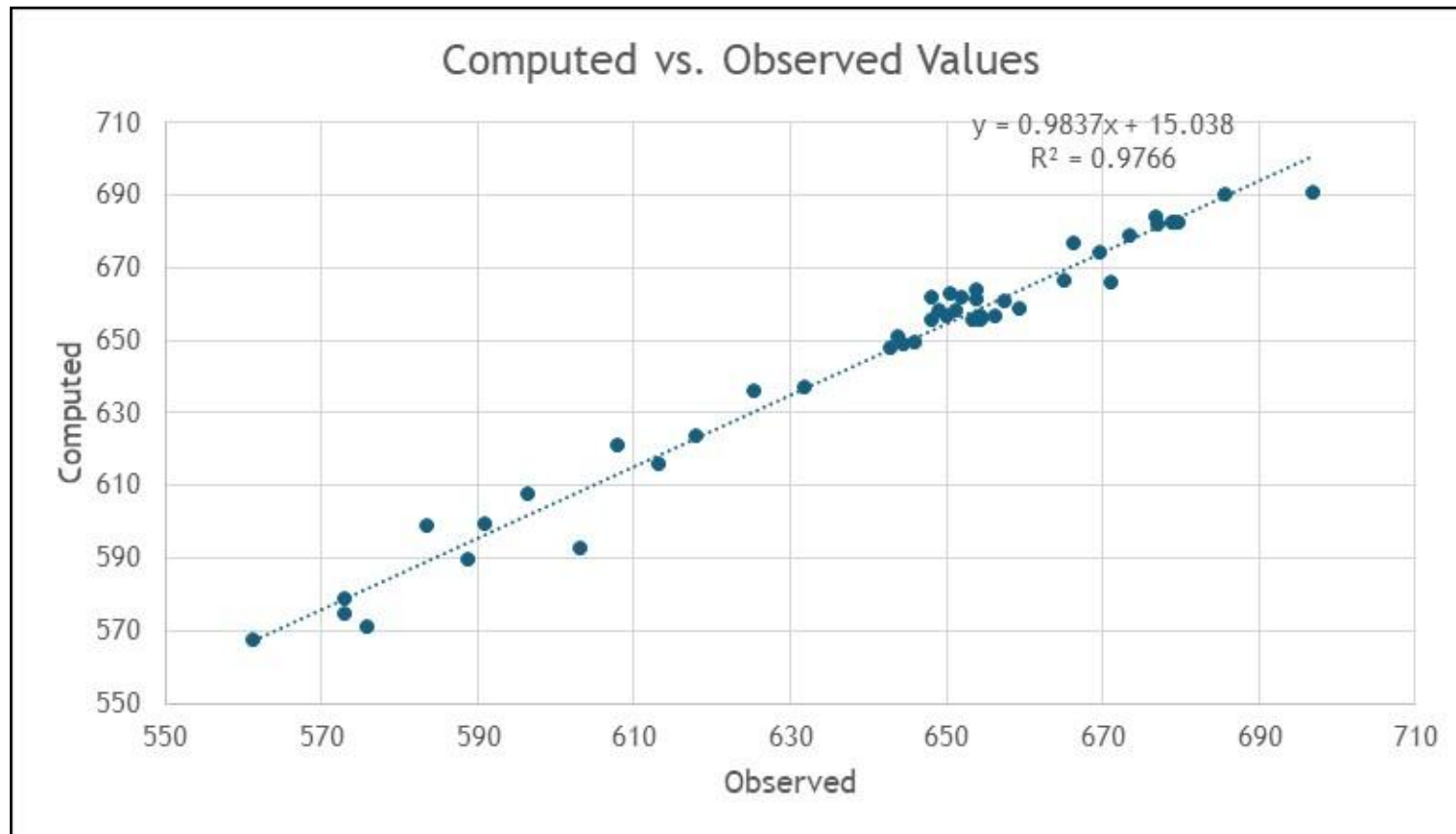


Figure 15: Water level Calibration Graph

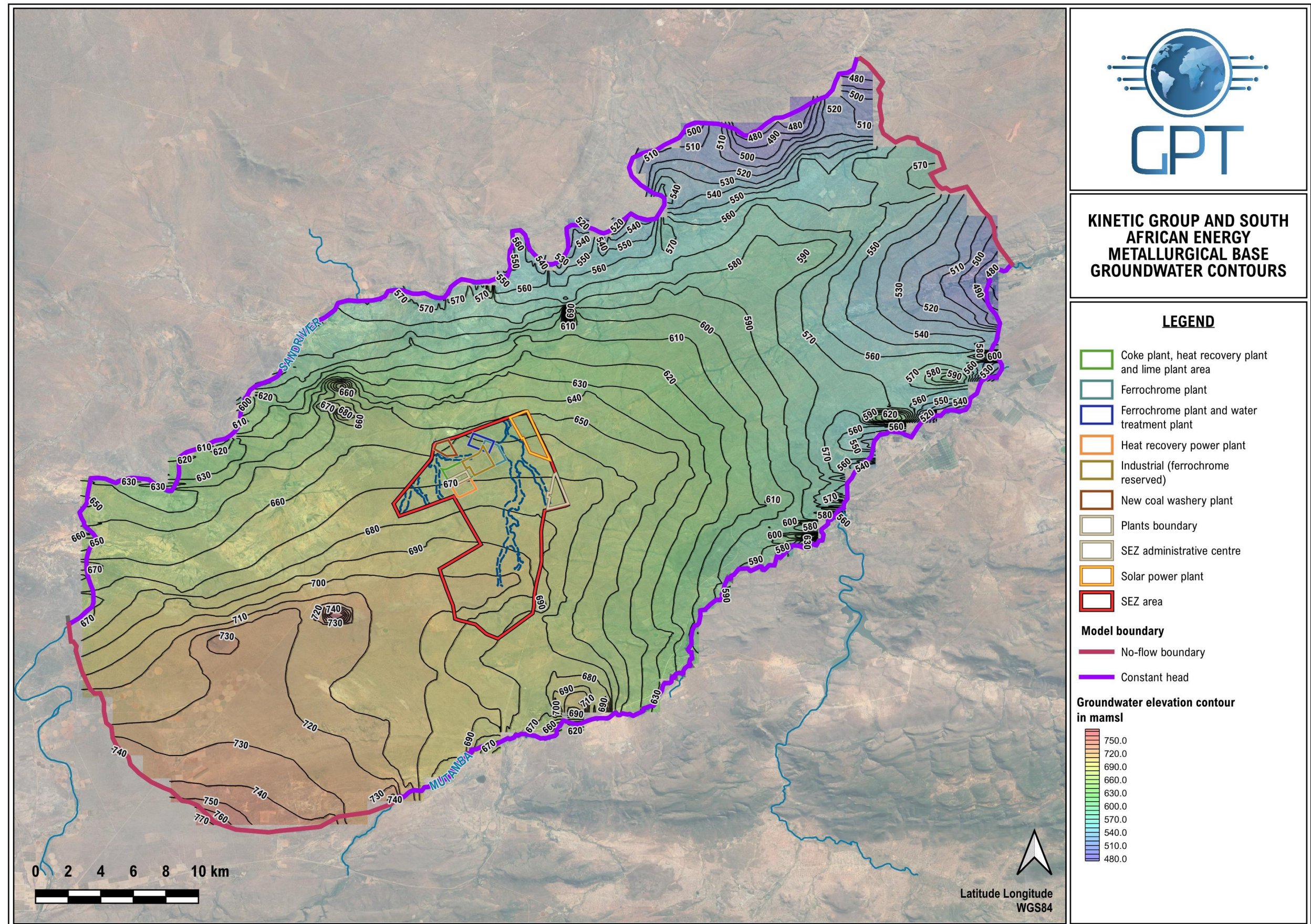


Figure 16: Modelled Groundwater Contours

13. HYDROGEOLOGICAL IMPACTS

It is the aim of this chapter to assess the likely hydrogeological impact that the proposed development might have on the groundwater regime.

The typical scenarios that will be considered in this section are:

- Construction Phase: The conditions expected to prevail during the construction phase.
- Operational Phase: The conditions expected to prevail during the operation of the site.
- Decommissioning Phase: Ceasing of onsite activities
- Cumulative Impact: The closing of operations as well as site clean-up and rehabilitation.

13.1. Operational Phase Impacts on Groundwater Quality

Groundwater quality is typically a primary consideration in hydrogeological assessments. However, as detailed in the Conceptual Site Model (CSM), the risk of contamination to the aquifer at this site is considered negligible due to the presence of a thick vadose zone, low recharge potential, and engineered control measures such as hardstanding areas and wastewater management systems. As such, no significant impact on the underlying aquifer is anticipated under normal operating conditions.

Nevertheless, it remains essential to maintain stringent preventative measures during both the construction and operational phases. While the risk of contaminant migration to groundwater is low, accidental spills, leaks, or poor handling of raw materials and waste must be prevented. All dirty water and process-related waste must be captured and in a dedicated wastewater management system, and regular inspections should be conducted to detect and rectify any potential leaks or containment failures.

Once operations commence, a waste classification study should be conducted to re-evaluate the potential risks associated with contaminant impacts. This assessment should include an estimation of waste volumes, potential leachate generation, and leaching characteristics to ensure that appropriate management and mitigation measures are in place.

13.2. Construction & Operational Phase Impacts on Groundwater Quantity

The primary anticipated effect on the groundwater system is the dewatering of the surrounding aquifer, which may result in a lowering of the local water table.

The construction and operational phases were both assumed to have a similar impact on groundwater quantity, primarily due to the relatively low yield of the production boreholes in comparison to the estimated water demand during operation. It is assumed that groundwater abstraction will occur continuously from the construction phase through to the operational phase, at rates recommended by Matukane & Associates (PTY) Ltd⁸.

The model was used to simulate drawdown from the existing groundwater levels at the site. The spatial extent of the predicted drawdown is illustrated in Figure 17, while Table 14 presents the corresponding declines in water levels at affected boreholes.

⁸ Matukane & Associates (PTY) Ltd (2021). Geohydrological Investigation for Groundwater Development MM-SEZ, Southern Area, Limpopo

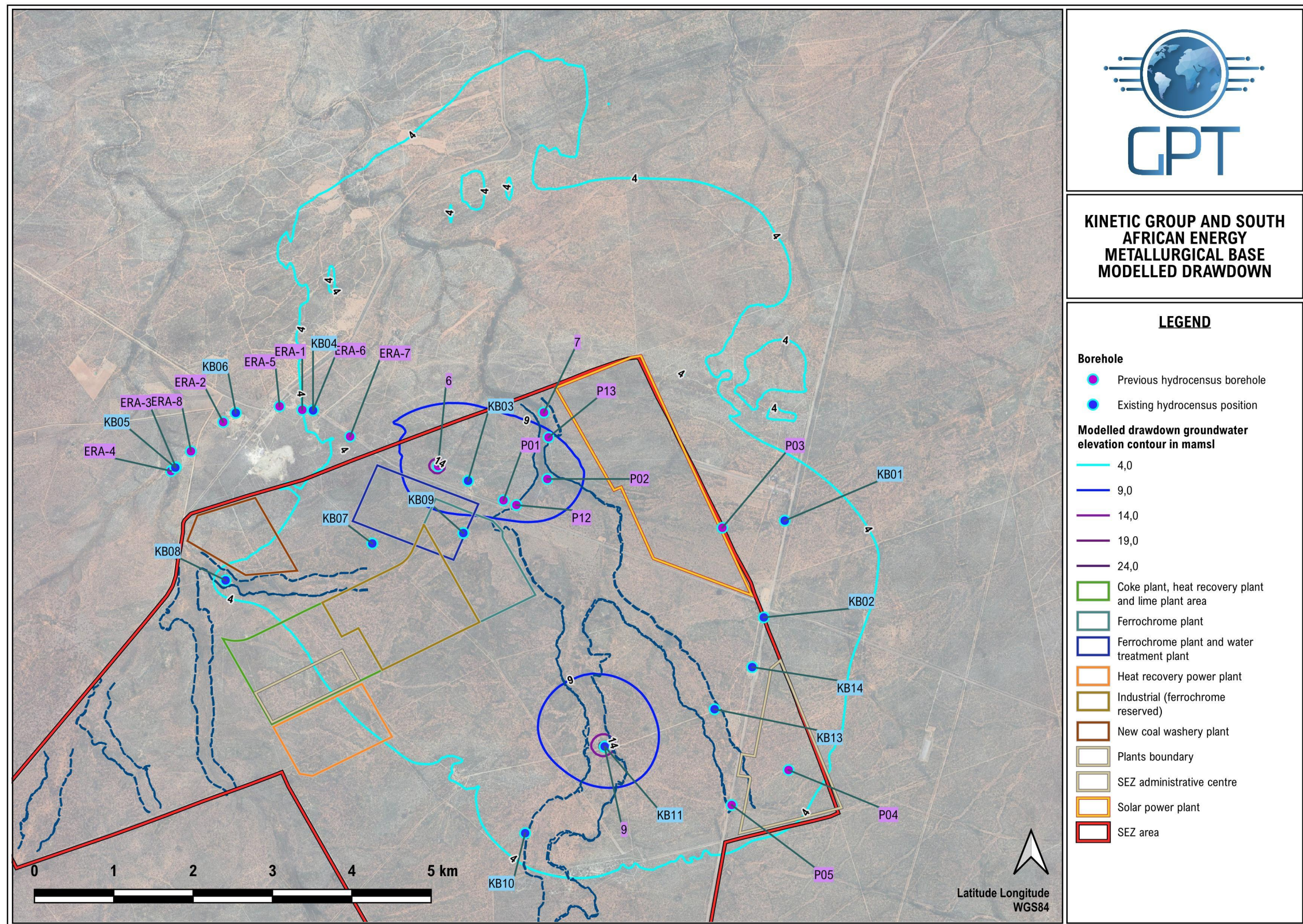


Figure 17: Modelled Drawdown

Table 14: Predicted Drawdown at affected Boreholes

BH	Drawdown (m)
Mopane Game Safaris	6.4
ERA-1	4
KB04	4.4
ERA-7	7
KB03	10.6
KB07	6
KB09	8.4
7	8.6
P13	9.3
P02	12.6
P01	9.5
P12	9.4
P03	6
KB01	5
KB02	5.9
KB14	6.1
KB13	6.9
P04	4.9
P05	5.5
KB10	4.8

The highest drawdown, exceeding 9 metres, is expected to remain confined within the site boundaries. Beyond the site, a broader area of influence is anticipated, extending northward, where water levels are projected to decline by approximately 4 to 9 metres. A number of boreholes that is used for domestic and livestock watering purposes will be affected.

13.3. Decommissioning Phase.

When abstraction activities from the boreholes cease, the estimated recovery period for groundwater levels to return to baseline conditions is approximately 34 years, based on a worst-case scenario. This recovery timeframe is influenced by several factors, with rainfall and natural recharge being the most significant.

During the decommissioning phase, all infrastructure, including hardstanding's, process areas, stockpile zones, and associated wastewater management systems, must be properly dismantled, cleaned, and managed to prevent any potential contamination of soil and groundwater. Residual materials, waste, and chemicals must be safely removed or disposed of in accordance with environmental regulations, and the site should be rehabilitated to ensure long-term protection of water quality.

14. IMPACTS QUANTIFICATION

14.1. ASSESSMENT CRITERIA

The criteria for the description and assessment of environmental impacts were drawn from the EIA Guidelines (DEAT, 1998) and as amended from time to time (DEAT, 2002)

The level of detail as depicted in the EIA Guidelines (DEAT, Environmental Impact Assessment Guidelines., 1998) (DEAT, Impact Significance, Integrated Environmental Management, Information series 5., 2002)) was fine-tuned by assigning specific values to each impact. In order to establish a coherent framework within which all impacts could be objectively assessed, it was necessary to establish a rating system, which was applied consistently to all the criteria. For such purposes each aspect was assigned a value, ranging from one (1) to five (5), depending on its definition. This assessment is a relative evaluation within the context of all the activities and the other impacts within the framework of the project.

An explanation of the impact assessment criteria is defined below.

Table 15: Impact Assessment Criteria

EXTENT	
Classification of the physical and spatial scale of the impact	
Footprint	The impacted area extends only as far as the activity, such as footprint occurring within the total site area.
Site	The impact could affect the whole, or a significant portion of the site.
Regional	The impact could affect the area including the neighbouring farms, the transport routes and the adjoining towns.
National	The impact could have an effect that expands throughout the country (South Africa).
International	Where the impact has international ramifications that extend beyond the boundaries of South Africa.
DURATION	
The lifetime of the impact that is measured in relation to the lifetime of the proposed development.	
Short term	The impact will either disappear with mitigation or will be mitigated through a natural process in a period shorter than that of the construction phase.
Short to Medium term	The impact will be relevant through to the end of a construction phase (1.5 years).
Medium term	The impact will last up to the end of the development phases, where after it will be entirely negated.
Long term	The impact will continue or last for the entire operational lifetime i.e. exceed 30 years of the development, but will be mitigated by direct human action or by natural processes thereafter.
Permanent	This is the only class of impact, which will be non-transitory. Mitigation either by man or natural process will not occur in such a way or in such a time span that the impact can be considered transient.
INTENSITY	
The intensity of the impact is considered by examining whether the impact is destructive or benign, whether it destroys the impacted environment, alters its functioning, or slightly alters the environment itself. The intensity is rated as	
Low	The impact alters the affected environment in such a way that the natural processes or functions are not affected.
Medium	The affected environment is altered, but functions and processes continue, albeit in a modified way.
High	Function or process of the affected environment is disturbed to the extent where it temporarily or permanently ceases.
PROBABILITY	
This describes the likelihood of the impacts actually occurring. The impact may occur for any length of time during the life cycle of the activity, and not at any given time. The classes are rated as follows:	
Improbable	The possibility of the impact occurring is none, due either to the circumstances, design or experience. The chance of this impact occurring is zero (0 %).
Possible	The possibility of the impact occurring is very low, due either to the circumstances, design or experience. The chances of this impact occurring is defined as 25 %.

Likely	There is a possibility that the impact will occur to the extent that provisions must therefore be made. The chances of this impact occurring is defined as 50 %.
Highly Likely	It is most likely that the impacts will occur at some stage of the development. Plans must be drawn up before carrying out the activity. The chances of this impact occurring is defined as 75 %.
Definite	The impact will take place regardless of any prevention plans, and only mitigation actions or contingency plans to contain the effect can be relied on. The chance of this impact occurring is defined as 100 %.

The status of the impacts and degree of confidence with respect to the assessment of the significance must be stated as follows:

- Status of the impact: A description as to whether the impact would be positive (a benefit), negative (a cost), or neutral.
- Degree of confidence in predictions: The degree of confidence in the predictions, based on the availability of information and specialist knowledge.

Other aspects to take into consideration in the specialist studies are:

- Impacts should be described both before and after the proposed mitigation and management measures have been implemented.
- All impacts should be evaluated for the full-life cycle of the proposed development, including construction, operation and decommissioning.
- The impact evaluation should take into consideration the cumulative effects associated with this and other facilities which are either developed or in the process of being developed in the region.
- The specialist studies must attempt to quantify the magnitude of potential impacts (direct and cumulative effects) and outline the rationale used. Where appropriate, national standards are to be used as a measure of the level of impact.

14.2. MITIGATION

The impacts that are generated by the development can be minimised if measures are implemented in order to reduce the impacts. The mitigation measures ensure that the development considers the environment and the predicted impacts in order to minimise impacts and achieve sustainable development.

14.2.1. DETERMINATION OF SIGNIFICANCE WITHOUT MITIGATION

Significance is determined through a synthesis of impact characteristics as described in the above paragraphs. It provides an indication of the importance of the impact in terms of both tangible and intangible characteristics. The significance of the impact “without mitigation” is the prime determinant of the nature and degree of mitigation required. Where the impact is positive, significance is noted as “positive”. Significance is rated on the following scale:

Table 16: Significance without mitigation

NO SIGNIFICANCE	The impact is not substantial and does not require any mitigation action.
LOW	The impact is of little importance but may require limited mitigation.

MEDIUM	The impact is of importance and is therefore considered to have a negative impact. Mitigation is required to reduce the negative impacts to acceptable levels.
HIGH	The impact is of major importance. Failure to mitigate, with the objective of reducing the impact to acceptable levels, could render the entire development option or entire project proposal unacceptable. Mitigation is therefore essential.

14.2.2. DETERMINATION OF SIGNIFICANCE WITH MITIGATION

Determination of significance refers to the foreseeable significance of the impact after the successful implementation of the necessary mitigation measures. Significance with mitigation is rated on the following scale:

Table 17: Significance with mitigation measures

NO SIGNIFICANCE	The impact will be mitigated to the point where it is regarded as insubstantial.
LOW	The impact will be mitigated to the point where it is of limited importance.
LOW TO MEDIUM	The impact is of importance, however, through the implementation of the correct mitigation measures such potential impacts can be reduced to acceptable levels.
MEDIUM	Notwithstanding the successful implementation of the mitigation measures, to reduce the negative impacts to acceptable levels, the negative impact will remain of significance. However, taken within the overall context of the project, the persistent impact does not constitute a fatal flaw.
MEDIUM TO HIGH	The impact is of major importance but through the implementation of the correct mitigation measures, the negative impacts will be reduced to acceptable levels.
HIGH	The impact is of major importance. Mitigation of the impact is not possible on a cost-effective basis. The impact is regarded as high importance and taken within the overall context of the project, is regarded as a fatal flaw. An impact regarded as high significance, after mitigation could render the entire development option or entire project proposal unacceptable.

14.3. ASSESSMENT WEIGHTING

Each aspect within an impact description was assigned a series of quantitative criteria. Such criteria are likely to differ during the different stages of the project's life cycle. In order to establish a defined base upon which it becomes feasible to make an informed decision, it was necessary to weigh and rank all the criteria.

14.3.1. RANKING, WEIGHTING AND SCALING

For each impact under scrutiny, a scaled weighting factor is attached to each respective impact (refer to Table 18). The purpose of assigning weights serves to highlight those aspects considered the most critical to the various stakeholders and ensure that each specialist's element of bias is taken into account. The weighting factor also provides a means whereby the impact assessor can successfully deal with the complexities that exist between the different impacts and associated aspect criteria.

Simply, such a weighting factor is indicative of the importance of the impact in terms of the potential effect that it could have on the surrounding environment. Therefore, the aspects considered to have a relatively high value will score a relatively higher weighting than that which is of lower importance.

Table 18: Description of assessment parameters with its respective weighting

EXTENT		DURATION		INTENSITY		PROBABILITY		WEIGHTING FACTOR (WF)		SIGNIFICANCE RATING (SR)	
Footprint	1	Short term	1	Low	1	Improbable	1	Low	1	Low	0-19
Site	2	Short to Medium	2			Possible	2	Low to Medium	2	Low to Medium	20-39
Regional	3	Medium term	3	Medium	3	Likely	3	Medium	3	Medium	40-59
National	4	Long term	4			Highly Likely	4	Medium to High	4	Medium to High	60-79
International	5	Permanent	5	High	5	Definite	5	High	5	High	80-100
MITIGATION EFFICIENCY (ME)						SIGNIFICANCE FOLLOWING MITIGATION (SFM)					
High				0.2		Low				0 - 19	
Medium to High				0.4		Low to Medium				20 - 39	
Medium				0.6		Medium				40 - 59	
Low to Medium				0.8		Medium to High				60 - 79	
Low				1.0		High				80 - 100	

14.3.1.1. Identifying the Potential Impacts Without Mitigation Measures (WOM)

Following the assignment of the necessary weights to the respective aspects, criteria are summed and multiplied by their assigned weightings, resulting in a value for each impact (prior to the implementation of mitigation measures).

Equation 1: Significance Rating (WOM) = (Extent + Intensity + Duration + Probability) x Weighting Factor

14.3.1.2. Identifying the Potential Impacts With Mitigation Measures (WM)

In order to gain a comprehensive understanding of the overall significance of the impact, after implementation of the mitigation measures, it was necessary to re-evaluate the impact.

14.3.1.2.1. Mitigation Efficiency (ME)

The most effective means of deriving a quantitative value of mitigated impacts is to assign each significance rating value (WOM) a mitigation efficiency (ME) rating (refer to Table 11 4). The allocation of such a rating is a measure of the efficiency and effectiveness, as identified through professional experience and empirical evidence of how effectively the proposed mitigation measures will manage the impact.

Thus, the lower the assigned value the greater the effectiveness of the proposed mitigation measures and subsequently, the lower the impacts with mitigation.

Equation 2: Significance Rating (WM) = Significance Rating (WOM) x Mitigation Efficiency or WM = WOM x ME

14.3.1.2.2. Significance Following Mitigation (SFM)

The significance of the impact after the mitigation measures are taken into consideration. The efficiency of the mitigation measure determines the significance of the impact. The level of impact is therefore seen in its entirety with all considerations taken into account.

The impact quantification was done using the procedures for the assessment and minimum criteria for reporting aquatic biodiversity in terms of sections 24(5)(a) and (h) and 44 of the National

Environmental Management Act, 1998. In terms of groundwater the proposed development impact on the functioning of the aquatic feature in terms of:

- base flows;
- quantity of water including change in the hydrological regime or hydroperiod of the aquatic ecosystem;
- quality of water;
- the location of areas not suitable for development, which are to be avoided during construction and operation, where relevant;
- additional environmental impacts expected from the proposed development
- the degree to which impacts and risks can be mitigated;
- the degree to which the impacts and risks can be reversed;
- the degree to which the impacts and risks can cause loss of irreplaceable resources;
- a suitable construction and operational buffer for the aquatic ecosystem, using the accepted methodologies;

14.4. ENVIRONMENTAL IMPACT ASSESSMENT (EIA) REGULATIONS, 2017

The Environmental Impact Assessment (EIA) 2014 Regulations [as amended] promulgated in terms of Sections 24 (5), 24M and 44 of the National Environmental Management Act, 1998 (Act No. 107 of 1998) [as amended] (NEMA), requires that all identified potential impacts associated with the proposed project be assessed in terms of their overall potential significance on the natural, social and economic environments. The criteria identified in the EIA Regulations (2014) include the following:

- Nature of the impact;
- Extent of the impact;
- Duration of the impact
- Probability of the impact occurring;
- Degree to which impact can be reversed;
- Degree to which impact may cause irreplaceable loss of resources;
- Degree to which the impact can be mitigated; and
- Cumulative impacts.

The impact assessment methodology described above determines the significance of potential impacts by evaluating the relevant temporal and spatial scales through the Extent, Magnitude, and Duration criteria. Although this method does not explicitly define each criterion individually, it combines them to provide an overall indication of significance. Using this approach, the significance of the hydrogeological impacts, along with the groundwater management and mitigation measures outlined in Section 13, was assessed, with the results presented in the table below.

Table 19: Significance Rating of Impact(s)

Phase	Impacts	Extent	Duration	Intensity	Probability	Weighting Factor	Significance Rating (WOM)		Mitigation Efficiency (ME)	Significance Rating (WM)	
Construction & Operational Phase	Groundwater Quantity	3	4	1	5	2	26	Low to Medium	1	26	Low to Medium
Operational Phase	Groundwater Quality	1	2	1	2	2	12	Low	0.8	9.6	Low
Decommission Phase	Groundwater Quality	1	2	1	2	2	12	Low	0.8	9.6	Low

15. GROUNDWATER MONITORING NETWORK

15.1. DESIGN CONSIDERATIONS

DWAF (1998) states that “A monitoring hole must be such that the section of the groundwater most likely to be polluted first, is suitably penetrated to ensure the most realistic monitoring result.”⁹

A groundwater monitoring network should contain monitoring positions which can assess the groundwater status at certain areas. The boreholes can be grouped classification according to the following purposes:

- **Source monitoring:** Monitoring boreholes are placed close to or in the source of contamination to evaluate the impact thereof on the groundwater chemistry.
- **Plume monitoring:** Monitoring boreholes are placed in the primary groundwater plume’s migration path to evaluate the migration rates and chemical changes along the pathway.
- **Impact monitoring:** Monitoring of possible impacts of contaminated groundwater on sensitive ecosystems or other receptors. These monitoring points are also installed as early warning systems for contamination break-through at areas of concern.
- **Background monitoring:** Background groundwater quality is essential to evaluate the impact of a specific action/pollution source on the groundwater chemistry.

15.2. MONITORING NETWORK RECOMMENDATIONS

Currently, no groundwater monitoring network exists at the site. Water level monitoring should be conducted at the abstraction boreholes, as well as at several additional boreholes located within the anticipated cone of depression. These boreholes were selected from the previous and current hydro-censuses, and access arrangements must be made with the respective landowners to facilitate data collection. The selected boreholes are listed in Table 20.

Once construction is complete and industrial activities commence, a limited number of monitoring boreholes should be installed downstream of the most likely contamination sources to verify and ensure that no groundwater pollution occurs. The selection of these monitoring locations should be coordinated with the waste classification assessment. It is important to note that a groundwater-monitoring network should also be dynamic. This means that the network should be extended over time to accommodate the migration of potential contaminants through the aquifer as well as the expansion of infrastructure and/or addition of possible pollution sources.

Table 20: Proposed Water Level Monitoring Boreholes

BH ID	Comment
6_	Production BH
P02	Production BH
KB08	Production BH
KB11	Production BH

⁹ Department of Water Affairs and Forestry (DWAF). (1998). Minimum Requirements for the Water Monitoring at Waste Management Facilities. CTP Book Printers. Cape Town.

KB06	Proposed WL Monitoring BH
KB04	Proposed WL Monitoring BH
KB03	Proposed WL Monitoring BH
P13	Proposed WL Monitoring BH
P03	Proposed WL Monitoring BH
KB02	Proposed WL Monitoring BH
KB13	Proposed WL Monitoring BH
P05	Proposed WL Monitoring BH
KB10	Proposed WL Monitoring BH

15.3. MONITORING FREQUENCY

During both the construction and operational phases, groundwater levels should be monitored bi-annually—once during the dry season (June-July) and once during the wet season (December-January).

In the operational and closure phases, it is recommended that both groundwater levels and groundwater quality be monitored bi-annually in the boreholes located downstream of the most likely contaminant sources and that water levels is continued to be measured in the Water Level monitoring boreholes.

15.4. MONITORING NETWORK PARAMETERS

15.5. Groundwater levels

The response of water levels to abstraction should be monitored. Static water levels are used to determine the flow direction and hydraulic gradient within an aquifer. Where possible all of borehole's water levels need to be recorded during each monitoring event.

15.6. Monitoring Constituents

The identification of the monitoring parameters is crucial and depends on the chemistry of possible pollution sources. They comprise a set of physical and/or chemical parameters (e.g. groundwater levels and predetermined organic and inorganic chemical constituents). Once a pollution indicator has been identified it can be used as a substitute to full analysis and therefore save costs. The use of pollution indicators should be validated on a regular basis in the different sampling positions. The parameters should be revised after each sampling event; some metals may be added to the analyses during the operational phase, especially if the pH drops.

15.6.1. Abbreviated analysis (pollution indicators)

Physical Parameters:

- Groundwater levels

Chemical Parameters:

- Laboratory analyses:
 - Major anions and cations (Cr^{3+} , Cr^6 , Ca, Na, Cl, SO_4 , PO_4 , NO_3)
 - Other parameters (pH & EC)

15.6.2. Full analysis

Physical Parameters:

Groundwater levels

Chemical Parameters:

Laboratory analyses:

- Anions and cations (Ca, Mg, Na, K, NO₃, Cl, SO₄, PO₄, F, Fe, Mn, Al, Cr³⁺, Cr⁶⁺ & Alkalinity)
- Other parameters (pH, EC, TDS)
- Petroleum hydrocarbon contaminants (where applicable, near workshops and petroleum handling facilities)
- Sewage related contaminants (E.Coli, faecal coliforms) in borehole in proximity to septic tanks or sewage plants.

16. CONCLUSIONS AND RECOMMENDATIONS

Geo Pollution Technologies (Pty) Ltd (GPT) was appointed by Gudani Consulting (Pty) Ltd to conduct a geohydrological study with a Numerical Flow Model for the MMSEZ site near Mopane. The area is situated in quaternary catchment A71K and A80F.

The MMSEZ site area is located adjacent to the South and East of Mopane in the Limpopo Province. The site area is characterised by a relatively flat topography that is gently sloping upwards to the south of the site. Small hills with moderate relief are present at both the norther and southern borders of the site. The average slope across the site is in the order of 1.3 :100 (0.013) with a maximum of 15.5: 100 at the Sothern hills.

The average annual rainfall (1970-2024) for the general site location is 325.8 mm per year, with the high rainfall months between November and March.

The investigated area falls within the 2228 Alldays 1:250 000 geology series maps. The site is predominantly underlain by Quaternary sandy soils, which form the main surface cover. Bedrock geology comprises outcrops of the Beit Bridge Complex (Gambu Group) in the central, northern, and southern areas, characterized by calc-silicate rocks, marble, leucogneisses, hornblende granitoid gneiss, metaquartzite, and amphibolite. South of the northern Gambu outcrop and beneath a fault line, the Karoo Supergroup is present, consisting of undifferentiated Mikambeni and Madzaringwe Formations with mudstone, shale, carbonaceous shale, sandstone, coal seams, and basal diamictite.

According to the 1:500 000 General Hydrogeological Map the rocks underlying the site typically act as secondary aquifers (intergranular and fractured rock aquifers). However, the multi-layered weathering system present on these rocks could prove to have up to two aquifer systems present in the form of a shallow, saprolitic aquifer with a weathered, intergranular soft rock base associated with the contact of fresh bedrock and the weathering zone; and an intergranular & fractured bedrock aquifer.

The GDT calculated a aquifer vulnerability value of 34%, which is medium.

A hydrocensus was conducted on the 27th March 2025. A total of 14 locations were visited based on the gathered information. Out of these, only 11 locations had boreholes where water level measurements could be taken. Three boreholes were found to be either dry or blocked. The water levels ranged between 17.34 mbgl and 33.42 mbgl with an average of 25.95 mbgl. The general groundwater flow direction is to the north of the site.

Based on information collected during the hydrocensus it can be concluded that the aquifer system in the study area can be classified as a Sole Aquifer System.

Most boreholes show exceedances in several water quality parameters based on drinking, domestic, and industrial use standards:

SANS Drinking Water

- TDS and EC exceed the aesthetic limits for KB03, 06, 07, 08 and 09.
- Sulphate exceeds the acute health limit in KB07
- Fluoride exceeds the chronic health limit in KB03, 06, 08 and 09.

- Sodium and Chloride both exceed aesthetic limits in KB03, 06, 07, 08 and 09.4
- E coli is detected in both KB08 and KB11
- Aluminium exceeds the operational limit in KB11.
- Total coliforms exceed the operational limits in all analysed boreholes.

DWAF Domestic Use

- Aluminium exceed the TWQR in KB11
- Calcium exceeds the TWQR in KN06, 07, 08 and 09.
- Chloride exceed the TWQR in KB06 and 07.
- Fluoride exceed the TWQR in KB03, 06, 08 and 09.
- Magnesium exceed the TWQR in KB03, 06, 07, 08 and 09.
- Sodium exceed the TWQR in KB03, 06, 07, 08 and 09.
- Sulphate exceed the TWQR in KB07
- TDS exceed the TWQR in KB03, 06, 07, 08 and 09

DWAF Industrial Use

- Total Alkalinity exceed the TWQR in KB006, 07, 08, 09 and 11.
- Chloride exceed the TWQR in all analysed boreholes.
- Sulphate exceed the TWQR in KB06, 07, 08 and 09.
- TDS exceed the TWQR in all analysed boreholes.

Based on the numerical flow and transport modelling performed, the following hydrogeological impacts were identified:

4. Groundwater Quantity:

Production-related groundwater abstraction during both construction and operational phases are modelled to lower the water table in the vicinity of the production boreholes. In a worst-case scenario, modelled drawdowns exceed 9 metres within the site boundaries. However, a broader zone of influence is anticipated to extend northward, with water level declines of approximately 4 to 9 metres. Several boreholes used for domestic and livestock watering purposes are likely to be impacted.

Predicted drawdown at affected boreholes:

BH	Drawdown (m)
Mopane Game Safaris	6.4
ERA-1	4
KB04	4.4
ERA-7	7
KB03	10.6
KB07	6
KB09	8.4

7	8.6
P13	9.3
P02	12.6
P01	9.5
P12	9.4
P03	6
KB01	5
KB02	5.9
KB14	6.1
KB13	6.9
P04	4.9
P05	5.5
KB10	4.8

5. Groundwater Quality:

The risk of contamination to the aquifer at this site is considered negligible due to the presence of a thick vadose zone, low recharge potential, and engineered control measures such as hardstanding areas and wastewater management systems. As such, no significant impact on the underlying aquifer is anticipated under normal operating conditions.

6. Decommission

When abstraction activities from the boreholes cease, the estimated recovery period for groundwater levels to return to baseline conditions is approximately 34 years , based on a worst-case scenario. This recovery timeframe is influenced by several factors, with rainfall and natural recharge being the most significant

Recommendations

- Conduct a detailed assessment to identify potential contaminant sources. The study must include determining the types of chemical substances used during operations and performing a waste classification study on industrial materials and waste generated at the site. This should be done once the planned industries become operational. The assessment should incorporate the identification of potential contamination locations and improve understanding of the nature, extent, and environmental impact of waste production.
- Conduct bi-annual water level monitoring at the abstraction boreholes and additional selected boreholes within the anticipated cone of depression. (Once abstraction begins)
- After construction and the start of industrial activities, install a limited number of monitoring boreholes downstream of likely contamination sources. Coordinate the selection of these downstream monitoring locations with the waste classification assessment. These boreholes should be monitored on a bi-annual basis according to the report recommendations for analysis.

APPENDIX I: LABORATORY CERTIFICATE OF ANALYSIS

**TEST REPORT****56235A****Client and Project Information**

Client: Geo Pollution Technologies	Attention: Willem van Biljon	Project number: PCZBH/24/12860
Address: Unit B 203, Buchanan Square, 160 Sir Lowry	Tel: (021) 462-6822	Project name: Blackheath Soil
Cape Town	Email: willem@gptglobal.com	Sampling - Added analysis
7925		

Sample Information

Sample ID: SS01	Matrix: Distilled Water	Date Received: 2025/02/12
Units: mg/l [ppm] (unless stated elsewhere)	Container: Glass & Plastic	Date Analysed: 2025/02/14
		Date Issued: 2025/02/20

Cations and Metals

As	<0.05	Fe	1.03	Zn	<0.05
Cd	<0.05	Mn	<0.05		
Co	<0.05	Ni	<0.05		
Cr(III)*	<0.05	Pb	<0.05		
Cu	<0.05	V	<0.05		

Anions (Discrete Analyser)

SO4	<2
NO3 as N	<0.5

Other Parameters

Hg*	<0.005
Cr(VI)*	<0.05
NH3 as N*	<0.02

Disclaimers

- 1) The results only relate to the test items provided, in the condition as received.
- 2) This report may not be reproduced, except in full, without the prior written approval of the laboratory.
- 3) Parameters marked " * " are not included in the SANAS Schedule of Accreditation for this laboratory.
- 4) A = Concentration outside calibration range, ** = Outsourced analysis, UTD = Unable to Determine, RTF = Results To Follow, NR = Not Requested.
- 5) Methods: EPL-WL-001 (Conductivity), EPL-WL-002 (Alkalinity), EPL-WL-003 (pH), EPL-WL-004 (TDS), EPL-WL-005 (Anions by IC), EPL-WL-006 (Cations by IC), EPL-WL-007 (Metals), EPL-WL-008 (Cr(VI)), EPL-WL-009 (TOC), EPL-WL-010 (Hg by DMA), EPL-WL-011 (Anions by Discrete Analyser), EPL-HPLC-001 (Formaldehyde), EPL-ML-001 (Micro).
- 6) Uncertainty of measurement for all methods included in the SANAS Schedule of Accreditation is available on request.
- 7) Cr(III) and Cr(VI) are assumed to be the two major oxidative states of Chromium.

Miche Kannemeyer
 Authorised Signatory

Page 1 of 9

www.epl.co.za

13 Sovereign Drive Route21 Corporate Park Irene South Africa

Tel: +27 12 345 1004 info@epl.co.za

**TEST REPORT****56235A****Client and Project Information**

Client: Geo Pollution Technologies	Attention: Willem van Biljon	Project number: PCZBH/24/12860
Address: Unit B 203, Buchanan Square, 160 Sir Lowry Cape Town 7925	Tel: (021) 462-6822	Project name: Blackheath Soil Sampling - Added analysis
	Email: willem@gptglobal.com	

Sample Information

Sample ID: SS03	Matrix: Distilled Water	Date Received: 2025/02/12
Units: mg/l [ppm] (unless stated elsewhere)	Container: Glass & Plastic	Date Analysed: 2025/02/14
		Date Issued: 2025/02/20

Cations and Metals

As	<0.05	Fe	2.68	Zn	0.29
Cd	<0.05	Mn	0.17		
Co	<0.05	Ni	<0.05		
Cr(III)*	<0.05	Pb	<0.05		
Cu	<0.05	V	<0.05		

Anions (Discrete Analyser)

SO4	<2
NO3 as N	<0.5

Other Parameters

Hg*	<0.005
Cr(VI)*	<0.05
NH3 as N*	<0.02

Disclaimers

- 1) The results only relate to the test items provided, in the condition as received.
- 2) This report may not be reproduced, except in full, without the prior written approval of the laboratory.
- 3) Parameters marked " * " are not included in the SANAS Schedule of Accreditation for this laboratory.
- 4) A = Concentration outside calibration range, ** = Outsourced analysis, UTD = Unable to Determine, RTF = Results To Follow, NR = Not Requested.
- 5) Methods: EPL-WL-001 (Conductivity), EPL-WL-002 (Alkalinity), EPL-WL-003 (pH), EPL-WL-004 (TDS), EPL-WL-005 (Anions by IC), EPL-WL-006 (Cations by IC), EPL-WL-007 (Metals), EPL-WL-008 (Cr(VI)), EPL-WL-009 (TOC), EPL-WL-010 (Hg by DMA), EPL-WL-011 (Anions by Discrete Analyser), EPL-HPLC-001 (Formaldehyde), EPL-ML-001 (Micro).
- 6) Uncertainty of measurement for all methods included in the SANAS Schedule of Accreditation is available on request.
- 7) Cr(III) and Cr(VI) are assumed to be the two major oxidative states of Chromium.

Miche Kannemeyer
Authorised Signatory

Page 2 of 9



TEST REPORT

56235A

Client and Project Information

Client: Geo Pollution Technologies	Attention: Willem van Biljon	Project number: PCZBH/24/12860
Address: Unit B 203, Buchanan Square, 160 Sir Lowry Cape Town 7925	Tel: (021) 462-6822	Project name: Blackheath Soil Sampling - Added analysis
	Email: willem@gptglobal.com	

Sample Information

Sample ID: SS04	Matrix: Distilled Water	Date Received: 2025/02/12
Units: mg/l [ppm] (unless stated elsewhere)	Container: Glass & Plastic	Date Analysed: 2025/02/14
		Date Issued: 2025/02/20

Cations and Metals

As	<0.05	Fe	0.71	Zn	0.23
Cd	<0.05	Mn	0.24		
Co	<0.05	Ni	<0.05		
Cr(III)*	<0.05	Pb	<0.05		
Cu	<0.05	V	<0.05		

Anions (Discrete Analyser)

SO4	8.19
NO3 as N	<0.5

Other Parameters

Hg*	<0.005
Cr(VI)*	<0.05
NH3 as N*	<0.02

Disclaimers

- 1) The results only relate to the test items provided, in the condition as received.
- 2) This report may not be reproduced, except in full, without the prior written approval of the laboratory.
- 3) Parameters marked " * " are not included in the SANAS Schedule of Accreditation for this laboratory.
- 4) A = Concentration outside calibration range, ** = Outsourced analysis, UTD = Unable to Determine, RTF = Results To Follow, NR = Not Requested.
- 5) Methods: EPL-WL-001 (Conductivity), EPL-WL-002 (Alkalinity), EPL-WL-003 (pH), EPL-WL-004 (TDS), EPL-WL-005 (Anions by IC), EPL-WL-006 (Cations by IC), EPL-WL-007 (Metals), EPL-WL-008 (Cr(VI)), EPL-WL-009 (TOC), EPL-WL-010 (Hg by DMA), EPL-WL-011 (Anions by Discrete Analyser), EPL-HPLC-001 (Formaldehyde), EPL-ML-001 (Micro).
- 6) Uncertainty of measurement for all methods included in the SANAS Schedule of Accreditation is available on request.
- 7) Cr(III) and Cr(VI) are assumed to be the two major oxidative states of Chromium.

Miche Kannemeyer
Authorised Signatory

Page 3 of 9

www.epl.co.za

13 Sovereign Drive Route21 Corporate Park Irene South Africa

Tel: +27 12 345 1004 info@epl.co.za

**TEST REPORT****56235A****Client and Project Information**

Client: Geo Pollution Technologies	Attention: Willem van Biljon	Project number: PCZBH/24/12860
Address: Unit B 203, Buchanan Square, 160 Sir Lowry Cape Town 7925	Tel: (021) 462-6822	Project name: Blackheath Soil Sampling - Added analysis
	Email: willem@gptglobal.com	

Sample Information

Sample ID: SS05	Matrix: Distilled Water	Date Received: 2025/02/12
Units: mg/l [ppm] (unless stated elsewhere)	Container: Glass & Plastic	Date Analysed: 2025/02/14
		Date Issued: 2025/02/20

Cations and Metals

As	<0.05	Fe	1.19	Zn	<0.05
Cd	<0.05	Mn	0.13		
Co	<0.05	Ni	<0.05		
Cr(III)*	<0.05	Pb	<0.05		
Cu	<0.05	V	<0.05		

Anions (Discrete Analyser)

SO4	10.40
NO3 as N	<0.5

Other Parameters

Hg*	<0.005
Cr(VI)*	<0.05
NH3 as N*	<0.02

Disclaimers

- 1) The results only relate to the test items provided, in the condition as received.
- 2) This report may not be reproduced, except in full, without the prior written approval of the laboratory.
- 3) Parameters marked " * " are not included in the SANAS Schedule of Accreditation for this laboratory.
- 4) A = Concentration outside calibration range, ** = Outsourced analysis, UTD = Unable to Determine, RTF = Results To Follow, NR = Not Requested.
- 5) Methods: EPL-WL-001 (Conductivity), EPL-WL-002 (Alkalinity), EPL-WL-003 (pH), EPL-WL-004 (TDS), EPL-WL-005 (Anions by IC), EPL-WL-006 (Cations by IC), EPL-WL-007 (Metals), EPL-WL-008 (Cr(VI)), EPL-WL-009 (TOC), EPL-WL-010 (Hg by DMA), EPL-WL-011 (Anions by Discrete Analyser), EPL-HPLC-001 (Formaldehyde), EPL-ML-001 (Micro).
- 6) Uncertainty of measurement for all methods included in the SANAS Schedule of Accreditation is available on request.
- 7) Cr(III) and Cr(VI) are assumed to be the two major oxidative states of Chromium.

Miche Kannemeyer
Authorised Signatory

Page 4 of 9

www.epl.co.za

13 Sovereign Drive Route21 Corporate Park Irene South Africa

Tel: +27 12 345 1004 info@epl.co.za



TEST REPORT 56235A

Client and Project Information

Client: Geo Pollution Technologies	Attention: Willem van Biljon	Project number: PCZBH/24/12860
Address: Unit B 203, Buchanan Square, 160 Sir Lowry Cape Town 7925	Tel: (021) 462-6822	Project name: Blackheath Soil Sampling - Added analysis
	Email: willem@gptglobal.com	

Sample Information

Sample ID: SS06	Matrix: Distilled Water	Date Received: 2025/02/12
Units: mg/l [ppm] (unless stated elsewhere)	Container: Glass & Plastic	Date Analysed: 2025/02/14
		Date Issued: 2025/02/20

Cations and Metals

As	<0.05	Fe	1.02	Zn	0.06
Cd	<0.05	Mn	0.08		
Co	<0.05	Ni	<0.05		
Cr(III)*	<0.05	Pb	<0.05		
Cu	<0.05	V	<0.05		

Anions (Discrete Analyser)

SO4	65.52
NO3 as N	<0.5

Other Parameters

Hg*	<0.005
Cr(VI)*	<0.05
NH3 as N*	<0.02

Disclaimers

- 1) The results only relate to the test items provided, in the condition as received.
- 2) This report may not be reproduced, except in full, without the prior written approval of the laboratory.
- 3) Parameters marked " * " are not included in the SANAS Schedule of Accreditation for this laboratory.
- 4) A = Concentration outside calibration range, ** = Outsourced analysis, UTD = Unable to Determine, RTF = Results To Follow, NR = Not Requested.
- 5) Methods: EPL-WL-001 (Conductivity), EPL-WL-002 (Alkalinity), EPL-WL-003 (pH), EPL-WL-004 (TDS), EPL-WL-005 (Anions by IC), EPL-WL-006 (Cations by IC), EPL-WL-007 (Metals), EPL-WL-008 (Cr(VI)), EPL-WL-009 (TOC), EPL-WL-010 (Hg by DMA), EPL-WL-011 (Anions by Discrete Analyser), EPL-HPLC-001 (Formaldehyde), EPL-ML-001 (Micro).
- 6) Uncertainty of measurement for all methods included in the SANAS Schedule of Accreditation is available on request.
- 7) Cr(III) and Cr(VI) are assumed to be the two major oxidative states of Chromium.

Miche Kannemeyer
Authorised Signatory

Page 5 of 9

www.epl.co.za

13 Sovereign Drive Route21 Corporate Park Irene South Africa

Tel: +27 12 345 1004 info@epl.co.za

**TEST REPORT****56235A****Client and Project Information**

Client: Geo Pollution Technologies	Attention: Willem van Biljon	Project number: PCZBH/24/12860
Address: Unit B 203, Buchanan Square, 160 Sir Lowry Cape Town 7925	Tel: (021) 462-6822	Project name: Blackheath Soil Sampling - Added analysis
	Email: willem@gptglobal.com	

Sample Information

Sample ID: SS07	Matrix: Distilled Water	Date Received: 2025/02/12
Units: mg/l [ppm] (unless stated elsewhere)	Container: Glass & Plastic	Date Analysed: 2025/02/14
		Date Issued: 2025/02/20

Cations and Metals

As	<0.05	Fe	783.70	Zn	0.22
Cd	0.10	Mn	2.74		
Co	<0.05	Ni	0.15		
Cr(III)*	0.24	Pb	<0.05		
Cu	0.14	V	<0.05		

Anions (Discrete Analyser)

SO4	2093.00
NO3 as N	<0.5

Other Parameters

Hg*	<0.005
Cr(VI)*	<0.05
NH3 as N*	0.24

Disclaimers

- 1) The results only relate to the test items provided, in the condition as received.
- 2) This report may not be reproduced, except in full, without the prior written approval of the laboratory.
- 3) Parameters marked " * " are not included in the SANAS Schedule of Accreditation for this laboratory.
- 4) A = Concentration outside calibration range, ** = Outsourced analysis, UTD = Unable to Determine, RTF = Results To Follow, NR = Not Requested.
- 5) Methods: EPL-WL-001 (Conductivity), EPL-WL-002 (Alkalinity), EPL-WL-003 (pH), EPL-WL-004 (TDS), EPL-WL-005 (Anions by IC), EPL-WL-006 (Cations by IC), EPL-WL-007 (Metals), EPL-WL-008 (Cr(VI)), EPL-WL-009 (TOC), EPL-WL-010 (Hg by DMA), EPL-WL-011 (Anions by Discrete Analyser), EPL-HPLC-001 (Formaldehyde), EPL-ML-001 (Micro).
- 6) Uncertainty of measurement for all methods included in the SANAS Schedule of Accreditation is available on request.
- 7) Cr(III) and Cr(VI) are assumed to be the two major oxidative states of Chromium.

Miche Kannemeyer
Authorised Signatory

Page 6 of 9

www.epl.co.za

13 Sovereign Drive Route21 Corporate Park Irene South Africa

Tel: +27 12 345 1004 info@epl.co.za

**TEST REPORT****56235A****Client and Project Information**

Client: Geo Pollution Technologies	Attention: Willem van Biljon	Project number: PCZBH/24/12860
Address: Unit B 203, Buchanan Square, 160 Sir Lowry Cape Town 7925	Tel: (021) 462-6822	Project name: Blackheath Soil Sampling - Added analysis
	Email: willem@gptglobal.com	

Sample Information

Sample ID: SS08	Matrix: Distilled Water	Date Received: 2025/02/12
Units: mg/l [ppm] (unless stated elsewhere)	Container: Glass & Plastic	Date Analysed: 2025/02/14
		Date Issued: 2025/02/20

Cations and Metals

As	<0.05	Fe	0.78	Zn	<0.05
Cd	<0.05	Mn	<0.05		
Co	<0.05	Ni	<0.05		
Cr(III)*	<0.05	Pb	<0.05		
Cu	<0.05	V	<0.05		

Anions (Discrete Analyser)

SO4	1977.00
NO3 as N	<0.5

Other Parameters

Hg*	<0.005
Cr(VI)*	<0.05
NH3 as N*	<0.02

Disclaimers

- 1) The results only relate to the test items provided, in the condition as received.
- 2) This report may not be reproduced, except in full, without the prior written approval of the laboratory.
- 3) Parameters marked " * " are not included in the SANAS Schedule of Accreditation for this laboratory.
- 4) A = Concentration outside calibration range, ** = Outsourced analysis, UTD = Unable to Determine, RTF = Results To Follow, NR = Not Requested.
- 5) Methods: EPL-WL-001 (Conductivity), EPL-WL-002 (Alkalinity), EPL-WL-003 (pH), EPL-WL-004 (TDS), EPL-WL-005 (Anions by IC), EPL-WL-006 (Cations by IC), EPL-WL-007 (Metals), EPL-WL-008 (Cr(VI)), EPL-WL-009 (TOC), EPL-WL-010 (Hg by DMA), EPL-WL-011 (Anions by Discrete Analyser), EPL-HPLC-001 (Formaldehyde), EPL-ML-001 (Micro).
- 6) Uncertainty of measurement for all methods included in the SANAS Schedule of Accreditation is available on request.
- 7) Cr(III) and Cr(VI) are assumed to be the two major oxidative states of Chromium.

Miche Kannemeyer
 Authorised Signatory

Page 7 of 9

www.epl.co.za

13 Sovereign Drive Route21 Corporate Park Irene South Africa

Tel: +27 12 345 1004 info@epl.co.za



TEST REPORT 56235A

Client and Project Information

Client: Geo Pollution Technologies	Attention: Willem van Biljon	Project number: PCZBH/24/12860
Address: Unit B 203, Buchanan Square, 160 Sir Lowry Cape Town 7925	Tel: (021) 462-6822	Project name: Blackheath Soil Sampling - Added analysis
	Email: willem@gptglobal.com	

Sample Information

Sample ID: SS09	Matrix: Distilled Water	Date Received: 2025/02/12
Units: mg/l [ppm] (unless stated elsewhere)	Container: Glass & Plastic	Date Analysed: 2025/02/14
		Date Issued: 2025/02/20

Cations and Metals

As	<0.05	Fe	1.27	Zn	<0.05
Cd	<0.05	Mn	0.35		
Co	<0.05	Ni	<0.05		
Cr(III)*	<0.05	Pb	<0.05		
Cu	<0.05	V	<0.05		

Anions (Discrete Analyser)

SO4	5.20
NO3 as N	<0.5

Other Parameters

Hg*	<0.005
Cr(VI)*	<0.05
NH3 as N*	<0.02

Disclaimers

- 1) The results only relate to the test items provided, in the condition as received.
- 2) This report may not be reproduced, except in full, without the prior written approval of the laboratory.
- 3) Parameters marked " * " are not included in the SANAS Schedule of Accreditation for this laboratory.
- 4) A = Concentration outside calibration range, ** = Outsourced analysis, UTD = Unable to Determine, RTF = Results To Follow, NR = Not Requested.
- 5) Methods: EPL-WL-001 (Conductivity), EPL-WL-002 (Alkalinity), EPL-WL-003 (pH), EPL-WL-004 (TDS), EPL-WL-005 (Anions by IC), EPL-WL-006 (Cations by IC), EPL-WL-007 (Metals), EPL-WL-008 (Cr(VI)), EPL-WL-009 (TOC), EPL-WL-010 (Hg by DMA), EPL-WL-011 (Anions by Discrete Analyser), EPL-HPLC-001 (Formaldehyde), EPL-ML-001 (Micro).
- 6) Uncertainty of measurement for all methods included in the SANAS Schedule of Accreditation is available on request.
- 7) Cr(III) and Cr(VI) are assumed to be the two major oxidative states of Chromium.

Miche Kannemeyer
Authorised Signatory

Page 8 of 9

www.epl.co.za

13 Sovereign Drive Route21 Corporate Park Irene South Africa

Tel: +27 12 345 1004 info@epl.co.za

**TEST REPORT****56235A****Client and Project Information**

Client: Geo Pollution Technologies	Attention: Willem van Biljon	Project number: PCZBH/24/12860
Address: Unit B 203, Buchanan Square, 160 Sir Lowry	Tel: (021) 462-6822	Project name: Blackheath Soil
Cape Town	Email: willem@gptglobal.com	Sampling - Added analysis
7925		

Sample Information

Sample ID: SS10	Matrix: Distilled Water	Date Received: 2025/02/12
Units: mg/l [ppm] (unless stated elsewhere)	Container: Glass & Plastic	Date Analysed: 2025/02/14
		Date Issued: 2025/02/20

Cations and Metals

As	<0.05	Fe	2.98	Zn	<0.05
Cd	<0.05	Mn	0.07		
Co	<0.05	Ni	<0.05		
Cr(III)*	<0.05	Pb	<0.05		
Cu	<0.05	V	<0.05		

Anions (Discrete Analyser)

SO4	77.02
NO3 as N	<0.5

Other Parameters

Hg*	<0.005
Cr(VI)*	<0.05
NH3 as N*	<0.02

Disclaimers

- 1) The results only relate to the test items provided, in the condition as received.
- 2) This report may not be reproduced, except in full, without the prior written approval of the laboratory.
- 3) Parameters marked " * " are not included in the SANAS Schedule of Accreditation for this laboratory.
- 4) A = Concentration outside calibration range, ** = Outsourced analysis, UTD = Unable to Determine, RTF = Results To Follow, NR = Not Requested.
- 5) Methods: EPL-WL-001 (Conductivity), EPL-WL-002 (Alkalinity), EPL-WL-003 (pH), EPL-WL-004 (TDS), EPL-WL-005 (Anions by IC), EPL-WL-006 (Cations by IC), EPL-WL-007 (Metals), EPL-WL-008 (Cr(VI)), EPL-WL-009 (TOC), EPL-WL-010 (Hg by DMA), EPL-WL-011 (Anions by Discrete Analyser), EPL-HPLC-001 (Formaldehyde), EPL-ML-001 (Micro).
- 6) Uncertainty of measurement for all methods included in the SANAS Schedule of Accreditation is available on request.
- 7) Cr(III) and Cr(VI) are assumed to be the two major oxidative states of Chromium.

Miche Kannemeyer
Authorised Signatory

Page 9 of 9

www.epl.co.za

13 Sovereign Drive Route21 Corporate Park Irene South Africa

Tel: +27 12 345 1004 info@epl.co.za

APPENDIX II: NUMERICAL MODEL METHODOLOGY AND SETUP

ELEVATION DATA

Elevation data is crucial for developing a credible numerical model, as the groundwater table in its natural state tend to follow topography.

The best currently available elevation data is derived from the STRM (Shuttle Radar Tomography Mission) DEM (Digital Elevation Model) data. The SRTM consisted of a specially modified radar system that flew on board the Space Shuttle Endeavour during an 11-day mission in February of 2000, during which elevation data was obtained on a near-global scale to generate the most complete high-resolution digital topographic database of Earth¹⁰. Data is available on a grid of 30 metres in the USA and 90 metres in all other areas.

Several studies have been conducted to establish the accuracy of the data and found that the data is accurate within an absolute error of less than five metres and the random error between 2 and 4 metres for Southern Africa¹¹. Over a small area as in this study, the relative error compared to neighbouring point is expected to be less than one metre. This is very good for the purpose of a numerical groundwater model, especially if compared to other uncertainties; and with the wealth of data this results in a much-improved model.

¹⁰ <http://www2.jpl.nasa.gov/srtm/>

¹¹ Rodriguez, E., et al, 2005. An assessment of the SRTM topographic products. Technical Report JPL D-31639, Jet Propulsion Laboratory, Pasadena, California.

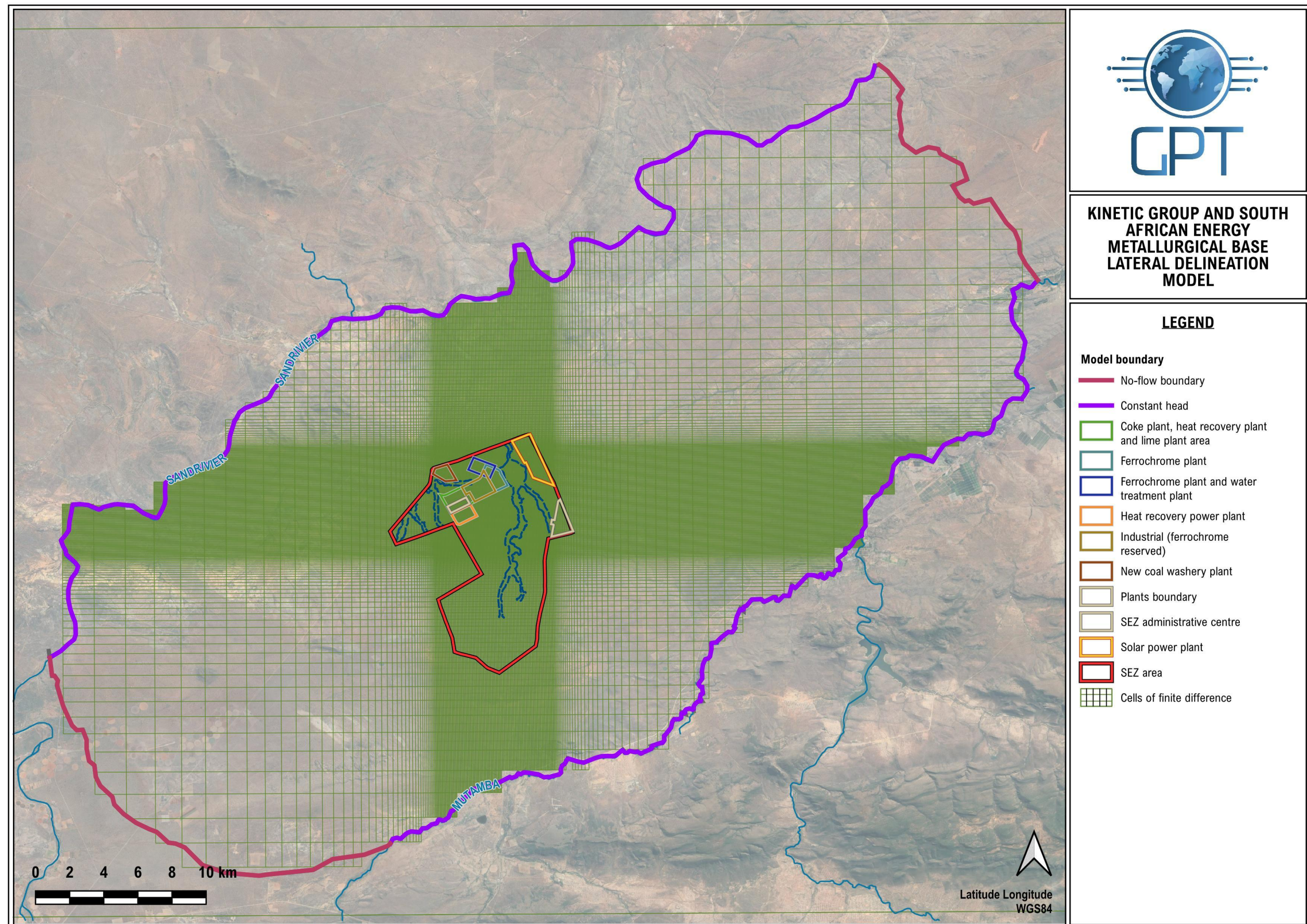


Figure 18: Lateral Delineation of the Regional Model

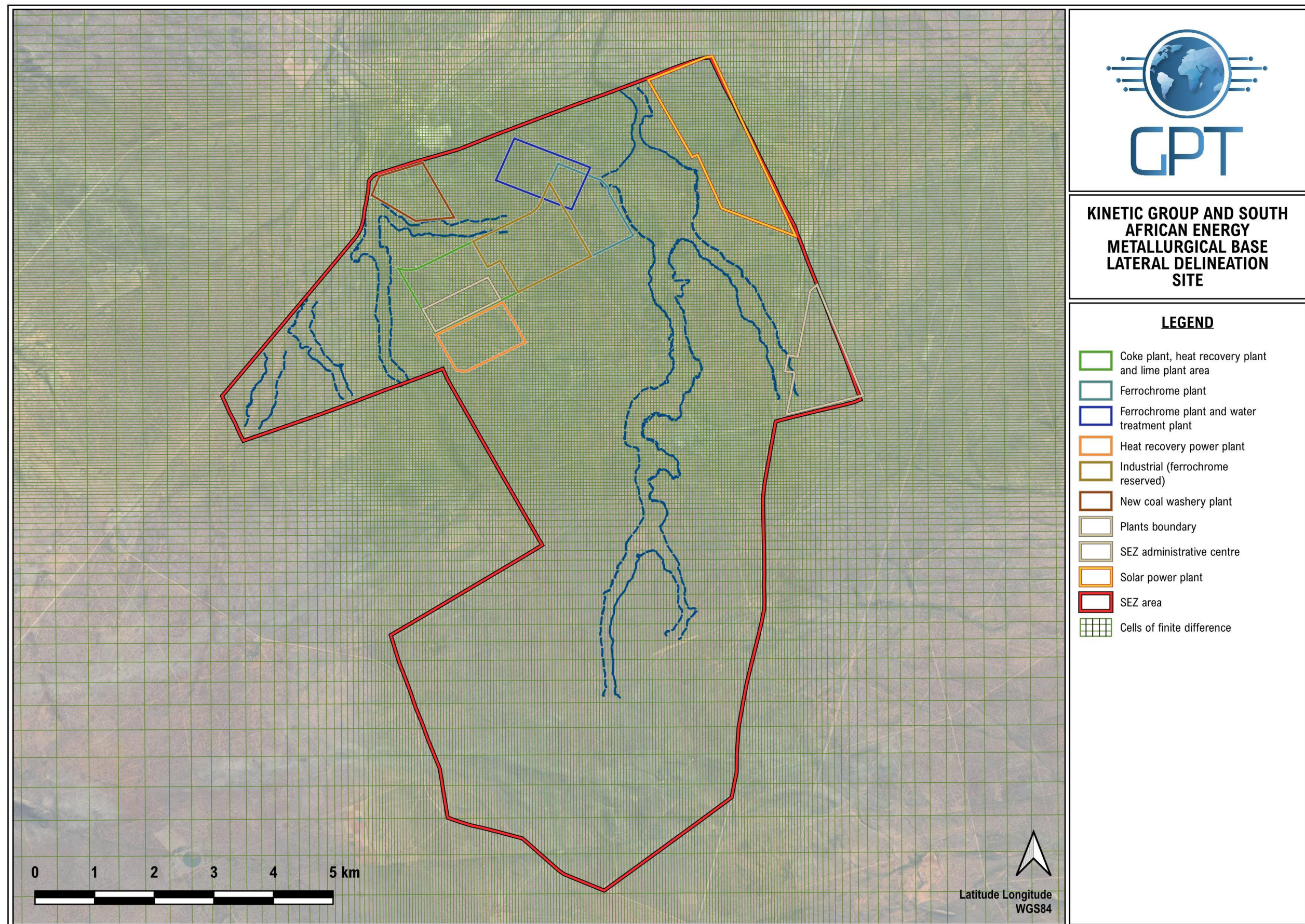


Figure 19: Lateral Delineation in the Site Area

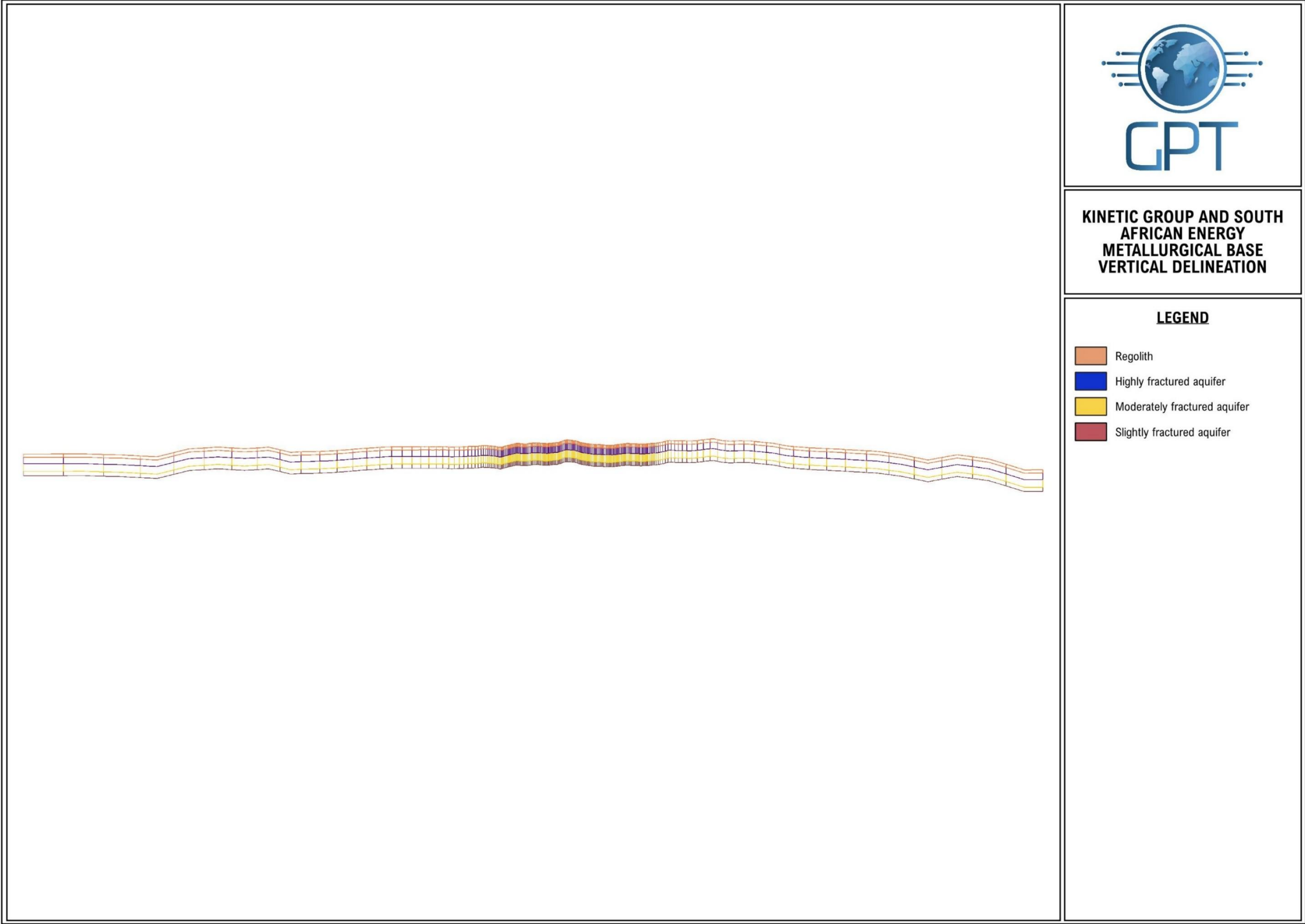


Figure 20: Vertical Delineation of the Modelled Area