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Geohydrological Assessment for the Proposed Vygenhoek Platinum Mine

Report

Version - 3

05 February 2021

Environmental Management Assistance (Pty) Ltd

GCS Project Number: 20-0607

Client Reference: Vygenhoek Geohydrology

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Director / Reviewer	Pieter Labuschagne (MSc, PriSciNat)		05 February 2021

DECLARATION OF INDEPENDENCE

GCS (Pty) Ltd (GCS) was appointed to conduct this specialist groundwater study and to act as the independent hydrogeological specialist. GCS objectively performed the work, even if this results in views and findings that are not favourable. GCS has the expertise in conducting the specialist investigation and has no conflict of interest in undertaking this study. This report presents the findings of the investigations which include the activities set out in the scope of work.

EXECUTIVE SUMMARY

GCS Water and Environment (Pty) Ltd (GCS) was appointed by Environmental Management Assistance (Pty) Ltd (EMA) to undertake a geohydrological assessment for the Proposed Vygenhoek Platinum Mine, situated 45km west of Mashishing, Mpumalanga Province.

Based on the outcome of the geohydrological study, no avoidance areas have been identified. Moreover, the study did not identify major risks associated with the preparation (construction), operational and closure phase of the proposed mine. Opencast mining the UG2 seam is feasible from a geohydrological perspective as long as mitigation measures (as per Section 10) are implemented, and the EA (Environmental Authorisation) recommendations below are considered.

The following recommendations are made, in terms of EA requirements:

- Dedicated groundwater monitoring boreholes should be drilled before pit expansion to obtain baseline water quality and quantity data. Drilling log data should be recorded and can supplement any future geohydrological work for the site (i.e. will help to better understand the local geohydrology).
  - 12 drilling positions have been identified for monitoring purposes. The recommended drilling positions are as follows:

ID	Slope	Latitude (WGS84, DD)	Longitude (WGS84, DD)	Depth (m)
485	Downstream	-25.038224	30.155169	40-60
535	Downstream	-25.039837	30.155298	40-60
559	Downstream	-25.040727	30.155575	40-60
590	Downstream	-25.042203	30.154971	40-60
684	Downstream	-25.047590	30.154404	40-60
666	Downstream	-25.033360	30.149479	40-60
Hwall 1	Upstream (background monitoring)	-25.04619	30.15076	40-60
Hwall 2	Upstream (background monitoring)	-25.03616	30.15056	40-60
WRD 1	Downstream WRD	-25.03353	30.16275	40-60
WRD 2	Downstream WRD	-25.03609	30.16474	40-60
WRD 3	Downstream WRD	-25.03034	30.16360	40-60
WRD 4	Upstream WRD	-25.03278	30.16877	40-60

- Additional rock samples should be collected during mining, to maintain a clear understanding of the AMD potential of the rock being mined. It is important to use ABA and NAG as pre-emptive tools to determine if any AMD may occur.

- The following can be done to improve the assumptions and understanding of the groundwater aquifer and hence improve the numerical groundwater model confidence:
    - All new exploration boreholes drilled in the area should note groundwater occurrences as well as strike depths. The data can be used to update the conceptual hydrogeological model which is incorporated into the numerical flow model.
    - Water levels of dedicated monitoring boreholes that will be drilled, as well as any new boreholes which are discovered in the area during routine hydrocensus updates, should be monitored bi-annually.
    - Dewatering volumes (during mining) should be recorded daily and reported bi-monthly.
- It is recommended that the numerical groundwater model and transport model be updated annually, to:
    - Recalibrate the flow system based on the dedicated monitoring boreholes drilled and routine water level monitoring data gathered for the site.
    - Confirm preferential flow paths and groundwater migration velocities as new geological data is attained via mining.
    - Evaluate the spatial impact (i.e. TDS plume) calibrated with the proposed monitoring borehole data.
    - Confirm long term liabilities associated with the workings (i.e. predict likely changes in flow fields etc.); and
    - Ensure no monitoring network gaps exist (i.e. check if the monitoring network is representative of the site).

The table below (Table 1) provides references to chapters within this report as per Appendix 6 of GNR 982, for the compilation of specialist reports as part of the EIA and WUL process.

Table 1: Executive Reference Table

Requirement	Check (√)	Report reference
(1) A specialist report prepared in terms of these Regulations must contain—	√	Appendix G
(a) details of— (i) the specialist who prepared the report; and (ii) the expertise of that specialist to compile a specialist report including a curriculum vitae;	√	Page ii and Appendix G
(b) a declaration that the specialist is independent in a form as may be specified by the competent authority;	√	Appendix G

Requirement	Check (√)	Report reference
(c) an indication of the scope of, and the purpose for which, the report was prepared;	√	Section 1
(cA) an indication of the quality and age of base data used for the specialist report;	√	Section 1.5
(cB) a description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change;	√	Section 1.2 and Section 8.1
(d) the duration, date and season of the site investigation and the relevance of the season to the outcome of the assessment;	√	Section 1.2 and Section 3.1
(e) a description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used;	√	Section 1.2, Section 9.1 to 9.2.6, Appendix A and Appendix E.
(f) details of an assessment of the specific identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure, inclusive of a site plan identifying site alternatives;	√	Section 10.
(g) an identification of any areas to be avoided, including buffers;	√	Section 8.1 to Section 8.5.2.
(h) a map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	√	Section 1, 2, 8 and 9.
(i) a description of any assumptions made and any uncertainties or gaps in knowledge;	√	Section 1.6 and Section 9.2.3.
(j) a description of the findings and potential implications of such findings on the impact of the proposed activity or activities;	√	Section 10.1
(k) any mitigation measures for inclusion in the EMPr;	√	Section 12.1.
(l) any conditions for inclusion in the environmental authorisation;	√	Section 12.1. and Executive summary
(m) any monitoring requirements for inclusion in the EMPr or environmental authorisation; cc	√	Section 11.1 to 11.3.
(n) a reasoned opinion—	√	Section 12.

Requirement	Check (√)	Report reference
(i) whether the proposed activity, activities or portions thereof should be authorised; (iA) regarding the acceptability of the proposed activity or activities; (ii) if the opinion is that the proposed activity, activities or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan;		
(o) a description of any consultation process that was undertaken during preparing the specialist report;	√	Section 1.5 and Section 3.1. (data gathering).
(p) a summary and copies of any comments received during any consultation process and where applicable all responses thereto; and	N/A	N/A
(q) any other information requested by the competent authority.	N/A	N/A
(2) Where a government notice *gazetted* by the Minister provides for any protocol or minimum information requirement to be applied to a specialist report, the requirements as indicated in such notice will apply.	√	Structured according to Annexure D of GN267 of 24 March 2017

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LIST OF ACRONYMS

Acronym	Description
µg	microgram
BA	Basic Assessment
BF	Baseflow
BH	Borehole
BHN	Basic Human Needs
CRT	Constant Rate Test
d	day
DMEA	Department of Mineral and Environmental Affairs
DTM	Digital Terrain Model
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
E	East
EC	Electrical Conductivity
EU	Existing Use
Fm	Formation
G3	Best Practice Guidelines: Monitoring
G4	Best Practice Guidelines: Impact Prediction
GCS	GCS Water and Environment (Pty) Ltd
GPS	Global Positioning System
GRAII	Groundwater Resource Assessment Ver. 2
GRDM	Groundwater Resource Directed Measures
GRIP	Groundwater Resource Information Project
GW	groundwater
IGRD	Intermediate Groundwater Reserve Determination
IWULA	Integrated Water Use License Application
km	kilometre
K-value	hydraulic conductivity
KZN	KwaZulu-Natal
l	litres
m	metres
MAE	Mean Annual Evaporation
Mag	magnetometer
mamsl	metres above mean sea level
MAP	Mean Annual Precipitation

mbcl	metres below collar level
mbgl	metres below ground level
mg	Milligram
mm	Millimetres
mS	Milli Siemens
n	Porosity
N	North
NGA	National Groundwater Archive
nT	magnetic intensity
NWA	National Water Act, 1998
Re	Recharge
Rem	Remainder
s	second
S	South
SA	South Africa
SCM	Site Conceptual Model
SPR	Source-Pathway-Receptor
SRTM	Shuttle Radar Topography Mission
T	Transmissivity
W	West
WL	Water level
WMA	Water Management Area
WRC	Water Research Council
WULA	Water Use License Application

1 INTRODUCTION

GCS Water and Environment (Pty) Ltd (GCS) was appointed by Environmental Management Assistance (Pty) Ltd (EMA) to undertake a geohydrological assessment for the Proposed Vygenhoek Platinum Mine, situated 45km west of Mashishing, Mpumalanga Province (refer to Figure 1-2).

1.1 Background

The Vygenhoek Project is located within the Eastern Limb of the Bushveld Igneous Complex (BIC). Chromitite Layers are situated in the Middle Group (MG) and Upper Middle Group (UMG) being UG2, UG1, MG4, MG3, MG2, MG1 and MG0 which occur in the Upper and Lower Critical zones of the BIC. The UG2 chromitite Layer will be the main target horizon for mining, with UG1 and MG layers as secondary horizons.

The mine will primarily target platinum group minerals and accessory minerals and metals found in the ore, which includes Platinum (Pt), Palladium (Pd), Rhodium (Rh), Iridium (Ir), Ruthenium (Ru) and Osmium (Os), Gold (Au) and Silver (Ag), Nickel (Ni), Copper (Cu), Cobalt (Co), Iron (Fe), Vanadium (V) and Chromite (Chrome Ore).

Opencast mining is proposed to mine the economical layers which sub-outcrops on the surface to a depth of approximately 60 metres below ground level (mbgl). The total mining right area is approximately 720 Ha.

The Vygenhoek project is a Greenfields project. There are several mines towards the north and south (>5km) from the site (Everest North and Everest South). However, it is fair to assume that no mining impacts are associated with the proposed site due to the site position to other mines and the fact that the area is still natural. This geohydrological assessment was compiled to evaluate potential geohydrological risk associated with the project, as part of the EIA and WUL process.

1.1.1 Proposed mine layout

The proposed Vygenhoek opencast section is shown in Figure 1-2. The mine layout proposed includes:

- An open cast pit in the order of 0.3 km^2;
- Temporary waste rock stockpiles placement areas;
- Ore stockpile placement areas;
- Offices and workshops;
- Roads and river crossings.

1.1.2 Mining schedule and Mine Reef Particulars

The Vygenhoek opencast will have a life of mine (LOM) of 10 years, and mining will start in the northern portion of the pit and propagate towards the south. Mining of the shallow UG2 reef will take place 1st, and footwall and mine towards the hanging wall which will be the deepest portion of the mine. The mine schedule is shown in Figure 1-1.

Mining will entail the opencast roll-over method, were mined out sections are rehabilitated as the new blocks are mined. Mining will take place to a depth ranging from 40 to 60 meters and will follow the dip of the UG2 main reef (approx. 10 degrees).

Available geological log data for exploration boreholes were used to conceptualise the main UG2 reef, and is shown in Figure 1-2. The main UG2 reef outcrops at the footwall of the proposed pit, and hence no drilling logs are available for these positions. *The data was clipped to the available data boundaries.*

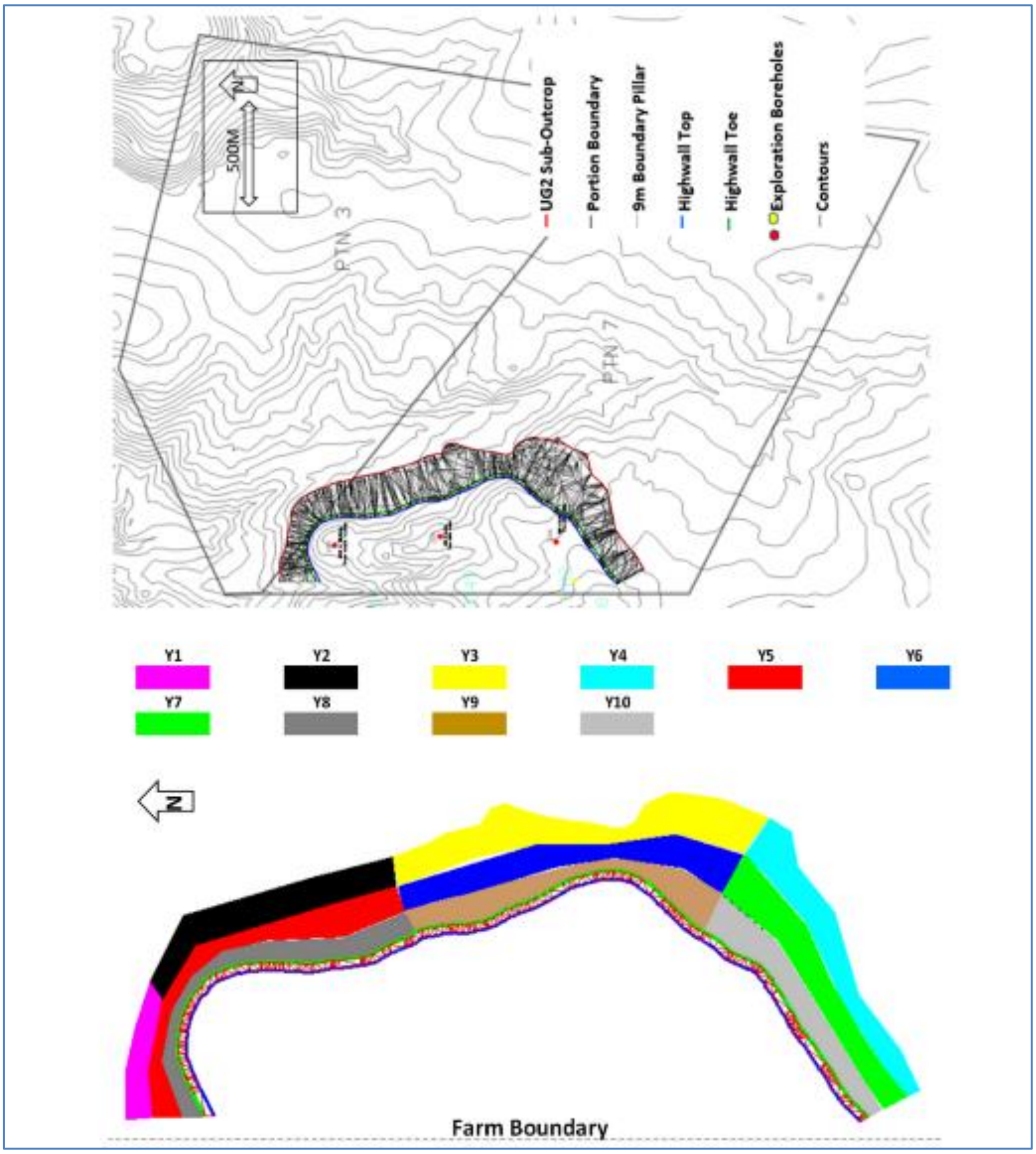


Figure 1-1: Proposed mining schedule

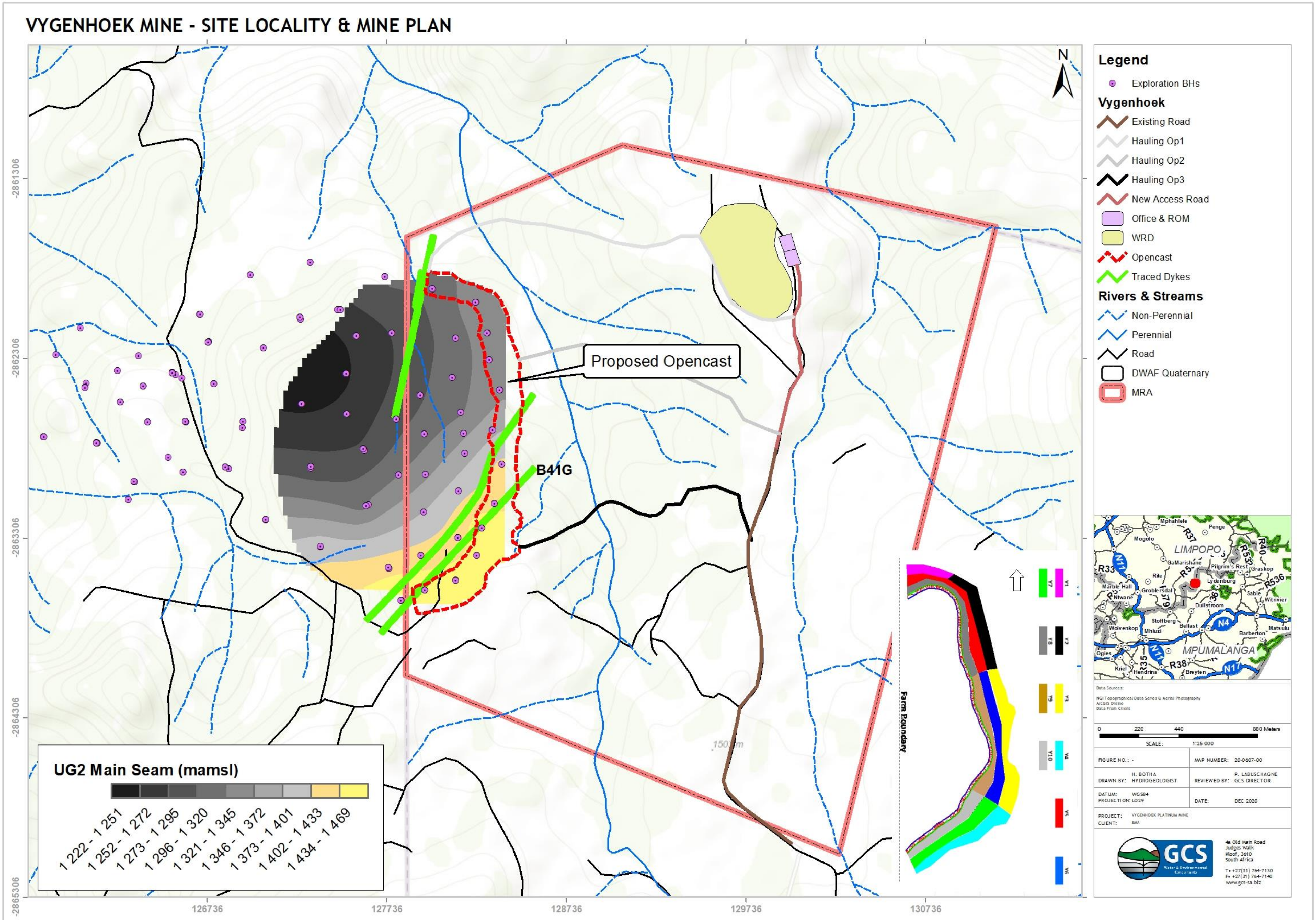


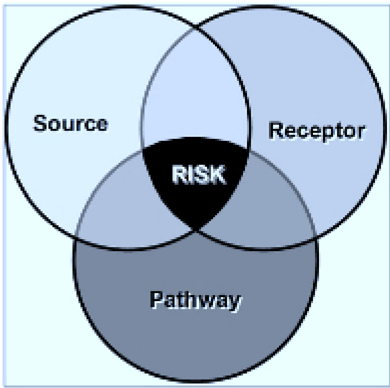
Figure 1-2: Site locality and mine plan

1.2 Study methodology

The geohydrological study aimed to identify the baseline (pre-mining) geohydrological conditions of the site. High-risk activities in terms of potential groundwater pollution during the construction (i.e. site preparation and clearing), operational phase (i.e. opencast workings, waste stockpiles, explosives and sewage-related infrastructure etc.) and closure phase (i.e. backfilling of the opencast workings and poor quality seepage associated with the backfilled waste rock material) were evaluated. The study was carried out as a once-off assessment, and is not seasonally bound.

A logical and holistic approach was adopted to assess the study area. The Best Practice Guidelines for Impact Prediction (G4) (DWAF, Best Practice Guidelines: Impact Prediction (G4), 2008), was considered to define and understand the three basic components of the hydrogeological risk (also referred to as "SPR"):

- **Source term** - The source of the risk (i.e. operational risk associated with the activities at the site);
- **Pathway** - The pathway along which the risk propagates (i.e. percolation to the groundwater aquifer or overland runoff); and
- **Receptor** - The target that experiences the risk (i.e. water bodies or groundwater users).



The approach was used to assess:

1. How the proposed mining activities could impact groundwater *Quality*; and
2. How the proposed mining activities could affect the groundwater *Quantity*.

Subsequently, a groundwater model was developed to illustrate the conceptual understanding of the groundwater flow system. Groundwater modelling is an efficient tool for groundwater management and remediation. Models are a simplification of reality to investigate certain phenomena or to predict future behaviour. The challenge is to simplify the reality in a way that does not adversely influence the accuracy and ability of the model output to meet the intended objectives. In terms of quality control, the Australian Groundwater Modelling Guidelines (Barnett, et al., 2012) were considered to ensure that the numerical model adheres to international norms and standards.

1.3 Aims and objectives

The main objectives of this report were to:

1. Undertake a desktop level assessment and evaluate the status of groundwater resources in general and any fatal flaws and /or sensitive areas.
2. Undertake a site visit and fieldwork to determine groundwater users and source pathway receiver (SPR) principles.
3. Evaluate groundwater quantity and quality data and develop a conceptual site model of the aquifer system.
4. Apply analytical and numerical models to illustrate the groundwater flow system and likely future risks pertaining to pit closure.
5. Undertake a risk assessment and provide mitigation measures;
6. Develop a groundwater monitoring network and programme; and
7. Present findings in an understandable and presentable format so that it can be used for decision-making purposes.

1.4 Scope of Work

The scope of work completed was as follows:

1. Desktop Assessment:
    a. All available reports relating to the site were assessed, including a review of all geohydrology, hydrology, hydrochemistry, and geology literature data.
    b. A desktop-level hydrocensus was conducted. The national groundwater archive (NGA), SADAC GIP and groundwater resource information project (GRIP) databases were assessed to identify existing groundwater users in the area.
2. Fieldwork & data assessment
    a. A hydrocensus (within 2.5km radius of the proposed opencast) was undertaken in the study area to identify groundwater users and evaluate the condition of exploration boreholes at the site.
    b. A remote census was undertaken to collect rock samples for geochemical testing.
    c. Several geophysical profile lines were conducted to confirm the presence and orientation of dolerite dykes at the site. The data was used to determine future monitoring borehole drilling positions.
    d. Several slug tests were conducted on suitable boreholes to obtain hydraulic parameters.

  e. Hydrochemical sampling of hydrocensus boreholes was conducted.
  f. All field data were evaluated and interpreted per best practice guidelines.

3. Site conceptual model development:
   a. A hydrogeological, geochemical and geological conceptual model was developed for the mine.
   b. The site conceptual model was used to develop a numerical groundwater flow and transport model.
4. Groundwater numerical modelling:
   a. A numerical model grid was developed and calibrated to a pre-mining steady-state scenario with all the available data gathered.
      i. The steady-state model was applied in transient state mode to enable scenario modelling.
   b. The following model scenarios were simulated:
      i. Likely aquifer drawdown.
      ii. The temporal and spatial extent of the likely pollution plume produced if backfilling with overburden material, was modelled. The 100Y plume, post-closure, was modelled.
5. Hydrogeological risk assessment:
   a. The source-pathway-receptor (SPR) principle was applied to the site, along with the conceptual site model and numerical model outputs to evaluate hydrogeological risk. The aim was to assess:
      i. Dewatering of the aquifer due to pit expansion;
      ii. Flooding potential and risk of decant;
      iii. Preferential groundwater flow paths; and
      iv. Point sources (i.e. backfilled voids or rock dumps)
6. Reporting:
   a. A geohydrological report encompassing all work done as well as a preliminary groundwater risk assessment and monitoring plan were compiled.

1.5 Available information

The following sources supply an overview of the hydrogeological conditions of the project review for this assessment:

- Groundwater Resource Information Project (GRIP, 2016) borehole data.
- SADC Groundwater Information Portal (SADC GIP) borehole data (SADC GIP, 2020)
- 2530 Nelspruit – 1:500 000 Hydrogeological map series (King, Maritz, & Jonck, 1998)
- 2530 Baberton – 1:250 000 Geological map series (DMEA, 1986)
- Literature on similar geology and hydrogeology:
    - A South African Aquifer System Management Classification (Parsons, 1995);
    - Aquifer Classification of South Africa (DWA, 2012);
    - The relationship between South African geology and geohydrology (Lourens, 2013).
- GCS internal database and reports for the Lydenburg & Steelpoort area (refer to reference list).
- Other sources:
    - Everest North Platinum Mine EIA & EMP - MPRDA. Volume 1 of 2 - EIA & EMP. Report Ref: MP30/5/1/2/2/1034PR (Digby Wells, 2012).
    - Vygenhoek exploration borehole data [Schedule_Drillholes_Sept2009].
    - Everest South groundwater investigation (GCS, 2007).
    - Final mine layout plan Nov 2020.
- GCS field generated data (data October 2020)

1.6 Limitations

The following limitations are recognised:

- No exploration drilling was undertaken for this study. Available borehole log data, internal GCS specialist reports for the study area and literature data for the lithological occurrences in the area were used to supplement the geohydrological conceptual model for the site. The gaps in lithostratigraphy and geohydrological information would be addressed during the establishment of the monitoring boreholes at the site (refer to Section 11).

- In the absence of sufficient groundwater water level data (i.e. only 3 boreholes were discovered in the area that will be mined and are old exploration boreholes) a catchment scale numerical flow model utilising available groundwater level data for the region had to be developed. The flow model and transport predictions would need to be updated as soon as dedicated monitoring boreholes are drilled at the site (i.e. to more accurately describe the flow system and possible mine impacts).

2 DESKTOP ASSESSMENT

The following section supplies a brief overview of the regional topography, climate and geological setting. The information in this section was obtained from public domain data and internal GCS databases.

2.1 Regional setting, topography and sub-catchment

The proposed Vygenhoek Platinum Mine ("The Site") is situated 45km west of Mashishing, Mpumalanga Province (refer to Figure 2-4). The site is situated in Quaternary Catchment B41G of the Olifants (DWS, 2016) Water Management Area (WMA 2). The project site is located in the upper catchment of the Groot Dwars River valley, and there is a significant change in altitude within this valley.

One (1) sub-catchment was delineated for the project area, and describes the natural drainage of the area. The topography west of the project site consists of a valley running from the south to the north. This valley holds a tributary of the Dwars River, which flows in a northerly direction (approximately 350m downstream of the proposed opencast pit). Elevations on the site typically range from 1 372 to 1 550 metres above mean sea level (mamsl).

Bare riverbed, dense forest & woodland, natural rock surfaces, fallow land, residential, scattered villages, natural grassland and open woodland land types dominate the sub-catchment (DEA, 2019).

2.2 Climate

Average yearly temperature (refer to Figure 2-1) for the project area ranges from 17 to 31 C (high) and -2 to 13 °C (Low). The Köppen Climate Classification suggest that the site is situated in a humid subtropical climate which receives rainfall in summer months (Kottek, Grieser, Beck, Rudolf, & Rubel, 2006).

Monthly rainfall for the site is likely to be distributed as shown in Figure 2-1, below. The Mean Annual Precipitation (MAP) is in the order of 650 mm/annum and the Mean Annual Evapotranspiration (MAE) in the order of 1500 mm/a (S-Pan) for the catchment (WRC, 2015).

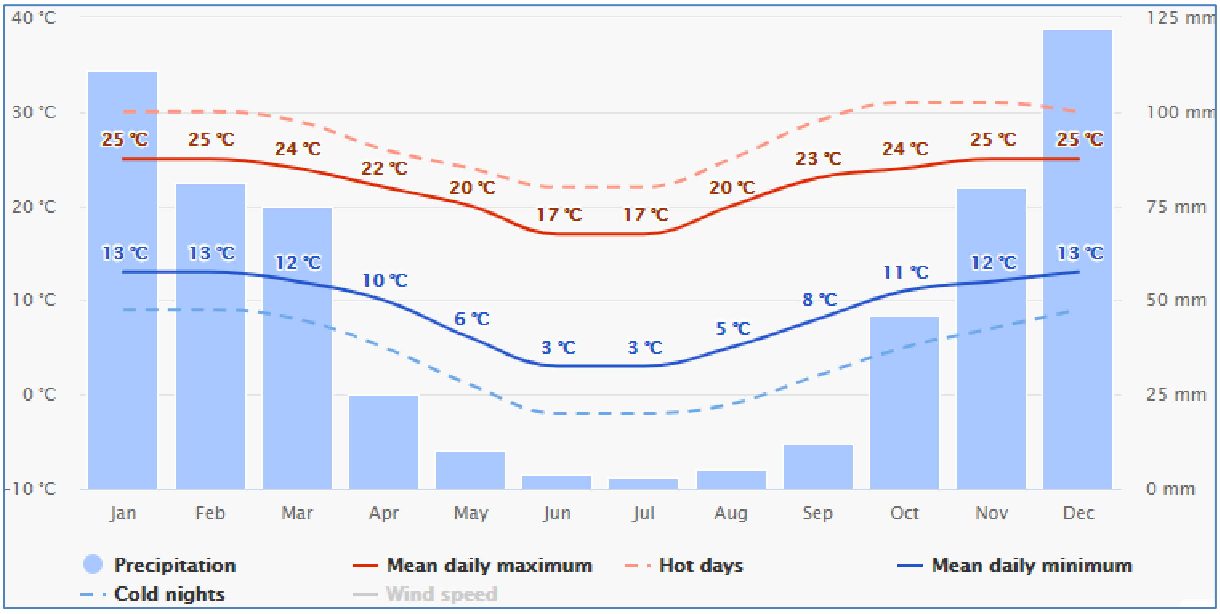


Figure 2-1: Monthly rainfall and temperatures (Meteoblue, 2020)

2.3 Local geology

According to 2530 Barberton-1:250 000 Geological map series (DMEA, 1986) the surface geology is characterised by quaternary sand deposits, Valium aged anorthosite, gabbro, norite (pyroxenite) and quartzite of the Dwars River and Shelter Norite Groups of the Rustenburg Layered Suite; and cross-bedded quartzite with arenite, shale and conglomerate layers of the Pretoria Group, of the Transvaal Sequence (refer to Figure 2-4).

2.3.1 Stratigraphy

The Vygenhoek area is underlain by gently north and north-west dipping layers of the Bushveld Igneous Complex (BIC), which intruded into the Transvaal Supergroup on the Kaapvaal Craton at about 2060 Ma. The Bushveld Complex consists of two lithological distinct units that are mainly intrusive into the Transvaal Supergroup:

- A lower sequence of layered mafic and ultramafic rocks, known as the Rustenburg Layered Suite (RLS); and
- An overlying unit of granite, known as the Lebowa Granite Suite.
- The chromitite and platinum mineralization is located in the RLS. The Rustenburg Layered Sequence comprises five stratigraphic zones:
- The Marginal Zone (with no economic potential);
- The Lower Zone (containing thin, high-grade chromitite seams); The Critical Zone (hosts all the significant PGM and chromite deposits);
- The Main Zone (locally exploited as dimension stone); and
- The Upper Zone (which host magnetite seams, some of which are exploited for Vanadium and iron ore).

The project area is underlain by the upper portion of the Critical Zone which in this area consists dominantly of anorthosite and mottled anorthosite with rare pyroxenite and chromitite layers (Digby Wells, 2012)

2.3.2 Structural geology

The ore body is an isolated basin-like structure. No major fault zones are expected to occur on the project site. Secondary discontinuities such as joints, shear joints and fault surfaces occur in the area and are likely to be an important control on the direction of groundwater flow (Digby Wells, 2012).

From the aerial magnetic map for the region, published by the Council of Geoscience South Africa (CGS, 2020), several magnetic anomalies associated with intrusive diabase/dolerite is noted (refer to Figure 2-2). The strikes of the magnetic anomalies (rocks) corresponds to NE-SW trending dykes as indicated on the 1:250 000 geological map series for this area and extend underneath Quaternary deposits. The UG2 outcrops are seen from N-S and NW-SE in the western part of the proposed mining area.

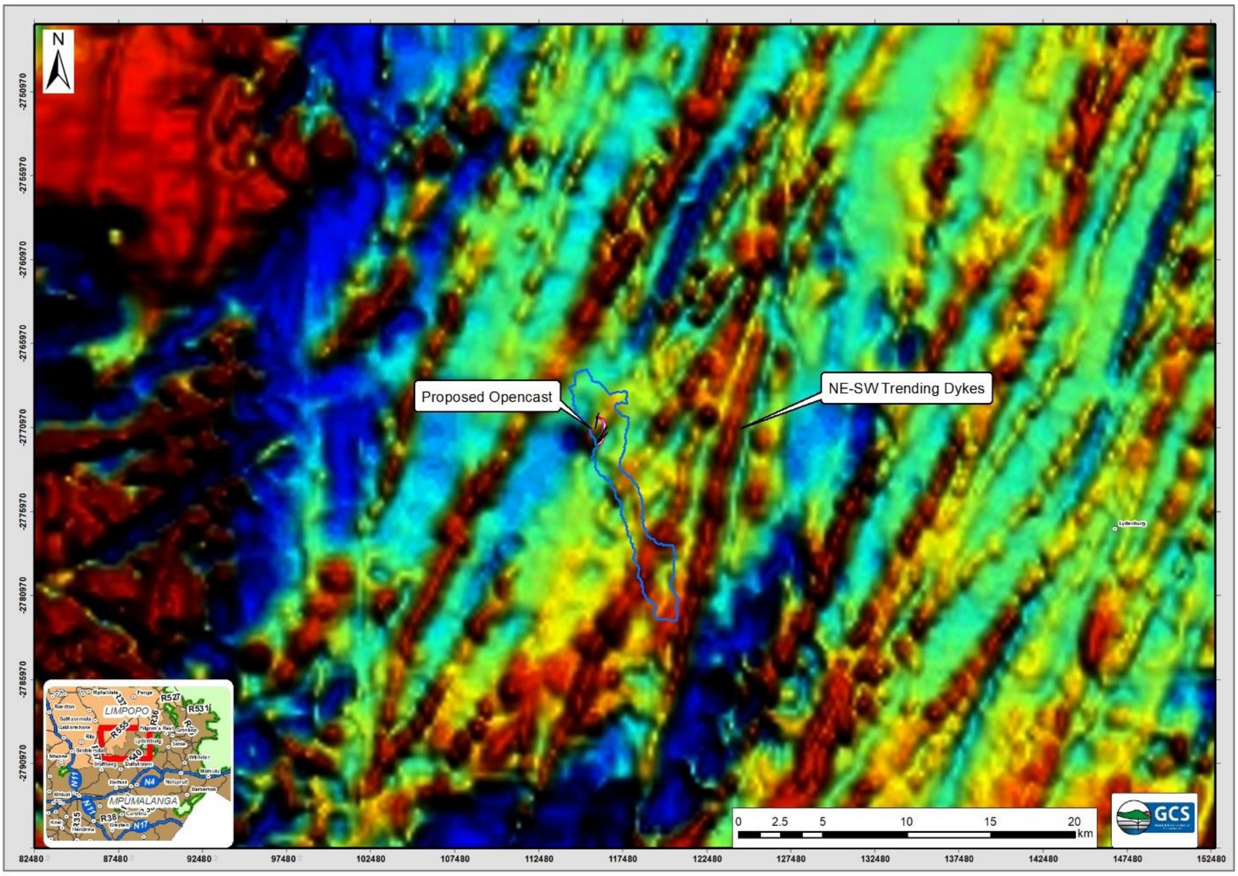


Figure 2-2: Magnetic map & structural geology (CGS, 2020)

2.3.3 Folding

The stereographic projection of poles to planes of layering illustrates that the Bushveld Complex has been subjected to gentle folding on a NNW-trending fold axis. Field data suggests that the Vygenhoek area is underlain by an open syncline structure. Such orientated folds may be within the stress field of the generally dextral Steelpoort Fault (Digby Wells, 2012)

2.3.4 Quartzite

Digby Wells (2012) indicated that an inlier of quartzite is found in the Bushveld rocks in the study area, with a sub-circular outcrop approximately 40 m in diameter forming a local topographic high point. The quartzite is presumed to be Pretoria Group, and is fractured in outcrop. Such fractures can be associated with the quartzite itself, or with chilling in the margin of the Bushveld rocks.

2.3.5 Weathering

Feldspars in anorthosite and mottled anorthosite layers are especially prone to chemical weathering, which was found to be particularly intense where surface watercourses flow over the bedrock. It is estimated that the weathered zone may be several metres thick (more than 3 m) in these areas. Weathered areas are characterised by the development of core stones and softer weathered rock, which is readily eroded into deep (more than 2 m) gullies by flowing surface water. Away from streams, the rocks remain relatively fresh even at the surface (Digby Wells, 2012)

2.3.6 Soils

According to the Land types of South Africa databases (ARC, 2006), the soils in the area predominantly consist of oxidised, sandy clay loam Hutton and Mispah soil forms, as well as bare rock. Moreover, reduced, moderately structured to strong structured clay (> 35% clay) soils associated with the Bonheim, Milkwood, Arcadia, Inhoek and Mayo soils occur in low topographical areas/valley bottoms.

2.3.7 Ore

The UG2 Reef in the Bushveld Complex commonly comprises ‘Leader’ and an underlying ‘Main’ chromitite seams. The Leader seams are thin, measuring from 5cm to 15cm apart and the underlying Main seam by similar widths of pyroxenite. The Main seam normally is a more massive chromitite seam measuring 30cm to 80cm (refer to Figure 2-3).

The UG2 Reef as found in two distinct reef types. The first type of occurrence is a composite chromitite band where the Leader seams and Main seam are not separated. The second type of occurrence is where UG2 chromitite has been split by an internal waste parting which reaches thicknesses of up to 6.78m.

The development of the internal parting is not necessarily at the position of the "stratigraphic" boundary between the Leader and Main Seam, but can occur anywhere within the UG2 chromitite. For this reason, it is chosen to refer to this reef as a split reef type with an Upper and Lower chromitite unit.

The Vygenhoek UG2 resource has the form of a half ellipse as the UG2 resource is bisected by the Vygenhoek-Mareesburg property boundary line. The maximum depth of the base of the UG2 reef was recorded with the depth of the base of the UG2 reef recorded at 141.29m. The depth below surface contours of the top of the UG2 reef reached a maximum depth at 140m approximately in the middle of the UG2 resource along the farm boundary. The average thickness of the UG2 reef (including internal waste parting) is 1.67m (Digby Wells, 2012).

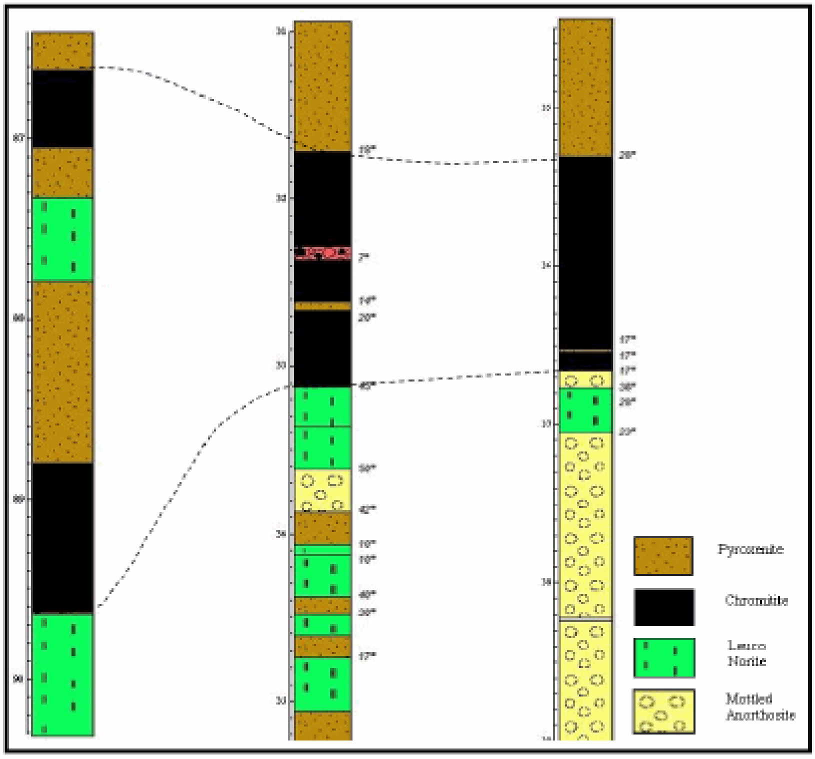


Figure 2-3: General stratigraphy and exploitable resource (Digby Wells, 2012)

2.4 Desktop hydrocensus

A review of SADC GIP (2020) and GRIP (2016) data for the study area indicates that there are seven (7) registered boreholes within a 5km radius of the proposed opencast mine. The groundwater users identified are listed in Table 2-1 and positions are shown in Figure 2-5. The boreholes plot towards the west of the proposed opencast workings and fall within a different sub-catchment. Limited water quality and quantity data is available for database boreholes.

Table 2-1: Boreholes identify within a 5km radius of the site

Borehole ID	Latitude (WGS84)	Longitude (WGS84)	Elevation (mamsl)	EC (mS/m)	Yield (l/sec)	Depth (m)	Water Level (mbgl)
SADAC 658654	-24.99924	30.17753	1463	*No Data*	3.3	80	*No Data*
SADAC 606151	-25.02753	30.12019	1046	51.4	*No Data*	*No Data*	*No Data*
SADAC 605899	-25.03	30.12	1062	55.7	*No Data*	*No Data*	*No Data*
SADAC 605898	-25.035	30.1201	1072	72.9	*No Data*	*No Data*	*No Data*
SADAC 605923	-25.03999	30.11961	1074	59	*No Data*	*No Data*	*No Data*
SADAC 680949	-25.03641	30.10669	1316	*No Data*	*No Data*	130	90
SADAC 680950	-25.04369	30.09003	1367	*No Data*	*No Data*	162	128
SADAC 680955	-25.06646	30.10781	1307	*No Data*	*No Data*	40	*No Data*
SADAC 680935	-25.03396	30.23309	1526	*No Data*	0.64	31.7	14
SADAC 680953	-25.0434	30.23586	1554	*No Data*	*No Data*	162	17
SADAC 680916	-25.0673	30.2331	1686	*No Data*	*No Data*	13.7	*No Data*
SADAC 680932	-25.13395	30.21642	1729	*No Data*	4	48	4
SADAC 680922	-25.15062	30.16642	1718	*No Data*	0.15	68	11.5
SADAC 680937	-25.15062	30.23308	1760	*No Data*	1.51	22.6	7.6
SADAC 680951	-25.15812	30.23503	1744	*No Data*	*No Data*	42	*No Data*

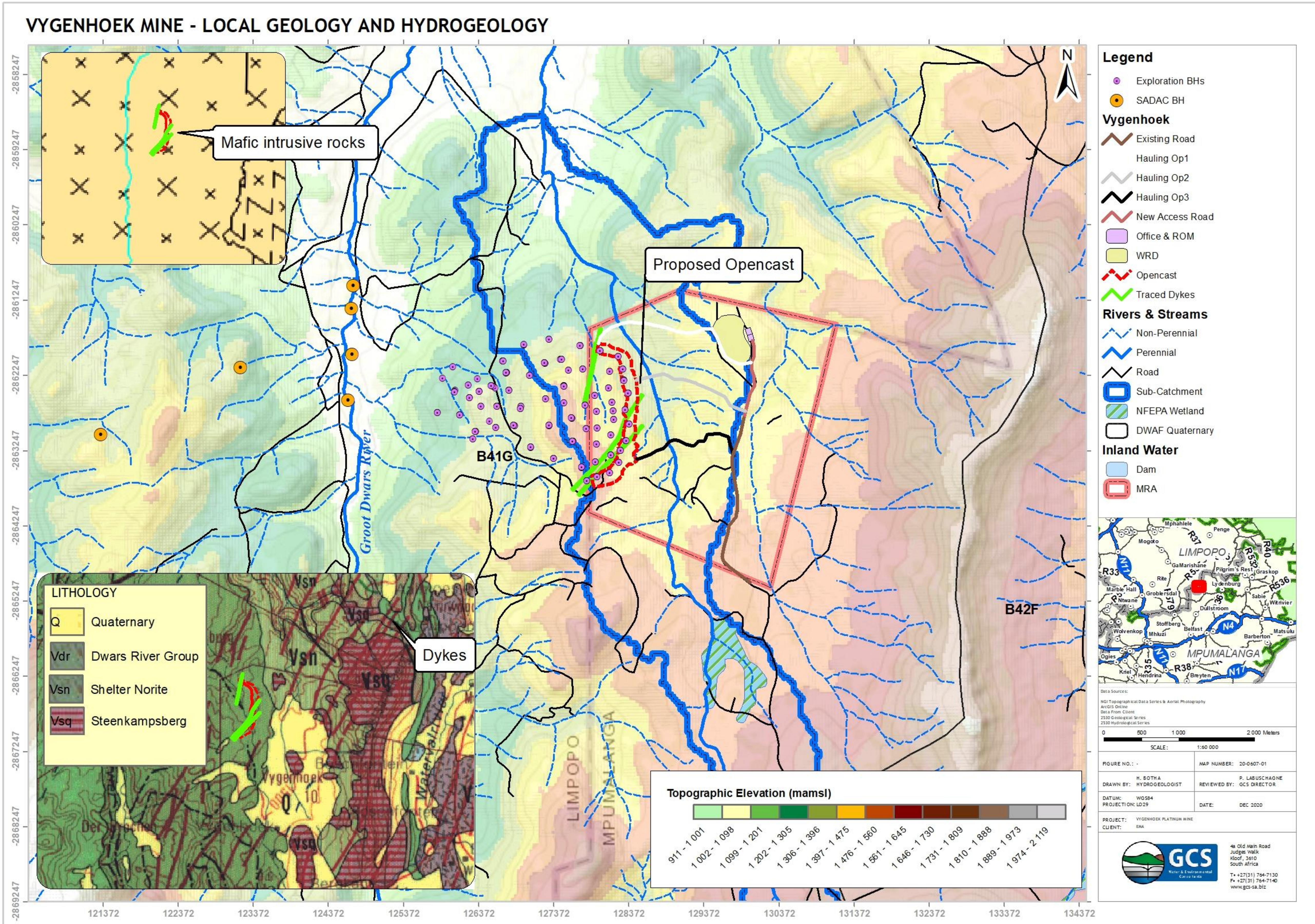


Figure 2-4: **Locality, proposed mine infrastructure, local geology and hydrogeology**

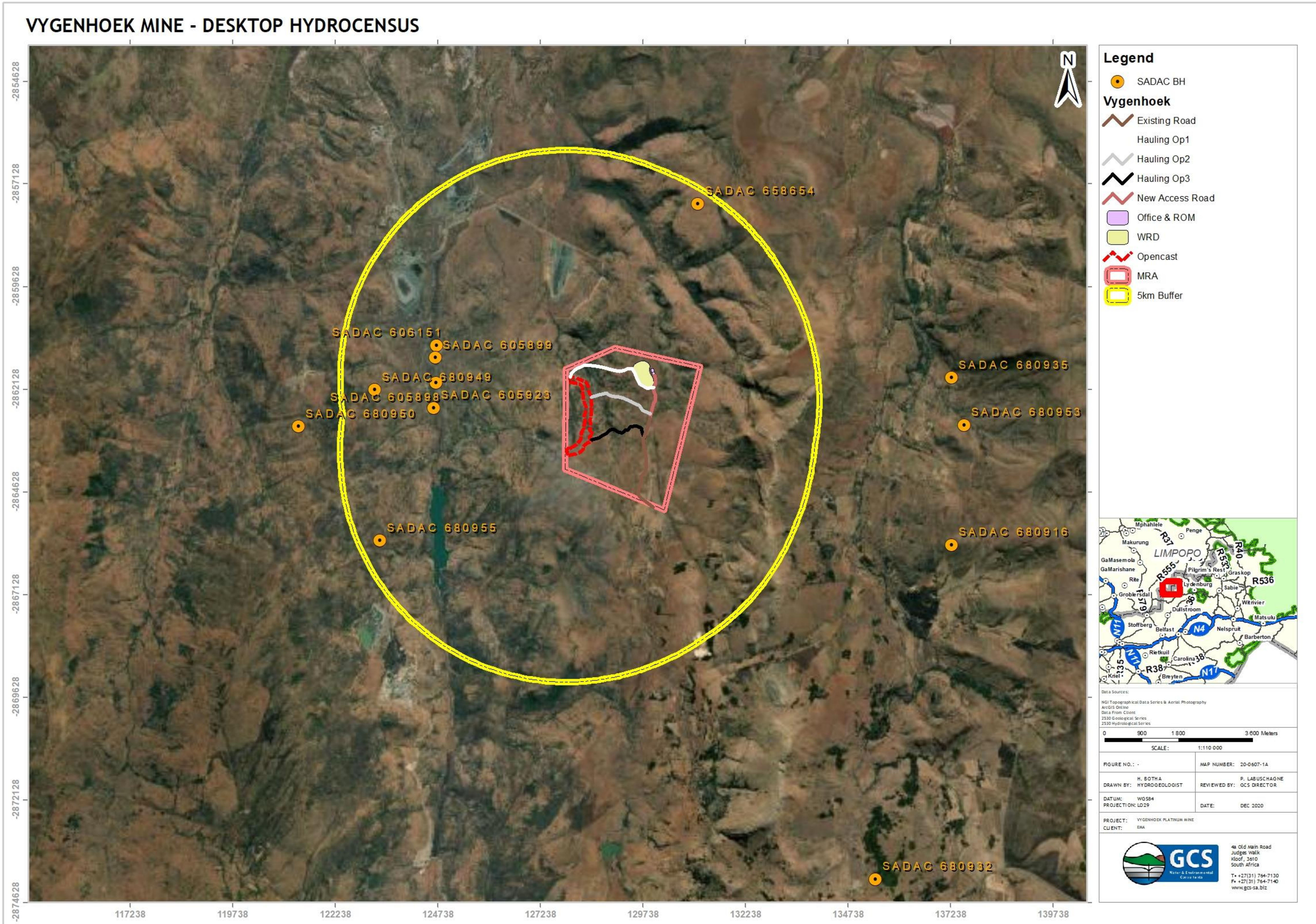


Figure 2-5: Desktop hydrocensus

3 FIELD INVESTIGATION

The field investigation took place from 7 to 9 October 2020. The following was completed as part of the site assessment:

- A hydrocensus was undertaken within a 2.5km radius of the proposed opencast operations.
- An exploration borehole census was completed to evaluate the condition of the exploration boreholes at the mine, and to identify other groundwater users which may occur in the study area.
- Remote sensing was completed to trace surface geological structures (i.e. dolerite) and to map the UG2 seam outcrop. Several rock samples were collected for geochemical testing.
- A geophysical investigation, with the use of a proton precession magnetometer, was completed on the footwall side of the proposed opencast workings. The aim was to trace dolerite dykes which intersect the pit, and to site future monitoring boreholes.
- Two (2) slug tests were performed on boreholes suitable for testing.

3.1 Field hydrocensus, remote sensing and exploration borehole mapping

A hydrocensus within a 2.5km radius of the proposed mine proved fruitless and no field boreholes were discovered. It appears as though domestic and irrigation water is attained from the tributary of the Dwars River. The proposed opencast area is situated in an isolated area (i.e. on a natural hilltop with limited development) and no existing groundwater uses were identified.

During the remote sensing five (5) rock samples were collected, namely:

- Pyroxenite contact with the UG2 seam.
- Pyroxenite form the high wall rock area.
- Spotted norite from the high wall; and
- 2 x UG2 samples from the UG2 outcrop that will be mined.

GCS was accompanied by the client to each of the existing exploration boreholes at the proposed mine. Water levels and water samples were taken, where possible. The findings of the hydrocensus are tabulated in Table 3-1, below. It was noted that several of the boreholes were destroyed and only three (3) could be sampled.

Table 3-1: Old exploration borehole mapping and remote sensing findings

ID	Type	Latitude (WGS84)	Longitude (WGS84)	Elevation (mamsl)	Collar (m)	Measured GW Level (mbgl)	Depth (m)	Comment
Vh01	Exploration Borehole (90 degrees)	-25.048370	30.149419	1487	0.75	24.32	30	Sampled
Vh09	Exploration Borehole (90 degrees)	-25.038642	30.150753	1423		Dry	10	Dry
Vh12	Exploration Borehole (90 degrees)	-25.039235	30.153127	1376	0.16	10.8	24	Sampled
Vh14	Exploration Borehole (90 degrees)	-25.037857	30.152615	1374	0.16	0.73	2	Not enough water for a sample
Vh15	Exploration Borehole (90 degrees)	-25.036599	30.152501	1376	0.18	14.77	24	Sampled
Vh16	Exploration Borehole (90 degrees)	-25.035215	30.151901	1372	0.2	Dry	5	Dry
Vh17	Exploration Borehole (90 degrees)	-25.034584	30.149799	1341	0.1	Dry	10	Dry
Vh18	Exploration Borehole (90 degrees)	-25.046762	30.151992	1456	N/A			Could not locate.
Vh19	Exploration Borehole (90 degrees)	-25.044394	30.152856	1445	0.18	Dry	11.79	Dry
Vh21	Exploration Borehole (90 degrees)	-25.044378	30.152857	1444	0.15	Dry	12	Dry
Vh20	Exploration Borehole (90 degrees)	-25.045564	30.152194	1468	N/A			Could not locate.
Vh11	Exploration Borehole (90 degrees)	-25.042703	30.153144	1445		N/A		Could not locate.
Vh02	Exploration Borehole (90 degrees)	-25.046799	30.149117	1503		N/A		Could not locate.
Vh03	Exploration Borehole (90 degrees)	-25.043898	30.151019	1468		N/A		Could not locate.
Vh05	Exploration Borehole (90 degrees)	-25.042171	30.151330	1445		N/A		Could not locate.
BH23331D	Exploration Borehole (90 degrees)	-25.041274	30.151266	1438		N/A		Could not locate.
Vh07	Exploration Borehole (90 degrees)	-25.040280	30.151157	1433		N/A		Could not locate.
Remote Sensing								
Chromite	Observation	-25.048482	30.151755	1468.047852				Exposed chromite seam. UG2, dips 10degrees
Dolerite Dyke	Observation	-25.037244	30.155762	1346.20166				Dolerite Dyke visible
Dolerite Dyke	Observation	-25.047735	30.150194	1478.622314				Dolerite Dyke visible
Fault	Observation	-25.041353	30.154343	1383.933105				Dolerite Dyke visible

3.2 Geophysical survey

The detailed geophysical investigation methodology and data interpretation are available in **Appendix A**. The findings are briefly summarised as follows:

- Five (5) magnetic profiles were completed. The spatial distribution of the profile lines is indicated in Figure 3-1. The aim was to trace dolerite dykes, contact zones and/or fault zones based on the magnetic response of the sub-surface geology (i.e. sudden changes in the magnetic intensity observed may relate to the above-mentioned structures).
- The geophysical investigation data suggest that several dolerite dykes and subsequent contact zones occur in the study area and cross the proposed opencast pit.
- The data suggest three (3) dykes which may act as preferential flow paths to hydraulically lower areas.
- Several drilling positions have been identified for monitoring purposes. The recommended drilling positions are as follows (refer to Table 3-2 and Figure 3-1).

Table 3-2: Proposed monitoring borehole drilling positions

Drilling Position	Latitude (WGS84, DD)	Longitude (WGS84, DD)	Depth (m)
485	-25.038224	30.155169	40-60
535	-25.039837	30.155298	40-60
559	-25.040727	30.155575	40-60
590	-25.042203	30.154971	40-60
684	-25.047590	30.154404	40-60
666	-25.033360	30.149479	40-60

3.3 Aquifer testing

There was sufficient water in exploration borehole VH12 and VH15 to undertake slug testing. The remaining exploration boreholes could not be tested. The test results and data analysis are available in **Appendix B** and are presented in Table 3-1.

GCS undertook several aquifer tests on boreholes situated at the Everest South (GCS, 2007) where similar geohydrological conditions exists. The results from the GCS (2007) aquifer testing is included in Table 3-3. The data was used to supplement the limited data gathered during the field investigation.

Table 3-3: Summary of available aquifer test data

BH	Test Type	Source	K (m/day)	Sat Zone (m)	T-value (m^2/day)	Aquifer
VH12	Slug	Field 2020	0.05186	6	0.3	Weathered
VH15	Slug	Field 2020	0.001	10	0.01	Weathered
BH5535	Packer	GCS (2007)	0.3	70	21	Weathered & Fractured
BH5544	Packer	GCS (2007)	0.03	22	0.7	Weathered
BH5635	Packer	GCS (2007)	4.3	10	43	Weathered
BH2739	Packer	GCS (2007)	0.1	50	5	Weathered & Fractured
BH5575	CD	GCS (2007)	0.01	35	0.2	Fractured
	Rec		0.19	35	6.7	
	Rec		0.01	35	0.2	
ES1	CD	GCS (2007)	0.28	25	7	Weathered
GCS1	Step	GCS (2007)	0.75	48	36	Weathered
GCS2	CD	GCS (2007)	0.01	35	0.2	Weathered
	Rec		0.005	35	0.16	Weathered
ESM1	CD	GCS (2007)	0.01	40	0.3	Fractured
	Rec		0.003	40	0.1	Fractured
Geometric Mean (Weathered)			0.05	19.32	0.96	
Geometric Mean (Fractured)			0.03	48.65	1.33	

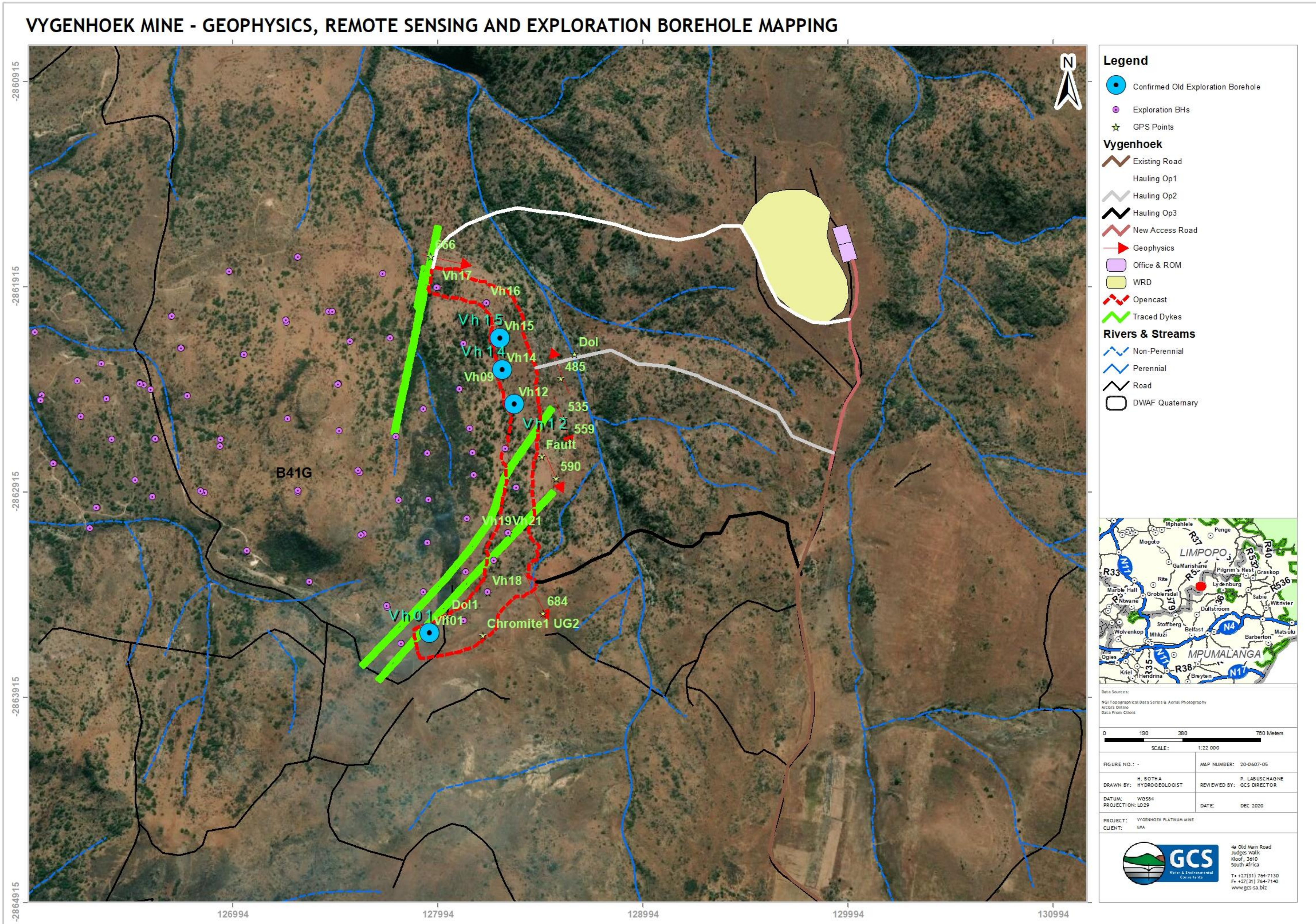


Figure 3-1: **Boreholes identified in the study area & fieldwork completed**

4 AQUIFER CHARACTERISTICS

The local aquifer host rock comprises mafic intrusive rocks (diabase, gabbro, norite and anorthosite) of the Rustenburg Layered Suite; and undifferentiated rocks and various mixed lithologies of the Pretoria Group.

Based on available literature and site data, three (3) aquifer types are envisaged:

1. Alluvium Aquifers:
    - An unconfined aquifer associated with alluvial deposits (confined to major rivers and floodplain areas).
2. Weathered Aquifers:
    - A semi-confined aquifer associated with weathered norite, anorthosite and pyroxenite rocks of the bushveld and Pretoria groups.
    - This aquifer has a widespread distribution occurring between 4 and 35 m below surface and is best developed underlying the alluvial aquifer and where overburden is generally greater than 2 m thick.
3. Deep Fractured Aquifers:
    - Deeper regional confined fractured bedrock aquifer covers associated with fresh and fractured bedrock below the weathered zone.
    - The aquifer's fractured zone is approx. 109 m thick (DWAF, 2006).

4.1 Preferential flow paths

Preferential groundwater flow is highly likely to be associated with bedding planes in contact with the UG2 seam, fault zones as well as along "baked" zones associated with the dolerite dyke and sills in the area. These intrusions can serve as both aquifers and aquifuges[1]. Several mafic dykes were mapped during the field investigation (refer to Section 3.2).

4.2 Primary groundwater occurrences

The hydrogeology is mainly controlled by weathering and secondary structures such as faulting and dykes. The pyroxenite unit, in both cases, plays a major role in controlling aquifer potential and the unit could be seen as the main aquifer in the area. The hanging wall pyroxenite is especially susceptible to weathering (GCS, 2007). Weathering is also associated with fracturing and dykes.

[1] **Aquifuge:** An impermeable body of rock which contains no interconnected openings or interstices and therefore neither absorbs nor transmits water.

Other important secondary hydrogeological features are three major steep-dipping, north-east to south-west striking dykes. The contact areas of dykes are often associated with fracturing and weathering. Contact fracturing is, however, very irregular and no major fracturing is in certain cases noticeable on the contact wall.

Towards the centre of the ore body, as the hanging wall shear dips deeper from the surface, two distinct aquifers may be encountered, namely an upper weathered zone aquifer and the lower hanging wall shear aquifer.

4.3 Groundwater levels

Available data suggests an average groundwater depth ranges from 10 to 17 mbgl (King et al., 1998; DWAF, 2006; Field 2020 data) for the mining area. Available data (refer Section 3) indicates a water level range from 4 to 128 mbgl for the groundwater sub-catchment. There is a linear relationship between the groundwater elevation and topography elevation (refer to Figure 4-1, R ≈ 96%), which suggests that the level of the regional groundwater table is highly likely to mimic the topography.

Bayesian interpolation of available groundwater level data was applied to the area to conceptualise the groundwater flow. Figure 4-2 indicates the generated Bayesian interpolated groundwater elevations for the area.

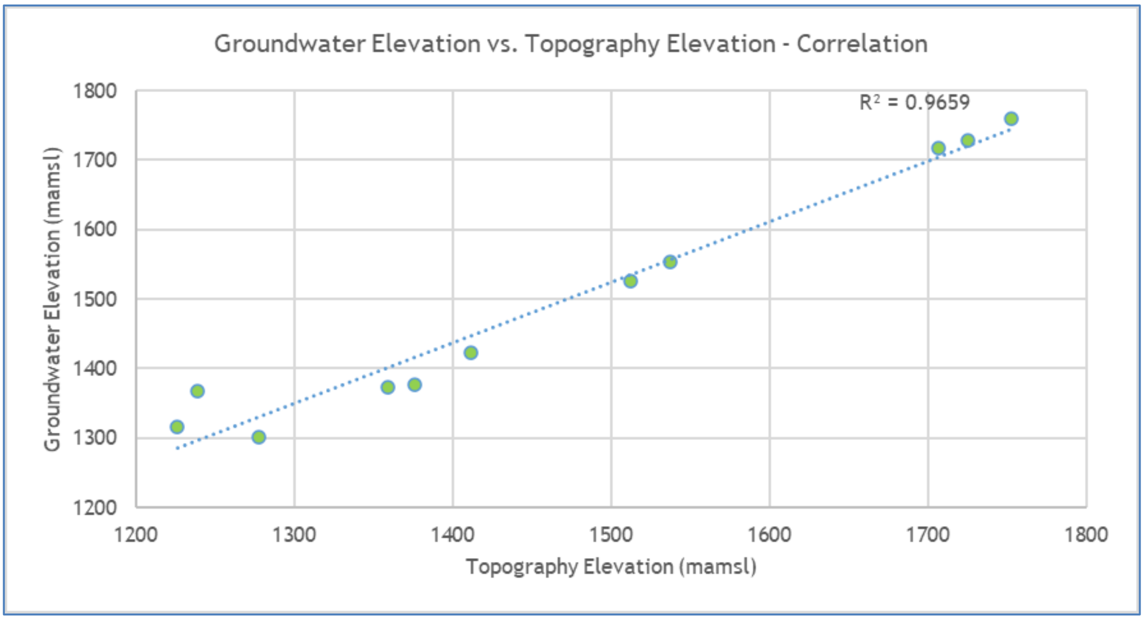


Figure 4-1: Groundwater elevation vs topography elevation - correlation

4.4 Aquifer yield & hydraulic conductivity

The aquifers occurring at the mine are moderate yielding aquifers, with reported yields ranging from 0.5 to 2 l/sec. Transmissivity (T) values for the weathered aquifer range between 0.001-5 m^2/d with S-values in the order of 0.001-0.0001 (Digby Wells, 2012; GCS, 2007).

The transmissivity of the deeper fractured bedrock aquifer, in the absence of open fracture systems, is characteristically low and estimated to be in the order of 0.0003-0.004 m^2/d (K of 0.00003-0.0004 m/d). The storativity for this aquifer varies between 0.001-0.0001.

Slightly higher transmissivity values up to $4.32x10^{-4}$ m^2/d are associated with dolerite dyke contacts. A summary of available K and T-values are presented in Section 3.3.

4.5 Aquifer recharge

Recharge to the underlying aquifer is estimated to range from 5.2 to 7.1% (average 6.1 % = 39.9 mm/yr.) of the MAP (650 mm) which falls within quaternary catchment B41G (DWAF, 2006). Recharge takes preferentially place through steep dipping fractures and at the weathered perimeter of the ore body. Steep dipping fractures were identified in vertical and inclined exploration boreholes

4.6 Aquifer classification

The aquifer present can be classified as a Minor Aquifer system (Parsons, 1995). These can be fractured or potentially fractured rocks which do not have a high primary permeability or other formations of variable permeability. The aquifer is an important contributor to groundwater baseflow to streams and rivers (King, Maritz, & Jonck, 1998).

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.

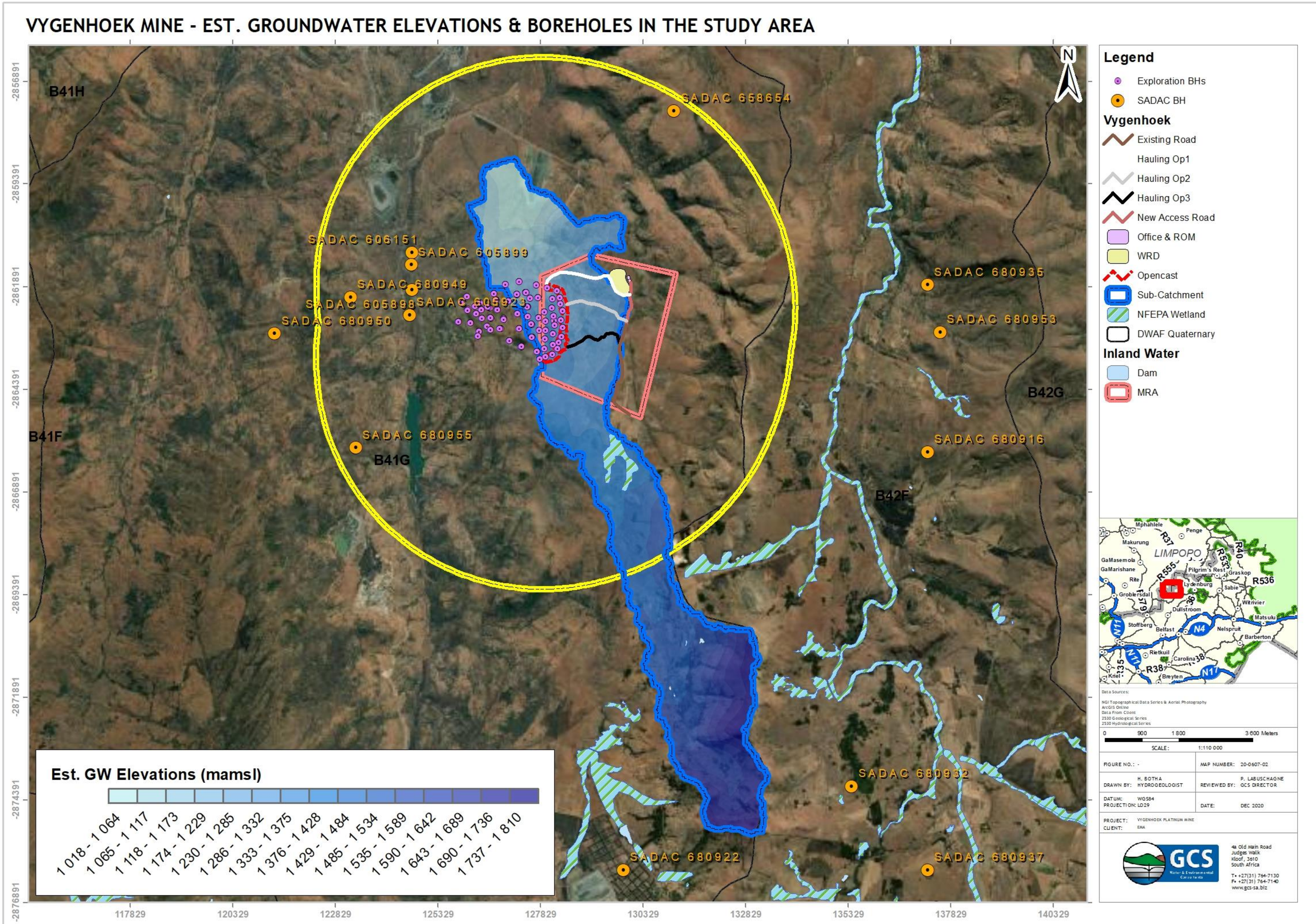


Figure 4-2: Estimated groundwater elevation (Bayesian interpolation)

5 GROUNDWATER QUALITY

The following section supplies an overview of the groundwater chemistry for the general study area. Data were derived from literature and site sample data.

5.1 Field sample procedure

Samples were collected and handled as follows:

- Samples were taken in 1 L polyethene containers.
- Samples were bailed, using a bio-degradable disposable bailer;
- Samples were not filtered or preserved with acid; and
- Samples were kept at a cool temperature and out of direct sunlight during storage and transport to Talbot Laboratories (SANS No. T0122), to slow down potential chemical reactions.

5.2 Catchment scale groundwater quality

Literature suggests that the electrical conductivity (EC) for the underlying aquifer generally ranges between 0 – 70 mS/m (milli Siemens/metre) and the pH ranges from 6 to 8. This means that groundwater abstracted from the aquifer can generally be used for domestic and recreational use (DWAF, 1996b).

5.3 Field sample water quality

Four (4) groundwater samples were collected, from BH01, VH12 and VH15. Moreover, a surface water sample (SW-D) was collected from the non-perennial river situated downstream of the proposed opencast pit. Refer to **Appendix C** for the analyses certificate.

The analytical results are listed in Table 5-1. The results are compared against SANS 241-1 (SANS, 2015) drinking water standards to contextualise the water quality data. The results are summarised as follows:

- All samples exhibit neutral pH conditions.
- The electrical conductance (EC) for all samples are within SANS limits for drinking water. Subsequently, major ions (Ca, Mg, Na, K, Cl, Fl, NO_3, SO_4) fall within the SANS limits for drinking water.
- Trivalent chromium (Cr^{3+}) is above SANS aesthetic limits for all groundwater samples. The high concentration likely relates to the UG2 seam which the boreholes intersects.
- Turbidity is high at all sample points compared to SANS limits. High turbidity is a reflection of high microbial activity in the water.
- A piper plot is presented in Figure 5-1. The following can be said about the sample data:

- The sample spread is toward the left of the left ternary diagram, which suggest that Ca is the dominant ion; and Na and Mg ion concentrations fluctuate.
- The sample spread is towards the left corner of the right ternary diagram. The sample data suggest that bicarbonate (HCO_3^-) is the dominant ion. SO_4, Cl and NO_3 are accessory ions.
- The sample spread plots towards the left corner of the centre diamond, and the water at the site can hence be classified as temporary hardened. This is typical of shallow-fresh groundwaters (i.e. the weathered aquifers).

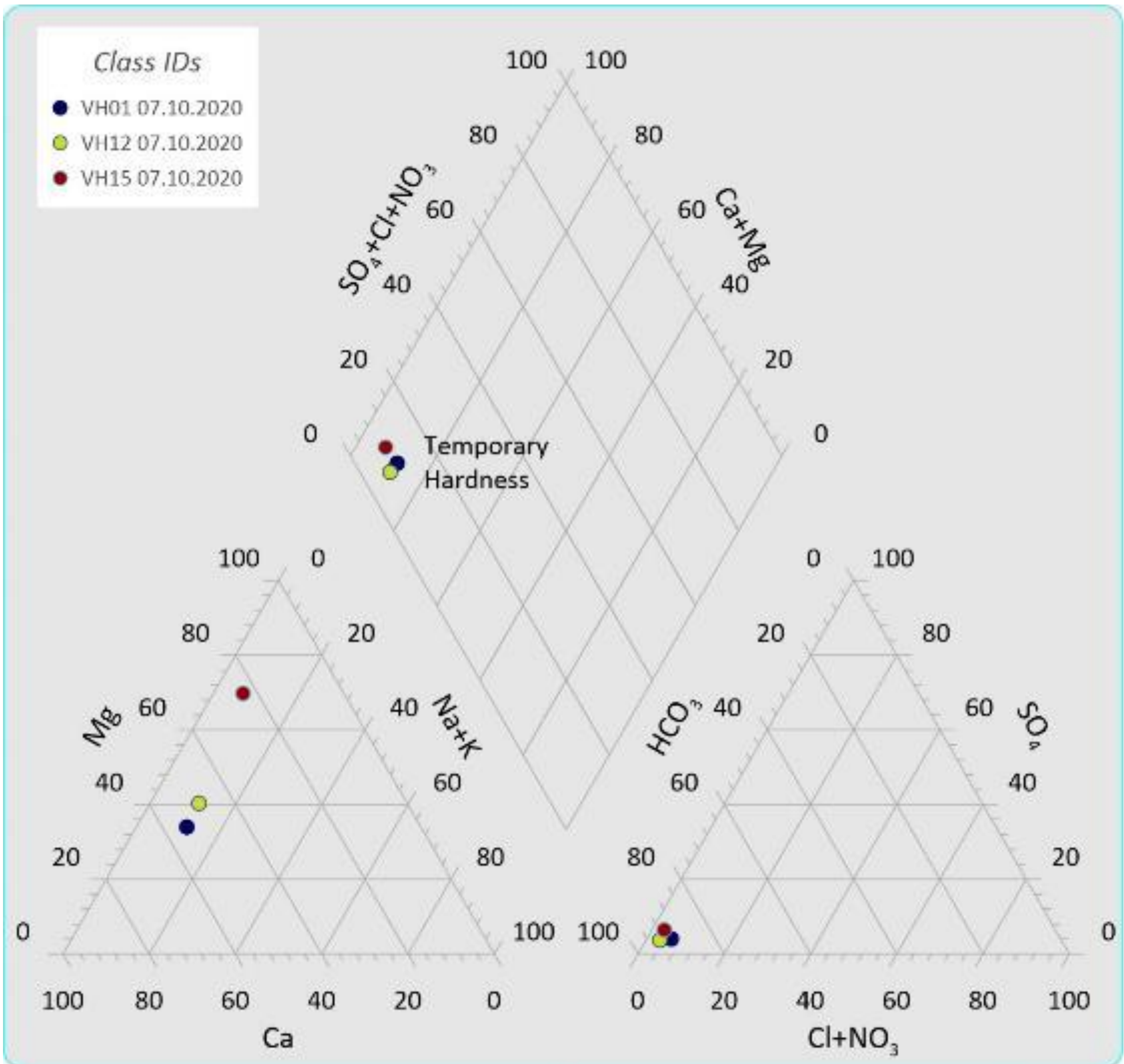


Figure 5-1: Groundwater piper plot

Table 5-1: Summary of hydrochemistry

Sample Name		VH01 07.10.2020	VH12 07.10.2020	VH15 07.10.2020	SW-D 07.10.2020	SANS 241-1:2015
Constituent	**Unit**					
pH at 25°C	**pH units**	7.40	7.30	7.30	7.60	5 - 9.7
Electrical Conductivity at 25°C	**mS/m**	53.40	51.50	49.50	11.90	<170
Total Alkalinity	**mg CaCO3/ℓ**	278.00	291.00	267.00	45.00	ns
Bicarbonate Alkalinity	**mg HCO3-/ℓ**	278.00	291.00	267.00	45.00	ns
Carbonate Alkalinity	**mg CaCO3/ℓ**	<3	<3	<3	<3	ns
Turbidity	**NTU**	>1000	384.00	140.00	69.00	Operational ≤ 1 Aesthetic ≤ 5
Calcium	**mg Ca/ℓ**	71.000	63.000	31.000	8.890	ns
Magnesium	**mg Mg/ℓ**	27.0000	32.0000	56.0000	7.1600	ns
Sodium	**mg Na/ℓ**	15.80	16.50	9.87	4.24	<200
Potassium	**mg K/ℓ**	3.06	0.87	1.01	3.71	ns
Chloride	**mg Cl/ℓ**	9.80	5.95	4.45	5.08	<300
Fluoride	**mg F/ℓ**	0.10	0.11	0.07	<0.03	<1.5
Nitrate	**mg N/ℓ**	0.82	0.10	0.70	0.30	<11
Sulphate	**mg SO4/ℓ**	9.81	8.92	14.90	4.33	<250
Chromium 3+	**mg Cr/ℓ**	0.180	0.140	0.200	0.020	<0.05
Chromium 6+	**mg Cr/ℓ**	0.0079	0.0212	0.0103	<0.0005	<0.05
		Not analysed			Above SANS 241-1: Aesthetical or Acute Limits	

6 GROUNDWATER QUANTITY

An Intermediate Groundwater Reserve Determination (IGRD) was conducted for the study area to establish the groundwater reserve. The IGRD aims to quantify the groundwater reserve and likely mining-related impacts on the reserve.

It is necessary, from a groundwater point of view, to quantify the groundwater quantity and likely future impacts on quantity.

The IGRD considers the following parameters:

- Effective recharge from rainfall and specific geological conditions.
- Basic human needs for the sub-catchment.
- Groundwater contribution to surface water (baseflow);
- Existing and proposed abstraction; and
- Surplus reserve.

The data used for the calculation was derived from the WRC 90 Water Resources of South Africa 2012 Study (WRC, 2015) and Groundwater Resource Assessment Ver. 2 (GRAII) datasets (DWAF, 2006).

6.1 Quaternary catchment

Data from relevant hydrogeological databases, including the Groundwater Resource Directed Measures (GRDM), was obtained from the Department of Water and Sanitation (DWS) and (Aquiworx, 2015). Table 6-1 summarises the quaternary catchment data.

Table 6-1: Summarised Quaternary Catchment Information (Aquiworx, 2015)

Quaternary Catchment	Total Area (km²)	Recharge (mm/a)	Rainfall (mm/a)	Baseflow (mm/a)	Population
B41G	442.27	39.9	650	9.76 {PITMAN Model]	Unknown

6.2 Sub-catchment delineation

A sub-catchment was delineated with Global Mapper. A 30m ALOS (JAXA, 2019) digital terrain model (DTM) was used as input and the drainage systems were delineated for the study area (1: 2500 stream count with a 15m DTM sink fill applied).

The delineated sub-catchment is indicated in Figure 4-2. The total extent of the sub-catchment area is approx. 26.21 km².

6.3 Existing groundwater usage (EU)

None of the identified SADAC GIP and GRIP boreholes fall within the delineated sub-catchment. Hence, the sub-catchment is poorly exploited, and no EU is allocated to the sub-catchment.

6.4 Basic human needs (BHN)

Available data suggest the sub-catchment is poorly exploited and no BHN is reserved.

6.5 Proposed groundwater usage (PU)

Based on the groundwater flux into the opencast pit and likely dewatering ZOI (refer to Section 9) a PU of 95 m^3/day is reserved. This is the average likely pit dewatering rate associated with the workings.

6.6 Land use (LU)

Bear riverbed, dense forest & woodland, natural rock surfaces, fallow land, residential, scattered villages, natural grassland and open woodland land types dominate the sub-catchment (DEA, 2019). Hence, the impact of land use on net-groundwater recharge is assumed to be negligible.

6.7 Groundwater balance

The groundwater balance and hence the reserve determination on a sub-catchment scale is summarised below:

- $GW_{available}$ = (Re) - (EU + BHN + BF)

Where:

- $Gw_{available}$ = Available groundwater for use.
- Re = Effective recharge to the aquifer.
- BF = Baseflow to surface water streams.
- EU = Existing groundwater abstraction / use (identified on sub-catchment, excluding applicant).
- BHN = Basic Human Needs.

Calculations:

- Re (sub-catchment) = 26.21 km^2 x 39.9 mm/yr = 1 045 779 m^3/a (2 865.14 m^3/day)
- BHN = 0 m^3/day (based on available data).
- EU = 0 m^3/day (based on available data).

- BF = 9.76 mm/yr x 26.21 km^2 = 255 809.6 m^3/a (647.61 m^3/day)
- $Gw_{available}$ = (2 865.14- [0 + 0 + 647.61]) m^3 = **+2 217.53 m^3/day**

The groundwater balance indicates a surplus-value of approx. + 2 217.53 m^3/day available for abstraction on a sub-catchment scale.

Allocating PU to the groundwater reserve suggest that there is a surplus amount of groundwater available. Hence, the impact on groundwater quantity and the reserve is marginal.

7 GEOCHEMICAL ASSESSMENT

Five (5) rock samples were collected during the field investigation and subjected to geochemical testing (XRD, ABA, NAG and DW1:4 testing). Table 7-1 lists geochemical sample data available for this assessment.

Table 7-1: Summary of rock samples collected

Sample ID	Rock Type	XRD	ABA	NAG	DW leach (1:4 or 1:2)
Pyroxenite Contact with UG2	Pyroxenite	✓	✓	✓	✓
Pyroxenite H Wall	Pyroxenite	✓	✓	✓	✓
Spotted Norite H Wall	Spotted Norite	✓	✓	✓	✓
UG2 (1)	Chromite	✓	✓	✓	✓
UG2 (2)	Chromite	✓	✓	✓	✓
Total		5	5	5	5

7.1 Geochemical screening

Two (2) types of static testing were used to assess the acid (short & long term) and neutralisation potential of the rock at the Vygenhoek mine, namely Acid-Base Accounting (ABA) and Net Acid Generation (NAG).

7.1.1 ABA

ABA is a static test where the net potential of the rock to produce acidic drainage is determined. The percentage sulfur (%S), the AP (acid potential), the NP (neutralisation potential) and the Net Neutralization Potential (NNP) of the rock material are determined in this test, as an important first-order assessment of the potential leachate that could be expected from the rock material. The ABA screening criteria as described by (Price, 1997) are listed in Table 7-2. The components of an ABA analysis are further explained below:

- If pyrite is the only sulphide in the rock the AP is determined by multiplying the %S with a factor of 31.25. The unit of AP is kg CaCO3/t rock and indicates the theoretical amount of calcite neutralized by the acid produced.
- The NP is determined by treating a sample with a known excess of standardized hydrochloric or sulfuric acid (the sample and acid are heated to ensure a completed reaction). The paste is then back titrated with standardized sodium hydroxide to determine the amount of unconsumed acid. NP is also expressed as kg CaCO3/t rock as to represent the amount of calcite theoretically available to neutralize the acidic drainage; and
- NNP is determined by subtracting AP from NP (EPA, 1994).

For the material to be classified in terms of their AD potential, the ABA results could be screened in terms of its NNP, %S and NP: AP ratio as follows:

- A rock with NNP < 0 kg $CaCO_3$/t will theoretically have a net potential for acidic drainage. A rock with NNP > 0 kg $CaCO_3$/t rock will have a net potential for the neutralization of acidic drainage. Because of the uncertainty related to the exposure of the carbonate minerals or the pyrite for reaction, the interpretation of whether a rock will be net acid generating or neutralizing is more complex. Research has shown that a range from -20 kg $CaCO_3$/t to 20 kg $CaCO_3$/t exists that is defined as a "grey" area in determining the net acid generation or neutralization potential of a rock. Material with an NNP above this range is classified as Rock Type IV - No Potential for Acid Generation, and material with an NNP below this range as Rock Type I - Likely Acid Generating; and
- (Soregaroli & Lawrence, 1998) further states that samples with less than 0.3% sulphide sulphur are regarded as having insufficient oxidisable sulphides to sustain long term acid generation. Material with a %S below 0.3% is therefore classified as Rock Type IV - No Potential for Acid Generation, and material with a %S of above 0.3%, as Rock Type I - Likely Acid Generating.

Table 7-2: ABA and NAG screening criteria (adapted from (Price, 1997) and (Fourie, 2014)

ABA: NPR Screening Criteria			ABA: %S Screening Criteria			ABA: NNP Screening Criteria		
Potential Acid Generation	**NP: AP (NPR)**	**Comments**	**Potential Acid Generation**	**% S**	**Comments**	**Potential Acid Generation**	**NP: AP (NPR)**	**Comments**
Rock Type I: Likely Acid Generating.	< 1	Likely AMD generating.	Rock Type IV: No Potential for Long Term Acid Generation	< 0.3%	Sample may produce AMD bit will be short term.	Rock Type IV: No potential Acid Generation.	> 20	No AMD potential
Rock Type II: Possibly Acid Generating.	1-2	Possibly AMD generating if NP is insufficiently reactive or is depleted at a faster rate than sulphides.				Rock Type I: Likely Acid Generation.	< -20	Likely AMD potential

ABA: NPR Screening Criteria			ABA: %S Screening Criteria			ABA: NNP Screening Criteria		
Potential Acid Generation	NP: AP (NPR)	Comments	Potential Acid Generation	% S	Comments	Potential Acid Generation	NP: AP (NPR)	Comments
Rock Type III: Low Potential for Acid Generation.	2-4	Not potentially AMD generating unless significant preferential exposure of sulphides along fracture planes, or extremely reactive sulphides in combination with insufficient reactive NP.	Rock Type I: Likely Long-Term Acid Generation	> 0.3%	Potential for long term AMD.	Uncertain	20 to -20	Sample may become acidic or remain neutral. Use with conjunction of the other criteria to resolve this uncertainty.
Rock Type IV: No Potential for Acid Generation.	> 4	No further AMD testing required unless materials are to be used as a source of alkalinity.						

7.1.2 NAG

In the NAG test hydrogen peroxide (H_2O_2) is used to oxidize sulphide minerals to predict the acid generation potential of the sample.

The NAG test provides a direct assessment of the potential for a material to produce acid after a period of exposure (to a strong oxidant) and weathering. The test can be used to refine the results of the ABA predictions (refer to Table 7-3).

In general, the static NAG test involves the addition of 25 ml of 30% H_2O_2 to 0.25 g of sample in a 250 ml wide mouth conical flask, or equivalent. The sample is covered with a watch glass and placed in a fume hood or well-ventilated area. Once "boiling" or effervescing ceases, the solution can cool to room temperature and the final pH (NAG pH) is determined. A quantitative estimation of the amount of net acidity remaining (the NAG capacity) in the sample is determined by titrating it with NaOH to pH 4.5 (and/or pH 7.0) to obtain the NAG Value (Lapakko & Lawrence, 1993).

Table 7-3: NAG screening methods used (Edited from (Miller, Robertson, & Donahue, 1997)

Rock Type	NAG pH	NAG Value (H_2SO_4 kg/t)	NNP ($CaCO_3$ kg/t)
Rock Type Ia. High Capacity Acid Forming.	< 4	> 10	Negative
Rock Type Ib. Lower Capacity Acid Forming.	< 4	≤ 10	-
Uncertain, possibly Ib.	< 4	> 10	Positive
Uncertain.	≥ 4	0	Negative
Rock Type IV. Non-acid Forming.	≥ 4	0	Positive

7.2 Mineralogy and total element analyses

The mineralogical composition of the solid rock samples was determined using x-ray diffraction (XRD). The XRD results and a simplified classification of the identified minerals are listed in Table 7-4. The results are summarised as follows:

- Anorthite and enstatite are the major minerals associated with the pyroxenite and norite samples, as well as was observed in the UG2 samples.
- Chromite is the major minors associated with the UG2 samples and was also observed to be present as secondary minerals in other samples collected.
- Diopside, anorthoclase and Illite are accessory minerals in all samples.
- Magnetite and pigeonite were observed to be major minerals associated with one of the UG2 samples.
- No carbonate or sulphide bearing minerals were identified which are typically associated with acid generation/neutralisation reactions.

Table 7-4: XRD results and mineral classification

Sample ID	Pyroxenite Contact with UG2	Pyroxenite H Wall	Spotted Norite H Wall	UG2 (1)	UG2 (2)
Rock Type > Mineralogy	**Pyroxenite**	**Pyroxenite**	**Norite**	**Chromite**	**Chromite**
Anorthite	78	38.9	70	45.1	17.3
Enstatite	11.8	45.8	26.3	20	5.6
Chromite	7.9	14.2	2.1	31.9	7.2
Pigeonite	2.2	1.1	1.7		27.6
Diopside	0.2				8.2
Illite					5.2
Magnetite					28.9
Anorthoclase				3	
Totals	100.1	100	100.1	100	100

7.3 Acid potential

The Acid-Base Accounting (ABA) and Net Acid Generation (NAG) screening results are presented in Table 7-2, Figure 7-1 and Figure 7-2. Based on the screening results, the following is noted:

- The %S, NPR and NNP of the rock samples, none of the samples are prone to cause acid generation (classified as Rock Type IV).
- All samples are not potentially acid generating (Non-PAG) and no long-term acid drainage is associated with the samples analysed (refer to Figure 7-1).
- NAG results suggest that samples are Non-PAG.

Table 7-5: Summary of ABA and NAG screening results

Sample ID	Pyroxenite H Wall	Spotted Norite H Wall	UG2 (1)	UG2 (2)
Description				
Paste pH	9.25	8.98	8.98	8.84
Total %S	0.024	0.018	0.026	0.033
Sulphide %S	0	0	0	0
AP CaCO3 kg/t	0.75	0.562	0.812	1.03
NP CaCO3 kg/t	12.5	24.9	12.3	10.8
NNP CaCO3 kg/t	12.2	24.6	12.3	10.5
NP/AP	16.7	44.3	15.1	10.5
NAG pH: (H2O2)	5.06	4.87	5.14	4.96
NAG (kg H2SO4/t)	0	0	0	0
Rock Type NNP	Uncertain	IV	Uncertain	Uncertain
Rock Type %S	IV	IV	IV	IV
Rock Type NP/AP	IV	IV	IV	IV

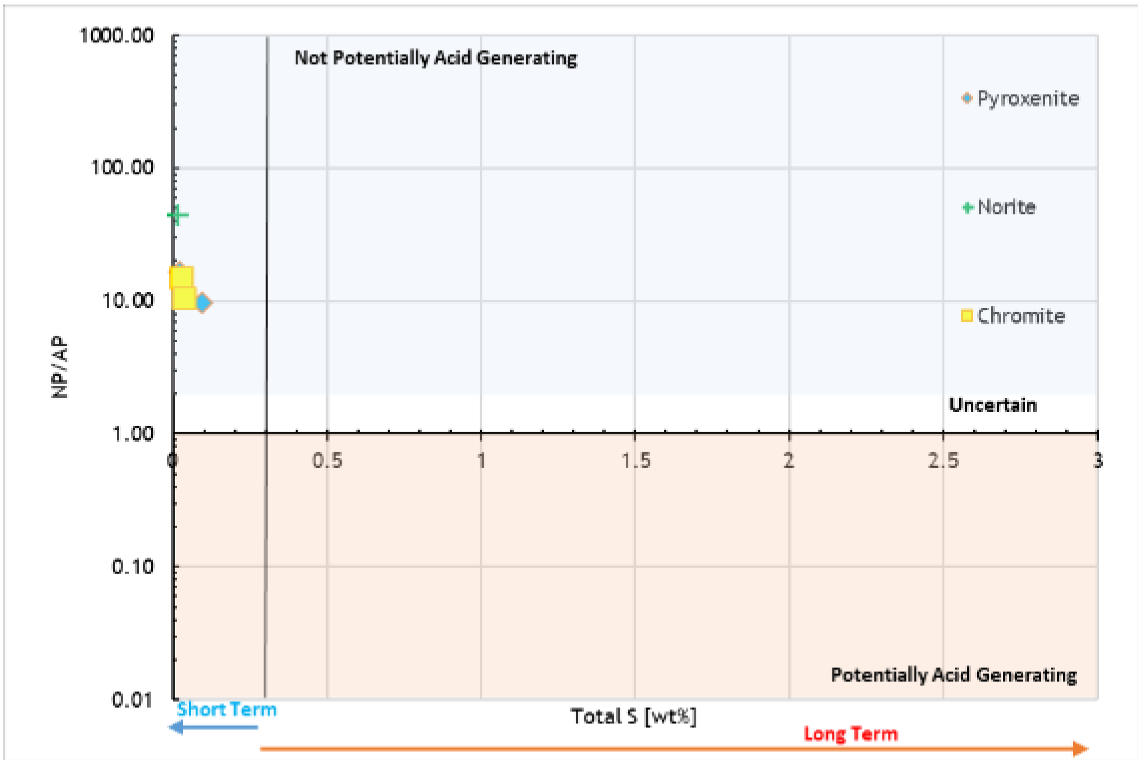


Figure 7-1: Summary of NP/AP vs. %S for Vygenhoek samples

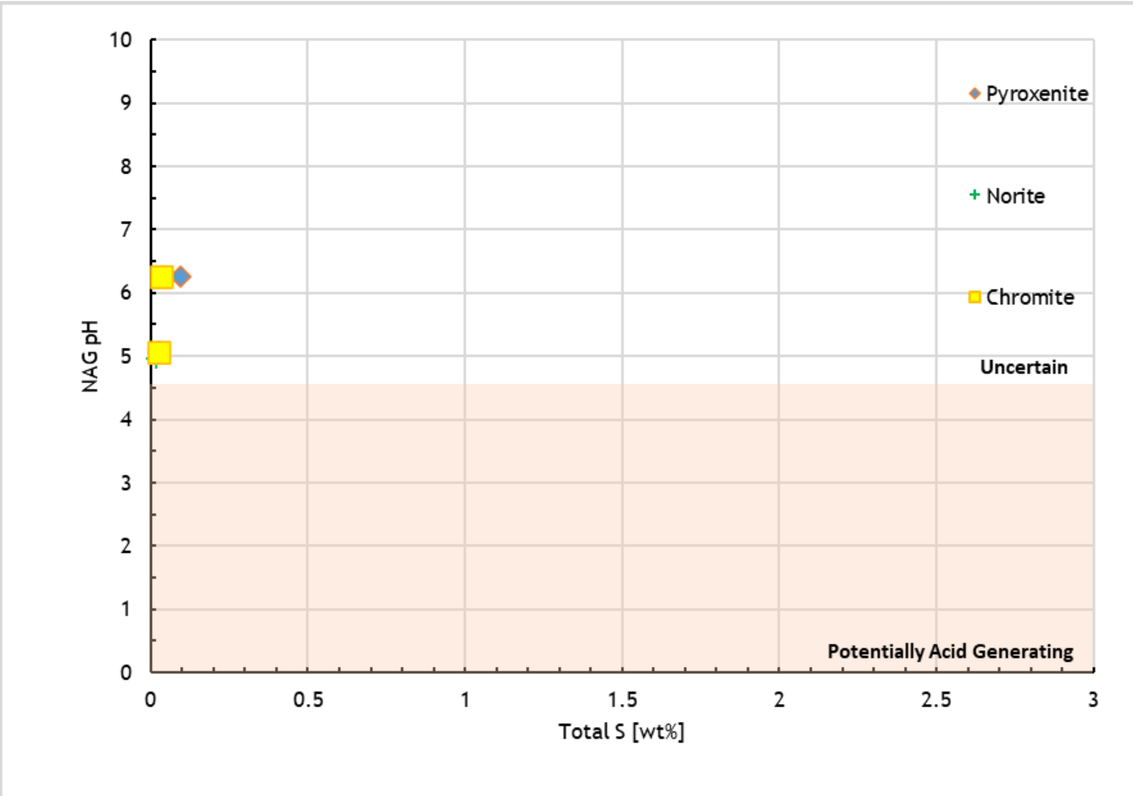


Figure 7-2: Summary of NAG pH vs. %S for Vygenhoek samples

7.4 Static leach testing

1-4 (rock to water ratio) distilled water (DW) tests were conducted on the samples obtained (UG2 seam – which is the ROM; and H-wall material). The leachate analytical results are summarised in Table 7-6, below. The following is noted from the static leach testing results:

- All samples exhibit neutral pH conditions.
- Aluminium is high for pyroxenite H Wall, spotted norite H Wall and UG2 (1) samples, compared to SANS 241-1:2015 aesthetic limits.
- Chromium is high in all samples compared to SANS 241-1:2015 aesthetical limits, except for the spotted norite H Wall sample. Chromite was observed to be associated with all samples (refer to Section 7.2).
- All other elements analysed are well within SANS 241-1:2015 limits for drinking water.

Table 7-6: Summary of 1:4 DW Leachate Analytical Results

Sample Name		Pyroxenite Contact with UG2	Pyroxenite H Wall	Spotted Norite H Wall	UG2 (1)	UG2 (2)	SANS 241-1: Aesthetical or Acute Limits
Constituent	Unit						
pH at 25°C	pH units	9.11	9.46	9.27	9.28	9.12	5 - 9.7
Electrical Conductivity at 25°C	mS/m	15.50	9.64	6.63	8.49	8.95	<170
Chloride	mg Cl/ℓ	12.40	3.54	3.22	3.87	4.40	<300
Dissolved Aluminium	mg Al/ℓ	0.1130	0.5650	1.8900	0.3150	0.1910	<0.3
Dissolved Barium	mg Ba/ℓ	<0.002	<0.002	<0.002	<0.002	<0.002	<0.07
Dissolved Beryllium	mg Be/ℓ	<0.005	<0.005	<0.005	<0.005	<0.005	ns
Dissolved Boron	mg B/ℓ	<0.013	<0.013	<0.013	<0.013	<0.013	<2.4
Dissolved Bismuth	mg Bi/ℓ	<0.004	<0.004	<0.004	<0.004	<0.004	ns
Dissolved Cadmium	mg Cd/ℓ	<0.002	<0.002	<0.002	<0.002	<0.002	<0.003
Dissolved Calcium	mg Ca/ℓ	11.600	2.350	2.760	3.540	3.300	ns
Dissolved Chromium	mg Cr/ℓ	0.1740	0.0890	0.0470	0.9230	0.7800	<0.05
Dissolved Cobalt	mg Co/ℓ	<0.003	<0.003	<0.003	<0.003	<0.003	ns
Dissolved Copper	mg Cu/ℓ	0.0110	0.0160	0.0100	0.0140	0.0120	<2
Dissolved Gallium	mg Ga/ℓ	0.0020	0.0020	<0.001	0.0020	<0.001	ns
Dissolved Iron	mg Fe/ℓ	0.0350	1.5300	0.4870	0.1710	0.0920	<2
Dissolved Lead	mg Pb/ℓ	<0.004	<0.004	<0.004	<0.004	<0.004	<0.01
Dissolved Lithium	mg Li/ℓ	<0.001	<0.001	<0.001	<0.001	<0.001	ns
Dissolved Magnesium	mg Mg/ℓ	5.2200	5.2100	2.0000	3.9100	4.1100	ns
Dissolved Manganese	mg Mn/ℓ	<0.001	0.0260	0.0190	<0.001	<0.001	<0.4
Dissolved Molybdenum	mg Mo/ℓ	0.0100	0.0120	0.0040	<0.004	<0.004	ns
Dissolved Nickel	mg Ni/ℓ	0.0460	0.0260	0.0120	0.0230	0.0180	<0.07
Dissolved Rubidium	mg Rb/ℓ	0.0080	0.0050	0.0040	0.0040	0.0050	ns
Dissolved Silver	mg Ag/ℓ	<0.001	<0.001	<0.001	<0.001	<0.001	ns
Dissolved Strontium	mg Sr/ℓ	0.0280	<0.001	<0.001	0.0050	0.0170	ns
Dissolved Tellurium	mg Te/ℓ	<0.001	0.0010	<0.001	<0.001	<0.001	ns
Dissolved Thallium	mg Tl/ℓ	<0.037	<0.037	<0.037	<0.037	<0.037	ns
Dissolved Vanadium	mg V/ℓ	<0.001	0.0230	0.0060	0.0010	<0.001	ns
Dissolved Zinc	mg Zn/ℓ	<0.002	<0.002	<0.002	<0.002	<0.002	ns
Nitrate	mg N/ℓ	0.67	<0.194	<0.194	<0.194	<0.194	<11
Orthophosphate	mg P/ℓ	<0.005	0.12	0.07	0.02	0.01	ns
Potassium	mg K/ℓ	5.39	4.47	2.69	3.87	4.04	ns
Sodium	mg Na/ℓ	4.80	6.06	5.00	4.39	4.54	<200
Sulphate	mg SO4/ℓ	19.20	11.90	1.22	13.40	18.30	<250
Total Alkalinity	mg CaCO3/ℓ	22.70	35.40	34.10	20.20	16.00	ns
		Not analysed			Above SANS 241-1: Aesthetical or Acute Limits		

8 CONCEPTUAL GEOHYDROLOGICAL MODEL

The following section presents an overview of the hydrogeological conceptual model used to develop the numerical groundwater flow and transport model. The site conceptual model (SCM) for the Proposed Vygenhoek Platinum Mine is shown in Figure 8-3 and Figure 8-4, below.

8.1 Mining schedule and closure philosophy

The Vygenhoek Platinum Mine is a Greenfields project. There are several mines towards the north and south (>5km) from the site (Everest North and Everest South). However, it is fair to assume that no mining impacts are associated with the proposed site due to the site position to other mines and the fact that the area is still natural.

The Vygenhoek Platinum Mine will have a life of mine (LOM) of 10 years, and mining will start in the northern portion of the pit towards the south. Mining will entail the opencast roll-over method, were mined out sections are rehabilitated as the new blocks are mined. Mining will take place to a depth ranging from 40 to 60 meters and will follow the dip of the UG2 seam (approx. 10 degrees). Ore will be transported via road of the Vygenhoek Platinum Mine.

Based on the site layout plan (refer to 1.1.2), the following will be situated at the site:

- An open cast pit in the order of 0.3 km^2;
- Temporary waste rock stockpiles placement areas;
- Ore stockpile placement areas;
- Offices and workshops;
- Roads and river crossings.

Closure will entail the backfilling of the opencast pit with waste rock and compaction of the waste rock material (refer to Figure 8-1). The high wall will remain partially exposed and hence the backfill will not be sloped to pre-mining topography conditions.

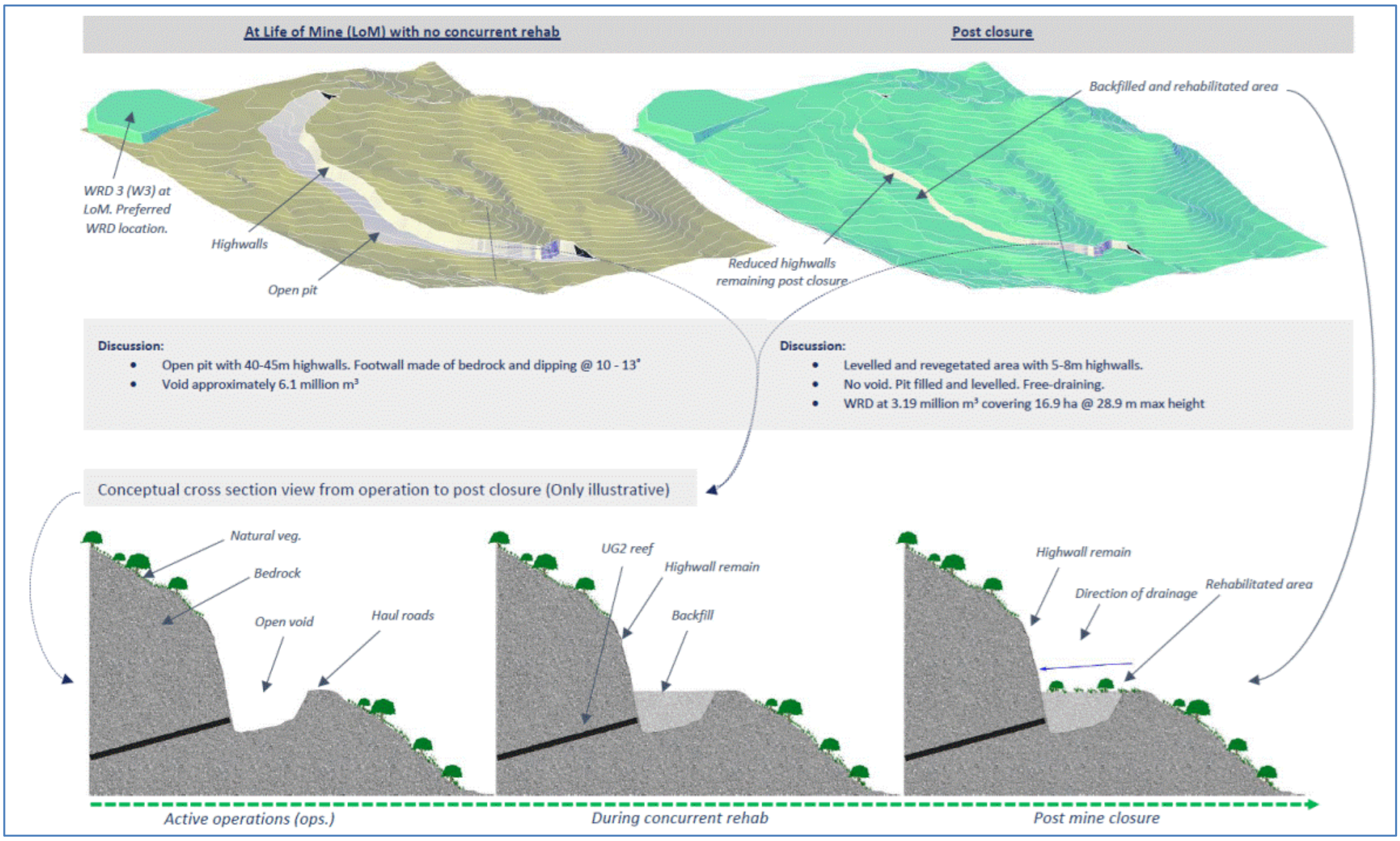


Figure 8-1: Closure philosophy (NettZero, 2020)

8.2 Potential groundwater pollution sources

Based on the available data, the following main groundwater pollution sources have been identified/are anticipated (refer to Figure 8-3).

1. **Preparational / construction phase (pre-mining phase):**
   - Vegetation clearing and disturbance of topsoils which may impact runoff and infiltration;
   - Oil and fuel spills from mining machinery; and
   - Temporary waste storage and handling facilities.
2. **Operational:**
   - Nitrate (NO_3) leaching into the surrounding aquifer from the use of explosives;
   - Waste rock dumps (consisting of mixtures of pyroxenite, norite and dolerite).
   - Groundwater dewatering;
   - Oil and fuel spills from mining machinery; and
   - Septic tanks and waste storage facilities associated with the office and workshops area.

3. **Rehabilitation / closure / post-closure:**
    - Backfilled pyroxenite, norite and dolerite backfilled into the opencast pit;
    - Rehabilitated office and workshops areas; and
    - Rehabilitated waste rock and ore laydown areas.

8.2.1 Receivers in the local area

There are no groundwater users situated downstream of the proposed opencast pit. The tributary of the Dwars River, situated approximately 350m downstream of the proposed opencast pit, is the receiver of likely shallow groundwater pollution, and overland runoff from the ore and waste rock stockpile areas.

Though there are no groundwater boreholes situated in the area, the opencast workings can be considered a “user” as dewatering will remove groundwater and a cone of depression will form. This zone of influence was simulated in Section 9).

8.3 Potential groundwater pollution migration velocities

Based on available aquifer data and Darcy’s Law[2] for groundwater flow through a saturated medium and aquifer hydraulic conductivity (K), the following pollution migration rates are likely:

1. Weathered aquifer zones:
    a. K values for the aquifer rock in the study area range from 0.01-0.0001 m/day.
    b. Based on the average hydraulic gradient of the area (0.04 to 0.7), pollution migration velocities in the range 1 x 10^{-4} to 0.001 m/day, are likely.
    c. The above mentioned suggest very slow-moving groundwater through the study area.
2. Fractured aquifer zones
    a. K values for the fractured aquifer is estimated in the order of 0.0047 m/day.
    b. Based on the average hydraulic gradient of the area (0.04 to 0.7), pollution migration velocities in the range 1 x 10^{-4} to 0.09 m/day, are likely.
    c. The above mentioned suggest very slow-moving groundwater through the study area.
3. Dolerite contact zones:
    a. Pollution migration is expected to be several orders of magnitude higher than the weathered and fractured zone. The pollution migration velocities can only be determined if boreholes drilled into these structures are pump tested.

[2] Darcy’s Flow (Q) = kiA
Darcy Velocity (v) = ki/θ
Where k = hydraulic conductivity (m/day), i = hydraulic head (ranges from 0.04 to 0.7), A = flow cross sectional area, θ = effective porosity of flow media (ranges from 0.1 to 0.3).

8.4 Mine flooding

Based on available groundwater level data for the proposed pit area, it is highly likely that the opencast workings will flood post-closure. This is due to the pit being partially situated underneath the groundwater table (i.e. the groundwater table is shallower towards the northern section of the opencast, and gradually deepens towards the south). Rainfall recharge into a rehabilitated pit will significantly increase the pit flooding rate.

The period it will take for opencast workings to flood post- closure was determined and is illustrated by the stage curve in Figure 8-2. The calculations are based on the following:

- An estimated recharge range of 20 to 25 % of the MAP (average is ± 650 mm) is estimated for the backfilled voids (Hodgson & Krantz, 1998).
- The pit is backfilled with waste rock, and decreases the effective open volume of the pit by approximately 75%. This means that flooding occurs in the pores within the backfill matrix.
- The estimate is based on a No-Capping scenario (i.e. no impermeable barrier is placed over the pit post-closure), where maximum infiltration can occur (with regards to the recharge range above).
- The estimate illustrates two (2) scenarios:
  - Scenario 1 = groundwater ingress is ignored; and
  - Scenario 2 = groundwater seepage is included in the flooding calculation. It is anticipated that the groundwater will contribute only a small fraction of the total recharge directly into the pit. Groundwater inflow is estimated to be in the range of 8.64 to 95 m^3/day, if aquifer layers are intercepted. The upper range of the estimate is used in the calculation.
- The pit volume estimate was determined by using the ore floor elevations and a 30m (Advanced Land Observing Satellite) ALOS (JAXA, 2019) DTM.
- Reduced pit volumes as a result of the proposed pit backfilling activities, were not considered in the calculations.

The total rainfall recharge to the Vygenhoek workings is estimated at 49 887.5 m^3/year, and groundwater influx is estimated at 34 675 m^3/year. Based on this figure and the pit layout, flooding to pre-mining water levels will occur within a period of 40 to 68 years.

It is important to note that in areas where the pit layout is lower than pre-mining water levels, that decant may occur (i.e. there will be a positive head from the highwall position to the footwall position). The likelihood of decant was assessed in the next section.

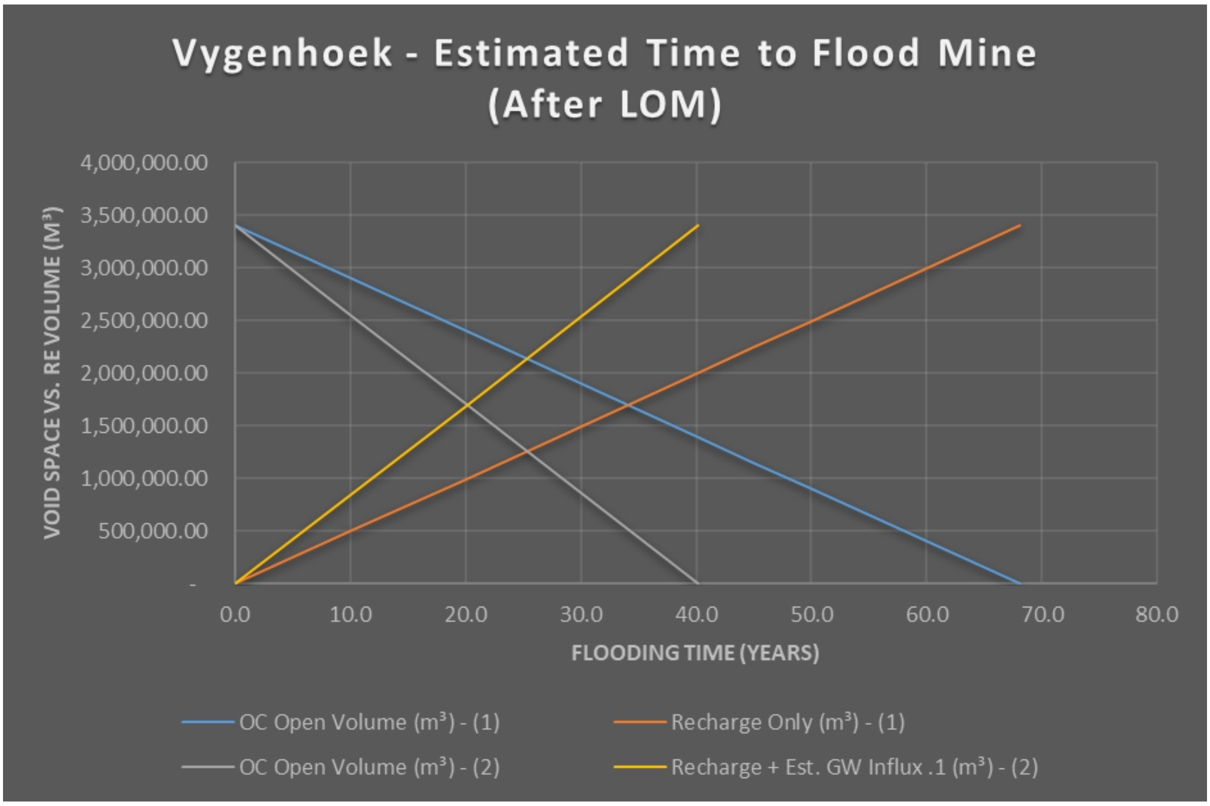


Figure 8-2: Estimated flooding time stage curve for the Vygenhoek Pit

8.5 Decant assessment

One (1) potential decant point has been identified, towards the north-eastern corner of the opencast pit (refer to Figure 8-3). The estimated decant elevation is 1365.99 mamsl.

8.5.1 Probability of decant

If backfilling does take place above the demarcated decant elevations, a positive hydraulic head may form in the pit, which could lead to decant. It is important to note that decant may not be a point source discharge (i.e. seen on the surface as a running stream of water such as a spring) but can occur from the pit via the weathered aquifer or vadose zone (i.e. as baseflow seepage).

8.5.2 Decant quantity and quality

Table 8-1 summaries the anticipated decant elevations, qualities, quantities of decant and the probability of decant occurring.

Table 8-1: Anticipated decant quantities and qualities

Opencast Area	Anticipated Decant Elevation (mamsl)	Estimated Decant Quantity (m^3/day)	Estimated Decant Quality (TDS in mg/l)	Probability
Vygenhoek Opencast	1365.99	136.68 m^3/day * Value based on steady-state recharge into the pit.	55 to 100 mg/l * value based on DW leach test of rock samples.	Low

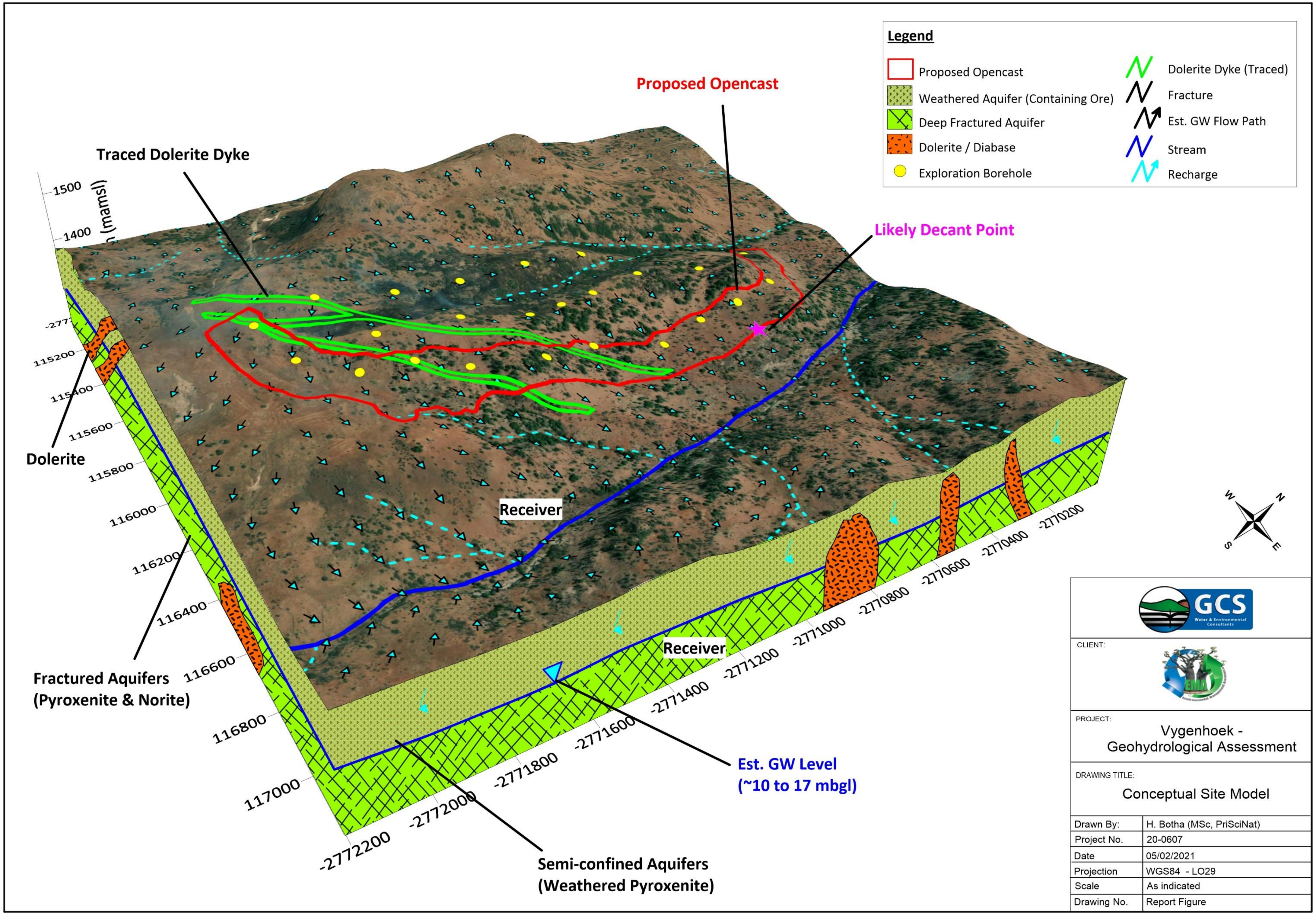


Figure 8-3: Site conceptual model

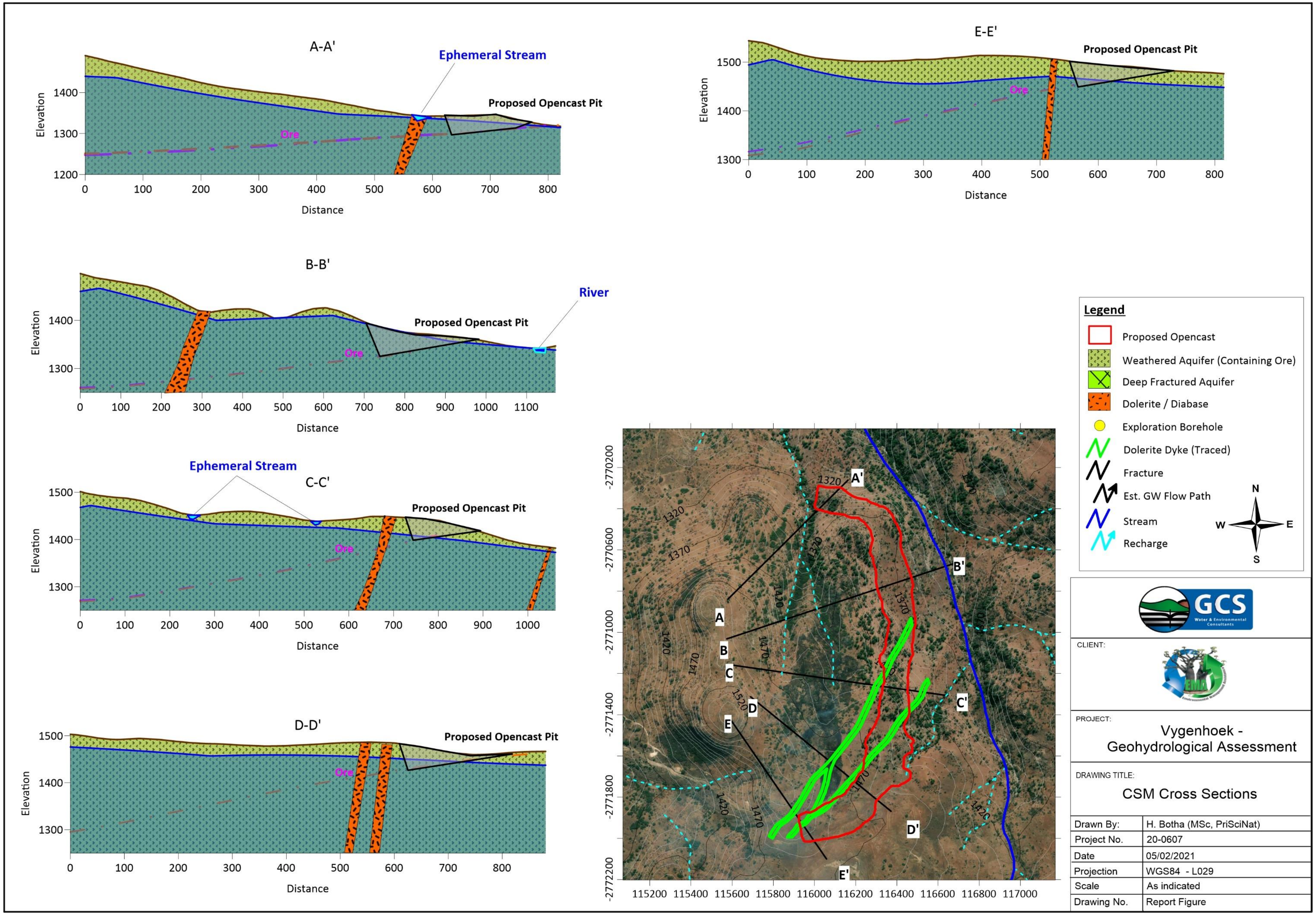


Figure 8-4: **Cross Sections**

9 NUMERICAL FLOW AND TRANSPORT MODEL

The numerical groundwater model developed describes the potential Zone of Influence (ZOI) for the Vygenhoek pit for the operational to post-closure phase (i.e. dewatering and pollution migration during this period). In terms of quantity and quality impacts on the groundwater regime, the constructional phase will highly likely only cause temporary and limited impacts. Hence, modelling focused on the long term impacts associated with the LOM and closure.

9.1 Objective of the model

As stated above, the groundwater flow and transport models were developed to:

- Simulate the operational and assumed post-closure groundwater flow system.
- Simulate the temporal and spatial extent of the pollution plume generated from the backfilling of waste rock into the Vygenhoek opencast pit (100Y plumes -post-closure).
- Simulate the likely aquifer drawdown at Life of Mine (LOM) for the opencast workings.

9.1.1 Modelling software

The numerical model for the project was constructed using Visual Modflow and Flex 6.1 Pro, Build 7088.31257, a pre-and post-processing package for the modelling code MODFLOW. MODFLOW is a modular three-dimensional groundwater flow model developed by the United States Geological Survey (Harbaugh A. , Banta, Hill, & McDonald, 2000). MODFLOW uses 3D finite-difference discretisation and flow codes to solve the governing equations of groundwater flow.

9.1.2 Governing Equations

The numerical model used in this modelling study was based on the conceptual model developed from the findings of the desktop and the baseline investigations. The simulation model simulates groundwater flow based on a three-dimensional cell-centred grid and may be described by the following partial differential equation:

$$\frac{\partial}{\partial x}(K_{xx}\frac{\partial h}{\partial x})+\frac{\partial}{\partial y}(K_{yy}\frac{\partial h}{\partial y})+\frac{\partial}{\partial z}(K_{zz}\frac{\partial h}{\partial z})\pm W = S_s\frac{\partial h}{\partial t} \quad \textit{Equation 1}$$

Where,

Kxx, Kyy, and Kzz are values of hydraulic conductivity along the x, y, and z coordinate axes, which are assumed to be parallel to the major axes of hydraulic conductivity (L/T);

h is the potentiometric head (L);

W is a volumetric flux per unit volume representing sources and/or sinks of water,

With,

W < 0.0 for flow out of the ground-water system, and W>0.0 for flow in (T-1);

Ss is the specific storage of the porous material (L-1); and

t is time (T).

Equation 1, when combined with boundary and initial conditions, describes transient three-dimensional groundwater flow in a heterogeneous and anisotropic medium, provided that the principal axes of hydraulic conductivity are aligned with the coordinate directions (Harbaugh *et al*., 2000).

9.2 Model process

The modelling processes followed is indicated in Figure 9-1 below.

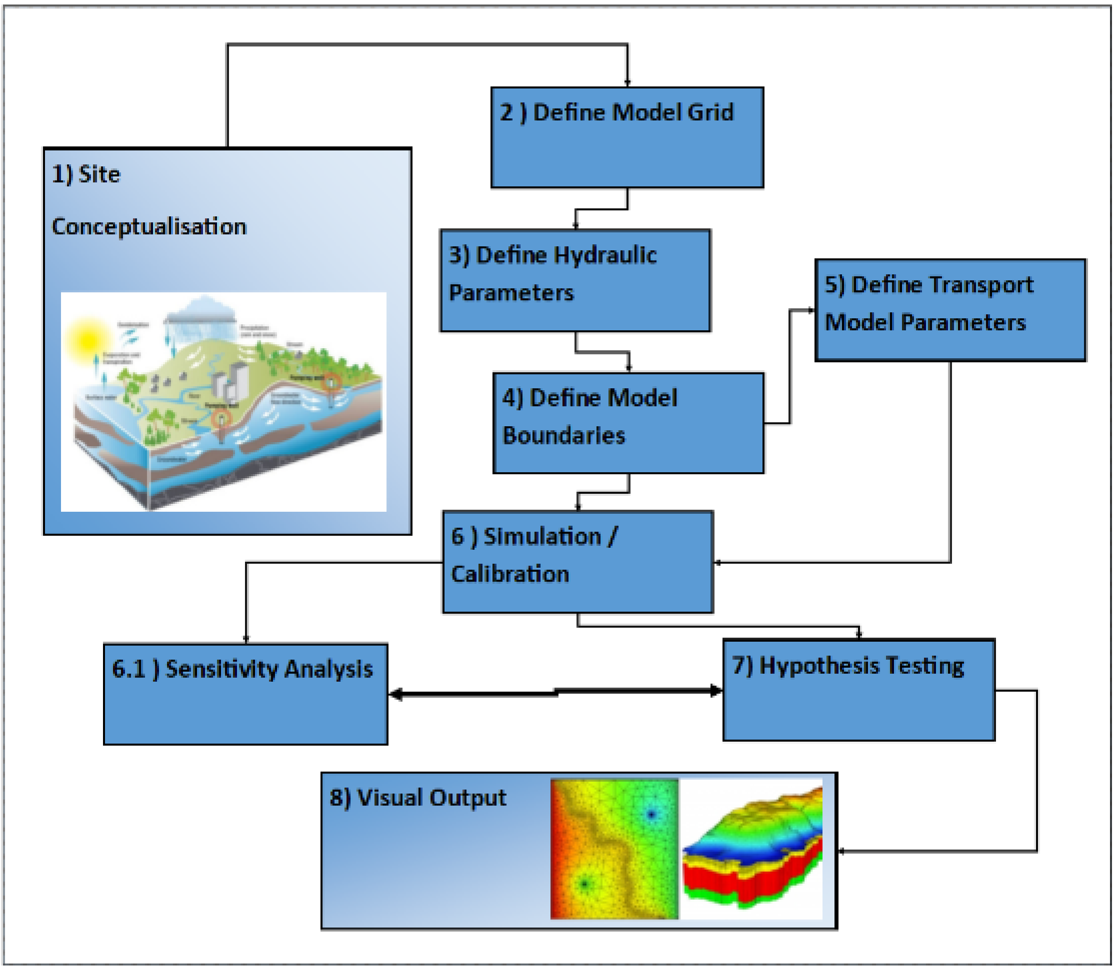


Figure 9-1: Modelling Approach

9.2.1 Model conceptualisation

The groundwater model grid and boundary condition visualisation are available in **Appendix D**.

Table 9-1 summarises the model constructs.

Table 9-1: Numerical modal constructs and conditions

Component	Model Conditions
Model Flow Engine	USGS MODFLOW NWT Solver Rewetting Enabled
Model Grid and Layers	Grid of 2.5 to 5 m. 3 Layers representing the weathered and fractured aquifer systems.
Boundary Conditions	Stream drains and rivers assigned at all identified streams and rivers. 5.2 to 7.1% (average 6.1 % = 39.9 mm/yr) of the MAP (650 mm). Recharge post-closure to pit area in the order of 20% applied to the pit area (130 mm/yr).
Time Discretization / Model Time	Both steady-state and transient state times defined. 2002 0 0 DATA AVAILABLE / CALIBRATION PERIOD 2020 6570 18 SS Cal Period / Y1 - Start 2021 6935 19 End Y1 2022 7300 20 End Y2 2023 7665 21 End Y3 2024 8030 22 End Y4 2025 8395 23 End Y5 2026 8760 24 End Y6 2027 9125 25 End Y7 2028 9490 26 End Y8 2029 9855 27 End Y9 2030 10220 28 End Y10 (LOM) - Closure 2050 17520 48 20Y After Closure 2070 24820 68 40Y After Closure 2130 46720 128 100Y After Closure
Initial Heads	The depth to water level ranged between 4 m (metre) and 128m, averaging at 10.
Conductivity	Varies from 0.1 to 0.0001 metre/day (m/d) for horizontal conductivity (Kx and Ky) and 0.01 to 0.0001 m/day for vertical conductivity (Kz).
Storage	Specific storage (Ss) ranges from 1 e^{-5} to 1 e^{-4}. Specific yield (Sy) ranges from 0.05 to 0.5. Effective porosity ranges from 0.001 to 0.5. Total porosity ranges from 0.003 to 0.5.
Dispersity	Norite / Pyroxenite = Dl of 7.5 m Backfill = Dl of 6.2 m Dolerite Weathered = Dl of 14 m Dolerite Fractured – Dl of 7.5 m
Model Calibration Points	89 Head Boreholes

9.2.2 Model calibration and output visualization process

The model calibration process was as follows:

- Due to the model objective, only the flow model was calibrated. The model aims to evaluate the movement of groundwater pollution from the backfilled pit, post-closure.
- Based on available monitoring data for Vygenhoek, TDS was used to model likely pollution migration.
- The plume presentation indicates 450 mg/l and 1000 mg/l TDS plume contour lines. The above mentioned was applied to demarcate potentially contaminated groundwater zones. The 450 mg/l and 1000 mg/l zones represent the DWAF (1996b) and SANS 241-1:2015 water quality ranges. These guidelines are not intended to be used for environmental compliance and are used only as a benchmark value, to contextualise the results.

9.2.3 Model assumptions

The following model assumptions and limitations are recognised:

- Artificial recharge or reduced recharge because of mining in the project area or the effects of climate change were not incorporated into the model.
- Groundwater-specific yield and specific storage values (refer to Section 4) were derived from reported ranges for the rock types encountered in the study area.
- The model does not consider kinetic mineral reactions. DW leach test was applied to the model domain to illustrate potential plume migration velocities and directions.
- The model grid was constructed based on the regional geology map for the area and refined in areas where there is available drilling log data and/or geophysical data.

9.2.4 Model confidence

The Australian Groundwater Modelling Guidelines (Barnett *et al.,* 2012) refer to the following two principles that were followed in the numerical calibration process.

- **Guiding Principle 2.3:** A target model confidence level classification should be agreed and documented at an early stage of the project to help clarify expectations. The classification can be estimated from a semi-quantitative assessment of the available data on which the model is based (both for conceptualisation and calibration), the way the model is calibrated and how the predictions are formulated.
- **Guiding Principle 2.4:** The initial assessment of the confidence level classification should be revisited at later stages of the project, as many of the issues that influence the classification will not be known at the model planning stage.

The model confidence rating is available in **Appendix F**.

9.2.5 Model calibration

In a catchment scale groundwater flow model, a difference between calculated and measured heads of up to several meters can be tolerated and is usually expressed as a function of the total range of observations. A model calibrated to a scaled absolute mean value (RMS) ranging from 10 to 15% is generally regarded as acceptable (Tiedeman and Hills, 2005).

The calibration was done under steady-state and transient state conditions. The steady-state model was calibrated to an RMS in the order of 11%, which can be considered a representative of the project area (refer to Figure 9-2). The steady-state model was used as the initial head input into the transient state model, and the transient state model was used for the dewatering estimations.

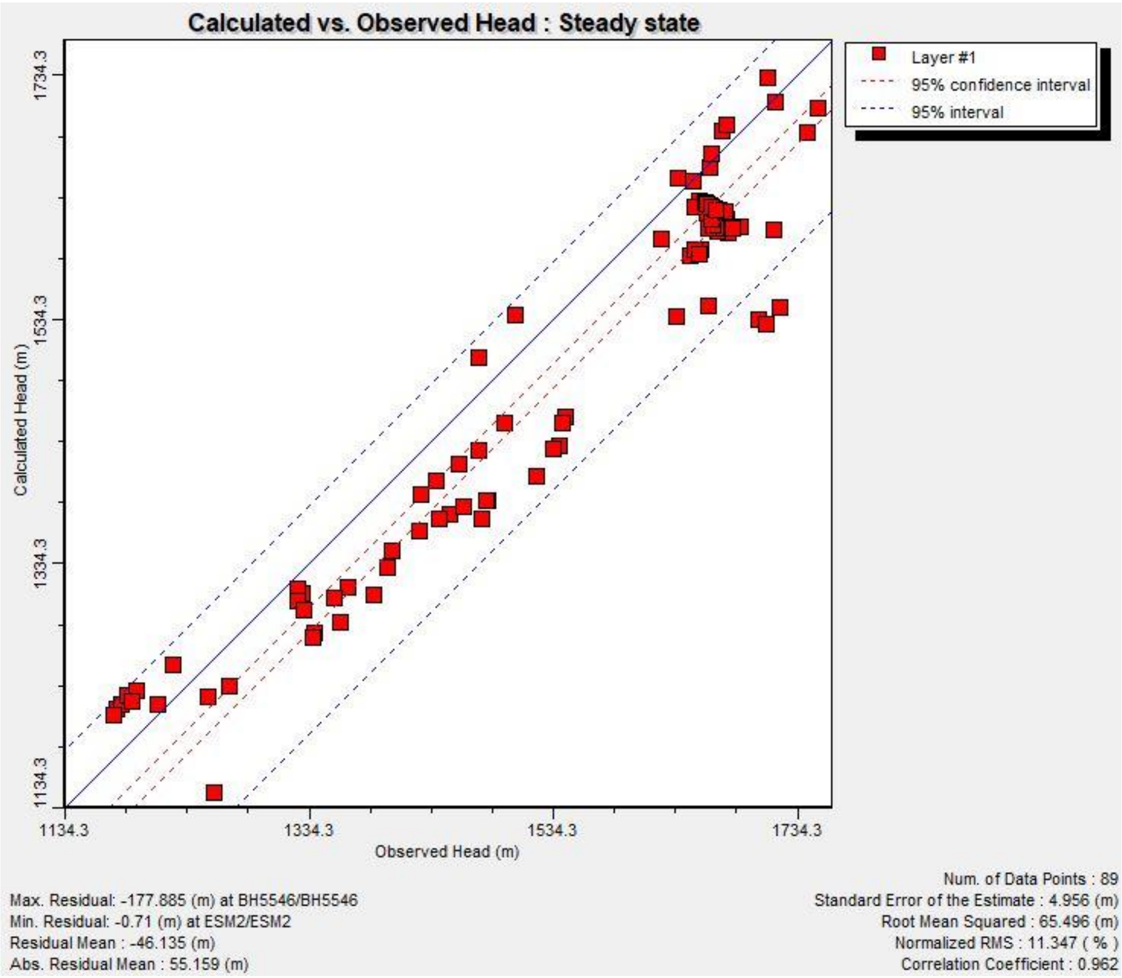


Figure 9-2: Steady-state model calibration achieved

9.2.6 Model sensitivity

A sensitivity analysis was carried out on the calibrated steady-state model using zones to assess the influence on groundwater level and flow dimensions by running the model in the Parameter Estimation (PEST) and sensitivity mode. The sensitivity report is available in **Appendix D**.

The following parameters were observed to be sensitive:

- Hydraulic conductivity in layer 1, 3 and 4.
- Storage in layer 1, 3 and 4.
- Recharge.

9.3 Model outputs

The calibrated steady-state model is shown in Figure 9-3, below. The groundwater flow model indicates groundwater flow velocities ranging from 0.01 (min) to 0.096 (max) m/day, indicating very slow-moving groundwater in the study area.

9.3.1 Dewatering estimation

The calibrated model was applied in a transient state to simulate aquifer stresses relating to dewatering. Drainage cells were positioned in the model domain at the approximate elevations corresponding to the pit layouts (i.e. the footwall and pit bottom). Constant discharge was assumed to simplify the dewatering. The dewatering rate correlates to the likely aquifer yield and hydraulic conductivity (T value range of 0.001-5 m^2/day).

The dewatering estimates at LOM is shown in Figure 9-4. A maximum drawdown in the order of 6.7m is simulated, and is focused towards the southern section of the opencast workings. Dewatering influence as a result of the dolerite dykes are noted. A marginal impact in terms of baseflow to the tributary of the Dwars River is anticipated (touches the 1.7m line in one area only).

9.3.2 Transport modelling

This scenario aims to describe the ZOI (i.e. the TDS plume movement in the aquifer and likely impact on local surface water streams) if the opencast workings are backfilled with waste rock and no rehabilitation or mitigation applied, simulating a worst-case scenario.

The following pertains to the no-mitigation scenario:

- A constant sulphate concentration of 1 200 mg/l is applied to the opencast area.
- Recharge in the range of 15-20% were assigned to the opencast areas (Hodgson & Krantz, 1998).
- The backfill overburden hydraulic properties (specific yield, effective porosity and total porosity) are assumed to be the same as that of bulk sandy gravel material.

The transport model output is shown in Figure 9-5 and present the 100Y TDS plume / ZOI. The transport output suggests that the plume will gradually migrate north-east towards the tributary of the Dwars River. The plume may intercept the non-perennial stream towards the north of the opencast workings. However, due to the ephemeral nature of this stream, marginal impacts are likely (i.e. the stream is a losing stream and may not always have water for TDS surface transport).

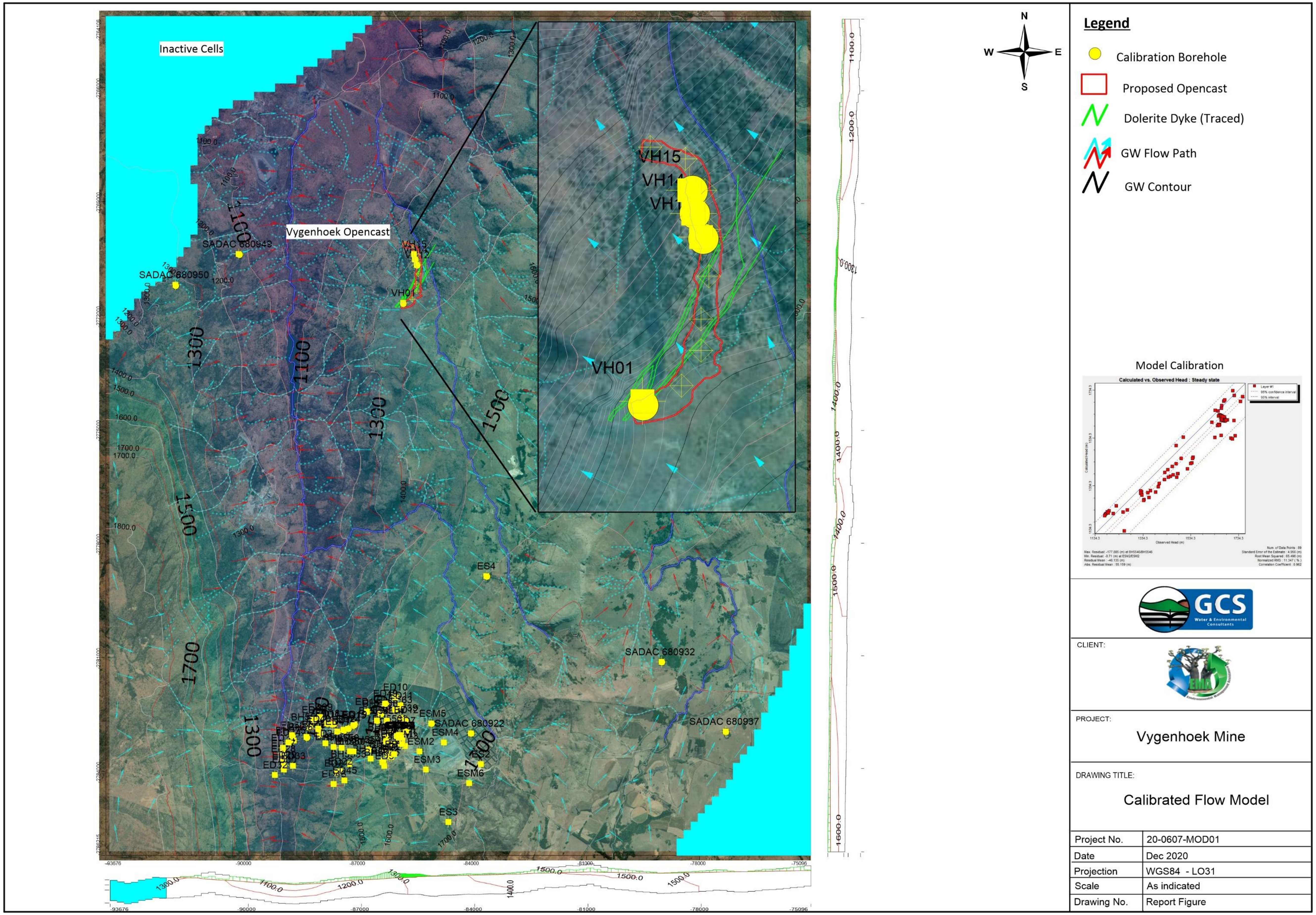


Figure 9-3: Calibrated flow model

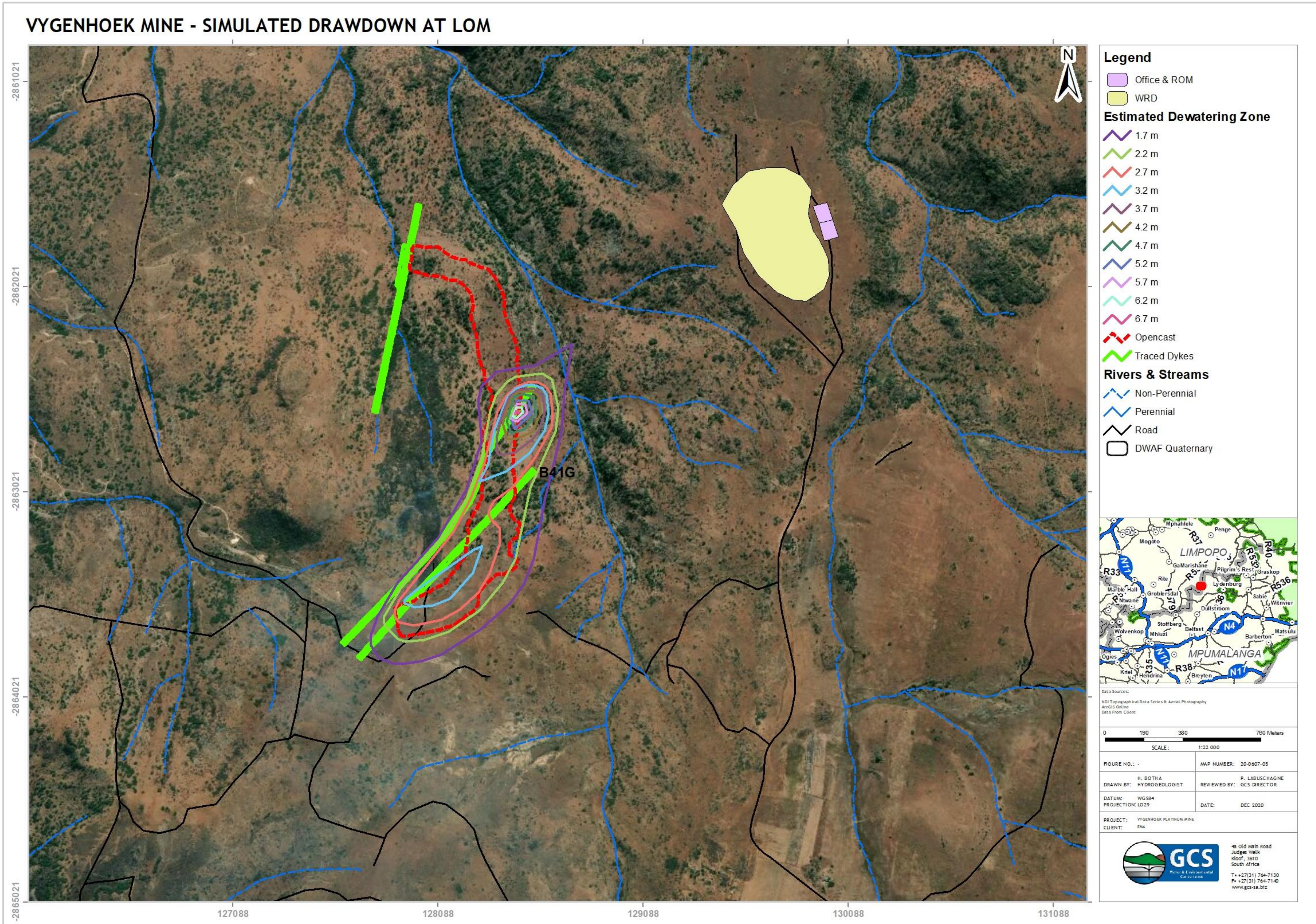


Figure 9-4: **Simulated drawdown at LOM**

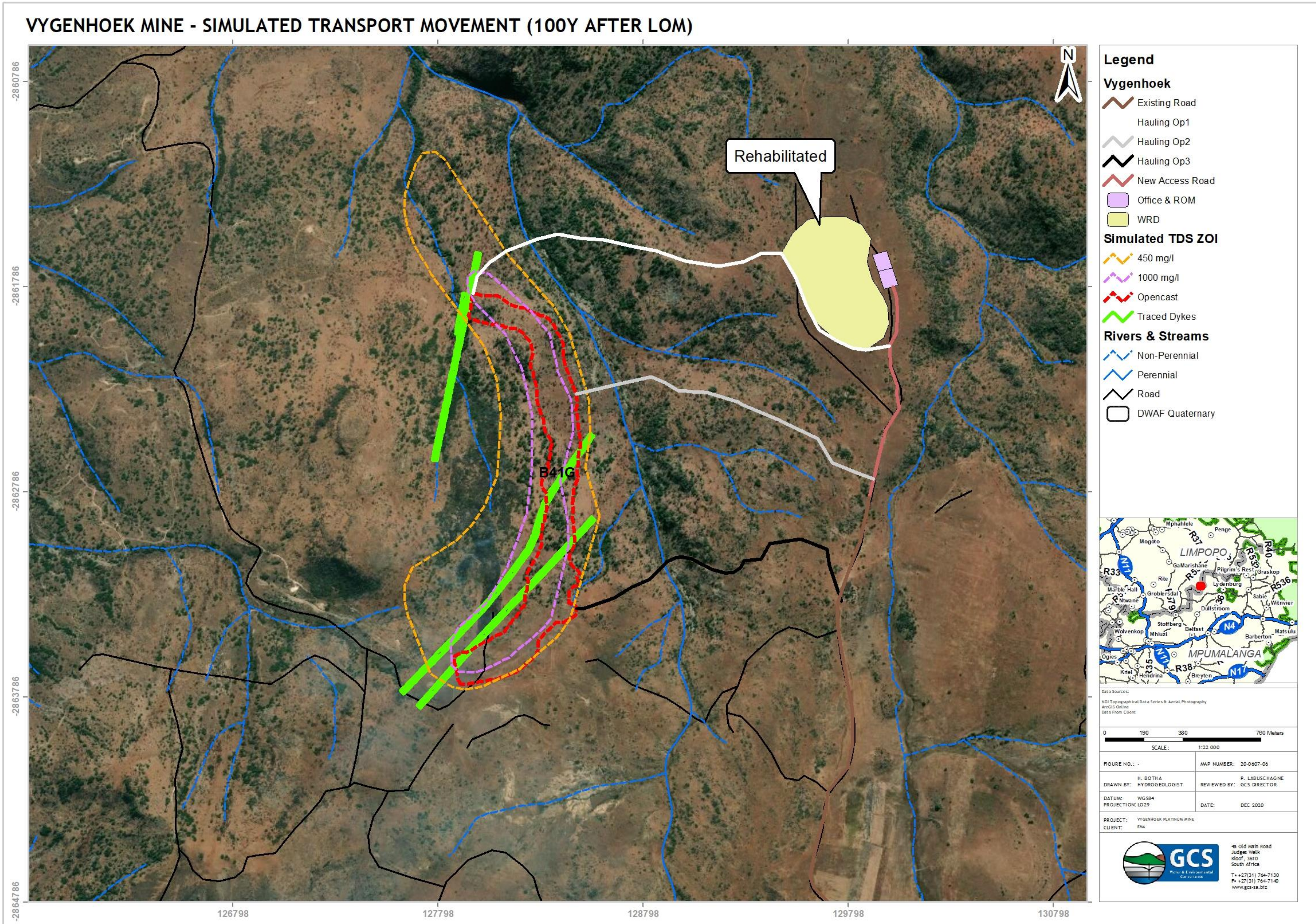


Figure 9-5: Simulated TDS plume at LOM and 100Y after closure

10 RISK AND IMPACT ASSESSMENT

The anticipated hydrogeological risk with regards to the project infrastructure and activities, in terms of likely contributors to groundwater risk, were assessed. The source-pathway-receptor (SPR) model (DWAF, 2008) was used to model potential pollution sources and primary receptors within the study area.

Risk assessment entails the understanding of the generation of a hazard, the probability that the hazard will occur, and the consequences should it occur.

The anticipated geohydrological impacts are indicated in Figure 10-1. Table 10-1 list preliminary impacts and mitigation measures for the Vygenhoek Platinum Mine. The risk rating methodology is discussed in **Appendix E**.

Based on the outcome of the risk assessment, no geohydrological avoidance areas or geohydrological buffers are required.

10.1 Proposed Groundwater Management Aspects

The following section supplies a brief groundwater management plan which could help to improve the groundwater conditions during the operational and decommissioning phases of the Vygenhoek Platinum Mine. As per the closure objectives, waste rock will be backfilled into the opencast workings. It is believed that other surface infrastructure (i.e. roads, change rooms, workshops, offices etc.) will be demolished and the areas will be rehabilitated.

10.1.1 Operational and decommissioning phase

To restrict the local groundwater and surface water impact, the following actions are proposed:

- Reduce the infiltration into stockpiles and rock dumps using temporary liners or geomembrane coverings. Alternatively, temporary rock cladding and compaction my help to reduce infiltration. Ongoing rehabilitation through implementing and maintenance of the above mentioned will reduce the impact on the groundwater.
- Re-use of groundwater seepage collected in soak ways, stormwater trenches, and cut-off trenches, underground workings and adequately size pollution control facilities.
- Keep dirty areas like workshops and oil and diesel storage areas as small as possible.
- Contain poor quality runoff from dirty areas and divert this water to PCD for re-use.
- Have oil/diesel spill kits on site.
- Confirm groundwater and surface water monitoring protocol and plans.

10.1.2 Groundwater closure objectives

To restrict the local groundwater and surface water impact, the following actions are proposed:

- Rehabilitate and revegetate waste rock dump footprints areas after waste has been backfilled into the opencast workings.
- Multiple-level monitoring boreholes (refer to Section 11) must be constructed to monitor base-flow quality within the identified sensitive zones (i.e. in the aquifer units and towards the tributary of the Dwars River) and to monitor groundwater level behaviour in the open cast pits (i.e. rebound in the aquifer post-mining). Use the results of the monitoring programme to confirm/validate the predicted impacts on groundwater availability and quality after closure;
- Update existing predictive tools to verify long-term impacts on groundwater, if required;
- Use monitoring data to determine compliance with the closure objectives set during the Decommissioning Phase;
- Negotiate and get groundwater closure objectives approved by the competent authority during the decommissioning phase of the project, based on the results of the monitoring information obtained during the construction and operational phases of the project, and through verification of the numerical model constructed for the project;
- Continue with groundwater quality and groundwater level monitoring for a period of at least two to four years after the pits and waste facilities are decommissioned to establish post-closure groundwater level and quality trends. The monitoring information must be used to update, verify and recalibrate the predictive tools used during the study to increase the confidence in the closure objectives and management plans;
- Present results of the monitoring programme to the competent authority on an annual basis. The post-closure monitoring programme will be re-evaluated on an annual basis in consultation with competent authority;
- Negotiate closure with competent authority based on the results of the groundwater monitoring undertaken, after the two to four-year post-closure monitoring periods.

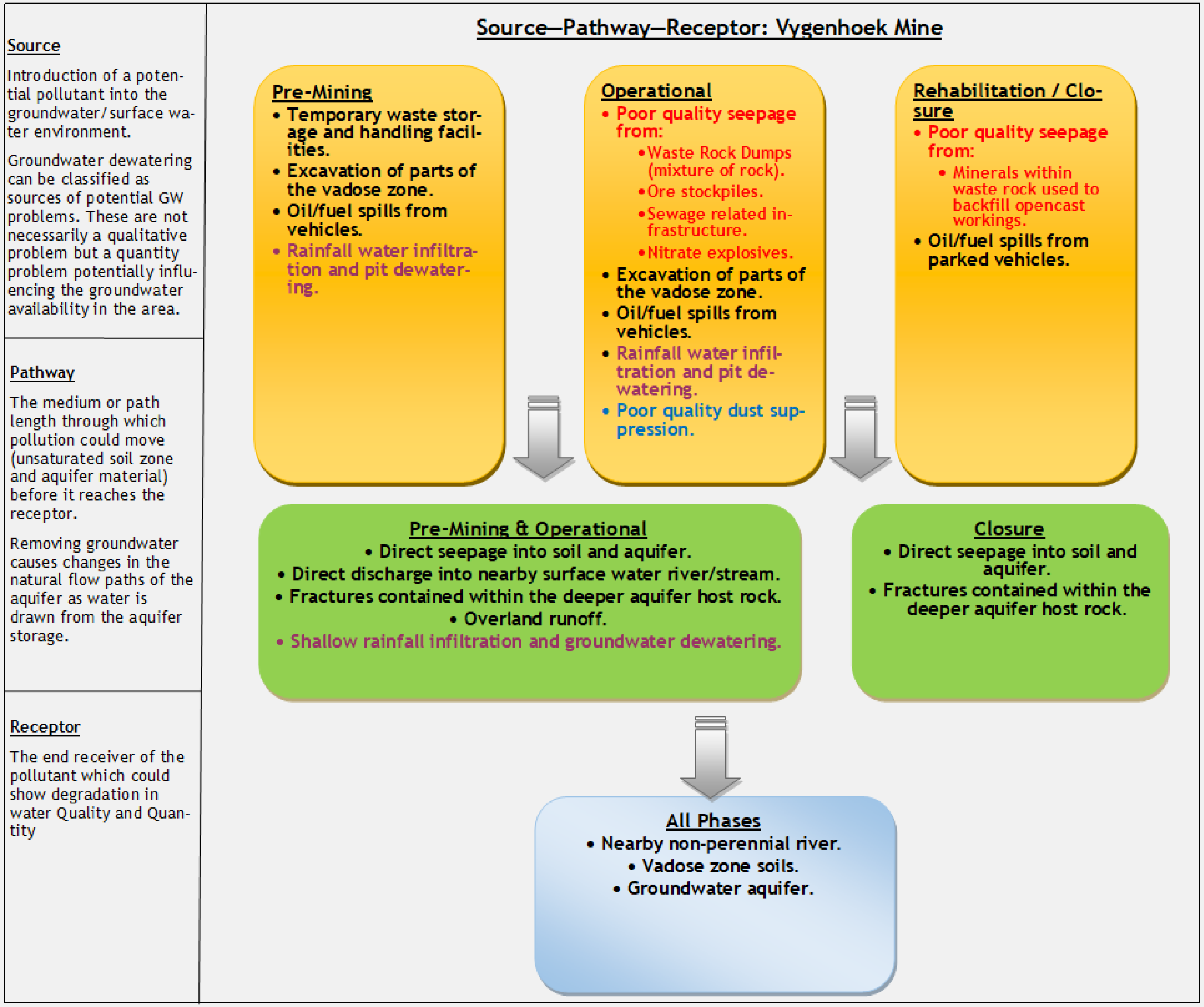


Figure 10-1: Vygenhoek - SPR

Table 10-1: Preliminary risk assessment and mitigation

POTENTIAL ENVIRONMENTAL IMPACT	APPLICABLE AREA	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION							RECOMMENDED MITIGATION MEASURES	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION						
			M	D	S	P	TOTAL	STATUS	SP		M	D	S	P	TOTAL	STATUS	SP
Matters About Hydrogeology (Groundwater Related Impacts)																	
Pre-Mining / Preparation Phase																	
• Exposure of soils, leading to increased runoff from cleared areas and erosion of the watercourses, and thus increased the potential for sedimentation of the watercourses. • Soil compaction; and • Soil erosion.	Site preparation, including placement of contractor laydown areas and storage (i.e. temporary stockpiles, bunded areas etc.) facilities	Earthworks	6	2	1	6	54	-	M	• Only excavate areas applicable to the project area. • Cover excavated soils with a temporary liner (i.e. plastic or geomembrane) to prevent contamination. Keep the site clean of all general and domestic wastes. • All development footprint areas to remain as small as possible and vegetation clearing to be limited to what is essential. • Retain as much indigenous vegetation as possible. • Exposed soils to be protected by means of a suitable covering. • Existing roads should be used as far as practical to gain access to the site, and crossing the rivers in areas where no existing crossing is apparent should be unnecessary, but if it is essential crossings should be made at right angles.	2	1	1	3	12	-	L
	Disturbing vadose zone during soil excavations / infilling activities	Earthworks	6	2	1	6	54	-	M		2	2	1	3	15	-	L
Surface water contamination	Leakages from vehicles and machines.	Mechanised machinery	2	1	1	5	20	-	L	• Visual soil assessment for signs of contamination at vehicle holding, parking and activity areas. • Place oil drip trays under parked construction vehicles and hydraulic equipment at the site.	0	1	1	2	4	-	L
Operational Phase																	
Soil disturbance	Opencast pits, waste stockpiles and ore stockpiles.	Earthworks	3	3	2	4	32	-	M	• Only excavate areas applicable to the project area. • Cover excavated soils with a temporary liner (i.e. plastic or geomembrane) to prevent contamination. • Keep the site clean of all general and domestic wastes. • All mine footprint areas to remain as small as possible and vegetation clearing to be limited to what is essential. • Retain as much indigenous vegetation as possible.	1	3	2	4	24	-	L
Hydrocarbon spills	Opencast pits, waste stockpiles and ore stockpiles.	Mechanised machinery	4	3	2	4	36	-	M	• Park vehicles in hard park areas lined with concrete or which are compacted and fitted with oil traps. • Ensure vehicles are in good condition and not leaking fuel or oil when entering the mining areas. • Do not service machinery in the opencast areas. Have oil & fuel spill kits on site.	2	2	2	2	12	-	L
Poor quality seepage from overburden dumps into the aquifer and downstream surface water bodies (non-perennial streams).	Opencast pits, waste stockpiles and ore stockpiles.	Seepage	4	3	2	4	36	-	M	• Reduce mine footprint areas to minimize the reaction flow path of rainfall water. • Ensure that ore stockpiles are not kept on-site to long (i.e. in line with the maximum time it takes to kinetically decompose the material to form poor quality seepage – to be determined via kinetic column leach testing). Moreover, stockpile footprint areas should be compacted before placement of ore, to minimize poor quality seepage.	4	2	2	3	24	-	L

POTENTIAL ENVIRONMENTAL IMPACT	APPLICABLE AREA	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION							RECOMMENDED MITIGATION MEASURES	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION						
			M	D	S	P	TOTAL	STATUS	SP		M	D	S	P	TOTAL	STATUS	SP
Drawdown of the regional water table as the opencast workings flood. Low to marginal impact likely due to dewatering ZOI.	Opencast pits	Aquifer drawdown	6	2	2	2	20	-	L	• Ensure any groundwater ingress into the opencast workings is sampled and that the inflow quantity is recorded.	6	1	2	2	18	-	L
Flooding of the opencast workings while operational. Potentially from contact zones or 1:100Y flooding events.	Opencast pits	Flooding	6	2	2	3	30	-	M	• Ensure that dewatering pumps are on standby to dewater should there be any seepage or accumulated rainwater in the pits. This is likely only to occur during high precipitation events or if mining intercepts a contact area under hydraulic pressure.	6	1	2	3	27	-	L
Closure / Decommissioning Phase																	
Poor quality mine drainage into nearby non-perennial streams, rivers and the groundwater aquifer system.	Opencast pits	Seepage	4	5	2	4	44	-	M	• Divert dirty water to temporary water holding facilities (i.e. PCDs or attenuation ponds). The water would need to be treated or taken off-site for disposal (depending on the quality of the water). • Install temporary surface cut-off drains in areas where seepage discharge is observed. Captured water needs to be diverted to PCDs. • Compact the backfilled opencast material to reduce infiltration into the workings. Reducing infiltration will reduce the groundwater seepage potential (i.e. less water will enter the pit which may react with minerals and produce seepage). • Rehabilitate and revegetate the waste rock dump footprint areas. • Revegetate the backfilled opencast pit.	4	5	2	3	33	-	M
	Remnant remains of waste rock dumps	Seepage	4	5	4	4	52	-	M		4	5	2	3	33	-	M
Decant from the opencast workings.	Opencast pits	Decant	1	1	1	1	3	-	L	• Compact the backfilled opencast material to reduce infiltration into the workings. Reducing infiltration will reduce the groundwater infiltration lower decant risk. Generally an acceptable compaction layer of 150mm compacted to 95% Standard Proctor Density.	1	1	1	1	3	-	L
Rebound of the regional water table as the opencast workings flood.	Opencast pits	Aquifer recovery	6	5	2	2	26	-	L	• No mitigation possible for aquifer rebound. However, water monitoring will be used to monitor the recovery and if decant risk is confirmed proper decant mitigation measures should be formulated during the monitoring programme and follow-up geohydrology studies.	6	5	2	1	13	-	L
Subsidence of surface topography	Opencast pits	Collapsible soils for infilled areas.	4	2	1	5	35	-	M	• Infilling material should be compacted to ensure a stable work platform. Generally an acceptable compaction layer of 150mm compacted to 95% Standard Proctor Density.	4	1	1	1	6	-	L

11 GROUNDWATER MONITORING

The monitoring network is based on the principles of a monitoring network design as described by (DWAF, 2007). The methodological approach which the monitoring plan follows is represented by Figure 11-1, below.

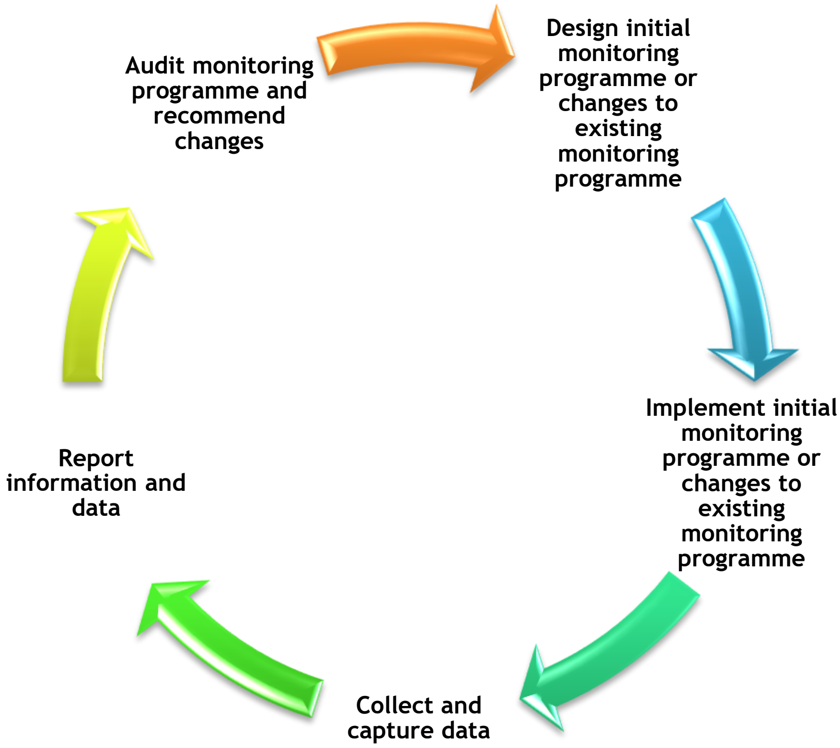


Figure 11-1: Monitoring Process

11.1 Establishment of the monitoring network

Currently, no groundwater and surface water monitoring is taking place. It is proposed that a proper monitoring programme be implemented to monitor both the water quality and quantity at the site. The monitoring programme is divided into two (2) phases:

- Phase 1: Monitoring during site preparation (pre-mining) and mine expansion activities (visual and sampling); and
- Phase 2: Monitoring during the operational phase and closure phase (long term).

11.1.1 Phase 1 monitoring (visual and sampling)

It is proposed that, during the initial phases of the mine (i.e. when contractors mobilise the site), water (i.e. areas where groundwater and surface water is noted) and soil (i.e. soil may become contaminated by oils or fuel which may leach into the vadose zone during rainfall periods) monitoring focus on:

1. Active excavation and laydown areas (i.e. areas where vegetation is cleared, workshop construction areas, opencast mine area, waste rock and ore laydown areas); and
2. Equipment / heavy machinery parking or housing areas. Placement and monitoring of drip trays underneath parked construction vehicles will help to determine which vehicles need to be repaired/taken off-site to prevent contamination while in service.

Regular visual inspections (weekly) of these areas need to be undertaken. If any signs of contamination or pollution is observed, it is recommended that water or soil samples be collected and submitted to a SANS accredited laboratory. The severity of the pollution or contamination can then be determined, and mitigation measures should be formulated. It is proposed that this monitoring be continued during the gradual expansion of the opencast workings, up to mine closure and rehabilitation.

11.1.2 Phase 2 monitoring (permanent monitoring)

From the risk assessment undertaken, it is anticipated that the vadose zone and groundwater aquifer are the receptors of likely pollution. Long term pollution may migrate to the nearby non-perennial stream (even though it is expected to be a losing stream) and perennial river. Therefore, long term monitoring should focus on these areas.

Due to the project, some degree of groundwater quality monitoring is proposed. This would involve installing a total of 12 monitoring boreholes (40 to 60 m) downstream and upstream of the opencast areas. A typical monitoring borehole construction is shown in Figure 11-2.

Table 11-1: Proposed monitoring points

ID	Slope	Latitude (WGS84, DD)	Longitude (WGS84, DD)	Depth (m)
485	Downstream	-25.038224	30.155169	40-60
535	Downstream	-25.039837	30.155298	40-60
559	Downstream	-25.040727	30.155575	40-60
590	Downstream	-25.042203	30.154971	40-60
684	Downstream	-25.047590	30.154404	40-60
666	Downstream	-25.033360	30.149479	40-60
Hwall 1	Upstream (background monitoring)	-25.04619	30.15076	40-60
Hwall 2	Upstream (background monitoring)	-25.03616	30.15056	40-60
WRD 1	Downstream WRD	-25.03353	30.16275	40-60
WRD 2	Downstream WRD	-25.03609	30.16474	40-60
WRD 3	Downstream WRD	-25.03034	30.16360	40-60
WRD 4	Upstream WRD	-25.03278	30.16877	40-60

Surface water monitoring at the site should take place in line with the hydrology assessment report for the Vygenhoek Platinum Mine.

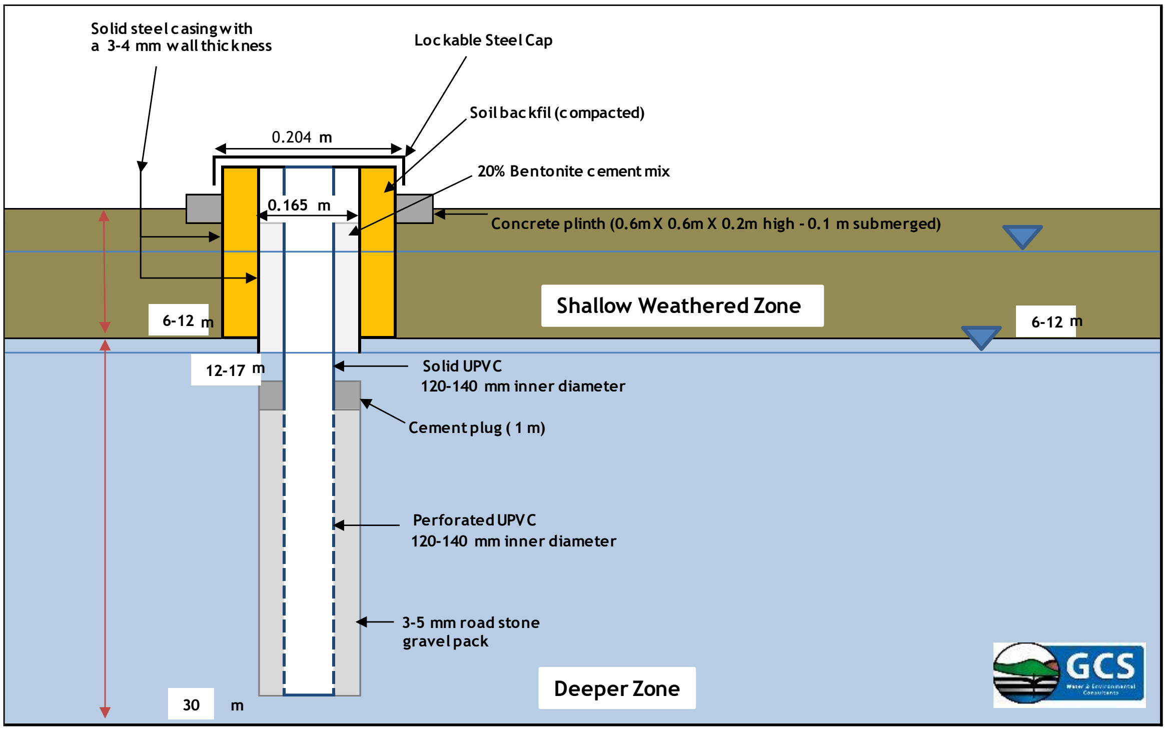


Figure 11-2: Proposed borehole construction

11.2 Monitoring duration

In terms of monitoring duration, it is proposed that monitoring be rolled out during the construction phase of the project up to 2-4 years after the closure of the opencast pit (i.e. 2-4 years after rehabilitation is completed). The need for further monitoring should be determined by the competent authorities.

11.3 Monitoring responsibility

It is proposed that the mine be responsible for Phase 1 and Phase 2 monitoring. However, an independent geohydrologist specialist / environmental consulting firm can also be appointed to undertake monitoring and submit monitoring reports to DWS and DMRE, on behalf of the applicant.

The proposed monitoring type, frequencies and constituents to monitor are listed in Table 11-2, below. Preliminary monitoring positions are indicated in Figure 11-3.

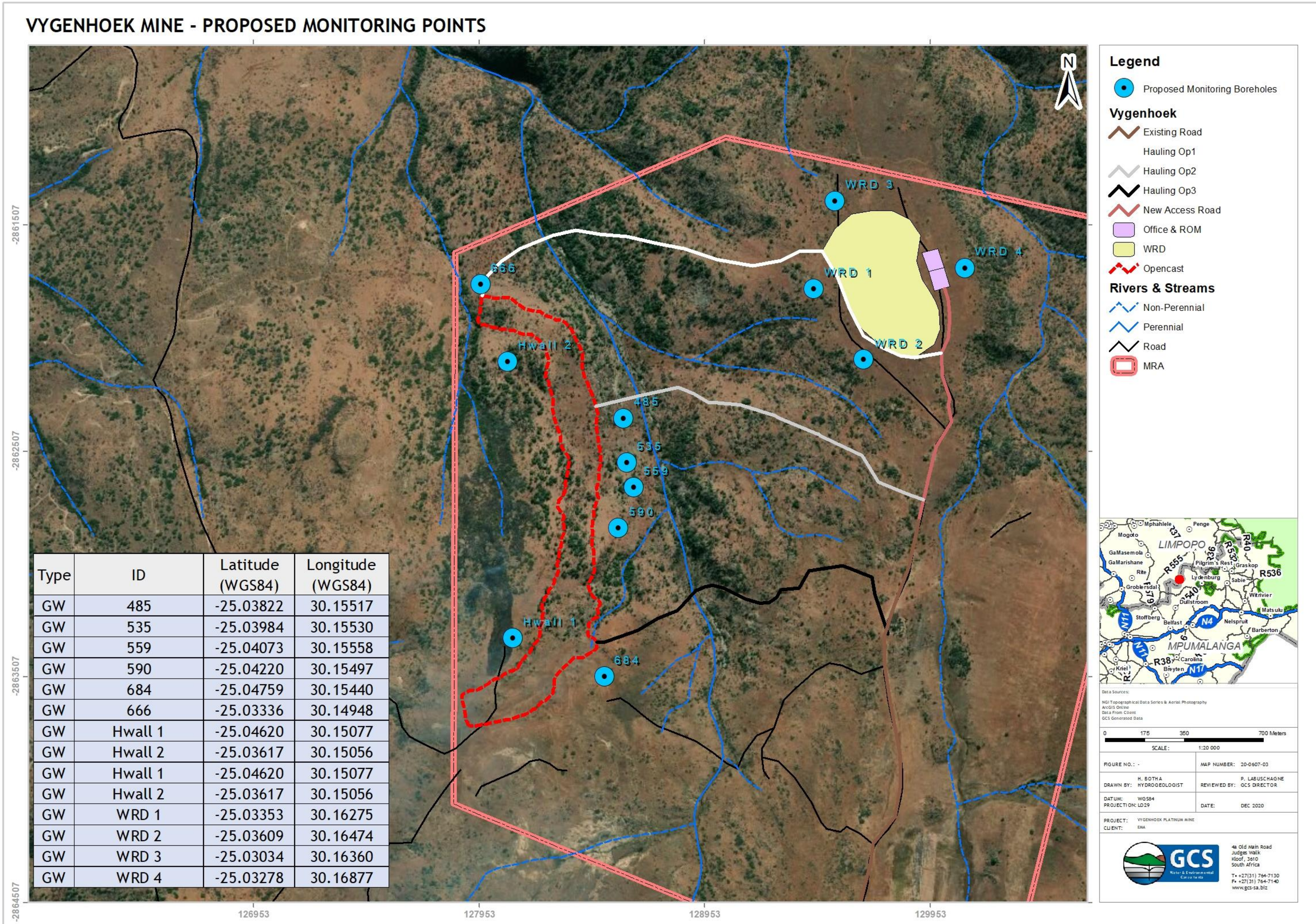
Table 11-2: Proposed monitoring points, frequencies and sample analyses

Type	Frequency	Field Measurements	Laboratory Analysis
Groundwater monitoring boreholes 12 Proposed (refer to section 11.1)	**Sample during drilling; and** **Sample bi-annual after drilling.**	pH EC / TDS Temp	The following should typically be analysed: • pH • Electrical Conductivity (EC) • Chloride

Type	Frequency	Field Measurements	Laboratory Analysis
		Dissolved Oxygen Groundwater Level (if applicable)	• Dissolved Aluminium • Dissolved Barium • Dissolved Beryllium • Dissolved Boron • Dissolved Bismuth • Dissolved Cadmium • Dissolved Calcium • Dissolved Chromium • Dissolved Cobalt • Dissolved Copper • Dissolved Gallium • Dissolved Iron • Dissolved Lead • Dissolved Lithium • Dissolved Magnesium • Dissolved Manganese • Dissolved Molybdenum • Dissolved Nickel • Dissolved Rubidium • Dissolved Silver • Dissolved Strontium • Dissolved Tellurium • Dissolved Thallium • Dissolved Vanadium • Dissolved Zinc • Nitrate • Orthophosphate • Potassium • Sodium • Sulphate • Total Alkalinity However based on the 1-4 DW leach testing, the following constituents should be focused on: • Dissolved Chromium • Dissolved Alluminium • Dissolved Iron • pH • EC
Sewer lines, septic tanks (if installed at offices), and stormwater drains (hydraulic monitoring)	**Monthly**	Visual assessment Sample spillage if applicable.	

11.4 Monitoring audit

It is proposed that the monitoring program be audited 1 year after the initial groundwater monitoring network has been established. It is important to continuously re-evaluate the monitoring network and assess the monitoring effectiveness (i.e. undertake a gap assessment and re-evaluate groundwater pollution sources and risk on an ongoing basis).



Type	ID	Latitude (WGS84)	Longitude (WGS84)
GW	485	-25.03822	30.15517
GW	535	-25.03984	30.15530
GW	559	-25.04073	30.15558
GW	590	-25.04220	30.15497
GW	684	-25.04759	30.15440
GW	666	-25.03336	30.14948
GW	Hwall 1	-25.04620	30.15077
GW	Hwall 2	-25.03617	30.15056
GW	Hwall 1	-25.04620	30.15077
GW	Hwall 2	-25.03617	30.15056
GW	WRD 1	-25.03353	30.16275
GW	WRD 2	-25.03609	30.16474
GW	WRD 3	-25.03034	30.16360
GW	WRD 4	-25.03278	30.16877

Figure 11-3: Proposed monitoring points

12 CONCLUSIONS

Concluding remarks concerning the investigation and the groundwater model are summarised as follows:

- The steady-state model was successfully converted into the transient state, and the model was successfully calibrated against monitoring and hydrocensus groundwater level data.
- Groundwater level data for more than 89 observation points within the study area were successfully applied.
- The conceptual groundwater model and understanding of the aquifer, based on available data, was successfully illustrated in this report.
- According to Guiding Principle 2.3 and 2.4 in the Australian groundwater modelling guidelines (Barnett *et al.,* 2012) the degree of confidence of the groundwater flow and transport model was evaluated:
    - The flow model is assigned a Class 2 confidence level due to the numerous groundwater heads available for calibration. Class 2 models are suitable for assessing higher risk developments in higher-value aquifers (i.e. major aquifer for groundwater supply or an aquifer highly susceptible to pollution). However, limited head data for the Vygenhoek area is recognised due to the lack of boreholes with water levels at the proposed mine.
    - The transport model is assigned a Class 2 confidence level due to the model being used for prediction modelling rather than calibration with known TDS values for monitoring boreholes (i.e. no monitoring boreholes exist and the flow model drives the transport model).
- It is fair to conclude that all data made available for this investigation, and data obtained from the site visit, has successfully been incorporated into the model. The model developed can be considered conceptual and represents the likely aquifer conditions (i.e. more geohydrological data is required for the mining area to be incorporated into an updated and re-calibrated flow model). The zone of influence of the project area was successfully simulated and presented in this report.
- Based on the outcome of the geohydrological study, no avoidance areas have been identified. Moreover, there are no major risks associated with the proposed mine. Opencast mining the UG2 seam is feasible from a geohydrological perspective as long as mitigation measures (as per Section 10) are implemented, and the recommendations in Section 12.1 are considered.

12.1 Recommendations for EA

The following recommendations are made:

- Dedicated groundwater monitoring boreholes should be drilled before pit expansion to obtain baseline water quality and quantity data. Drilling log data should be recorded and can supplement any future geohydrological work for the site (i.e. will help to better understand the local geohydrology).
    - 12 drilling positions have been identified for monitoring purposes. The recommended drilling positions are as follows:

ID	Slope	Latitude (WGS84, DD)	Longitude (WGS84, DD)	Depth (m)
485	Downstream	-25.038224	30.155169	40-60
535	Downstream	-25.039837	30.155298	40-60
559	Downstream	-25.040727	30.155575	40-60
590	Downstream	-25.042203	30.154971	40-60
684	Downstream	-25.047590	30.154404	40-60
666	Downstream	-25.033360	30.149479	40-60
Hwall 1	Upstream (background monitoring)	-25.04619	30.15076	40-60
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WRD 1	Downstream WRD	-25.03353	30.16275	40-60
WRD 2	Downstream WRD	-25.03609	30.16474	40-60
WRD 3	Downstream WRD	-25.03034	30.16360	40-60
WRD 4	Upstream WRD	-25.03278	30.16877	40-60

- Additional rock samples should be collected during mining, to maintain a clear understanding of the AMD potential of the rock being mined. It is important to use ABA and NAG as pre-emptive tools to determine if any AMD may occur.
- The following can be done to improve the assumptions and understanding of the groundwater aquifer and hence improve the numerical groundwater model confidence:
    - All new exploration boreholes drilled in the area should note groundwater occurrences as well as strike depths. The data can be used to update the conceptual hydrogeological model which is incorporated into the numerical flow model.
    - Water levels of dedicated monitoring boreholes that will be drilled, as well as any new boreholes which are discovered in the area during routine hydrocensus updates, should be monitored bi-annually.

  - Dewatering volumes (during mining) should be recorded daily and reported bi-monthly.

- It is recommended that the numerical groundwater model and transport model be updated annually, to:
  - Recalibrate the flow system based on the dedicated monitoring boreholes drilled and routine water level monitoring data gathered for the site.
  - Confirm preferential flow paths and groundwater migration velocities as new geological data is attained via mining.
  - Evaluate the spatial impact (i.e. TDS plume) calibrated with the proposed monitoring borehole data.
  - Confirm long term liabilities associated with the workings (i.e. predict likely changes in flow fields etc.); and
  - Ensure no monitoring network gaps exist (i.e. check if the monitoring network is representative of the site).

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APPENDIX A: GEOPHYSISCS METHODOLOGY & DATA

1. Methodology

The geophysical systems used in this investigation was a Geonics G5-proton precession magnetometer (Mag). The aim was to identify if there are dolerite intrusive rock or contact areas in the area, extrapolate the likely spatial spread of these structures, and to site future monitoring boreholes.

Magnetic Investigation Methodology

The presence of magnetic minerals in rocks cause deviations in the earth's magnetic field. The proton precision magnetometer measures the remnant magnetic field strength of these rocks. The instrument measures the magnetic field strength in Nano Tesla (nT). Rock associated with magmatic intrusions, such as dolerite sills and dykes, have more magnetic minerals than the surrounding sedimentary rocks or metamorphic rocks. The zone between the intruding rocks is known as the bake zone (a zone which is weathered and cracked due to intruding magmatic rock heat and pressure) and is known to be associated with preferential flow paths of groundwater. It is these structures that are primarily targeted in Karoo aquifer systems for groundwater development and as potential pollution transmitters/boundaries. Hence, the purpose of the survey was to identify structures which may/may not promote groundwater flow.

2. Survey orientation and spacing length

Five (5) Mag profiles were completed in the study area. Mag traverse varied from approximately 200 to 400 m in length, due to limited movement space. Mag readings were taken at 5 m intervals. Moreover, each spacing was recorded with a handheld GPS.

3. Potential inference

Some magnetic interference sources were noted in the survey areas (several fences, pipes and access gates). The profile lines were shifted to best avoid these magnetic interference sources, or to maintain a constant magnetic interference throughout the profile.

4. Data analyses

The data obtained from the magnetic survey was analysed as follows:

- All magnetic data was captured in Microsoft Excel ®, and profile trend graphs for the profile lines walked were constructed. A 3-point average algorithm was applied to smooth the data. The magnetic anomalies observed were then interpreted based on the magnetic field strength observed along the profile lines.

5. Results

The Mag profile lines show the magnetic field strength (measured in Nano Tesla – nT) measured along the profile lines. The geophysical results are summarised as follows:

- **Line 1**
  - The nT along line 1 shows a distinct parabola anomaly at x ≈ 70 to x ≈110m. The anomaly likely relates to the known (near vertical) dolerite dyke traversing the area.
- **Line 2**
  - The nT along line 2 shows several anomalies, and one distinct parabola anomaly from x ≈ 90 to x ≈ 180, followed by a second parabola anomaly near the end of the line. The anomalies likely relate to a thick vertical dyke / sill and thin dyke nearing the end of the line.
- **Line 3**
  - The nT along line 3 shows a magnetic depression at x ≈ 50m, which possibly relates to a dyke or a contact/fault zone. Moreover, a second parabolic anomaly is observed from x ≈ 100 to x ≈ 150m wich possibly relates to a dolerite dyke. Dolerite boulders were noted in the survey area.
- **Line 4**
  - The nT along line 4 shows a magnetic increase from x ≈ 120 with a peak anomaly observed at x ≈200, followed by a parabola drop. The nT fluctuation at x ≈200 to x ≈225 is likely associated with a dolerite dyke and contact zone.
- **Line 5**
  - The nT along line 5 shows several small magnetic anomalies at the beginning of the line.

Summary:

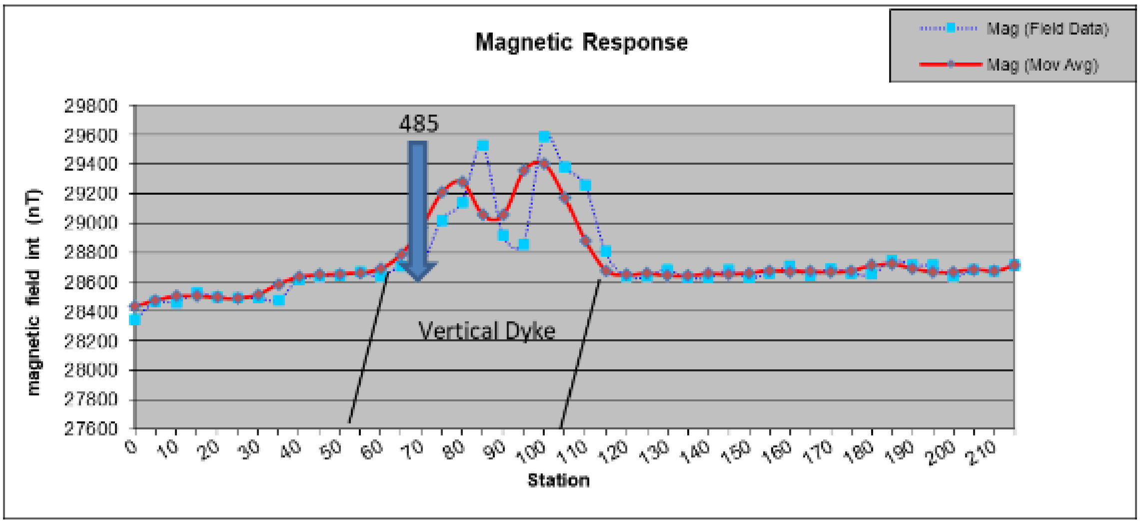
The geophysical investigation suggest several dolerite dykes and subsequent contact occur in the study area, and cross the proposed opencast pit. The data suggest three (3) dykes which may act as preferential flow paths to hydraulically lower areas. Several drilling positions have been identified for monitoring purposes. The recommended drilling positions are as follows:

Drilling Position	Latitude (WGS84, DD)	Longitude (WGS84, DD)	Depth (m)
485	-25.038224	30.155169	40
535	-25.039837	30.155298	40
559	-25.040727	30.155575	40
590	-25.042203	30.154971	40
684	-25.047590	30.154404	40
666	-25.033360	30.149479	40

Line 1

Project:	Vygenhoek Mine Geohydrology	**Traverse Number:**	T1
Project Number:	20-0607	**Traverse Direction:**	NW-SE
Survey Area:	Lydenburg (Mashishing)	**Station Spacing:**	5m
Date of Survey:	08 October 2020	**Operator:**	Siphe (GCS Technician)

Station	Station Coordinates		Mag	
Station	Latitude (y)	Longitude (x)	Mag	Mag (Mov Average)
0	-25.038771	30.155487	28344.5	28433.6
5	-25.038741	30.155456	28465.3	28478.075
10	-25.038661	30.155484	28459.3	28504
15	-25.038693	30.155399	28528.4	28505.475
20	-25.038633	30.155365	28499.9	28495.25
25	-25.038589	30.155324	28493.7	28489.675
30	-25.038560	30.155301	28493.7	28516.3
35	-25.038516	30.155285	28477.6	28587.475
40	-25.038468	30.155267	28616.3	28635.675
45	-25.038441	30.155242	28639.7	28650.65
50	-25.038392	30.155227	28647	28655.925
55	-25.038354	30.155201	28668.9	28664.15
60	-25.038326	30.155197	28638.9	28692.4
65	-25.038258	30.155175	28709.9	28787.925
70	-25.038224	30.155169	28710.9	28973.1
75	-25.038165	30.155143	29020	29208.125
80	-25.038116	30.155132	29141.5	29279.05
85	-25.038070	30.155119	29529.5	29054.6
90	-25.038046	30.155095	28915.7	29055.3
95	-25.038003	30.155079	28857.5	29355.05
100	-25.037969	30.155058	29590.5	29402.225
105	-25.037928	30.155046	29381.7	29174.175
110	-25.037903	30.155023	29255	28875.875
115	-25.037859	30.155015	28805	28680.125
120	-25.037820	30.155012	28638.5	28650.35
125	-25.037772	30.155005	28638.5	28660.475
130	-25.037728	30.154985	28685.9	28644.3
135	-25.037679	30.154973	28631.6	28643.675
140	-25.037648	30.154958	28628.1	28658.35
145	-25.037611	30.154947	28686.9	28652.425
150	-25.037567	30.154933	28631.5	28664.2
155	-25.037521	30.154920	28659.8	28678.825
160	-25.037486	30.154897	28705.7	28672.275
165	-25.037436	30.154880	28644.1	28674.2
170	-25.037394	30.154864	28695.2	28667.625
175	-25.037348	30.154842	28662.3	28677.9
180	-25.037307	30.154838	28650.7	28715.275
185	-25.037252	30.154816	28747.9	28722.225
190	-25.037210	30.154793	28714.6	28694.025
195	-25.037161	30.154787	28711.8	28668.075
200	-25.037116	30.154778	28637.9	28670.8
205	-25.037075	30.154753	28684.7	28688
210	-25.037049	30.154742	28675.9	28675.9
215	-25.036995	30.154730	28715.5	28715.5



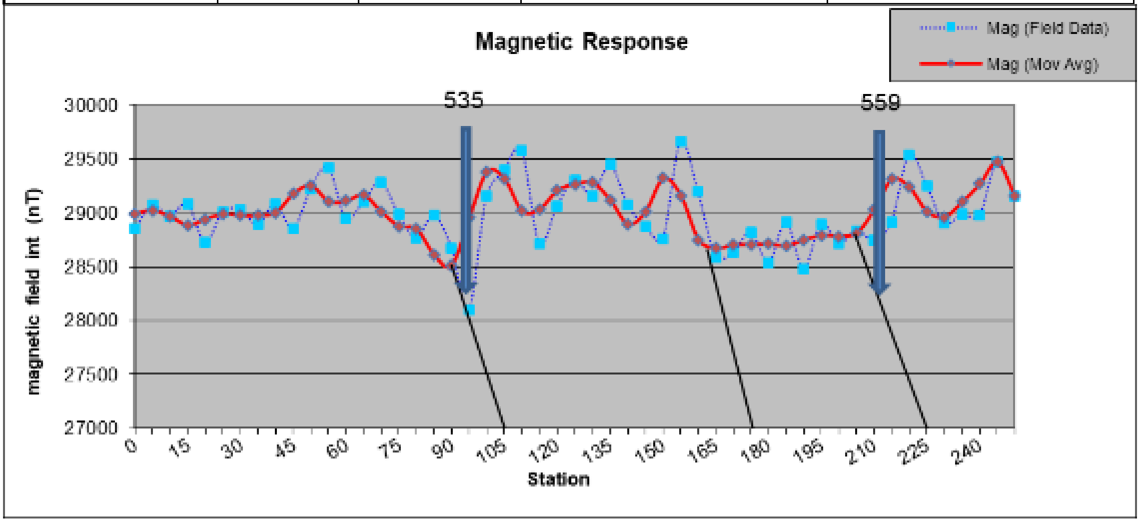
Line 2

Project:	Vygenhoek Mine Geohydrology	Traverse Number:	T2
Project Number:	20-0607	Traverse Direction:	NW-SE
Survey Area:	Lydenburg (Mashishing)	Station Spacing:	5m
Date of Survey:	08 October 2020	Operator:	Siphe (GCS Technician)

Station	Station Coordinates		Mag	
Station	Latitude (y)	Longitude (x)	Mag	Mag (Mov Average)
0	-25.038946	30.154873	28846	28987.275
5	-25.039013	30.154918	29068.6	29020.475
10	-25.039052	30.154947	28965.9	28962.35
15	-25.039100	30.154976	29081.5	28880.975
20	-25.039134	30.154997	28720.5	28937.975
25	-25.039164	30.155039	29001.4	28986.2
30	-25.039189	30.155063	29028.6	28971.4
35	-25.039221	30.155089	28886.2	28975.275
40	-25.039262	30.155109	29084.6	28998.575
45	-25.039310	30.155123	28845.7	29176.1
50	-25.039349	30.155138	29218.3	29252.525
55	-25.039391	30.155157	29422.1	29104.4
60	-25.039434	30.155175	28947.6	29107.85
65	-25.039477	30.155193	29100.3	29163.075
70	-25.039524	30.155215	29283.2	29004.75
75	-25.039563	30.155229	28985.6	28872.65
80	-25.039603	30.155254	28764.6	28846.55
85	-25.039647	30.155270	28975.8	28604.325
90	-25.039687	30.155276	28670	28507
95	-25.039741	30.155282	28101.5	28950.925
100	-25.039787	30.155290	29155	29380.1
105	-25.039837	30.155298	29392.2	29315.775
110	-25.039877	30.155300	29581	29013.8
115	-25.039924	30.155307	28708.9	29032.1
120	-25.039962	30.155318	29056.4	29205.725
125	-25.039987	30.155330	29306.7	29264.6
130	-25.040037	30.155332	29153.1	29278.675
135	-25.040076	30.155347	29445.5	29113.675
140	-25.040123	30.155352	29070.6	28890.625
145	-25.040162	30.155350	28868	29010.875
150	-25.040208	30.155361	28755.9	29319.175
155	-25.040247	30.155368	29663.7	29159.25
160	-25.040307	30.155367	29193.4	28748.075
165	-25.040338	30.155374	28586.5	28664.325
170	-25.040361	30.155385	28625.9	28699.15
175	-25.040402	30.155401	28819	28698.325
180	-25.040432	30.155423	28532.7	28707

Project:	Vygenhoek Mine Geohydrology	**Traverse Number:**	T2
Project Number:	20-0607	**Traverse Direction:**	NW-SE
Survey Area:	Lydenburg (Mashishing)	**Station Spacing:**	5m
Date of Survey:	08 October 2020	**Operator:**	Siphe (GCS Technician)

Station	Station Coordinates		Mag	
Station	Latitude (y)	Longitude (x)	Mag	Mag (Mov Average)
185	-25.040469	30.155435	28908.9	28689.125
190	-25.040513	30.155461	28477.5	28743.5
195	-25.040546	30.155486	28892.6	28786.625
200	-25.040573	30.155503	28711.3	28779.6
205	-25.040625	30.155525	28831.3	28808.075
210	-25.040653	30.155539	28744.5	29026.65
215	-25.040700	30.155559	28912	29310.575
220	-25.040705	30.155551	29538.1	29235.625
225	-25.040727	30.155575	29254.1	29007.775
230	-25.040762	30.155592	28896.2	28959.075
235	-25.040802	30.155592	28984.6	29099.275
240	-25.040837	30.155594	28970.9	29265.6
245	-25.040878	30.155611	29470.7	29470.7
250	-25.040914	30.155629	29150.1	29150.1



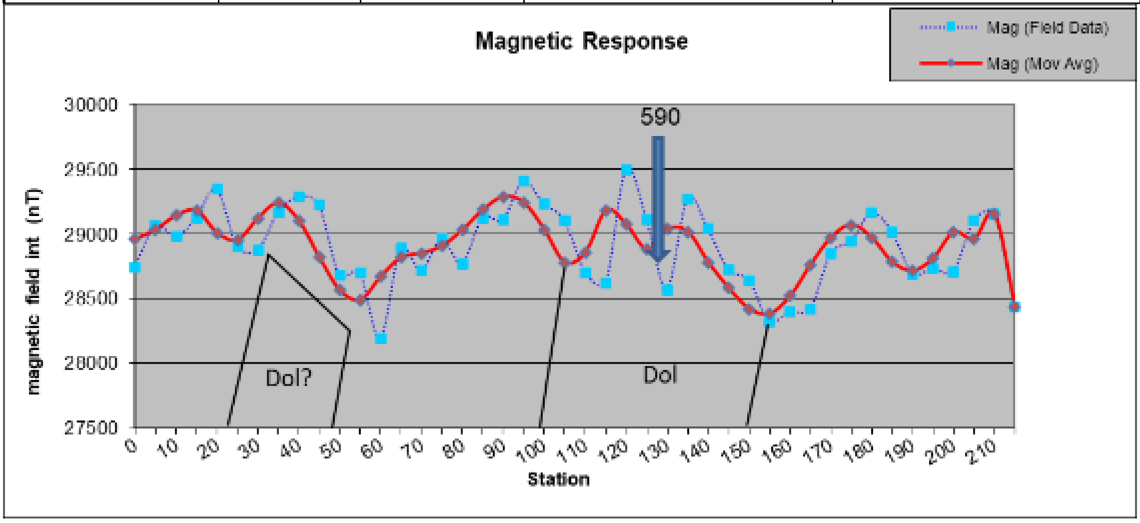
Line 3

Project:	Vygenhoek Mine Geohydrology	**Traverse Number:**	T3
Project Number:	20-0607	**Traverse Direction:**	NW-SE
Survey Area:	Lydenburg (Mashishing)	**Station Spacing:**	5m
Date of Survey:	08 October 2020	**Operator:**	Siphe (GCS Technician)

Station	Station Coordinates		Mag	
Station	Latitude (y)	Longitude (x)	Mag	Mag (Mov Average)
0	-25.041181	30.154437	28739.4	28959.85
5	-25.041224	30.154454	29062.3	29033.775
10	-25.041268	30.154461	28975.4	29141.9
15	-25.041301	30.154486	29122	29180.4
20	-25.041353	30.154498	29348.2	29007.475
25	-25.041395	30.154513	28903.2	28953.5
30	-25.041437	30.154538	28875.3	29121
35	-25.041488	30.154540	29160.2	29240
40	-25.041527	30.154561	29288.3	29103.125
45	-25.041562	30.154583	29223.2	28819
50	-25.041595	30.154604	28677.8	28565.15
55	-25.041630	30.154621	28697.2	28490.125
60	-25.041663	30.154653	28188.4	28668.425
65	-25.041705	30.154674	28886.5	28817.6
70	-25.041706	30.154679	28712.3	28850.525

Project:	Vygenhoek Mine Geohydrology	Traverse Number:	T3
Project Number:	20-0607	Traverse Direction:	NW-SE
Survey Area:	Lydenburg (Mashishing)	Station Spacing:	5m
Date of Survey:	08 October 2020	Operator:	Siphe (GCS Technician)

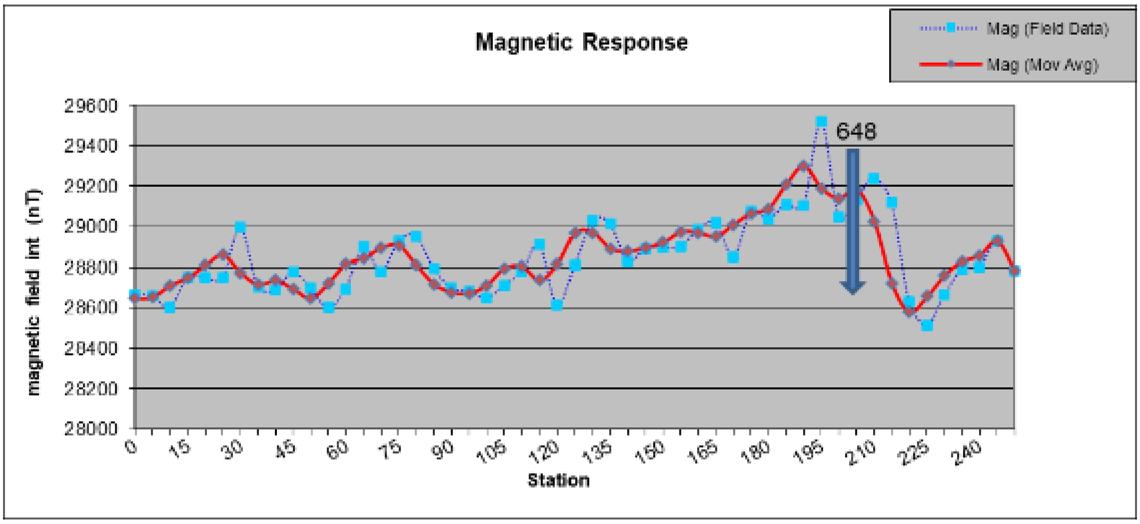
Station	Station Coordinates		Mag	
Station	Latitude (y)	Longitude (x)	Mag	Mag (Mov Average)
75	-25.041744	30.154701	28959.3	28905.975
80	-25.041777	30.154723	28771.2	29031.375
85	-25.041824	30.154742	29122.2	29186.8
90	-25.041865	30.154770	29109.9	29287.95
95	-25.041906	30.154800	29405.2	29242.475
100	-25.041945	30.154818	29231.5	29034.1
105	-25.041984	30.154857	29101.7	28780.55
110	-25.042032	30.154877	28701.5	28859.55
115	-25.042068	30.154925	28617.5	29182.225
120	-25.042106	30.154950	29501.7	29071.85
125	-25.042145	30.154963	29108	28879.275
130	-25.042203	30.154971	28569.7	29036.725
135	-25.042225	30.154976	29269.7	29016.625
140	-25.042265	30.154990	29037.8	28779.7
145	-25.042303	30.155000	28721.2	28580.05
150	-25.042349	30.155016	28638.6	28419.5
155	-25.042390	30.155027	28321.8	28382.45
160	-25.042424	30.155048	28395.8	28518.5
165	-25.042464	30.155058	28416.4	28762.325
170	-25.042507	30.155082	28845.4	28973.2
175	-25.042549	30.155108	28942.1	29070.6
180	-25.042547	30.155109	29163.2	28970.1
185	-25.042624	30.155159	29013.9	28781.35
190	-25.042656	30.155188	28689.4	28715.8
195	-25.042681	30.155199	28732.7	28812.15
200	-25.042734	30.155247	28708.4	29014.625
205	-25.042765	30.155257	29099.1	28958.9
210	-25.042782	30.155258	29151.9	29151.9
215	-25.042811	30.155274	28432.7	28432.7



Line 4

Project:	Vygenhoek Mine Geohydrology	**Traverse Number:**	T4
Project Number:	20-0607	**Traverse Direction:**	NW-SE
Survey Area:	Lydenburg (Mashishing)	**Station Spacing:**	5m
Date of Survey:	08 October 2020	**Operator:**	Siphe (GCS Technician)

Station	Station Coordinates		Mag	
Station	Latitude (y)	Longitude (x)	Mag	Mag (Mov Average)
0	-25.045988	30.153567	28667.5	28646.575
5	-25.046017	30.153583	28657.9	28652.975
10	-25.046043	30.153594	28603	28712.025
15	-25.046066	30.153609	28748	28748.3
20	-25.046101	30.153636	28749.1	28809.575
25	-25.046137	30.153653	28747	28860.625
30	-25.046176	30.153660	28995.2	28773.5
35	-25.046205	30.153666	28705.1	28715.15
40	-25.046266	30.153680	28688.6	28735.625
45	-25.046308	30.153683	28778.3	28693.55
50	-25.046345	30.153701	28697.3	28648.825
55	-25.046396	30.153720	28601.3	28722.725
60	-25.046447	30.153741	28695.4	28817
65	-25.046491	30.153753	28898.8	28844
70	-25.046506	30.153754	28775	28895.425
75	-25.046576	30.153782	28927.2	28906.325
80	-25.046618	30.153796	28952.3	28809.45
85	-25.046657	30.153818	28793.5	28718.1
90	-25.046731	30.153850	28698.5	28677.675
95	-25.046774	30.153872	28681.9	28672.7
100	-25.046816	30.153890	28648.4	28712.75
105	-25.046844	30.153903	28712.1	28794.7
110	-25.046885	30.153928	28778.4	28803.35
115	-25.046922	30.153947	28909.9	28737.35
120	-25.046973	30.153963	28615.2	28815.675
125	-25.047010	30.153974	28809.1	28969.95
130	-25.047042	30.153988	29029.3	28970.925
135	-25.047081	30.154029	29012.1	28891.15
140	-25.047117	30.154064	28830.2	28877.725
145	-25.047162	30.154086	28892.1	28896.95
150	-25.047198	30.154114	28896.5	28921.55
155	-25.047229	30.154142	28902.7	28973.2
160	-25.047269	30.154166	28984.3	28970.125
165	-25.047300	30.154197	29021.5	28950.35
170	-25.047336	30.154219	28853.2	29009.675
175	-25.047370	30.154235	29073.5	29064.875
180	-25.047416	30.154275	29038.5	29089.65
185	-25.047456	30.154304	29109	29208.55
190	-25.047483	30.154330	29102.1	29298.175
195	-25.047515	30.154352	29521	29187.75
200	-25.047536	30.154374	29048.6	29138.725
205	-25.047590	30.154404	29132.8	29183.1
210	-25.047634	30.154440	29240.7	29027.525
215	-25.047666	30.154465	29118.2	28723.825
220	-25.047692	30.154480	28633	28579.5
225	-25.047725	30.154516	28511.1	28656.75
230	-25.047735	30.154521	28662.8	28760.3
235	-25.047752	30.154528	28790.3	28828.475
240	-25.047784	30.154547	28797.8	28858.8
245	-25.047821	30.154582	28928	28928
250	-25.047864	30.154612	28781.4	28781.4



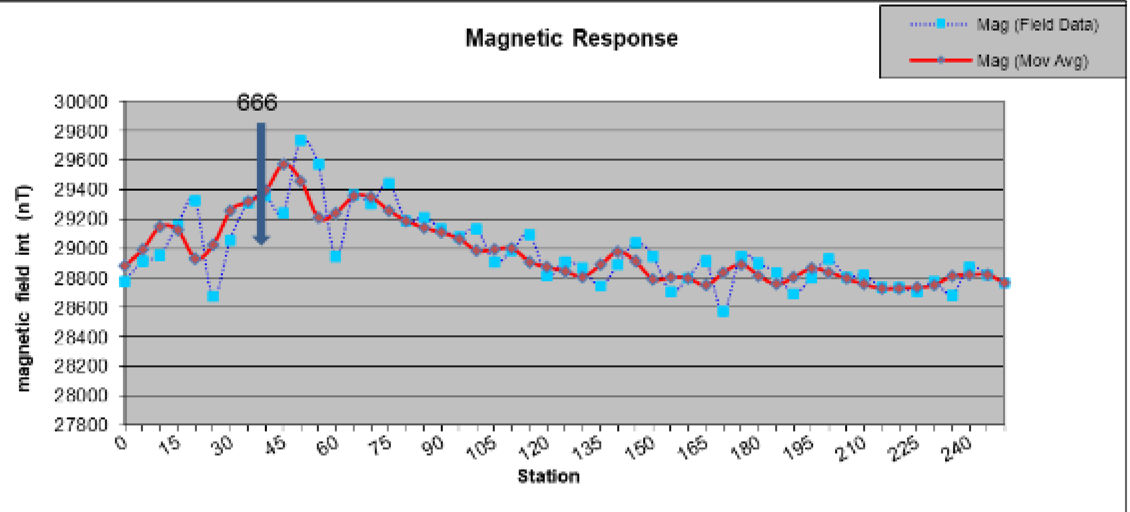
Line 5

Project:	Vygenhoek Mine Geohydrology	**Traverse Number:**	T5
Project Number:	20-0607	**Traverse Direction:**	NW-SE
Survey Area:	Lydenburg (Mashishing)	**Station Spacing:**	5m
Date of Survey:	08 October 2020	**Operator:**	Siphe (GCS Technician)

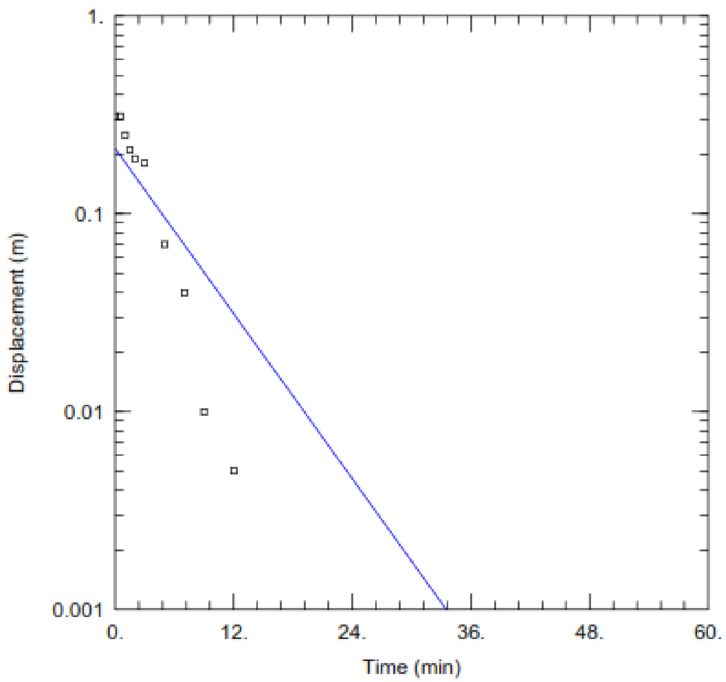
Station	Station Coordinates		Mag	
Station	Latitude (y)	Longitude (x)	Mag	Mag (Mov Average)
0	-25.033284	30.149070	28775.6	28887.85
5	-25.033284	30.149116	28912.4	28992.825
10	-25.033288	30.149171	28951	29147.9
15	-25.033277	30.149205	29156.9	29121.3
20	-25.033281	30.149251	29326.8	28932.5
25	-25.033302	30.149300	28674.7	29023.45
30	-25.033311	30.149349	29053.8	29258.6
35	-25.033318	30.149377	29311.5	29316.775
40	-25.033343	30.149437	29357.6	29394.375
45	-25.033360	30.149479	29240.4	29573.35
50	-25.033363	30.149519	29739.1	29458.15
55	-25.033364	30.149554	29574.8	29206.475
60	-25.033376	30.149586	28943.9	29244.075
65	-25.033384	30.149638	29363.3	29354.75
70	-25.033396	30.149678	29305.8	29345.15
75	-25.033413	30.149730	29444.1	29257
80	-25.033415	30.149770	29186.6	29185.975
85	-25.033425	30.149816	29210.7	29140.025
90	-25.033432	30.149856	29135.9	29106.35
95	-25.033429	30.149893	29077.6	29064.175
100	-25.033446	30.149943	29134.3	28984.425
105	-25.033451	30.149987	28910.5	28993.125
110	-25.033457	30.150041	28982.4	28998.875
115	-25.033479	30.150138	29097.2	28911.275
120	-25.033476	30.150141	28818.7	28877.175
125	-25.033482	30.150205	28910.5	28847.6
130	-25.033490	30.150243	28869	28811.1
135	-25.033498	30.150258	28741.9	28890.9
140	-25.033511	30.150330	28891.6	28979.575
145	-25.033514	30.150379	29038.5	28911.9
150	-25.033515	30.150391	28949.7	28792.075
155	-25.033514	30.150392	28709.7	28805.6
160	-25.033541	30.150514	28799.2	28799.875
165	-25.033550	30.150545	28914.3	28751.375
170	-25.033556	30.150566	28571.7	28841
175	-25.033572	30.150622	28947.8	28895.325
180	-25.033589	30.150680	28896.7	28817.8
185	-25.033604	30.150725	28840.1	28757.35
190	-25.033603	30.150742	28694.3	28807.325
195	-25.033613	30.150798	28800.7	28868
200	-25.033633	30.150864	28933.6	28841.175

Project:	Vygenhoek Mine Geohydrology	**Traverse Number:**	T5
Project Number:	20-0607	**Traverse Direction:**	NW-SE
Survey Area:	Lydenburg (Mashishing)	**Station Spacing:**	5m
Date of Survey:	08 October 2020	**Operator:**	Siphe (GCS Technician)

Station	Station Coordinates		Mag	
Station	Latitude (y)	Longitude (x)	Mag	Mag (Mov Average)
205	-25.033640	30.150906	28804.1	28796.35
210	-25.033646	30.150946	28822.9	28758.1
215	-25.033647	30.150986	28735.5	28730.75
220	-25.033665	30.151039	28738.5	28733.775
225	-25.033676	30.151094	28710.5	28736.4
230	-25.033680	30.151125	28775.6	28755.275
235	-25.033696	30.151161	28683.9	28815.7
240	-25.033700	30.151170	28877.7	28822.7
245	-25.033713	30.151214	28823.5	28823.5
250	-25.033736	30.151251	28766.1	28766.1



APPENDIX B: SLUG TESTING ANALYSES



WELL TEST ANALYSIS

Data Set: D:\...\VH12.aqt
Date: 11/17/20 Time: 12:30:19

PROJECT INFORMATION

Company: GCS
Client: EMA
Project: 20-0607
Location: Vygenhoek
Test Well: VH12
Test Date: 8 October 2020

AQUIFER DATA

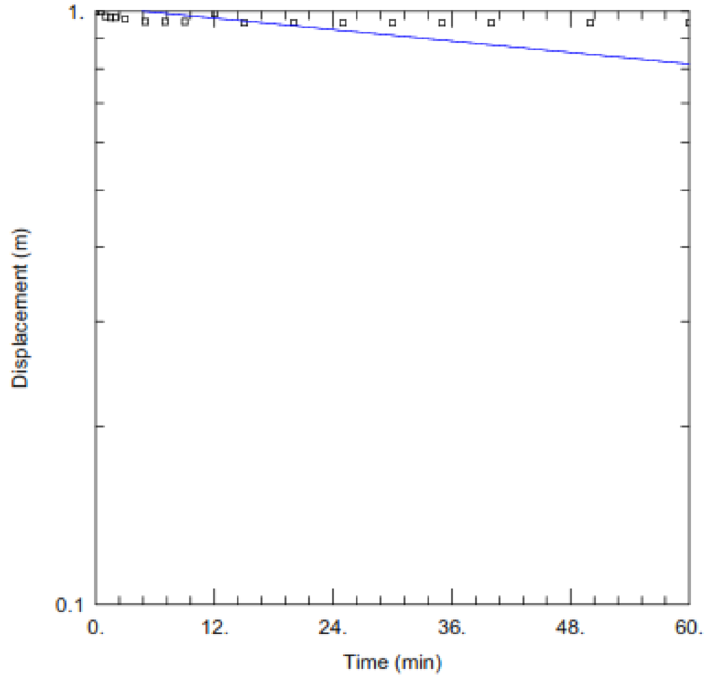
Saturated Thickness: 20. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Initial Displacement: 0.31 m
Total Well Penetration Depth: 20. m
Casing Radius: 0.0425 m
Static Water Column Height: 10.98 m
Screen Length: 20. m
Well Radius: 0.0425 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice
K = 0.05186 m/day y0 = 0.2134 m



WELL TEST ANALYSIS	
Data Set: D:\...\VH15.aqt	
Date: 11/17/20	Time: 12:30:40
PROJECT INFORMATION	
Company: GCS	
Client: EMA	
Project: 20-0607	
Location: Vygenhoek	
Test Well: VH12	
Test Date: 8 October 2020	
AQUIFER DATA	
Saturated Thickness: 20. m	Anisotropy Ratio (Kz/Kr): 1.
WELL DATA	
Initial Displacement: 1. m	Static Water Column Height: 15.94 m
Total Well Penetration Depth: 20. m	Screen Length: 20. m
Casing Radius: 0.0425 m	Well Radius: 0.0425 m
SOLUTION	
Aquifer Model: Unconfined	Solution Method: Bouwer-Rice
K = 0.001198 m/day	y0 = 1.018 m

APPENDIX C: GEOCHEMISTRY & HYDROCEHMISTRY LABORATORY CERTIFICIATES

TALBOT
A Level 2 B-BBEE company

sanas

[006584/20], [2020/10/26]

Certificate of Analysis

Project details

Customer Details

Customer reference:	VYGENHOEK MINE 20-0607
Order number:	20-0607
Company name:	GCS (PTY) LTD DURBAN
Contact address:	P O BOX 819, GILLITS, 3603
Contact person:	HENRI BOTHA
Additional customer information:	CLIENT: EMA

Sampling Details

Sampled by:	CUSTOMER
Sampled date:	2020/10/07

Sample Details

Sample type(s):	GROUNDWATER SAMPLES
Date received:	2020/10/12
Delivered by:	CUSTOMER - GILLITTS DEPOT
Temperature at sample receipt (°C):	16.0

Report Details

Testing commenced:	2020/10/12
Testing completed:	2020/10/21
Report date:	2020/10/26
Our reference:	006584/20

Talbot Laboratories (Pty) Ltd Reg: 2016/334237/07
P.O Box 22598 Pietermaritzburg 3203 South Africa
+27 (0) 33 346 1444 www.talbot.co.za

Page 1 of 6

Analytical Results

Methods	Determinands	Units	018707/20 VH01 07.10.2020	018708/20 VH12 07.10.2020
Chemical				
85	Dissolved Calcium	mg Ca/ℓ	71	63
85	Potassium	mg K/ℓ	3.06	0.87
85	Dissolved Magnesium	mg Mg/ℓ	27	32
84	Sodium	mg Na/ℓ	15.8	16.5
68G	Hexavalent Chromium	mg Cr/ℓ	0.0079	0.0212
Calc.	Trivalent Chromium*	mg/ℓ	0.18	0.14
10	Total Alkalinity	mg $CaCO_3$/ℓ	278	291
Calc.	Bicarbonate Alkalinity*	mg HCO_3^-/ℓ	278	291
Calc.	Carbonate Alkalinity*	mg $CaCO_3$/ℓ	<3	<3
16G	Chloride	mg Cl/ℓ	9.80	5.95
2A	Electrical Conductivity at 25°C	mS/m	53.4	51.5
18G	Fluoride	mg F/ℓ	0.10	0.11
65Gc	Nitrate	mg N/ℓ	0.82	0.10
4	Turbidity	NTU	>1000	384
1	pH at 25°C	pH units	7.4	7.3
67G	Sulphate	mg SO_4/ℓ	9.81	8.92

Methods	Determinands	Units	018709/20 VH15 07.10.2020	018710/20 SW-D 07.10.2020
Chemical				
85	Dissolved Calcium	mg Ca/ℓ	31	8.89
85	Potassium	mg K/ℓ	1.01	3.71
85	Dissolved Magnesium	mg Mg/ℓ	56	7.16
84	Sodium	mg Na/ℓ	9.87	4.24
68G	Hexavalent Chromium	mg Cr/ℓ	0.0103	<0.0005
Calc.	Trivalent Chromium*	mg/ℓ	0.20	0.02
10	Total Alkalinity	mg $CaCO_3$/ℓ	267	45
Calc.	Bicarbonate Alkalinity*	mg HCO_3^-/ℓ	267	45
Calc.	Carbonate Alkalinity*	mg $CaCO_3$/ℓ	<3	<3
16G	Chloride	mg Cl/ℓ	4.45	5.08
2A	Electrical Conductivity at 25°C	mS/m	49.5	11.9
18G	Fluoride	mg F/ℓ	0.07	<0.03
65Gc	Nitrate	mg N/ℓ	0.70	0.30
4	Turbidity	NTU	140	69
1	pH at 25°C	pH units	7.3	7.6

Methods	Determinands	Units	018709/20	018710/20
			VH15 07.10.2020	SW-D 07.10.2020
67G	Sulphate	mg SO_4/ℓ	14.9	4.33

Refer to the "Notes" section at the end of this report for further explanations.

Specific Observations

None

aquatico Laboratories (Pty). Ltd.

Test Report

Page 1 of 1

Client: Groundwater Consulting Services (GCS)
Address: 63 Wessel Road, Woodmead, 2191
Report no: 94157
Project: Vygenhoek Mine

Date of report: 09 November 2020
Date accepted: 19 October 2020
Date completed: 09 November 2020
Date received: 16 October 2020

Lab no:				54467	54468	54469	54470	54471
Date sampled:				16-Oct-20	16-Oct-20	16-Oct-20	16-Oct-20	16-Oct-20
Aquatico sampled:				No	No	No	No	No
Sample type:				Geochem	Geochem	Geochem	Geochem	Geochem
Locality description: Analyses				UG2 (1)	UG2 (2)	Pyroxenite H Wall	Spotted Norite H Wall	Pyroxenite Contact with UG2
		Unit	Method					
N	Geo - Milling 75um	-	Geochem	Yes	Yes	Yes	Yes	Yes
N	Paste pH (1:2)	pH	Geochem	8.98	8.84	9.25	8.98	9.11
N	Net acid generation (NAG)	CaCO3 kg/t	Geochem	0	0	0	0	0
N	NAGpH	pH	Geochem	5.14	4.96	5.06	4.87	6.26
N	Total Sulphur	%	Geochem	0.026	0.033	0.024	0.018	0.094
N	Sulphide Sulphur	%	Geochem	0	0	0	0	0.038
N	Sulphate Sulphur	%	Geochem	0.025	0.033	0.024	0.018	0.056
N	Acid Potential based Total Sulphur	CaCO3 kg/t	Geochem	0.812	1.03	0.750	0.562	2.94
N	Acid Potential based Sulphide Sulphur	CaCO3 kg/t	Geochem	<0.3125	<0.3125	<0.3125	<0.3125	1.19
N	Neutralization Potential (NP)	CaCO3 kg/t	Geochem	12.3	10.8	12.5	24.9	28.4
N	Net Neutralization Potential (NNP)	CaCO3 kg/t	Geochem	12.3	10.5	12.2	24.6	27.2
N	NP / AP (TS)	-	Geochem	15.1	10.5	16.7	44.3	9.67
N	NP / AP (SS)	-	Geochem	394	34.6	40.0	79.7	23.9

Out = Outsourced Sub = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine ATR = Alternative test report
Results only apply to the samples as received and tested; Results reported against the limit of detection.
The report shall not be reproduced except in full without approval of the laboratory
The results apply to the sample received.

M. Swanepoel
Technical Signatory

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leaders in environmental monitoring
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office: 012 450 3800 • fax: 012 450 3851

63 WESSEL ROAD
WOODMEAD
2191

ATTENTION: GROUNDWATER CONSULTING SERVICES (GCS)

6 NOVEMBER 2020

Vygenhoek Mine
(TEST REPORT 94158)

Qualitative and quantitative XRD results

Geochem samples (5) were submitted to Aquatico Laboratories on **19 October 2020** for Rietveld analysis.

The samples were milled and the material was prepared for XRD analysis using a front-loading preparation method

The samples were analysed with a PANalytical Empyrean diffractometer with X'Celerator detector and fixed slits with a Cu-Kα radiation.
The phases were identified by using X'Pert Highscore plus software.

Comments:

- If the results in this report do not correspond to results of other analytical techniques, please contact us for further review of the XRD results.
- The mineral names in this report may not reflect the specific mineral identified, but rather the mineral group.
- Due to preferred orientation and crystallite size effects as well as small sample amounts, results may not be as accurate as shown.
- Small amounts of additional phases may be present.
- **It may be advisable to confirm results using alternative analytical techniques.**
- Amorphous phases, if present, were not taken into account during quantification.

If you have any further queries please contact the laboratory.

Analyst
Paula Aucamp
BSc (Hons) Geology

Samples will be stored for 1 month after which it will be discarded

directors: R. Erdmann (CEO) • B.J. de Klerk • H. Holtzhousen • P.J. Naudé • L.A. Shezi • T.B. Sefolo.
company registration number: 2006/028605/07. vat no: 4360195723.

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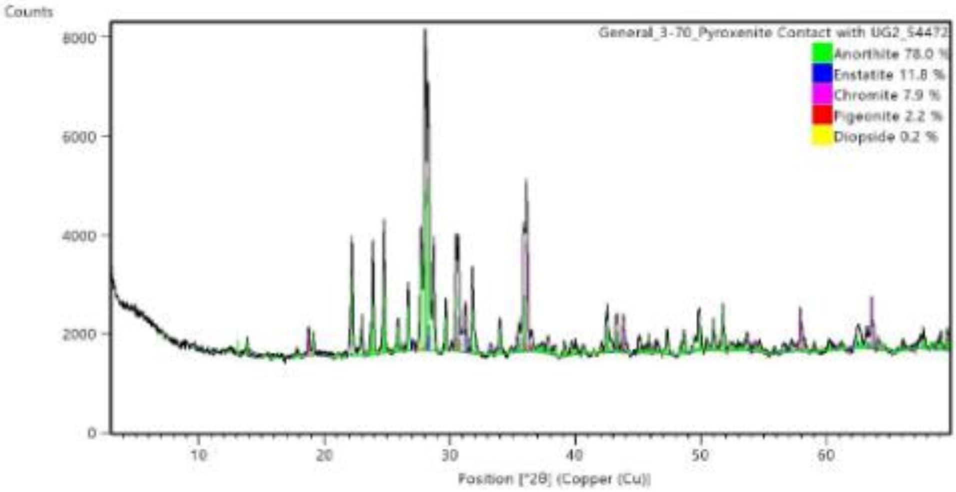
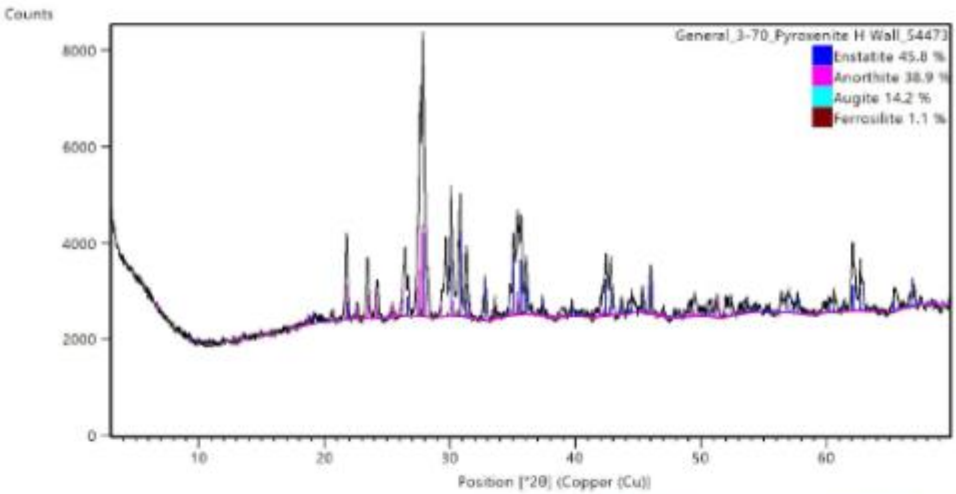
office: 012 450 3800 • fax: 012 450 3851

Results:





directors: R. Erdmann (CEO) • B.J. de Klerk • H. Holtzhousen • P.J. Noudé • L.A. Shezi • T.B. Sefolo.
company registration number: 2006/028605/07. vat no: 4360195723.

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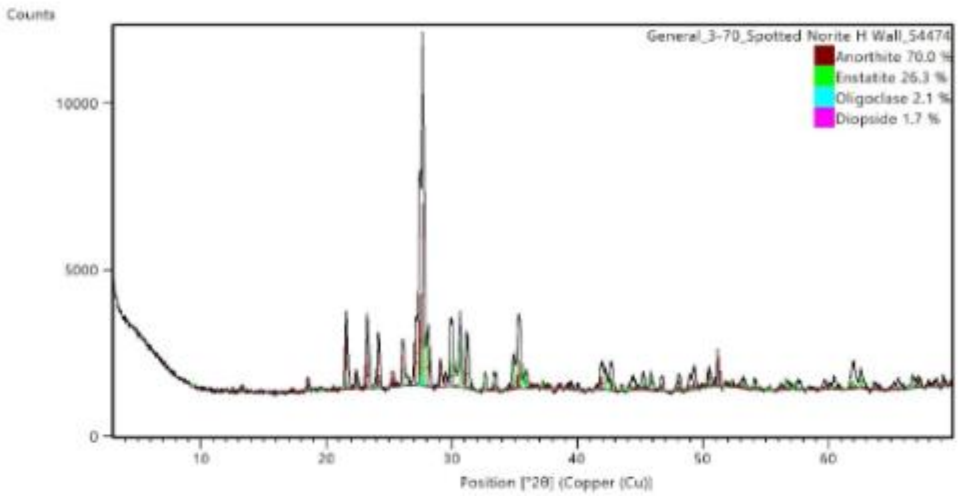

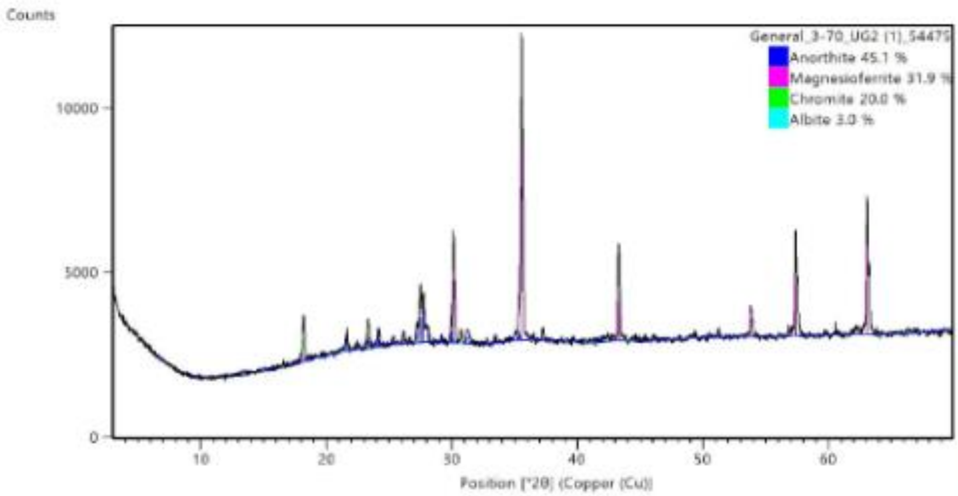

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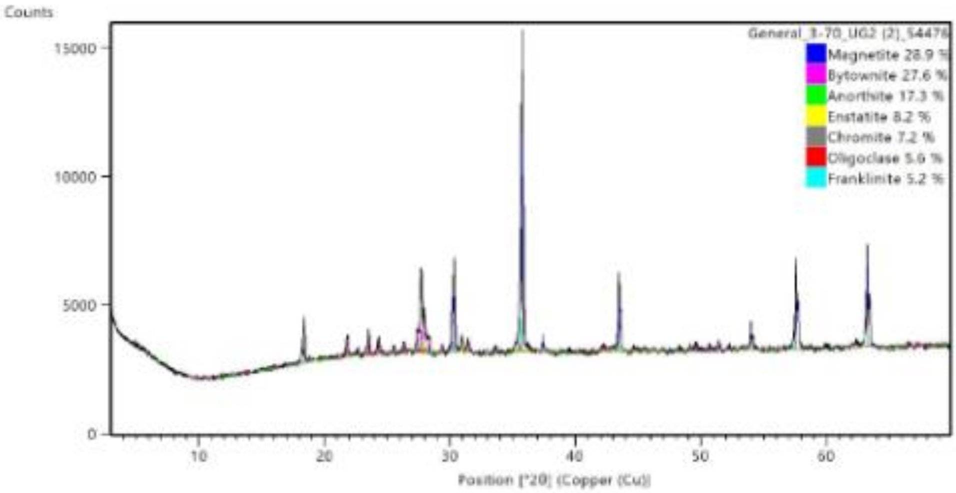

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office: 012 450 3800 • fax: 012 450 3851

Mineral description:

Mineral	Chemical formula	Description
Albite	$NaAlSi_3O_8$	Albite is the sodium-rich endmember of the plagioclase feldspar group of minerals. Albite typically has a white colour and is commonly found in felsic igneous rocks (e.g., granite), low-grade metamorphic rocks and pegmatites.
Anorthite	$CaAl_2Si_2O_8$	Anorthite is a feldspar mineral and the calcium-rich endmember in the plagioclase feldspar solid solution range. Plagioclase feldspar is a common rock-forming mineral and a major constituent of Earth's crust.
Augite	$(Ca,Na)(Mg,Fe,Al)(Si,Al)_2O_6$	Augite is generally the most common clinopyroxene mineral typically found in basalts, gabrros and various other dark-coloured igneous rocks.
Bytownite	$(Ca,Na)(Si,Al)_4O_8$	Bytownite belongs to the plagioclase feldspar group of minerals and falls within the calcium-rich compositional range (similar to anorthite).
Chromite	$Fe^{2+}Cr_2O_4$	Chromite is an important economic mineral that belongs to the spinel group of minerals. Chromite crystals usually have a metallic-grey to black colour.
Diopside	$MgCaSi_2O_6$	Diopside is a pyroxene mineral and belongs to the clinopyroxene sub-group. It is an important rock-forming mineral in mafic igneous rocks and can also be found in metamorphic rocks.
Enstatite	$Mg_2Si_2O_6$	Enstatite is part of the pyroxene group of minerals and is a common rock forming mineral in ultramafic-mafic igneous rocks and metamorphic rocks. Enstatite belongs to the orthopyroxene subgroup and typically occurs as grey to greenish brown crystals.
Ferrosilite	$FeSiO_3$	Ferrosilite is the iron-rich endmember of the orthopyroxene group of minerals. Pyroxene minerals are found in mafic igneous rocks like peridotites, basalts and pyroxenites.
Franklinite	$ZnFe_2O_4$	Franklinite is a zinc iron oxide which is part of the spinel group of minerals. Similar to magnetite, franklinite can contain both ferric (Fe^{3+}) and ferrous (Fe^{2+}) iron with manganese commonly occurring together with zinc.
Magnesioferrite	$MgFe^{3+}_2O_4$	Magnesioferrite is part of the spinel group of minerals. It is a black, sub-metallic to metallic mineral that can occur in burning coal heaps and high-grade combustion-metamorphosed marls.
Magnetite	Fe_3O_4	Magnetite is part of the spinel group of minerals. The mineral has a metallic black colour and is magnetic.
Oligoclase	$(Na,Ca)(Si,Al)_4O_8$	Oligoclase belongs to the plagioclase feldspar group of minerals and is situated between the minerals albite and andesine in the solid solution range. Oligoclase can be found in granite pegmatites and metamorphic rocks.

References:

1. Cairncross, B., 2004. Field Guide to Rocks and Minerals of South Africa. South Africa, Struik Nature.
2. Dutrow, B., & Klein, C., 2007. The Manual of Minerals Science. 23rd Edition, United States of America, Jay O'Callaghan.

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Test Report Page 1 of 2

Client: Groundwater Consulting Services (GCS)
Address: 63 Wessel Road, Woodmead, 2191
Report no: 94159
Project: Vygenhoek Mine

Date of report: 10 November 2020
Date accepted: 19 October 2020
Date completed: 10 November 2020
Date received: 16 October 2020

Lab no:				54477	54478	54479	54480	54481
Date sampled:				16-Oct-20	16-Oct-20	16-Oct-20	16-Oct-20	16-Oct-20
Aquatico sampled:				No	No	No	No	No
Sample type:				Geochem	Geochem	Geochem	Geochem	Geochem
Locality description: **Analyses**				Pyroxenite Contact with UG2	Pyroxenite H Wall	Spotted Norite H Wall	UG2 (1)	UG2 (2)
		Unit	**Method**					
N	DI 1:4 Static Leach	-	Geochem	Yes	Yes	Yes	Yes	Yes
N	pH @ 25°C	pH	ALM 20	9.11	9.46	9.27	9.28	9.12
N	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	15.5	9.64	6.63	8.49	8.95
N	Total alkalinity	mg CaCO3/l	ALM 01	22.7	35.4	34.1	20.2	16.0
N	Chloride (Cl)	mg/l	ALM 02	12.4	3.54	3.22	3.87	4.40
N	Sulphate (SO4)	mg/l	ALM 03	19.2	11.9	1.22	13.4	18.3
N	Orthophosphate (PO4) as P	mg/l	ALM 04	<0.005	0.115	0.065	0.018	0.008
N	Nitrate (NO3) as N	mg/l	ALM 06	0.674	<0.194	<0.194	<0.194	<0.194
N	Calcium (Ca)	mg/l	ALM 30	11.6	2.35	2.76	3.54	3.30
N	Magnesium (Mg)	mg/l	ALM 30	5.22	5.21	2.00	3.91	4.11
N	Sodium (Na)	mg/l	ALM 30	4.80	6.06	5.00	4.39	4.54
N	Potassium (K)	mg/l	ALM 30	5.39	4.47	2.69	3.87	4.04
N	Aluminium (Al)	mg/l	ALM 31	0.113	0.565	1.89	0.315	0.191
N	Iron (Fe)	mg/l	ALM 31	0.035	1.53	0.487	0.171	0.092
N	Manganese (Mn)	mg/l	ALM 31	<0.001	0.026	0.019	<0.001	<0.001
N	Cadmium (Cd)	mg/l	ALM 31	<0.002	<0.002	<0.002	<0.002	<0.002
N	Cobalt (Co)	mg/l	ALM 31	<0.003	<0.003	<0.003	<0.003	<0.003
N	Chromium (Cr)	mg/l	ALM 31	0.174	0.089	0.047	0.923	0.780
N	Copper (Cu)	mg/l	ALM 31	0.011	0.016	0.010	0.014	0.012
N	Nickel (Ni)	mg/l	ALM 31	0.046	0.026	0.012	0.023	0.018
N	Lead (Pb)	mg/l	ALM 31	<0.004	<0.004	<0.004	<0.004	<0.004
N	Zinc (Zn)	mg/l	ALM 31	<0.002	<0.002	<0.002	<0.002	<0.002
N	Boron (B)	mg/l	ALM 33	<0.013	<0.013	<0.013	<0.013	<0.013
N	Barium (Ba)	mg/l	ALM 33	<0.002	<0.002	<0.002	<0.002	<0.002
N	Beryllium (Be)	mg/l	ALM 33	<0.005	<0.005	<0.005	<0.005	<0.005
N	Vanadium (V)	mg/l	ALM 33	<0.001	0.023	0.006	0.001	<0.001
N	Bismuth (Bi)	mg/l	ALM 32	<0.004	<0.004	<0.004	<0.004	<0.004
N	Silver (Ag)	mg/l	ALM 32	<0.001	<0.001	<0.001	<0.001	<0.001

Out = Outsourced Sub = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine ATR = Alternative test report
Results only apply to the samples as received and tested; Results reported against the limit of detection.

The results apply to the sample received.

M. Swanepoel
Technical Signatory

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Test Report Page 2 of 2

Client: Groundwater Consulting Services (GCS)
Address: 63 Wessel Road, Woodmead, 2191
Report no: 94159
Project: Vygenhoek Mine

Date of report: 10 November 2020
Date accepted: 19 October 2020
Date completed: 10 November 2020
Date received: 16 October 2020

Lab no:				54477	54478	54479	54480	54481
Date sampled:				16-Oct-20	16-Oct-20	16-Oct-20	16-Oct-20	16-Oct-20
Aquatico sampled:				No	No	No	No	No
Sample type:				Geochem	Geochem	Geochem	Geochem	Geochem
Locality description: **Analyses**				Pyroxenite Contact with UG2	Pyroxenite H Wall	Spotted Norite H Wall	UG2 (1)	UG2 (2)
		Unit	**Method**					
N	Gallium (Ga)	mg/l	ALM 32	0.002	0.002	<0.001	0.002	<0.001
N	Lithium (Li)	mg/l	ALM 32	<0.001	<0.001	<0.001	<0.001	<0.001
N	Molybdenum (Mo)	mg/l	ALM 33	0.010	0.012	0.004	<0.004	<0.004
N	Rubidium (Rb)	mg/l	ALM 32	0.008	0.005	0.004	0.004	0.005
N	Strontium (Sr)	mg/l	ALM 33	0.028	<0.001	<0.001	0.005	0.017
N	Tellurium (Te)	mg/l	ALM 32	<0.001	0.001	<0.001	<0.001	<0.001
N	Thallium (Tl)	mg/l	ALM 32	<0.037	<0.037	<0.037	<0.037	<0.037

Out = Outsourced Sub = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine ATR = Alternative test report
Results only apply to the samples as received and tested; Results reported against the limit of detection.
The report shall not be reproduced except in full without approval of the laboratory
The results apply to the sample received.

Authenticated signature on first page

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APPENDIX D: NUMERICAL MODEL GRID AND SENSITIVITY ANALYSES

The Jacobian matrix for the numerical model is shown below (Figure A). The following parameters are sensitive to changes:

- Hydraulic conductivity in layer 1, 3 and 4.
- Storage in layer 1, 3 and 4.
- Recharge.

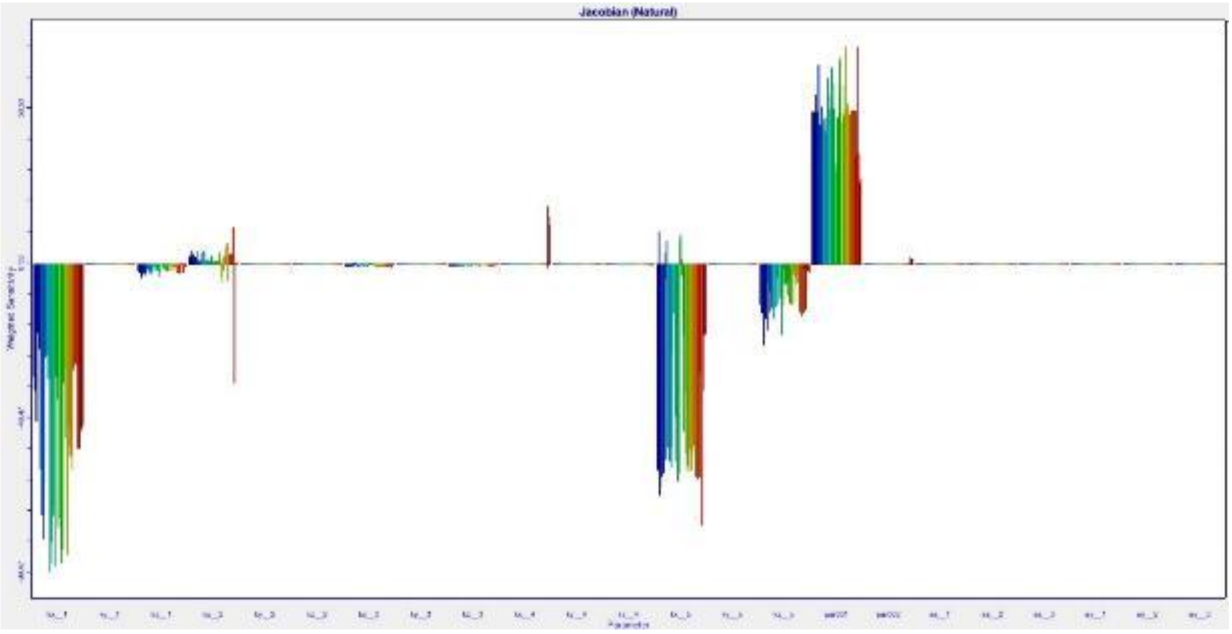

Figure A: Jacobian illustrating model sensitivities

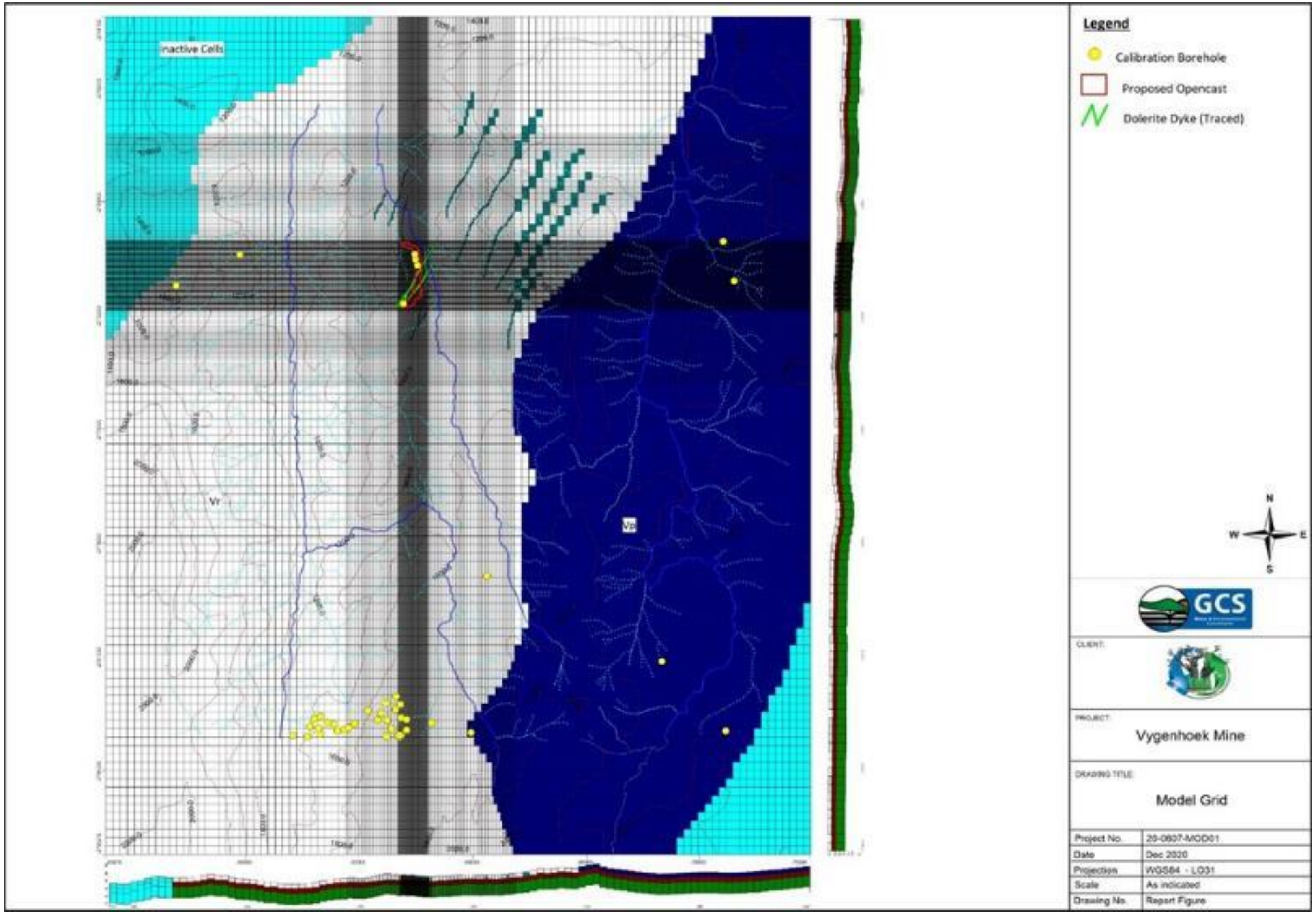

Figure B: Model Grid

APPENDIX E: RISK ASSESSMENT METHODOLOGY

The likely groundwater impacts associated with the opencast area (for the operational and closure phase) was assessed in terms of probability (likelihood of occurring), scale (spatial scale), magnitude (severity) and duration (temporal scale). To enable a scientific approach to the determination of the environmental significance (importance), a numerical value is linked to each rating scale.

The following criteria were applied:

- <u>**Occurrence:**</u>
  - Probability of occurrence (how likely is it that the impact may occur?); and
  - Duration of occurrence (how long the impact may last).
- <u>**Severity:**</u>
  - Magnitude (severity) of impact (will the impact be of high, moderate or low severity?); and
  - Scale/extent of impact (will the impact affect the national, regional or local environment or only that of the site?).

The impact assessment rankings used are listed in Table 1. The significance of the impact was determined by the formula below and was screened according to Table 2.

SP (significance of impact) = (magnitude + duration + scale) x probability

The likely impacts and significance of the impacts identified are added in Table 3.

Table 1: Impact assessment rankings

Status of Impact	
+: Positive (A benefit to the receiving environment)	
N: Neutral (No cost or benefit to the receiving environment)	
-: Negative (A cost to the receiving environment)	
Magnitude: =M	**Duration: =D**
10: Very high/don't know	5: Permanent
8: High	4: Long-term (ceases with the operational life)
6: Moderate	3: Medium-term (5-15 years)
4: Low	2: Short-term (0-5 years)
2: Minor	1: Immediate
0: Not applicable/none/negligible	0: Not applicable/none/negligible
Scale: =S	**Probability: =P**

5: International	5: Definite/don't know
4: National	4: Highly probable
3: Regional	3: Medium probability
2: Local	2: Low probability
1: Site only	1: Improbable
0: Not applicable/none/negligible	0: Not applicable/none/negligible

Table 2: Impact significance ratings

Significance	Environmental Significance Points	Colour Code
High (positive)	>60	H
Medium (positive)	30 to 60	M
Low (positive)	<30	L
Neutral	0	N
Low (negative)	>-30	L
Medium (negative)	-30 to -60	M
High (negative)	<-60	H

APPENDIX F: NUMERICAL MODEL CONFIDENCE MATRIX

In the development of the numerical model, a detailed data review was conducted. Data confidence and data availability dictate model confidence. A summary of the required data versus the data available is outlined below; 3: indicates sufficient data availability, 2: indicates moderate availability, 1: indicates limited or no availability.

As indicated in the table below, critical data required for development of a low-medium confidence model is available. Based on the model, key data gaps will be identified. These data gaps will be required to be filled before updating the model and producing a higher confidence model suitable for defendable predictive modelling.

Table 1: Model Data Confidence (1: low, 2: moderate, 3: high)

Data types	**Confidence**
Spatial and temporal distribution of groundwater head observations are required to adequately define groundwater behaviour, especially in areas of greatest interest and where outcomes are to be reported.	2
Spatial distribution of bore logs and associated stratigraphic interpretations clearly define aquifer geometry.	2
Rainfall and evaporation data is available.	3
Aquifer-testing data to define key parameters.	2
Streamflow and stage measurements are available with reliable base flow estimates at a number of points.	1
Reliable land-use and soil mapping data available.	2
Good quality and adequate spatial coverage of digital elevation model to define ground surface elevation.	2
Geometry of the existing opencast workings.	1
Geometry and temporal plan of future mine workings.	2
Transport model calibration points and confidence of constant sampling data	1
Aquifer dewatering rates / verified estimates	1
Model Data Confidence Rating	*Class 2*
	58%

Class 1: Low Confidence Model	***Score <16.5 (50%)***
Class 2: Intermediate Confidence Model	***Score 16.5 - 24.75 (50-80%)***
Class 3: High Confidence Model	***Score <24.75 (80 - 100%)***

APPENDIX G: DISCLAIMER AND DECELERATION OF INDEPENDENCE

The opinions expressed in this Report have been based on site /project information supplied to GCS Water and Environment (Pty) Ltd (GCS) by Environmental Management Assistance (Pty) Ltd (EMA) and is based on public domain data and data supplied to GCS by the client. GCS has acted and undertaken this assessment objectively and independently and assumes that all data provided is scientifically accurate.

GCS has exercised all due care in reviewing the supplied information. Whilst GCS has compared key supplied data with expected values, the accuracy of the results and conclusions are entirely reliant on the accuracy and completeness of the supplied data. GCS does not accept responsibility for any errors or omissions in the supplied information and does not accept any consequential liability arising from commercial decisions or actions resulting from them.

Opinions presented in this report, apply to the site conditions and features as they existed at the time of GCS's investigations, and those reasonably foreseeable. These opinions do not necessarily apply to conditions and features that may arise after the date of this report, about which GCS had no prior knowledge nor had the opportunity to evaluate.

DETAILS OF THE SPECIALIST, DECLARATION OF INTEREST AND UNDERTAKING UNDER OATH

	(For official use only)
File Reference Number:	
NEAS Reference Number:	DEA/EIA/
Date Received:	

Application for authorisation in terms of the National Environmental Management Act, Act No. 107 of 1998, as amended and the Environmental Impact Assessment (EIA) Regulations, 2014, as amended (the Regulations)

PROJECT TITLE

Geohydrological Assessment for the Proposed Vygenhoek Platinum Mine

Kindly note the following:

1. This form must always be used for applications that must be subjected to Basic Assessment or Scoping & Environmental Impact Reporting where this Department is the Competent Authority.
2. This form is current as of 01 September 2018. It is the responsibility of the Applicant / Environmental Assessment Practitioner (EAP) to ascertain whether subsequent versions of the form have been published or produced by the Competent Authority. The latest available Departmental templates are available at https://www.environment.gov.za/documents/forms.
3. A copy of this form containing original signatures must be appended to all Draft and Final Reports submitted to the department for consideration.
4. All documentation delivered to the physical address contained in this form must be delivered during the official Departmental Officer Hours which is visible on the Departmental gate.
5. All EIA related documents (includes application forms, reports or any EIA related submissions) that are faxed; emailed; delivered to Security or placed in the Departmental Tender Box will not be accepted, only hardcopy submissions are accepted.

Departmental Details

Postal address:
Department of Environmental Affairs
Attention: Chief Director: Integrated Environmental Authorisations
Private Bag X447
Pretoria
0001

Physical address:
Department of Environmental Affairs
Attention: Chief Director: Integrated Environmental Authorisations
Environment House
473 Steve Biko Road
Arcadia

Queries must be directed to the Directorate: Coordination, Strategic Planning and Support at:
Email: EIAAdmin@environment.gov.za

1. SPECIALIST INFORMATION

Specialist Company Name:	GCS Water and Environment			
B-BBEE	Contribution level (indicate 1 to 8 or non-compliant)	4	Percentage Procurement recognition	
Specialist name:	Hendrik Botha			
Specialist Qualifications:	MSc. Environmental Science			
Professional affiliation/registration:	PriSciNat (400139/17)			
Physical address:	4a Old Main Road, Kloof, 3610			
Postal address:	4a Old Main Road, Kloof, 3610			
Postal code:	3610	Cell:	071 102 3819	
Telephone:	+27 (0) 31 764 7130	Fax:		
E-mail:	hendrikb@gcs-sa.biz			

2. DECLARATION BY THE SPECIALIST

I, Hendrik Botha, declare that –

- I act as the independent specialist in this application;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, Regulations and any guidelines that have relevance to the proposed activity;
- I will comply with the Act, Regulations and all other applicable legislation;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- all the particulars furnished by me in this form are true and correct; and
- I realise that a false declaration is an offence in terms of regulation 48 and is punishable in terms of section 24F of the Act.

Signature of the Specialist

GCS Water and Environment (Pty) Ltd

Name of Company:

05 February 2021

Date

3. UNDERTAKING UNDER OATH/ AFFIRMATION

I, ___________________________________, swear under oath / affirm that all the information submitted or to be submitted for the purposes of this application is true and correct.

Signature of the Specialist

Name of Company

Date

Signature of the Commissioner of Oaths

Date

CVS OF SPECIALIST TEAM

Hendrik Botha
Hydrogeologist / Modeller

PROFILE

Hendrik (Henri) Botha is a Hydrogeologist at GCS (Pty) Ltd. He has been an employee since the beginning of 2014. He has good communication and leadership skills. Groundwater and surface water sampling, knowledge of water chemistry together with GIS and modelling skill is some of his sought after expertise. General and applied logical knowledge is his key elements in problem-solving.

Henri has specialist skills in the following areas:

- Aquifer vulnerability assessments
- Aquifer test data analyses and interpretation
- Drilling supervision, logging and data interpretation
- Geochemical sampling, data interpretation and modelling
- Geophysical surveys and data interpretation
- GIS
- Water quality sampling and data interpretation
- Groundwater impact and risk assessments
- Hydrocensus surveys
- Numerical and Conceptual Visual Modelling (Visual Modflow, ModflowFLEX, Voxler, RockWorks, Surfer and Excel)
- Hydropedology (Hydrological Soil Types) & Soils Assessments
- Floodline Modelling (HEC-RAS)

CORE SKILLS

- Project management
- Analytical and numerical groundwater modelling
- Geochemical assessments and geochemical modelling
- Hydropedology and hydrological assessments
- Floodline Modelling
- Groundwater vulnerability, impact and risk assessments
- Technical report writing
- GIS and mapping

Details

Qualifications

- BSc Chemistry and Geology (Environmental Sciences)
- BSc Hons Hydrology (Environmental Sciences)
- MSc Geohydrology and Hydrology (Environmental Sciences)

Memberships

- SACNASP Professional Natural Scientist *(400139/17)*
- Groundwater Division of GSSA
- Groundwater Association of KwaZulu Natal Member
- **International Mine Water Association (IMWA)**

Languages

Key project experience

PROFESSIONAL EXPERIENCE: -

Year	*Client*	*Project Description*	*Role / Responsibility*
Water Monitoring			
2014 2016	Buffalo Coal	Buffalo Coal Water Monitoring	Field Specialist, Reporting
2018	Tripo4 Sustainable Solutions (Pty) Ltd	Groutville D Sanitation Programme - Water Monitoring	Project Manager, Field Specialist, Assessments, Reporting, Client liaison
2016	Tripo4 Sustainable Solutions (Pty) Ltd	Monitoring Plan for the Proposed Bhamshela Filling Station	Project Manager, Field Specialist, Reporting, Client liaison
2014-2015	Total Coal South Africa (TCSA)	Steincoalspruit Colliery Water Monitoring for Closure	Project Manager, Field Specialist, Reporting, Client liaison
2016-2019	Tripo4 Sustainable Solutions (Pty) Ltd	Avon Peaking Power Plant Groundwater and Surface Water Monitoring	Project Manager, Field Specialist, Assessments, Reporting, Client liaison
2015-2019	Tripo4 Sustainable Solutions (Pty) Ltd	King Shaka Mall Monitoring Plan and Water Monitoring	Project Manager, Field Specialist, Reporting, Client liaison
2014-Ongoing	Tendele Coal (Pty) Ltd	Somkhele Anthracite Mine Water Monitoring	Project Manager, Field Specialist, Reporting, Client liaison
Geohydrological, Hydrological and Hydropedological Assessments (WULA, BA, IWULA, EMP) - **Numerical and Analytical Modelling Application,** Floodline Modelling, CSWMP, Water Balances and Hydropedology			
2020	Green Door Environmental	Justin Lusso Poultry Farm – Geohydrology and Hydrological Assessments	Project Manager, Field Specialist, Reporting, Client liaison

Year	*Client*	*Project Description*	*Role / Responsibility*
2020	Metamorphosis Environmental Consulting	Proposed Shongweni Landfill Hydrological Assessment	Project Manager, Field Specialist, Reporting, Client liaison
2020	Green Door Environmental	Middeldrift Bulk Augmentation Hydrological and Hydropedological Assessment	Project Manager, Field Specialist, Reporting, Client liaison
2020	EnviroMatrix	Manyatseng Cemetery Geohydrological and Flood Line Assessment	Project Manager, Field Specialist, Reporting, Client liaison
2020	Wallace & Green	Glendale Sugar Mill Hydrology Assessment & Groundwater Numerical Model Development	Project Manager, Field Specialist, Reporting, Client liaison
2019	Green Door Environmental	Hydrological Assessment for the Chep Weatherboard Dam	Project Manager, Field Specialist, Reporting, Client liaison
2019	Triplo4 Sustainable Solutions (Pty) Ltd	Elaleni Hydropedology Assessment	Project Manager, Field Specialist, Reporting, Client liaison
2019	Green Door Environmental	Geohydrological Assessment for the Sani Pass Hotel Expansion	Project Manager, Field Specialist, Modler, Analyst, Reporting, Client liaison
2019	Green Door Environmental	Evergreen Hilton Retirement Village Geo hydrological Assessment	Project Manager, Field Specialist, Modler, Analyst, Reporting, Client liaison
2019	Cato Scrap CC	Cato Scrap Metal Facility Geohydrological Assessment	Project Manager, Field Specialist, Modler, Analyst, Reporting, Client liaison
2019	Green Door Environmental	Hydrogeological Assessment for the Goedgedacht Farm	Project Manager, Field Specialist, Modler, Analyst, Reporting, Client liaison
2019	ACER (Africa) Environmental Consultants	Hydrogeological Assessment for the Mtuzini Sewage Works	Project Manager, Field Specialist, Modler, Analyst, Reporting, Client liaison

Year	Client	Project Description	Role / Responsibility
2019	Tripo4 Sustainable Solutions (Pty) Ltd	Hydrogeological Assessment for the Sezela Mill Molasses Bladder Development Site	Project Manager, Field Specialist, Modler, Analyst, Reporting, Client liaison
2018	GIBB	Illovo Automotive Supplier Park (ASP) Geohydrological Assessment	Project Manager, Field Specialist, Modler, Analyst, Reporting, Client liaison
2018	Kangra Coal (Pty) Ltd	Numerical Groundwater Model update for the Maquasa East, Maquasa West and Nooitgezien mining operations	Project Manager, Field Specialist, Modler, Analyst, Reporting, Client liaison
2018	Tripo4 Sustainable Solutions (Pty) Ltd	Hydrogeological Assessment and Numerical Groundwater Model Development for the Illovo Noodsburg Sugar Mill	Project Manager, Field Specialist, Modler, Analyst, Reporting, Client liaison
2018	Zululand Anthracite Colliery (ZAC)	Hydrogeological Assessment and Numerical Model Development for the Deep E Opencast and New Mngeni Shaft operational areas.	Project Manager, Field Specialist, Modler, Analyst, Reporting, Client liaison
2018	Green Door Environmental	Hydrogeological Assessment for the Isandlwana Settlement Development	Project Manager, Field Specialist, Assessments, Reporting, Client liaison
2018	Green Door Environmental	Hydrogeological Assessment for the Rem 8532 Northington Farm Bottling Plant	Project Manager, Field Specialist, Assessments, Reporting, Client liaison
2018	EnvironMatrix	Hydrogeological Assessment for the Spilsbury Piggery	Project Manager, Field Specialist, Assessments, Reporting, Client liaison
2018	Tripo4 Sustainable Solutions (Pty) Ltd	Hydrogeological Assessment for the UCL Sugar Mill	Project Manager, Field Specialist, Assessments, Reporting, Client liaison
2018	Triplo4 (Pty) Ltd	Hydrogeological investigation for the Noodsburg Sugar Mill	Project Manager, Field Specialist, Modler, Analyst, Reporting, Client liaison

Year	*Client*	*Project Description*	*Role / Responsibility*
2018	Green Door Environmental	Hydrogeological Assessment for the Burnlea farm, situated near Underburg.	Project Manager, Field Specialist, Assessments, Reporting, Client liaison
2018	EcoLeges	Hydrogeological Assessment for the Proposed Development of Chicken Farms near Klippan	Project Manager, Field Specialist, Assessments, Reporting, Client liaison
2018	EcoLeges	Hydrogeological Assessment for the E&T Abattoir	Project Manager, Assessments, Reporting, Client liaison
2017	Zinoju Coal (Buffalo Coal)	Numerical Groundwater Model Update for the Magdalena Colliery	Project Manager, Field Specialist, Modler, Analyst, Reporting, Client liaison
2017	Tendele Coal (Pty) Ltd (Somkhele Anthracite Mine)	Hydrogeological Investigation for KwqQubuka and Luhlanga Opencast Operations	Project Manager, Field Specialist, Modler, Analyst, Reporting, Client liaison
2017	Glencore	Numerical Groundwater Flow and Transport Model Development for the Lydenburg Smelter	Project Manager, Field Specialist, Modler, Analyst, Reporting, Client liaison
2017	Tripo4 Sustainable Solutions (Pty) Ltd	Hydrogeological investigation for the Ilovo Eston Sugar Mill	Project Manager, Field Specialist, Modler, Analyst, Reporting, Client liaison
2017	Frame Knitting Factory	Hydrogeological investigation for the Frame Knitting Factory - As part of the WULA	Project Manager, Analyst, Reporting, Client liaison
2017	Royal HaskoningDHV - South Africa	Hydrogeological Assessment for the proposed Ballito Hills Development project	Project Manager, Field Specialist, Modler, Analyst, Reporting, Client liaison
2016	Tripo4 Sustainable Solutions (Pty) Ltd	Geohydrological Assessment for the Priority 1 Sewer Pipeline Development Project	Project Manager, Field Specialist, Assessments, Reporting, Client liaison
2016	Tongaat Hulett Developments (Pty) Ltd	Geohydrological Assessment for the Tinley Manor Development Project	Project Manager, Field Specialist, Assessments, Reporting, Client liaison

Year	Client	Project Description	Role / Responsibility
2016	Tongaat Hulett Developments (Pty) Ltd	Geohydrological Assessment for the Inyaninga Development Project	Project Manager, Field Specialist, Assessments, Reporting, Client liaison
2016	GIBB	Umzimkhulu WWTW Geohydrological Assessment	Project Manager, Field Specialist, Assessments, Reporting, Client liaison
2015	Magalela and Associates	Geohydrological Assessment Elandspruit	Project Manager, Field Specialist, Modler, Analyst, Reporting, Client liaison
2015	Tripo4 Sustainable Solutions (Pty) Ltd	Gledhow Sewer Pipeline Geohydrological Assessment	Project Manager, Field Specialist, Analyst, Reporting, Client liaison
2015	Ground Truth	Matuba Mall Geohydrological Assessment for WULA	Project Manager, Field Specialist, Analyst, Reporting, Client liaison
2015	Royal HaskoningDHV	Desktop Geohydrological Assessment for Sibaya Sewer Pump Stations	Project Manager, Field Specialist, Analyst, Reporting, Client liaison
2015	Anglo Gold Ashanti	AngloGold Ashanti VR, MWS and WW Salt Load Allocations per Source Facility Update	Project Manager, Field Specialist, Analyst, Reporting, Client liaison
2014	Anglo Gold Ashanti	Surface and Groundwater Monitoring Assessment	Reporting, Analyst, Reporting, Client liaison
2014	EIMS	De Wittekrans Groundwater Update and Hydrocensus	Field Specialist
2014	Kangra Coal (Pty) Ltd	Ballengeich Pollution Control Project	Project Manager, Field Specialist, Analyst, Reporting, Client liaison
2014	Kemafahla and Trading	Cornfields Geohydrological Assessment	Project Manager, Field Specialist, Analyst, Reporting, Client liaison
2014	Total Coal South Africa (TCSA)	Dorsfontein and Forzando Geohydrological Assessment	Project Manager, Field Specialist, Analyst, Reporting, Client liaison
2014	Sivest	Preliminary and Desktop Hydrogeological Assessment for the Msinga Local Municipality Landfill Site in the	Reporting

Year	*Client*	*Project Description*	*Role / Responsibility*
		Pomeroy Area	
2014	Tripo4 Sustainable Solutions (Pty) Ltd	King Shaka Mall Geohydrological Assessment	Project Manager, Field Specialist, Analyst, Reporting, Client liaison
2014	Tripo4 Sustainable Solutions (Pty) Ltd	Steve Biko Housing Development Geohydrological Assessment	Project Manager, Field Specialist, Analyst, Reporting, Client liaison
2014-2016	Tendele Coal (Pty) Ltd	Somkhele Waste and Geochemical Management Plan	Project Manager, Field Specialist, Analyst, Reporting, Client liaison
2016-2018	Tendele Coal (Pty) Ltd	Area 1 Pit Lake Feasibility Assessment	Project Manager, Field Specialist, Modler, Analyst, Reporting, Client liaison
Geochemistry, Waste Classification, Geochemical Modelling, Soil Chemistry and Water Chemistry Assessments			
2019 - ongoing	Thalo Environmental	Waste Classification for the Fortuna WTW	Project Manager, Assessor, Reporting, Client liaison
2019	Buffalo Coal (Pty) Ltd	Aviemore Colliery Decant and Stream Loss Assessment	Project Manager, Modler, Analyst, Reporting, Client liaison
2019	Buffalo Coal (Pty) Ltd	Aviemore Colliery AMD Treatment Strategy	Project Manager, Modler, Analyst, Reporting, Client liaison
2018	Tendele Coal (Pty) Ltd	Geochemical Model Development for the Somkhele Anthracite Mine	Project Manager, Field Specialist, Modler, Analyst, Reporting, Client liaison
2017-ongoing	Tendele Coal (Pty) Ltd	Kinetic Column Leach Test Assessments for Mining Area 8 and Area 9 at the Somkhele Anthracite Mine	Project Manager, Field Specialist, Analyst, Reporting, Client liaison
2016	Tendele Coal (Pty) Ltd	Somkhele Co-Disposal Assessment	Project Manager, Field Specialist, Modler, Analyst, Reporting, Client liaison
2015	Crest Choice Chicken	Potchefstroom Bottling Facility WQ Analysis	Interpretation and Analysis, Reporting

Year	*Client*	*Project Description*	*Role / Responsibility*
2015	Total Coal South Africa (TCSA)	Springbok Siding Soil Analyses	Interpretation and Analysis, Reporting
2015	Exxaro	(Matla Mine) Water Chemistry Analysis	Interpretation and Analysis, Reporting
2015	Tendele	AdHoc: Somkhele Sample Water Quality	Interpretation and Analysis, Reporting
2015	Hatch Goba	Mukulu Soil Analysis	Interpretation and Analysis, Reporting
2015	Northam Platinum	Soil Chemistry Interpretation	Interpretation and Analysis, Reporting
2015	Private Client	Soil Chemistry Analysis and Interpretation	Interpretation and Analysis, Reporting
2015	Molo	Molo Graphite Project Soil Analysis	Interpretation and Analysis, Reporting
2014	Estima	Soil and water chemistry analyses	Interpretation and Analysis, Reporting
2014	Kangra	Bokoni Platinum - Soil Monitoring	Interpretation and Analysis, Reporting
2014	Booysendal Mine	Soils, Land-Use and Land Capability Assessment for Booysendal Mine: Soil Chemistry Analysis	Interpretation and Analysis, Reporting
2014	Kangra	Longridge Soil Testing to identify Fertilizer Use: Soil Chemistry Interpretation	Interpretation and Analysis, Reporting
Water Supply			
2018	MBB Projects	Groundwater Supply Investigation for the iSimangaliso Wetland Park	Project Manager, Analyst, Reporting, Client liaison
2016-2017	Focus Project Management	GZN Dough Relief Borehole Feasibility Study	Project Manager, Field Specialist, Modler, Analyst, Reporting, Client liaison
2016	Condor Construction (Pty) Ltd	Geohydrological Investigation and Drilling Feasibility for Mount Ayliff Police Station	Project Manager, Field Specialist, Analyst, Reporting, Client liaison
2015	Tendele Coal (Pty) Ltd	Somkhele Water Supply	Project Manager, Field Specialist, Reporting, Client liaison

Year	*Client*	*Project Description*	*Role / Responsibility*
2015	DWS	Rural Water Supply & Resource Management	Field Specialist
2018	MBB Projects	Groundwater Supply Investigation for the iSimangaliso Wetland Park	Project Manager, Analyst, Reporting, Client liaison

PAPERS / DISSERTATIONS: -

Year	***Title***	***Presented***
2013	*Hydrological Modelling of the Boskop Dam Catchment with SWMM (Thesis)*	*North West University*
2015	Understanding Site Hydrology of the Northern Kwazulu-Natal Anthracite Coal Fields With Special Reference to Discard and Tailings Disposal Practices (Paper)	14th Biennial Groundwater Division Conference: From Theory to Action
2016	Geohydrological impact of co-disposed coal material into an opencast pit (Thesis)	North West University
2018	Viability Of Converting A South African Coal Mining Pit Lake System Into A Water Storage Facility	ICARD 2018
2019	Evaluating Groundwater Availability Based on Land Cover and Local Hydrogeology – A Groundwater Balance Approach	*16th Groundwater Conference and Exhibition, Port Elizabeth, 20-23 October 2019.*

CONFERENCES/ TRAINING: -

Year	***Course/ Conference***

2015	14th Biennial Groundwater Division Conference: From Theory to Action
2015	Fire Prevention and Protection Training Course
2018	*International Mine Water Association (IMWA) – International Convention for Acid Rock Drainage (ICARD) Conference*
2019	*16th Groundwater Conference and Exhibition, Port Elizabeth, 20-23 October 2019.*