4a Old Main Road, Judges Walk, Kloof, Kwazulu-Natal, South Africa, 3610
PO Box 819, Gillitts, 3603, South Africa
Tel: +27 (0) 31 764 7130 **Fax:** +27 (0) 31 764 7140 **Web:** www.gcs-sa.biz

Desktop geohydrological & preliminary risk assessment for the Proposed Vygenhoek Platinum Mine

(As Part of the Scoping Phase)

Report

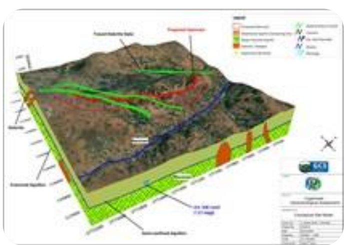
Version - Final V2

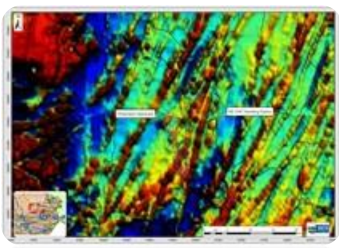
21 July 2020

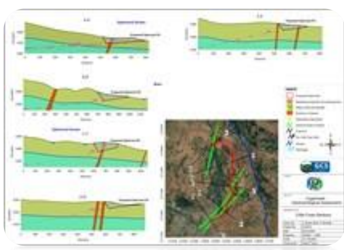
Environmental Management Assistance (Pty) Ltd

GCS Project Number: 20-0614

Client Reference: Vygenhoek Scoping Geohydrology







GCS (Pty) Ltd. **Reg No:** 2004/000765/07 Est. 1987
Offices: **Durban** Gaboronе Johannesburg Lusaka Maseru Ostrava Pretoria Windhoek
Directors: AC Johnstone (CEO) AD Gunn (COO) PF Labuschagne AWC Marais S Napier W Sherriff (Financial)
Non-Executive Director: B Wilson-Jones
www.gcs-sa.biz

DESKTOP GEOHYDROLOGICAL & PRELIMINARY RISK ASSESSMENT FOR THE PROPOSED VYGENHOEK PLATINUM MINE

Report
Version - Final V2

21 July 2020

Environmental Management Assistance (Pty) Ltd

20-0614

DOCUMENT ISSUE STATUS

Report Issue	Final V2		
GCS Reference Number	GCS Ref - 20-0614		
Client Reference	Vygenhoek Scoping Geohydrology		
Title	Desktop geohydrological & preliminary risk assessment for the Proposed Vygenhoek Platinum Mine		
	Name	**Signature**	**Date**
Author / Editor	Hendrik Botha (MSc, PriSciNat)		21 July 2020
Director / Reviewer	Pieter Labuschagne(MSc, PriSciNat)		21 July 2020

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.

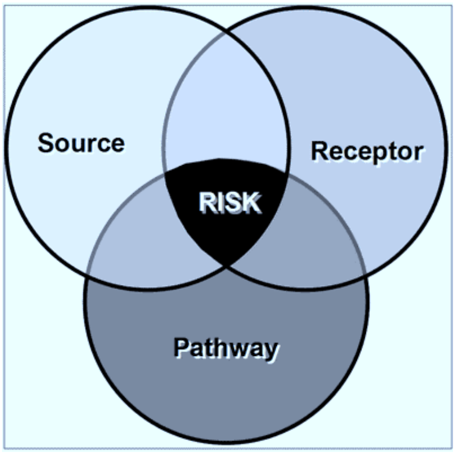
EXECUTIVE SUMMARY

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

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. Opencast mining is proposed to mine the economical layers which sub-outcrops on the surface to a depth of approx. 150 metres below ground level (mbgl). The total mining right area is approx. 720 Ha.

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

- **Source term** - The source of the risk.
- **Pathway** - The pathway along which the risk propagates; and
- **Receptor** - The target that experiences the risk.



The approach was used to assess:

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

This desktop-level geohydrological assessment was compiled to evaluate potential geohydrological risk as part of the **DMR Scoping Phase**. A desktop-level seismicity assessment was included in this report (refer to Section 3).

A preliminary geohydrological site conceptual model (SCM) has been developed for the proposed mine and is discussed in Section 5. Based on the SCM, several preliminary geohydrological risks have been identified, and are discussed in Section 5. Preliminary mitigation measures have been provided to circumvent probable negative impacts.

A preliminary groundwater monitoring plan is presented in Section 6. Several recommendations have been made for follow-up geohydrological work to supplement the SCM, risk assessment and Water Use License Application (WULA).

CONTENTS PAGE

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

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 desktop level geohydrological assessment for the Proposed Vygenhoek Platinum Mine, situated 45km west of Mashishing, Mpumalanga Province (refer to Figure 2-1).

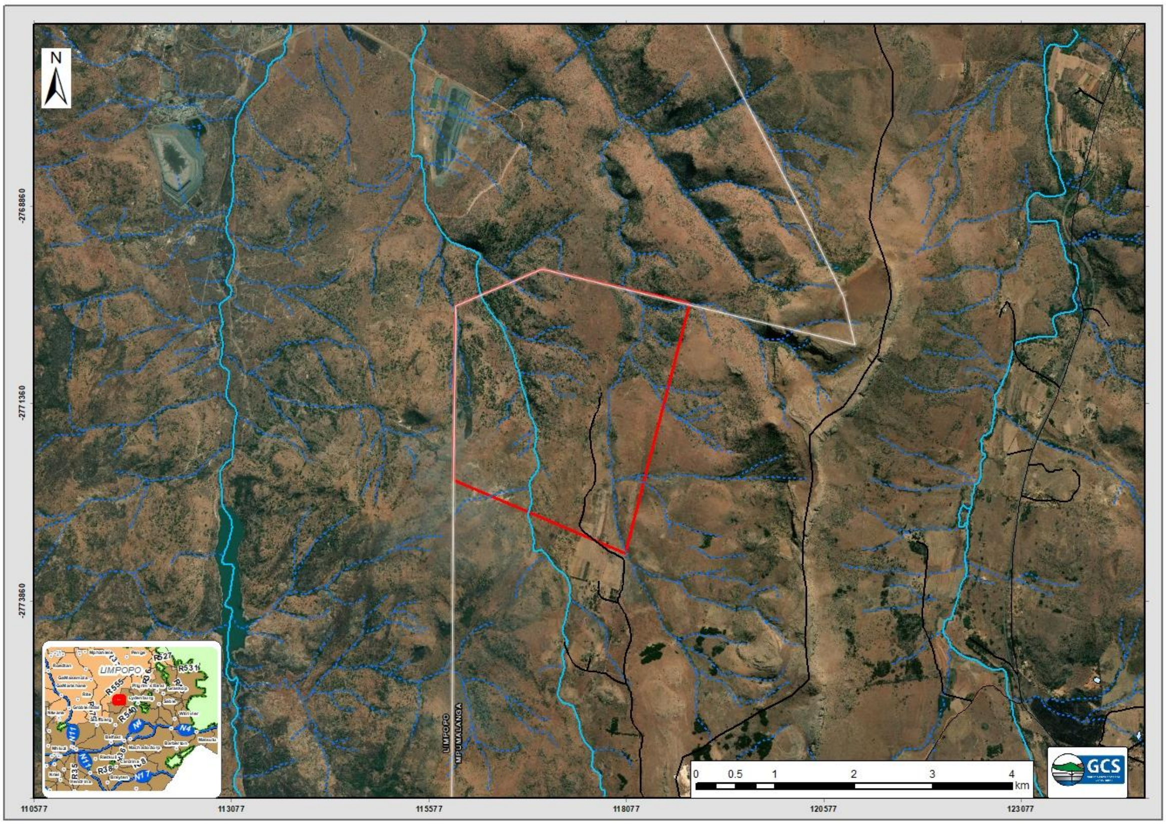


Figure 1-1: Site locality

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 approx. 150 metres below ground level (mbgl). The total mining right area is approx. 720 Ha.

This desktop-level geohydrological assessment was compiled to evaluate potential geohydrological risk as part of the DMR Scoping Phase.

1.2 Aims and objectives

The main objectives of this report are to:

- Give an overview of the geohydrological conditions of the site and expected water quality and quantity.
- Evaluate the likely status of groundwater resources in general and any fatal flaws and /or sensitive areas.
- Undertake a desktop level seismicity assessment.
- Determine preliminary groundwater risks associated with the proposed activities on the groundwater environment.
- Present findings in an understandable and presentable format so that it can be used for decision-making purposes.

1.3 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. Desktop seismicity assessment:
    a. A desktop-level seismicity assessment was included to evaluate the risk associated with tremors.
3. Hydrogeological Risk Assessment:
    a. A hydrogeological and geological site conceptual model was developed with data obtained for the study area.
    b. A groundwater balance was undertaken to classify the groundwater safe yield. This safe yield has been used to assesses the development impact on the aquifer on a sub-catchment scale.
    c. A preliminary risk assessment was conducted based on the Source-Pathway-Receptor (SPR) model; and standard DWS risk assessment.

4. Monitoring Plan:
    a. A groundwater and surface water monitoring plan, with mitigation measures, was developed for the site based on the baseline assessment of the site conditions.
5. Reporting:
    a. A geohydrological report encompassing all work done as well as a preliminary groundwater risk assessment and monitoring plan were compiled.

1.4 Limitations

The following limitations are recognised:

- No intrusive geohydrological work was completed as part of this study. It is understood that a detailed geohydrological assessment will be undertaken as part of the Integrated Water Use License Application (WULA) and Environmental Impact Assessment (EIA) for the proposed mine. Gaps identified in this study will be addressed during the ground-truthed geohydrological assessment.
- No geochemical data is available for the rock that will be mined. Hence, source terms (i.e. and potential and metal leaching potential etc.) were not defined. No kinetic modelling or transport modelling can be undertaken until the data is made available.
- No lithology data was supplied for the exploration boreholes drilled, except for ore floor elevations. Hence, no 3D geological model could be developed to supplement the site conceptual model.
- No numerical flow and transport modelling was undertaken to evaluate long term impacts.

2 SITE ASSESSMENT

The following section supplies a brief overview of the regional setting, topography, climate and geological occurrences in the project area. 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 2-1). 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

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). 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).

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 and norite (pyroxenite) 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 2-1).

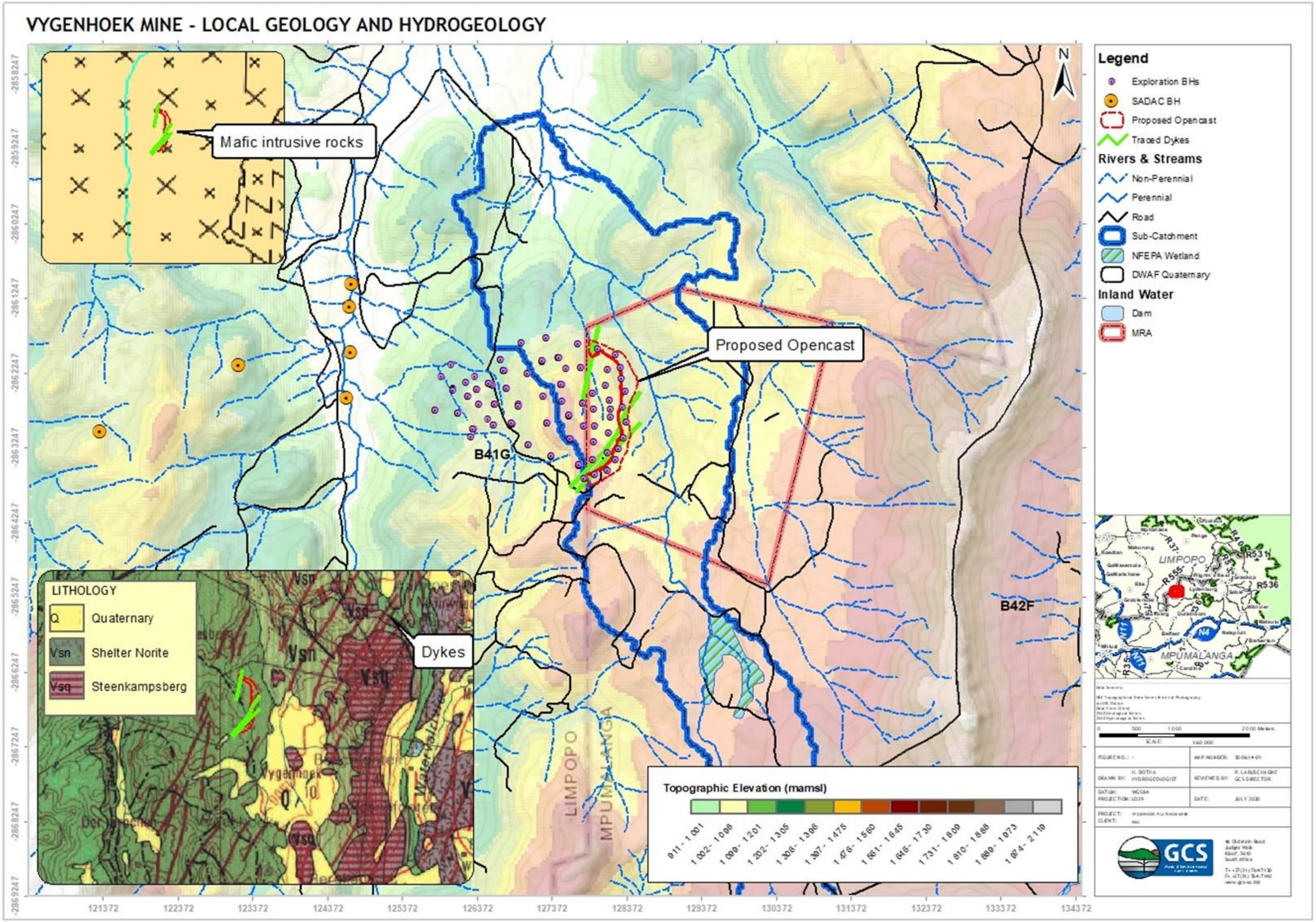


Figure 2-1: Locality, local geology and hydrogeology

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 property.

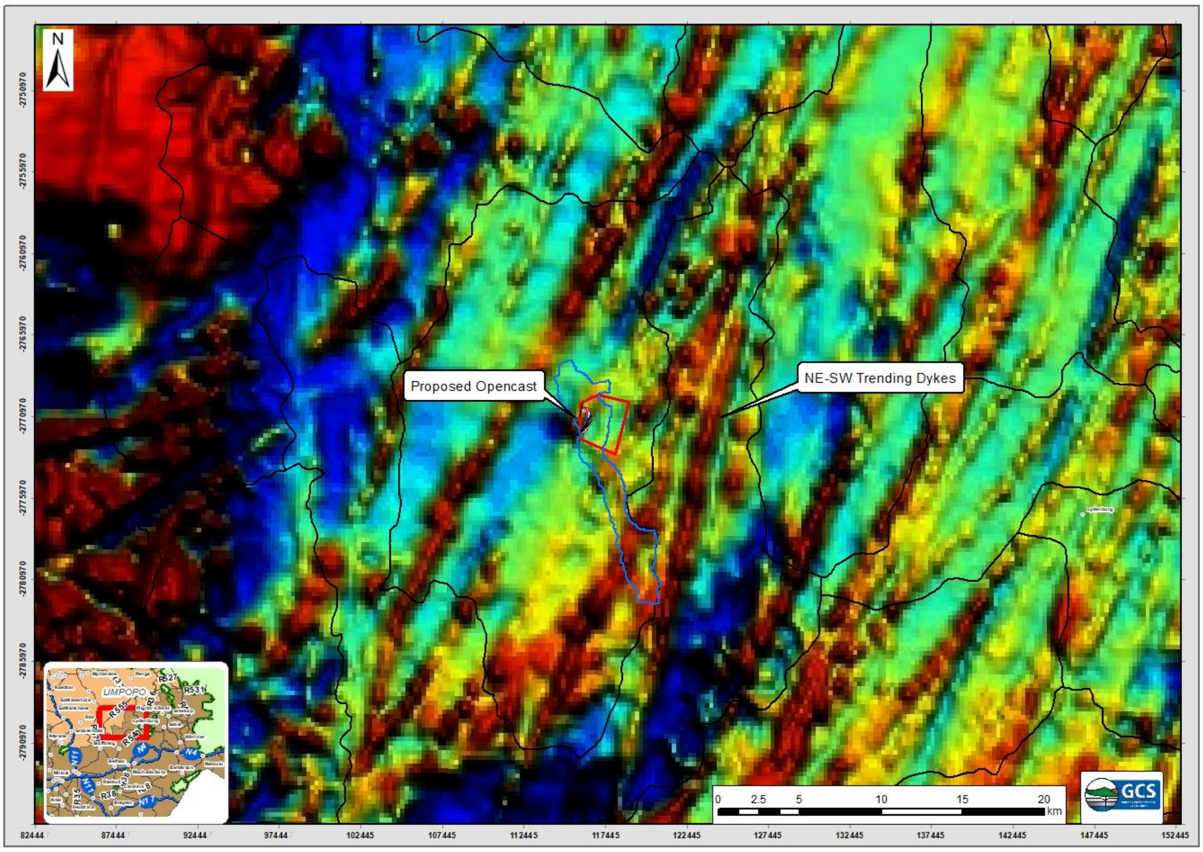


Figure 2-2: Magnetic map & structural geology (CGS, 2020)

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 very soft 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).

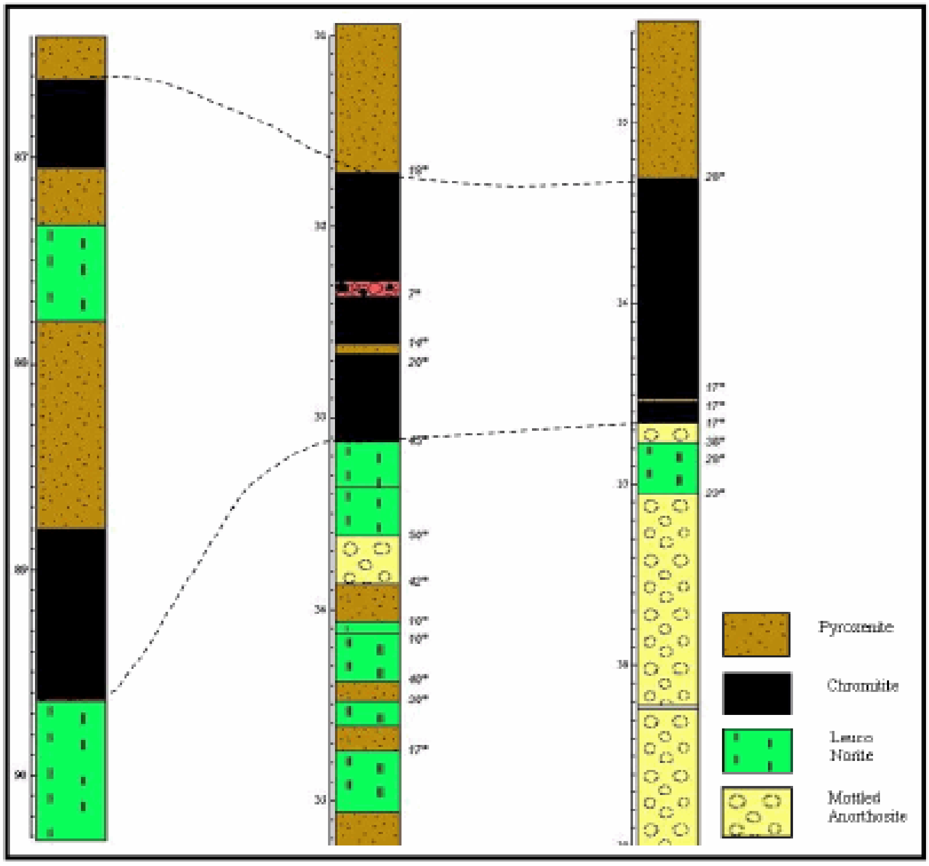


Figure 2-3: General stratigraphy and exploitable resource (Digby Wells, 2012)

2.4 Wetland areas

No National Wetland Freshwater Ecosystem Priority Areas (NFEPA) is situated downstream of the site and proposed activity areas (Van Deventer, 2018). However, an NFEPA wetland has been identified upstream, south, of the proposed opencast mine. The wetland is classified as a seepage (SEEP) wetland which has been heavily modified (NFEPA condition D/E/F) and is currently a poorly protected wetland.

2.5 Present ecological state (PES)

The PES for quaternary catchment B41G, is classified as Class B: Largely Natural and the Ecological Importance and Sensitivity (EIS) as highly sensitive (SANBI, 2011).

3 SEISMICITY ASSESSMENT

The seismicity assessment is based on the following data sources:

- Seismic Hazard in South Africa (Brandt, 2011);
- Sinkholes and subsidence in South Africa (Oosthuizen, 2011);
- Landslides Geohazards in South Africa (Singh, et al., 2011);
- The History of Geophysics in Southern Africa (de Beer, 2016);
- Seismotectonic map of Africa (Meghraoui, 2016);
- Seismotectonic Models for South Africa (Bejaichund, Kijko, & Durrheim, 2009);
- Geohazard Atlas of South Africa (Council of Geoscience, 2020); and
- USGS Earthquake Hazards Program (USGS, 2020).

3.1 Terminology

The terminology used in the seismicity assessment is briefly summarized in Table 3-1, below.

Table 3-1: Summary of seismicity assessment terminology

Magnitude (M)	Magnitude (M) is a measure of the energy released by the earthquake and the amount of slip on the fault. Seismograms recorded by many widely-spread seismograph stations are used to assign a single magnitude to an event. The SANSN uses either the local magnitude scale (ML) or the moment magnitude scale (Mw), which are essentially equivalent for M<6.5. The ML scale uses the maximum amplitude of ground motion recorded at the various local stations, is quick and easy to measure, but saturates above M6.5. The Mw scale takes the entire seismogram into account and is derived from an assessment of the mass of rock moved (or work done, hence the subscript 'w') by the earthquake. Mw does not saturate and can be estimated from local, regional or global stations. It has been calibrated to match ML for M<6.5. Earthquakes are generally divided into the following categories: micro M<3, small 3<M<5, moderate 5<M<7 and major M>7. Natural earthquakes are generally only felt when M>3 and only cause significant damage when M>6. However, people unaccustomed to earthquakes may be frightened by the shaking that is produced by an M5 event, even though the amplitude of ground motion is only 1/10 that of an M6 event. It should be noted that earthquakes induced by mining or fluid injection may cause damage if 5<M<6 because they generally occur at much shallower depths than natural events
Intensity (I)	Intensity (I) describes the shaking experienced on the surface of the earth. Intensity generally decreases with distance from the epicentre (the point on the earth's surface above the earthquake source), but is also affected by near-surface geology. Shaking is generally amplified where there is a thick layer of alluvium. Reports by many widespread observers are collated to derive Intensity Data Points (IDPs) and compile an isoseismal map. The SANSN uses the Modified Mercalli Intensity (MMI) scale.

	The levels of the intensity scale can be roughly related to the Peak Ground Acceleration (PGA), a quantity that is used by engineers to design structures. It is expressed either in terms of gals (cm/s^2) or the acceleration of gravity (g, 9.8 m/s^2). To give some examples: an MMI of III (0.001 – 0.002 g) indicates ground motion that is perceptible to people, especially on the upper floors of buildings; VI (0.02 – 0.05 g) is felt by all, many people are frightened and run out of doors, and a few buildings may be slightly damaged; VIII (0.1 – 0.2 g) causes slight damage to earthquake-resistant structures, considerable damage to solid buildings, and great damage to poorly-built buildings; while XII (> 2 g) indicates destruction, with objects thrown into the air. The resonant frequency of structures depends on their height and footprint. Thus engineers make use of estimates of the Peak Spectral Acceleration (PSA), a measure of ground motion at particular frequencies, to determine if structures will respond to an earthquake.

3.2 Background

Southern Africa is, by global standards, a seismically quiet region as it is far from the boundaries of tectonic plates and active continental rifts. Seismicity in South Africa arises from both natural sources (e.g. plate tectonic forces, buoyant uplift of the continent after erosion) and human-induced sources (e.g. rock failure caused by mining-induced stresses, slip on faults caused by changes in load and pore fluid pressure during the filling of reservoirs, and vibrations produced by blasting for open-pit mining, civil excavation and the disposal of expired munitions). Most earthquakes are induced by deep-level mining for gold and platinum, and thus restricted to the mining districts (refer to Figure 3-3). However, natural earthquakes do take place from time to time. They are driven by various tectonic forces, such as the spreading of the seafloor along the mid-Atlantic and mid-Indian ocean ridges, the propagation of the East African Rift System, and the response of the crust to erosion and uplift (Durrheim & Manzunzu, 2019).

3.3 Seismic intensity of the project area

Based on the location of the site, the seismic intensity is (MMS) VI (Council of Geoscience, 2020) and the corresponding liquefaction hazard is "Marginal" with a peak horizontal ground acceleration of between 50 and 100 cm/s^2 (refer to Figure 3-3).

In terms of SABS 0160 (1989) and updated by the CGS (2003) for the design of structures, this is equivalent to a max of 0.1g and represents the lower level above which additional structural elements need to be considered to accommodate any excess movement/vibration due to earthquakes.

3.4 Landslides

Comprehensive surveys of the landslide hazards in South Africa have been conducted by Singh et al. (2008, 2011). The landslide susceptibility map is shown in Figure 3-1. [Note that the predominant trigger of landslides is intense rainfall, not earthquakes.]

Landslide susceptibility ranges from very-low to low for the proposed Vygenhoek mine area.

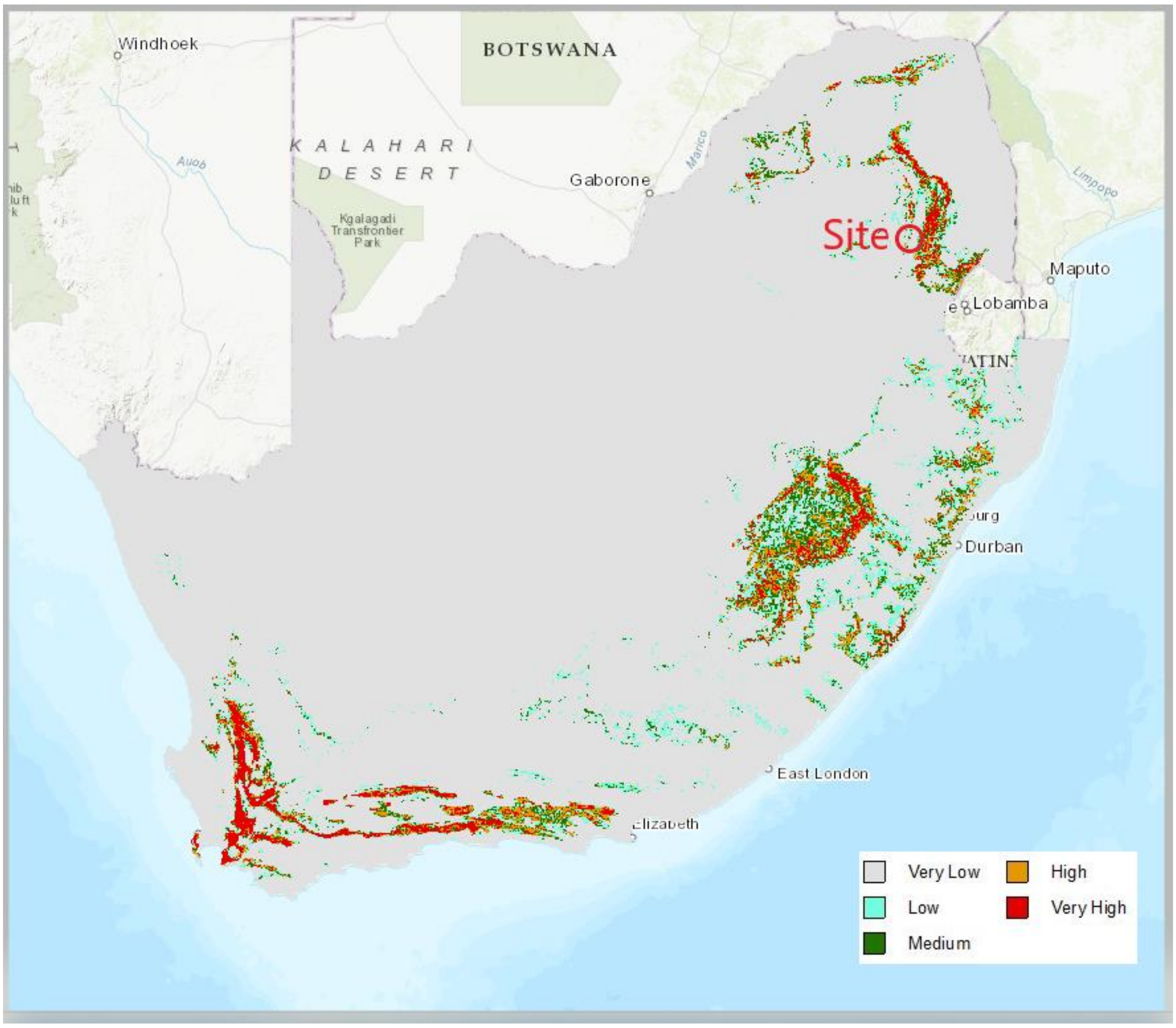


Figure 3-1: Landslide susceptibility map (Council of Geoscience, 2020)

3.5 Collapsible soils

Collapsible soils, also known as metastable soils, are unsaturated soils that undergo a large volume change upon saturation. The sudden and usually large volume change could cause considerable structural damage. The most common types are aeolian soils, typically wind-deposited sands and or silts, such as loess, aeolic beaches, and volcanic dust deposits characterized by showing in-situ high void ratios and low unit weights; and residual soils, which are a product of the in-situ weathering of local parent rocks that leaches out soluble and colloidal materials producing soils with a large range of particle size distribution and large void ratios.

The proposed Vygenhoek mine falls within an area not associated with collapsible soils. Hence, no collapses in soils due to seismic activity is anticipated.

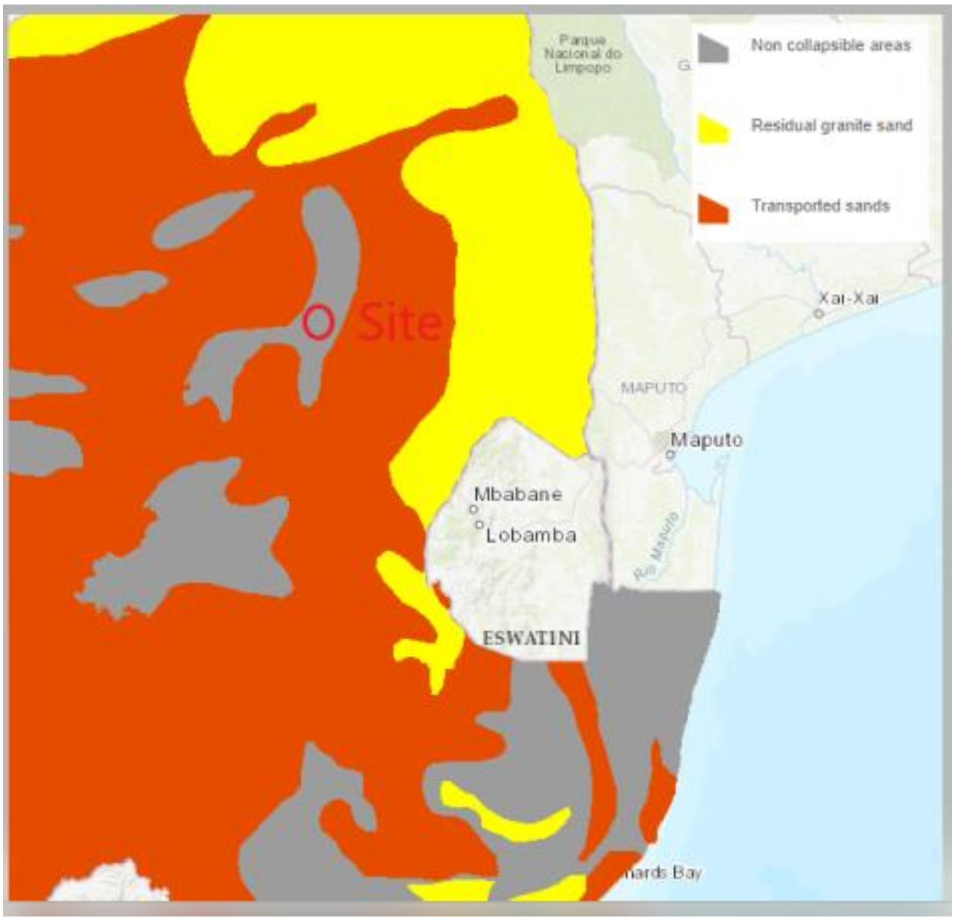


Figure 3-2: Collapsible soils (Council of Geoscience, 2020)

3.6 Concluding remarks

Based on the desktop level seismicity assessment undertaken, the following conclusions are drawn:

- The proposed Vygenhoek mine is situated in an area where seismic intensity is low, and the liquefaction hazard is "Marginal".
- The proposed Vygenhoek mine is situated in an area not prone to cause collapsible soils; and
- The proposed Vygenhoek mine is situated in an area with a very low to low probability of causing landslides.

Based on the above no further seismic intrusive work would be required. However, it is recommended that a slope stability assessment be conducted to inform the mine plan as soon as mining starts. The slope stability assessment can help prevent landslides typically associated with high walls and steep-sloped areas.

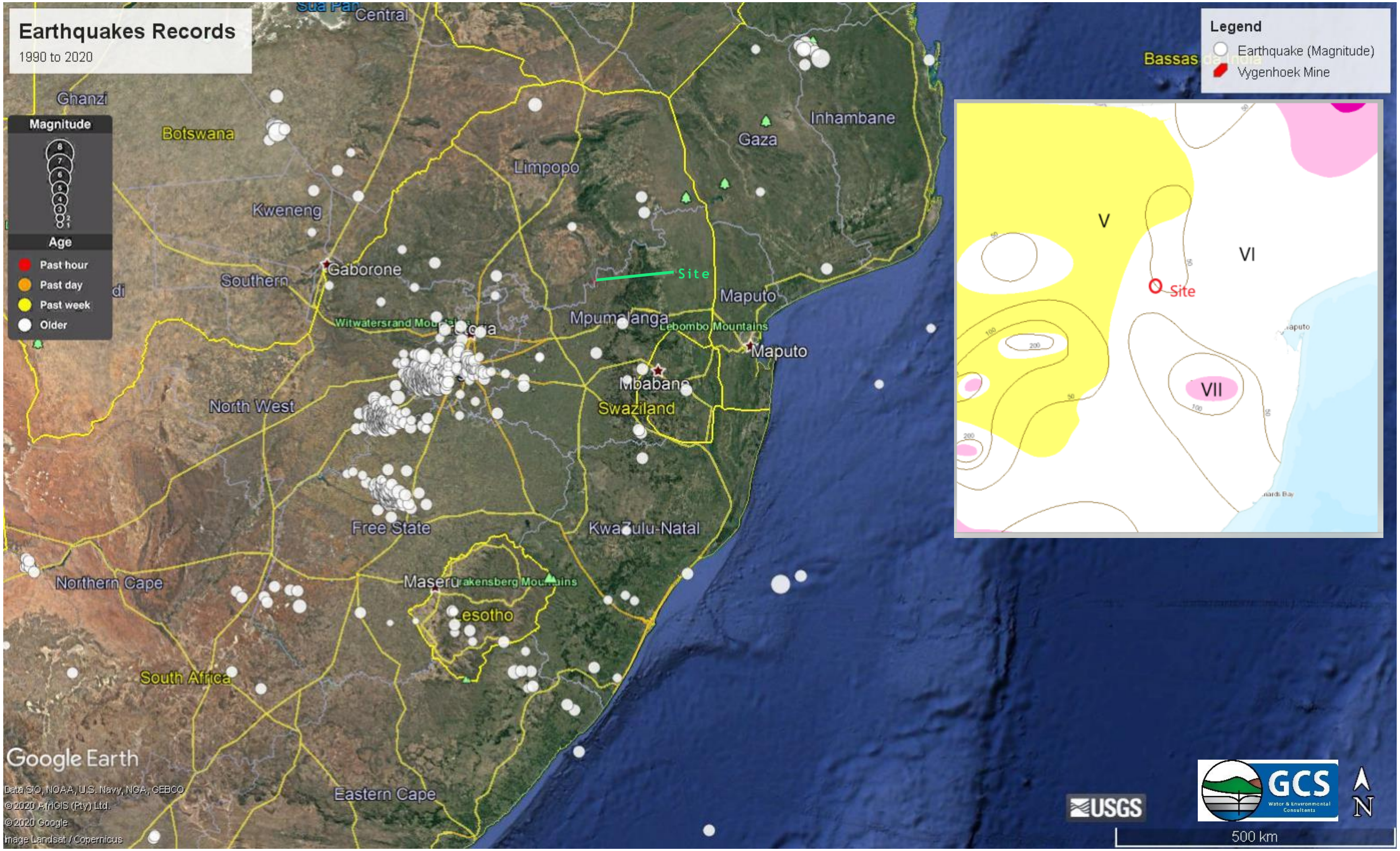


Figure 3-3: Location of recorded earthquakes in Southern Africa from 1900-2020 and MMS

4 HYDROGEOLOGICAL SETTING

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]

4.1 Aquifer characteristics, classification and groundwater recharge

The general aquifer characteristics and aquifer classification are summarised in Table 4-1, below.

Table 4-1: Aquifer characteristics and classification

Aquifer Characteristics	Aquifer Classification
The aquifer host rock comprise mafic intrusive rocks (dolerite, diabase, gabbro, norite and anorthosite) of the Rustenburg Layered Suite; and undifferentiated rocks and various mixed lithologies of the Pretoria Group. The aquifer has a low to medium hydraulic conductivity (K-value) and porosity (n-value). The aquifer can be referred to as being primarily I fractured (King, Maritz, & Jonck, 1998).	The aquifer present is classified as a Minor Aquifer system (Parsons, 1995). Three (3) aquifer systems are envisaged, often visualised as an interconnected aquifer: • **Alluvium Aquifer:** • An unconfined aquifer associated with alluvial deposits (confined to major rivers and floodplain areas). • **Weathered Aquifers:**

Aquifer Characteristics	Aquifer Classification
The aquifer's weathered zone is reported to be approx. 21 m thick, with the fractured zone approx. 109 thick (DWAF, 2006). The combined aquifer thickness is estimated to be in the order of 130 m. Groundwater is typically encountered in: • Fractures along contact zoned related to heating and cooling of host rock caused by intrusions of diabase and dolerite sills and dykes. • Faults or shear zones; • Fractures related to tensional or compressional stresses and/or off-loading; and • Along sedimentary/igneous rock contacts (King, Maritz, & Jonck, 1998). 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). The aquifer is an important contributor to groundwater baseflow to streams and rivers (King, Maritz, & Jonck, 1998).	• 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. • **Deep Fractured Aquifers:** • Deeper regional confined fractured bedrock aquifer covers associated with fresh and fractured bedrock below the weathered zone. The aquifer underlying the site can be considered a moderate yielding aquifer, with reported yields ranging from 0.5 to 2 l/sec (Class B3 aquifer).

4.2 Desktop hydrocensus / groundwater users in the area

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 4-2 and positions are shown by Figure 4-2. 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.

Existing use should be confirmed by undertaking a ground-truthed hydrocensus within the study area.

Table 4-2: 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

Borehole ID	Latitude (WGS84)	Longitude (WGS84)	Elevation (mamsl)	EC (mS/m)	Yield (l/sec)	Depth (m)	Water Level (mbgl)
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*
Average Water level (mbgl)							*38.9*

4.3 Depth to groundwater

Literature suggests a groundwater depth in the order of 17 mbgl (King et al., 1998; DWAF, 2006) on a quaternary catchment scale. Available data (refer to previous section) indicates a water level range from 4 to 128 mbgl.

Available data suggest that there is a linear relationship between the groundwater elevation and topography elevation (refer to Figure 4-1, R ≈ 98%), 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.

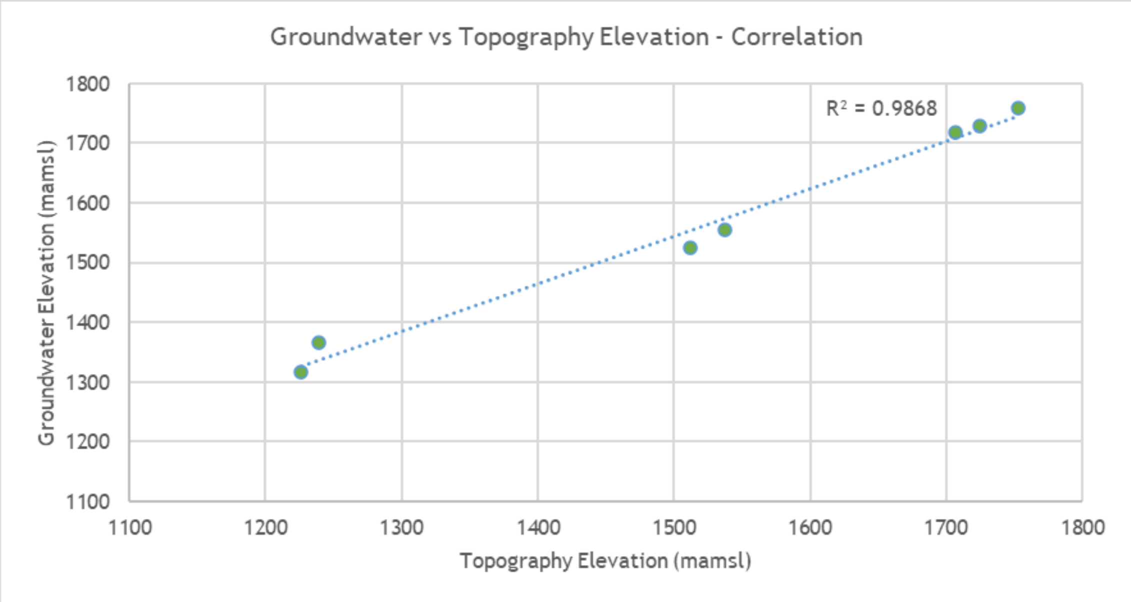


Figure 4-1: Groundwater elevation vs topography elevation - correlation

4.4 Saturated hydraulic conductivity

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). The permeability 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/d (T of 0.00003-0.0004 m^2/d). The storativity for this aquifer varies between 0.001-0.0001. Slightly higher permeability (0.0047 m/d) and transmissivity values up to 4.32×10^{-4} m^2/d are associated with dolerite dyke contacts.

4.5 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, 1998).

Ambient water quality (pre-mining) should be further evaluated by undertaking a follow-up geohydrological assessment.

4.6 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).

4.6.1 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 4-3 summarises the quaternary catchment data.

Table 4-3: Summarised Quaternary Catchment Information (Aquiworx, 2015)

Quaternary Catchment	Total Area (km^2)	Recharge (mm/a)	Rainfall (mm/a)	Baseflow (mm/a)	Population
B41G	442.27	39.9	650	9.76 {PITMAN Model]	Unknown

4.6.2 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 km^2.

4.6.3 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.

As stated previously, existing users should be confirmed by undertaking a ground-truthed hydrocensus within the study area.

4.6.4 Basic human needs (BHN)

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

4.6.5 Proposed groundwater usage (PU)
No PU is reserved in the water balance and should be confirmed as soon as mining commences. Any dewatering activities at the proposed Vygenhoek Platinum Mine will fall under PU and may impact groundwater quantity.

4.6.6 Land use (LU)
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). Hence, the impact of land use on net-groundwater recharge is assumed to be negligible.

4.6.7 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. Hence, if groundwater dewatering and use at the Vygenhoek mine exceeds the surplus amount, the groundwater reserve may be negatively impacted.

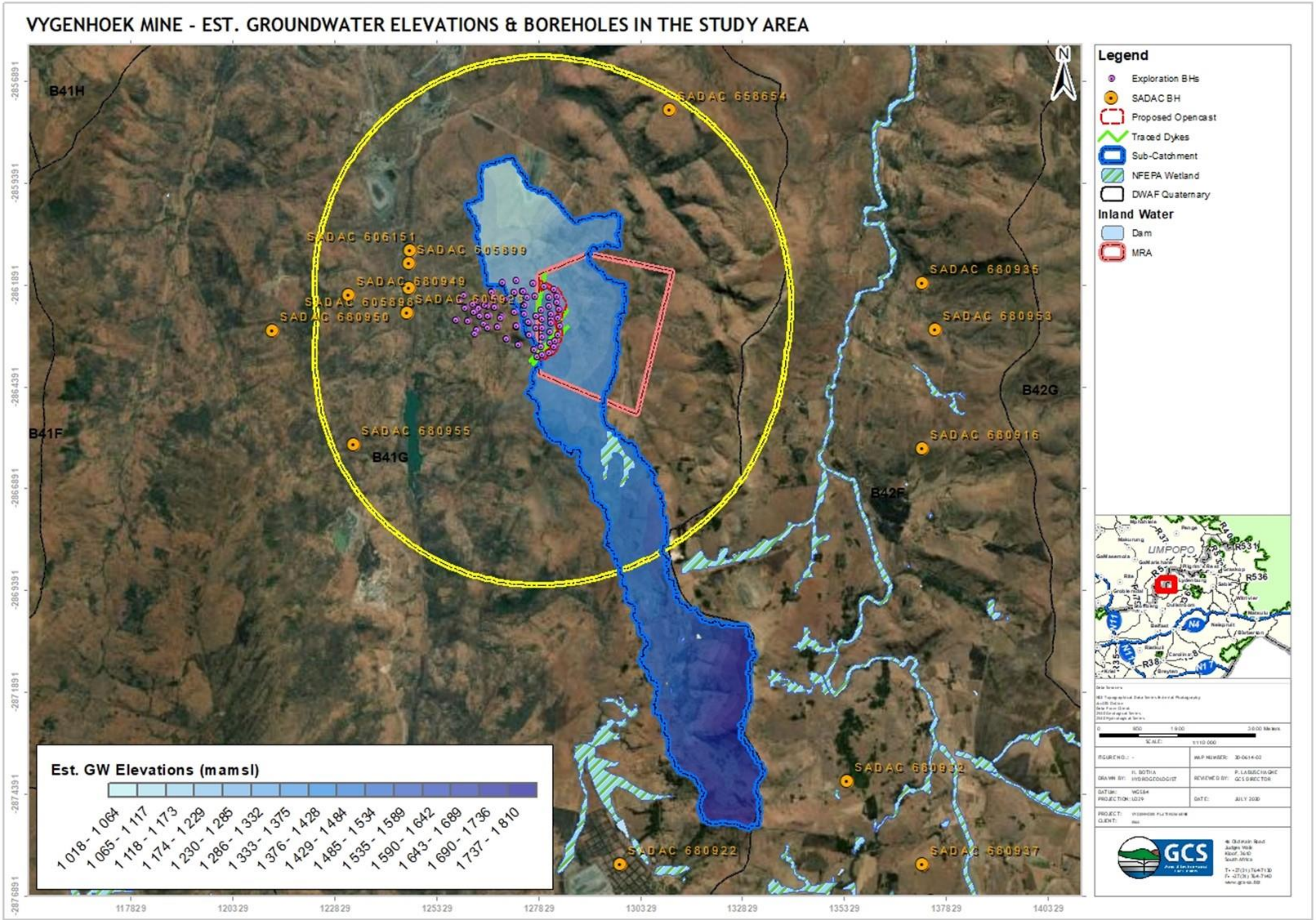


Figure 4-2: **Est. groundwater elevation and groundwater users**

5 PRELIMINARY 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.

5.1 Preliminary site conceptual model

The preliminary site conceptual model (SCM) for the Proposed Vygenhoek mine is shown in Figure 5-1, below.

Ore floor elevation data and anticipated geological occurrences were derived from available site data. The SCM should be updated when a ground-truthed geohydrological investigation (i.e. drilling and geophysical investigations) is undertaken.

5.2 Potential groundwater pollution migration velocities

Based on available aquifer data and Darcy's Law[1] 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 0.01-0.001 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 0.01 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 0.06 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.

It is recommended that groundwater flow velocities and poor quality pollution plume migration should be further evaluated via numerical flow and transport modelling.

[1] 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).

5.3 Preliminary decant areas

Decant was assessed based on the bayesian extrapolated water levels and ore floor elevations. The decant areas are deemed preliminary and should be re-evaluated during the follow-up geohydrological assessment. Due to the mining depth and the estimated groundwater table, no decant points were identified (refer to Figure 5-2). Decant probability is low, based on available data.

The status of decanting and likelihood should be re-evaluated when more site water level and drilling data is available.

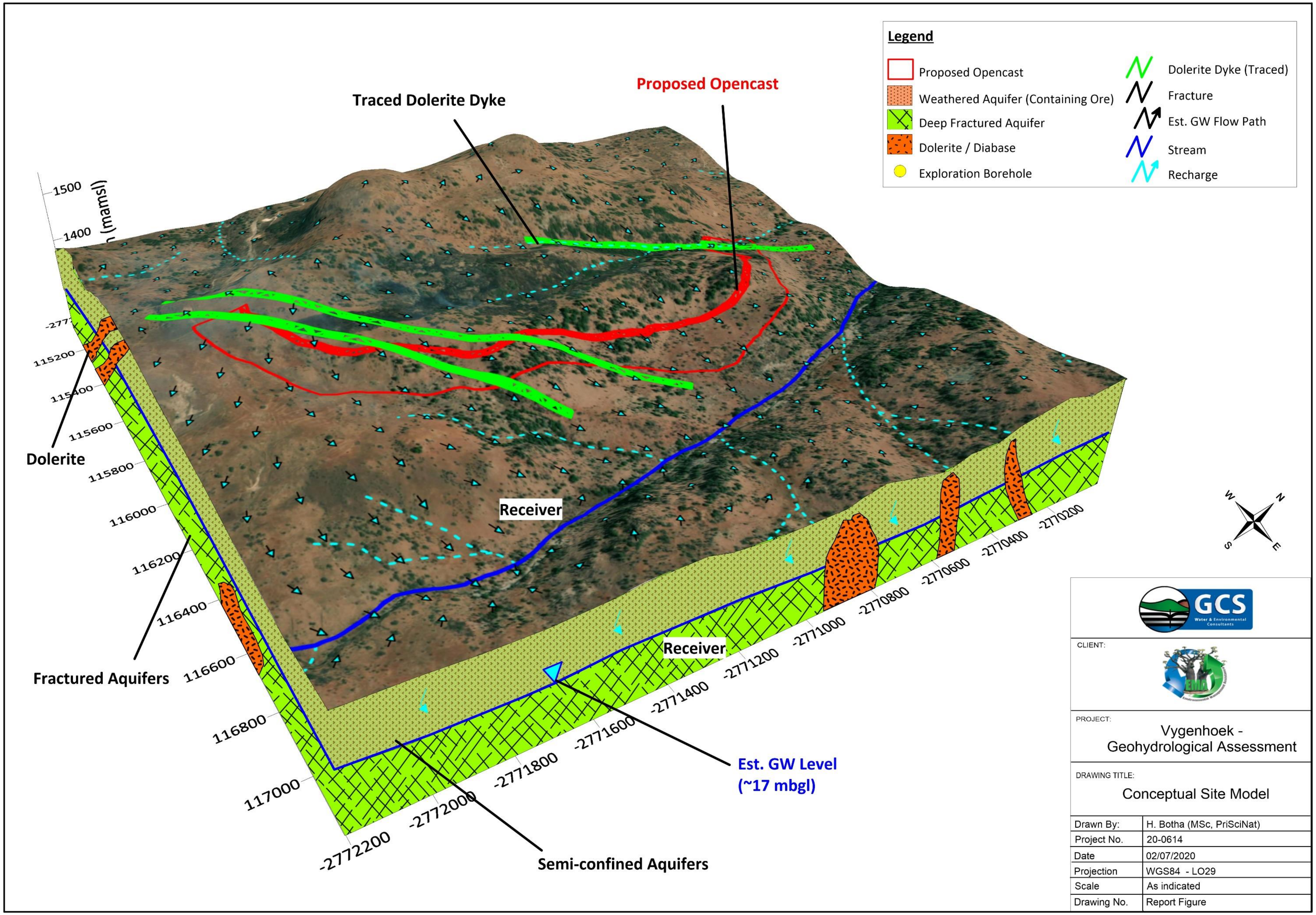


Figure 5-1: Site conceptual model

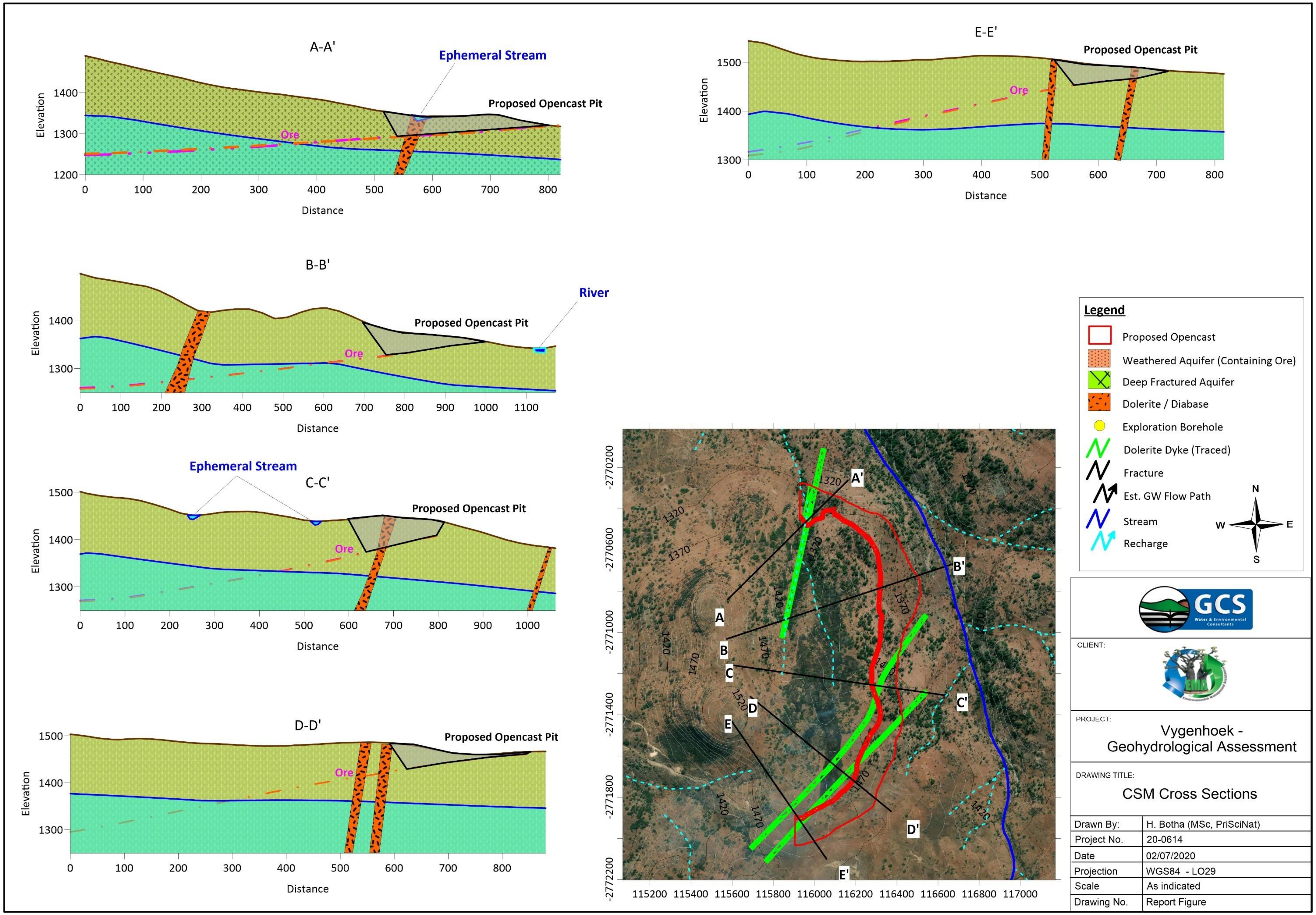


Figure 5-2: Cross Sections

5.4 Preliminary impacts and mitigation measures

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

Key assumptions made:

- The risk/impact assessment conducted for the site is based on available data, as discussed earlier in the report.
- The risk/impact assessment incorporates a worst-case scenario approach.
- Average aquifer transmissivity and groundwater velocities calculated in Section 4.4, applied to the general study area.
- Groundwater levels mimic the topography.
- Bayesian interpolation of available on-site water level was applied to conceptualise the groundwater flow and groundwater depth in the study area.

The anticipated geohydrological impacts are indicated in and Figure 5-3. Table 5-1 list preliminary impacts and mitigation measures for the Proposed Vygenhoek Mine. The risk rating methodology is discussed in **Appendix A**.

It is recommended that a follow-up geohydrological assessment, incorporating numerical flow and transport modelling be undertaken to refine the preliminary risk and impact assessment.

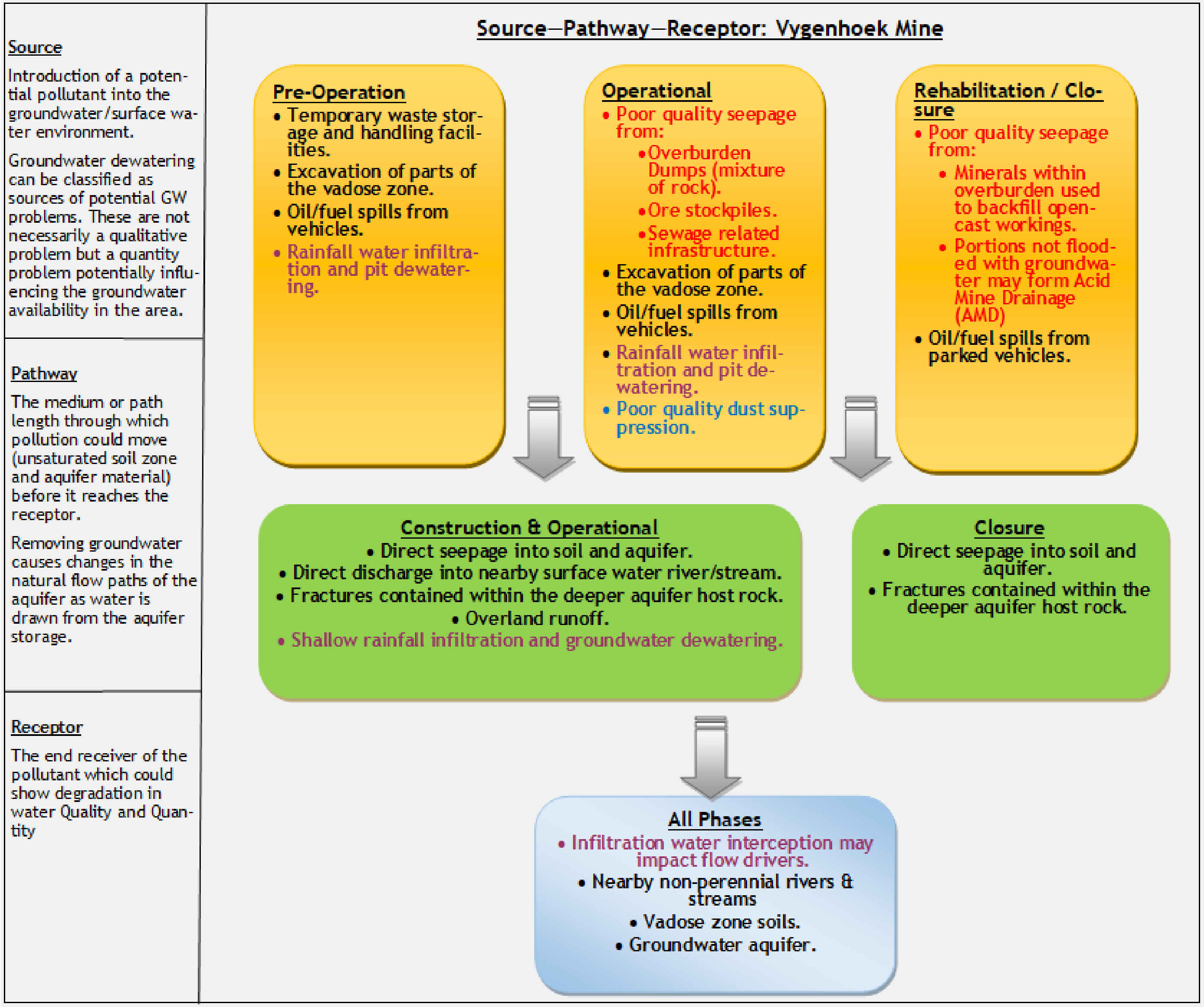


Figure 5-3: Vygenhoek - SPR

Table 5-1: 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 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.	2	1	1	3	12	-	L
	Disturbing vadose zone during soil excavations / infilling activities	Earthworks	6	2	1	6	54	-	M	• 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	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	Earthworks	3	3	2	4	32	-	M	• Only excavate areas applicable to the project area. • Cover excavated soils with a temporary liner 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.	1	3	2	4	24	-	L
Hydrocarbon spills	Opencast pits	Mechanised machinery	4	3	2	4	36	-	M	Park vehicles in areas lined with concrete or fitted 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	Seepage	4	3	2	4	36	-	M	Reduce footprint areas to minimize the reaction flow path of rainfall water.	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. Possible reduced baseflow of streams within 500 m of the workings.	Opencast pits	Aquifer drawdown	6	2	2	2	20	-	L	Water level monitoring in nearby boreholes.	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 and the groundwater aquifer system.	Opencast pits	Seepage	4	5	2	4	44	-	M	Divert poor quality water to treatment facilities. Backfill the area which is likely to form a pit lake. Capping/covering of the pits to reduce infiltration and subsequent poor quality seepage. Moreover, co-disposal will decrease poor quality AMD (as proved by the kinetic leach testing). Update predictive groundwater flow and geochemical numerical models yearly. Water monitoring for a term at least 2-3 years after pit closure, to reconfirm closure objectives.	4	5	2	3	33	-	M
	Overburden 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	Ensure opencast workings are infilled below the regional groundwater table (if possible). However, if infilling must proceed above the remaining water level than it should be below the identified decant levels - to be re-evaluated in followup-geohydrological studies). Water quality monitoring.	1	1	1	1	3	-	L
Drawdown of the regional water table as the opencast workings flood. Possible reduced baseflow of streams within 500 m of the workings.	Opencast pits	Aquifer drawdown	6	5	2	2	26	-	L	Water level monitoring in nearby boreholes.	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. Stability testing before capping layer is installed.	4	1	1	1	6	-	L

6 PRELIMINARY 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 6-1, below.

Figure 6-1: Monitoring Process

6.1 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; and
- Phase 2: Monitoring during the operational phase and closure phase (long term).

6.1.1 Phase 1 monitoring

It is proposed that, during the initial phases of the mine (i.e. when contractors mobilise the site), water and soil monitoring focus on active excavation and equipment / heavy machinery parking or housing areas. Regular visual inspections of these areas need to be undertaken. Moreover, 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.

It is proposed that this monitoring be continued during the gradual expansion of the opencast workings, up to mine closure and rehabilitation.

6.1.2 Phase 2 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 several monitoring boreholes (up to 30 m) upstream and downstream of the and upstream of the opencast areas. It is recommended that boreholes be sited via geophysical methods and drilled into dykes/contact areas. These are known to be preferential groundwater flow paths. A typical monitoring borehole construction is shown in Figure 6-2. Alternatively, some of the existing exploration boreholes at the site can be considered as monitoring boreholes.

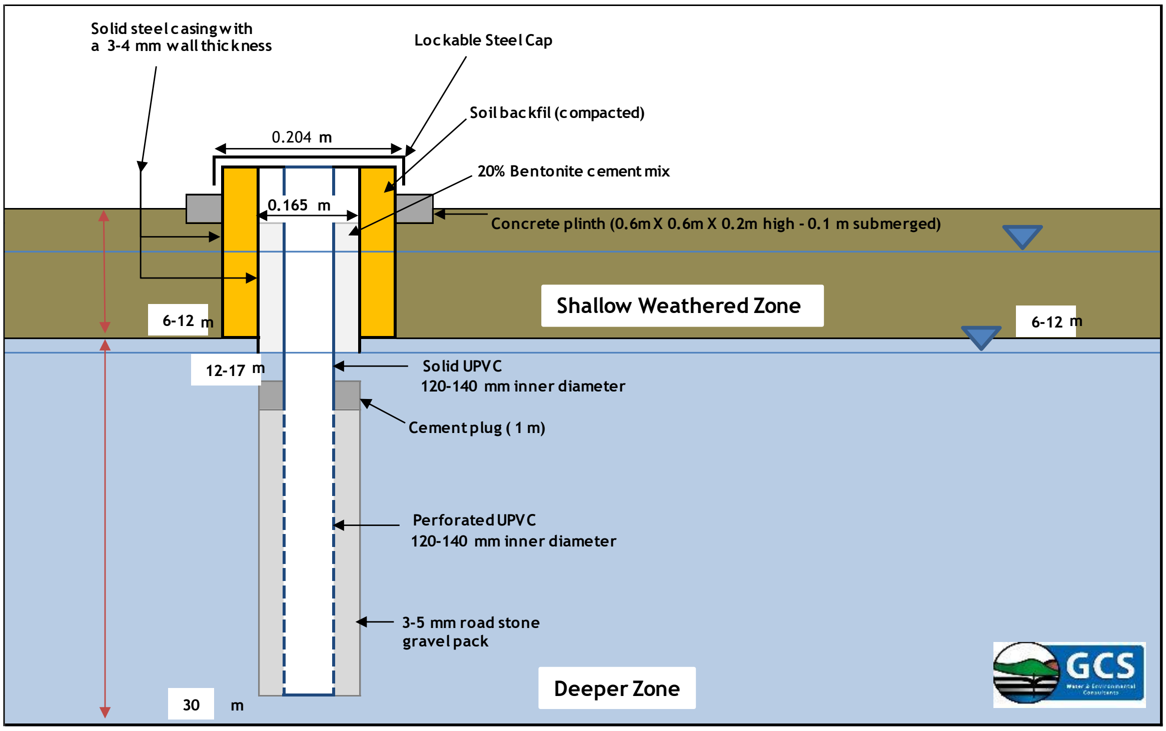


Figure 6-2: Proposed borehole construction

It is proposed that surface water monitoring also be conducted at the site. It is proposed that an upstream, midstream and downstream surface water monitoring points be established in the perennial river downstream of the mine. Moreover, any other surface water (i.e. the ephemeral streams which drain the mine) need to be monitored. Water quality monitoring of the stream will determine if any site activities are impacting the stream.

6.2 Monitoring duration

In terms of monitoring duration, permanent monitoring is recommended. Monitoring after closure should be further evaluated

6.3 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, on behalf of the applicant.

The proposed monitoring type, frequencies and constituents to monitor are listed in Table 6-1, below. Preliminary monitoring positions are indicated in Figure 6-3.

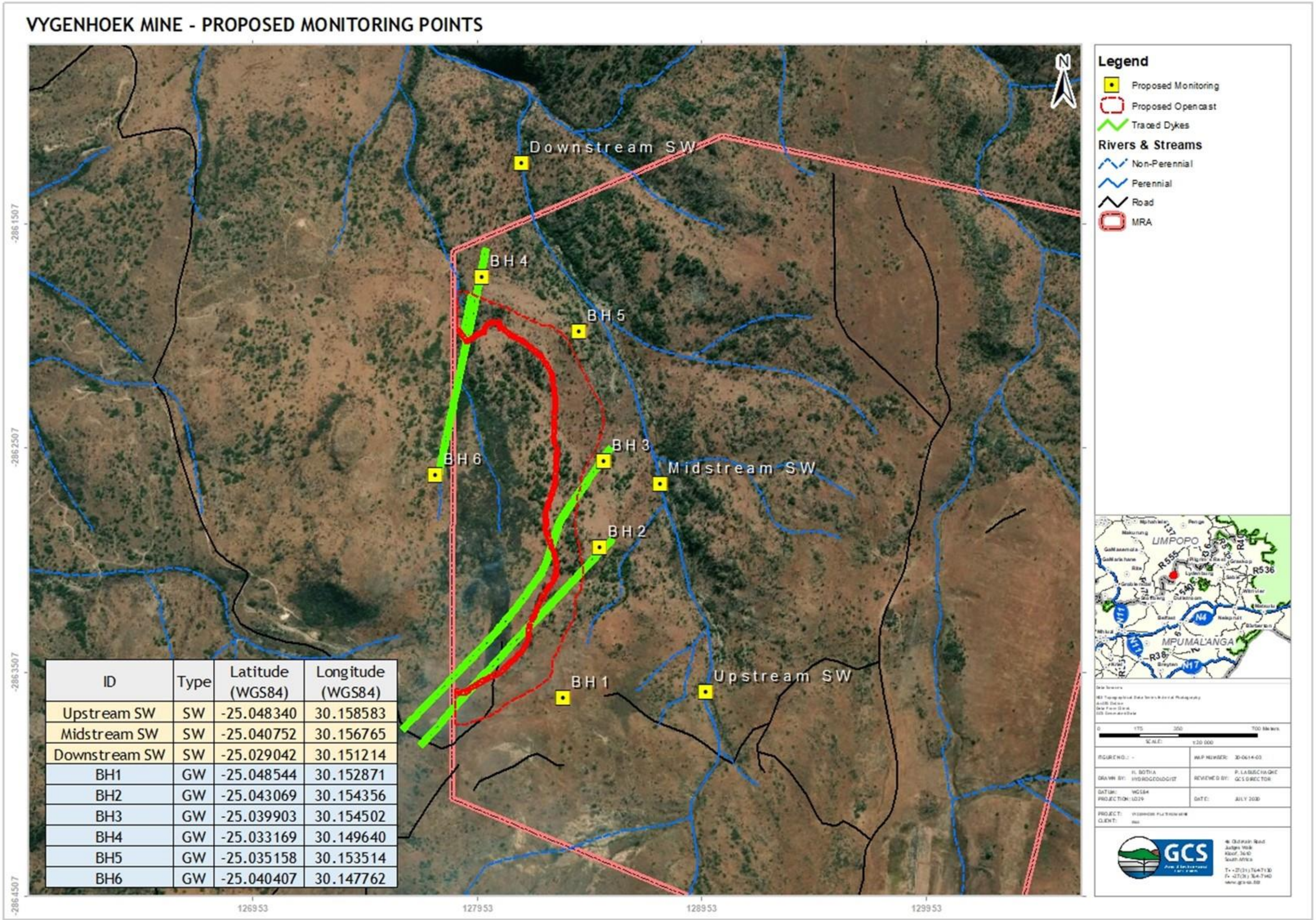
Table 6-1: Proposed monitoring points, frequencies and sample analyses

<table>
<tr><th>Type</th><th>Frequency</th><th>Field Measurements</th><th>Laboratory Analysis</th></tr>
<tr><td>Groundwater monitoring boreholes

<u>4 Proposed</u></td><td>Quarterly</td><td>pH
EC / TDS
Temp
Dissolved Oxygen
Groundwater Level (if applicable)</td><td rowspan="3">If field measurements indicate a contaminant trend, it is advised that a sample be submitted for analytical testing.

The following should typically be analysed:
• pH, Conductivity, Total dissolved solids (TDS), total suspended solids (TSS) and turbidity (TUR).
• Biological oxygen demand (BOD).
• Calcium, Magnesium, Sodium, Potassium, Carbonate, Bicarbonate, Chloride, Sulphate, Nitrate, Iron, Manganese, Fluoride, Aluminium, Total Alkalinity (TALK), Ammonia, Ammonium.

If hydrocarbons vapours or traces are observed (i.e. by a photon ion detector or free phase meter), the following needs to be analysed:
• BTEX; and
• Total petroleum hydrocarbons (TPH)</td></tr>
<tr><td>Sewer lines, septic tanks (if installed), and stormwater drains (hydraulic monitoring)</td><td>Monthly</td><td>Visual assessment
Sample spillage if applicable.</td></tr>
<tr><td>Non-perennial and perennial streams</td><td>Quarterly</td><td>pH
EC / TDS
Temp
Dissolved Oxygen</td></tr>
</table>



ID	Type	Latitude (WGS84)	Longitude (WGS84)
Upstream SW	SW	-25.048340	30.158583
Midstream SW	SW	-25.040752	30.156765
Downstream SW	SW	-25.029042	30.151214
BH1	GW	-25.048544	30.152871
BH2	GW	-25.043069	30.154356
BH3	GW	-25.039903	30.154502
BH4	GW	-25.033169	30.149640
BH5	GW	-25.035158	30.153514
BH6	GW	-25.040407	30.147762

Figure 6-3: Preliminary monitoring points

7 CONCLUSIONS

Based on the investigation undertaken, the following conclusions are made:

- Three (3) aquifer systems are envisaged, often visualised as an interconnected aquifer:
    - Alluvium Aquifer (unconfined);
    - Weathered Aquifers (semi-confined); and
    - Deep Fractured Aquifers (confined).
- Available data indicates a water level range from 4 to 128 mbgl, for the study area.
- Based on the Source-Pathway-Receptor (SPR) model, the following receptors are noted for the project area:
    - Several non-perennial streams and one (1) perennial river;
    - Vadose zone soils; and
    - Groundwater aquifer (water table).
- Based on the intermediate groundwater reserve determination (IGRD) conducted for the delineated sub-catchment, the groundwater balance indicates an approx. + 2 217.53 m^3/day available for abstraction on a sub-catchment scale.
    - If groundwater dewatering and use at the Vygenhoek mine exceeds the surplus amount, the groundwater reserve may be negatively impacted.
- Several preliminary geohydrological risks have been identified, and are discussed in Section 5. Preliminary mitigation measures have been provided to circumvent probable negative impacts.

7.1 Recommendations

- It is recommended that a follow-up hydrological assessment be undertaken before mining:
    - A geophysical assessment of the mining areas should be undertaken as soon as the areas are cleared for mining. It is important to map preferential groundwater flow paths towards the receiving environment and to update the groundwater risk assessment. Subsequently, dedicated groundwater monitoring boreholes should be drilled in these preferential flow path areas to update and improve the proposed monitoring network.
    - At least three (3) constant rate pump tests should be undertaken (once-off) as part of the monitoring programme, to update aquifer hydraulic parameters and the site conceptual models.

    - A geochemical assessment including geochemical testing of ore and overburden rock is recommended to update the source terms for the mine.

- Develop a numerical groundwater flow and transport model to:
    - Evaluate preferential flow paths and groundwater migration velocities.
    - Evaluate long term and post-closure transport movement into the surrounding aquifer;
    - Track preferential flow paths and changes to groundwater flow;
    - Ensure no monitoring network gaps exist (i.e. check if the monitoring network is representative of the site); and
    - Update the numerical groundwater model annually.
- Undertake baseline water quality sampling and a hydrocensus to verify existing groundwater users in the study area; and baseline water quality (ambient water quality).
- A groundwater management and acid mine drainage (AMD) management plan should be formulated to ensure the impact on the groundwater environment is limited and mitigated.

8 REFERENCES

Aquiworx. (2015). Aquiworx Software Integrated Information.

ARC. (2006). *Lan Types of South Africa.* Pretoria: Agricultural Reserach Council.

Bejaichund, M., Kijko, A., & Durrheim, R. (2009). *Seismotectonic Models for South Africa: Synthesis of Geoscientific Information, Problems, and the Way Forward.* Seismological Research Letters, 2009, Volume 80, Pages 65-33.

Brandt, M. (2011). *Seismic Hazard in South Africa. Council for Geoscience Report Number 2011-0061.* Council of Geoscience.

CGS. (2020). *Geophysical Data.* https://www.geoscience.org.za/index.php/2019-03-13-12-40-41/publications/284-geophysical-data.

Council of Geoscience. (2020). *Geohazard Atlas of South Africa.* Retrieved from Geohazard Atlas of South Africa: http://197.96.144.125/jsviewer/Geohazards/index.html#

de Beer, J. H. (2016). *The History of Geophysics in Southern Africa.*

DEA. (2019). *South African National Land-Cover (SANLC) 2018.* South Africa: DEA on 1st October 2019.

Digby Wells. (2012). *Everest North Platinum Mine EIA & EMP - MPRDA. Volume 1 of 2 - EIA & EMP. Report Ref: MP30/5/1/2/2/1034PR.*

DMEA. (1986). *2530 Barberton - 1:500 000 Hydrological Map Series of the Republic of South Africa.*

Durrheim, R., & Manzunzu, B. (2019). *STRATEGIC ENVIRONMENTAL ASSESSMENT FOR THE EXPANSION OF 2 ELECTRICITY GRID INFRASTRUCTURE IN SOUTH AFRICA.*

DWA. (2012). *Aquifer Classification of South Africa map.* Hydrological Services - Groundwater Information.

DWAF. (2006). *Groundwater Resource Assessment II.*

DWAF. (2007). *Best Practice Guidelines – G3: Water Monitoring Systems.* DWAF.

DWAF. (2008). *Best Practice Guidelines: Impact Prediction (G4).* DWS.

DWS. (2016). *New Water Management Areas.* South Africa: Government Gazette No. 40279.

GRIP. (2016). *Groundwater Resource Information Project .*

JAXA. (2019). *Advanced Land Observation Satellite (ALOS) Global Digital Surface Model (DSM).* Tokyo: Earth Observation Research Center (EORC), Japan Aerospace Exploration Agency (JAXA).

King, G., Maritz, E., & Jonck, F. (1998). *2530 Nelspruit - 1:500 000 Hydrological Map Series of the Republic of South Africa.*

Kottek, M., Grieser, J., Beck, C., Rudolf, B., & Rubel, F. (2006). *World Map of the Köppen-Geiger climate classification updated. Meteorol. Z.15, 259-263. doi:10.1127/0941-2948/2006/0130.*

Lourens, P. (2013). *The relationship between South African geology and geohydrology.* IGS, University of the Free State, Bloemfontein. Masters Dissertation.

Meghraoui, M. &. (2016). *The Seismotectonic Map of Africa. Episodes. 39. 10.18814/epiiugs/2016/v39i1/89232.* .

Oosthuizen, A. &. (2011). *Sinkholes and subsidence in South Africa. Council for Geoscience Report number: 2011-0010.* Council of Geoscience.

Parsons, R. (1995). *A South African Aquifer System Management Classification.* Water Research Commission Report No. KV 7795.

SADC GIP. (2020). *SADC Groundwater Information Portal (SADC GIP).*

SANBI. (2011). *National Wetland Freshwater Priority Areas (FEPAs),.*

Singh, R., Forbes, C., Chiliza, G., Diop, S., Musekiwa, C., & D., &. C. (2011). *Landslide geohazards in South Africa: Landslide susceptibility mapping, socio-economic impacts, mitigation and remediation measures. Council for Geoscience Report Number: 2011-0016.* Council of Geoscience.

USGS. (2020). *Earthquake Hazards Program.* Retrieved from Earthquake Hazards Program: https://earthquake.usgs.gov/earthquakes

Van Deventer, H. S.-A. (2018). *NBA2018 National Wetland Map 5.*

WRC. (2015). *http://www.waterresourceswr2012.co.za/resource-centre/.* Retrieved from Water Resources of South Africa, 2012 Study (WR2012).

APPENDIX A: 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 B: 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.