ENVIRONMENTAL & ENGINEERING

REPORT

IPP – NNDAGANENI MINE

GEOHYDROLOGICAL REPORT FOR INPUT INTO THE IWUL

REPORT REF: 22-1732-GEOH (IPP NNDAGANENI GEOHYDRO)

Version AA

Document and Quality Control:

Document No:	22-1732-GEOH (IPP Nndaganeni Geohydro)			
AA – draft	2022/11/04	Elida Naude	Naude	First draft for review / comments
BB– draft		Leoni le Roux		Quality review
CC – draft		Henno Engelbrecht		Technical Review
DD - draft				Final Review
Approved for Distribution:				
0.0		Henno Engelbrecht		Final report

Quality Control By:

Nature of Signoff:	Responsible Person:	Role / Responsibility	Qualification
Author	Elida Naude	Senior Geohydrologist	M.Sc. Geohydrology
Quality Reviewer	Leoni le Roux	Administrator	Professional Secretary and Personal Assistant
Reviewer	Henno Engelbrecht		
Client			

DISCLAIMER:

DECLARATION OF INDEPENDENCE

I, Elida Naude, 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 71 and is punishable in terms of section 24F of the Act.

ENaude.

2022/11/03

Signature **Date**

Mrs. Elida Naude

MSc Geohydrology (UFS)

Pr.Sci.Nat. (400286/14)

EXECUTIVE SUMMARY

BACKGROUND

Eco Elementum (Pty) Ltd was contracted by IPP Mining Equipment (Pty) Ltd to conduct a Geohydrological Investigation as part of the Water Use License for the proposed Nndaganeni mining project. The Nndaganeni project is located approximately 16 km east of Middelburg and less than 6 km north of the Optimum Opencast pit in the Mpumalanga Province.

The Nndaganeni area is located on a tributary of the Klein Olifants River. Drainage is from the site towards the west. The site is located in the B12C quaternary catchment which falls within the Klein Olifants Resource of the Olifants Water Management Area (WMA).

The Nndaganeni is underlain by rocks from the Karoo Supergroup. The site is also situated in the Witbank Coalfields which is the most important coal-producing coalfields in South Africa. Five coal seams exist in the coalfield, but not all are economically viable. These coal seams are hosted in Vryheid Formation the middle Ecca Group sediments. The number 1 seam is the lowest or deepest while the 5 seam is the uppermost coal seam. The number 2 and 4 seams are the most exploited throughout the Witbank Coalfields. Mining at Nndaganeni mining will be down to the number 2 seam.

The following infrastructure will form part proposed for the Nndaganeni mining operation:

- Opencast Pit.

CONCLUSION / RECOMMENDATION

The geohydrological environment at the Nndaganeni mining area can be summarised as follows:

- The IPP Nndanganeni mining area is located in the highveld region of Mpumalanga and in a summer rainfall region;
- The mean annual precipitation is ± 680 mm/annum, while the evaporation is estimated at 1 797 mm/annum;
- The recharge can be up to 3 to 5% of the mean annual precipitation;
- The IPP Nndanganeni mining area is situated on a groundwater divide area. Groundwater from the area will flow towards the north-west and west;
- A large portion of the project site is covered with unconsolidated sediments. The encountered lithology's were generally similar in each hydrogeological exploration hole consisting of:
    - Weathered sandstone and / or shale – weathering is relatively shallow ranging between ~1 m (bgl) and ~6 m (bgl);
    - Coal seam – coal seams interlayered with sandstone, shale and siltstone of various thickness;
    - Interlayered Sandstone and Shale – fresh sandstone and shale; and
    - In addition to the above, rhyolite was also encountered in some boreholes.
- Geological structures such as dykes and faults are known to exist in the region of the IPP Nndanganeni mining area. These structures and the weathered zone are possible pathways of elevated groundwater flow and contamination migration;
- Two main aquifer systems are found in the IPP Nndanganeni mining region. Firstly, the shallow weathered aquifer and secondly, the deeper, secondary aquifer;
- Water levels in the monitoring and hydrocensus boreholes varied between 0.2 and 17 mbs.
- The cone of depression due to dewatering is not expected to extent more 450 400 m from the pit areas;
- Significantly elevated sulphate concentrations have been observed in BH2, BH3, BH4, KM2 and KM6 over the 2022 monitoring period. Increasing trends over this period has also been observed in these boreholes. The increasing sulphate concentrations in evident of increasing impacts from the coal mining activities;

- The following was observed after assessing the water quality of the groundwater samples taken around the Nndanganeni Colliery Kopermyn, Nndanganeni Colliery Hartogshof Extension (NCHE):
  - The pH level of BTP3 exceeds the SANS Limits.
  - The manganese concentration of BH 2, BH 4 and KM 4 exceed the SANS Limits.
  - The sulphate concentration of BH 2, BH 3 and BH 4 exceed the SANS Limits.
  - The TDS concentration of BH 2, BH 3 and BH 4 exceed the SANS Limits.
  - BH10, KM2, KM4, BTP 3, MB3 and MB6 display corrosive characteristics.
  - BH3 and BH4 display scaling characteristics.

The following impacts may be expected from the proposed Nndaganeni mining operations:

- Construction phase:
  - Impacts in terms of groundwater levels are expected during this phase. The dewatering of the box-cut will cause a drawdown in the water levels within the immediate vicinity of the cut.
  - Fuel spillages from construction vehicles may occur during this phase.
- Operational phase:
  - Impacts in terms of groundwater levels are expected during this phase. The dewatering of the pit will cause a drawdown in the water levels within the immediate vicinity of the opencast activities.
  - The drawdown of the water levels is expected to impact on the Northern pan water make since groundwater partially contributes to the water make of the pan.
  - No adverse impacts on the groundwater qualities surrounding the opencast are expected during this phase.
  - The simulated results of the operational phase in terms of the water levels are indicated in the table below:

Opencast Pit	Maximum simulated drawdown (m)	Maximum drawdown cone extent from pit boundary (m)
Nndaganeni	11	450

- Post Closure:
  - The water level post-closure will start to rise as the back-filled pit starts to fill.
  - Decant may occur once the water level in the back-filled opencast pit has recovered.
  - Once the water levels have recovered, a groundwater pollution plume will start to migrate down gradient away from the pit areas.
  - The Northern Pan is expected to be impacted on in terms of sulphate contamination at 100 years post closure.

Opencast Pit	100 years Post closure maximum simulated sulphate concentrations (mg/l)	100 years Maximum plume extent from potential surface sources (m)
Nndaganeni	2 700	850

The proposed mitigation measures for the proposed mining operation are summarised below:

Phase	Mitigation Measures
Construction Phase	• Should fuel spillages occur during the construction phase immediate action is required to minimise the impact on the groundwater regime. • No management can be incorporated to limit the impacts of dewatering should the box-cut floor be lower than the groundwater level.
Operational Phase	• Groundwater levels in the monitoring boreholes should be measured on at least a quarterly interval.

	• Should the water levels of surrounding users be influenced in terms of groundwater level or quality decline, the users should be compensated. • Monitor groundwater inflow rates on a monthly basis throughout the mining operation. • The groundwater quality in the monitoring boreholes should be analysed on a quarterly basis. • Annual reporting on the groundwater qualities and levels should be conducted and submitted to the DWA. • The numerical model should be updated once more time-series monitoring data (water levels and qualities) are available and on an annual basis. • Remove as much coal from the mining pit as possible to prevent continuous acid generation.
Post-Closure Phase	• Carbonaceous material should be placed at the deeper base of the opencast pit to allow flooding with groundwater as soon as possible. This will reduce the redox reaction potential as oxygen is excluded from the system. • Rehabilitation should occur in such a manner that surface runoff is directed away from the rehabilitated pit and recharge to the pit minimized. • Flow paths which include fracture zones should be sealed to reduce inflow of fresh groundwater and outflow of contaminated groundwater. • Methods of handling the potential decant should be investigated and may include a down gradient- intercepting trench. • The groundwater quality in the monitoring boreholes should continue to be analysed on a quarterly interval basis. • Monitoring of surface water features including the Northern Pan should be conducted on a quarterly interval.

CONTENTS

List of Appendixes

List of Figures

List of Tables

List of Abbreviations

ARD-	Acid Rock Drainage
EC-	Electrical Conductivity
EIA-	Environmental Impact Assessment
EMP-	Environmental Management Plan
GQM-	Groundwater Quality Management
Ha-	Hectares
Km^{2}-	Square Kilometre
L/s-	Litres per second
Meq/l –	Milliequivalent per litre
Mamsl-	Metres above mean sea level
MAP-	Mean Annual Precipitation
MAE-	Mean Annual Evaporation
Ml/d-	Mega litres per day
m/d-	meter per day
m-	Meter
mbs-	meter below surface
mm-	Millimetre
mm/a-	Millimetres per annum
mS/m-	Millisiemens per metre
m^{3}-	Cubic metre
NGA-	National Groundwater Archive
PCD-	Pollution Control Dam

1. INTRODUCTION

Eco Elementum (Pty) Ltd was contracted by IPP Mining Equipment (Pty) Ltd to conduct a Geohydrological Investigation as part of the Water Use License for the proposed Nndaganeni mining project. The Nndaganeni project is located approximately 16 km east of Middelburg and less than 6 km north of the Optimum Opencast pit in the Mpumalanga Province.

The Nndaganeni area is located on a tributary of the Klein Olifants River. Drainage is from the site towards the west. The site is located in the B12C quaternary catchment which falls within the Klein Olifants Resource of the Olifants Water Management Area (WMA).

The Nndaganeni is underlain by rocks from the Karoo Supergroup. The site is also situated in the Witbank Coalfields which is the most important coal-producing coalfields in South Africa. Five coal seams exist in the coalfield, but not all are economically viable. These coal seams are hosted in Vryheid Formation the middle Ecca Group sediments. The number 1 seam is the lowest or deepest while the 5 seam is the uppermost coal seam. The number 2 and 4 seams are the most exploited throughout the Witbank Coalfields. Mining at Nndaganeni mining will be down to the number 2 seam.

The following infrastructure will form part proposed for the Nndaganeni mining operation:

- Opencast Pit.

The location of the Nndaganeni mining site is indicated in **Figure 1**.

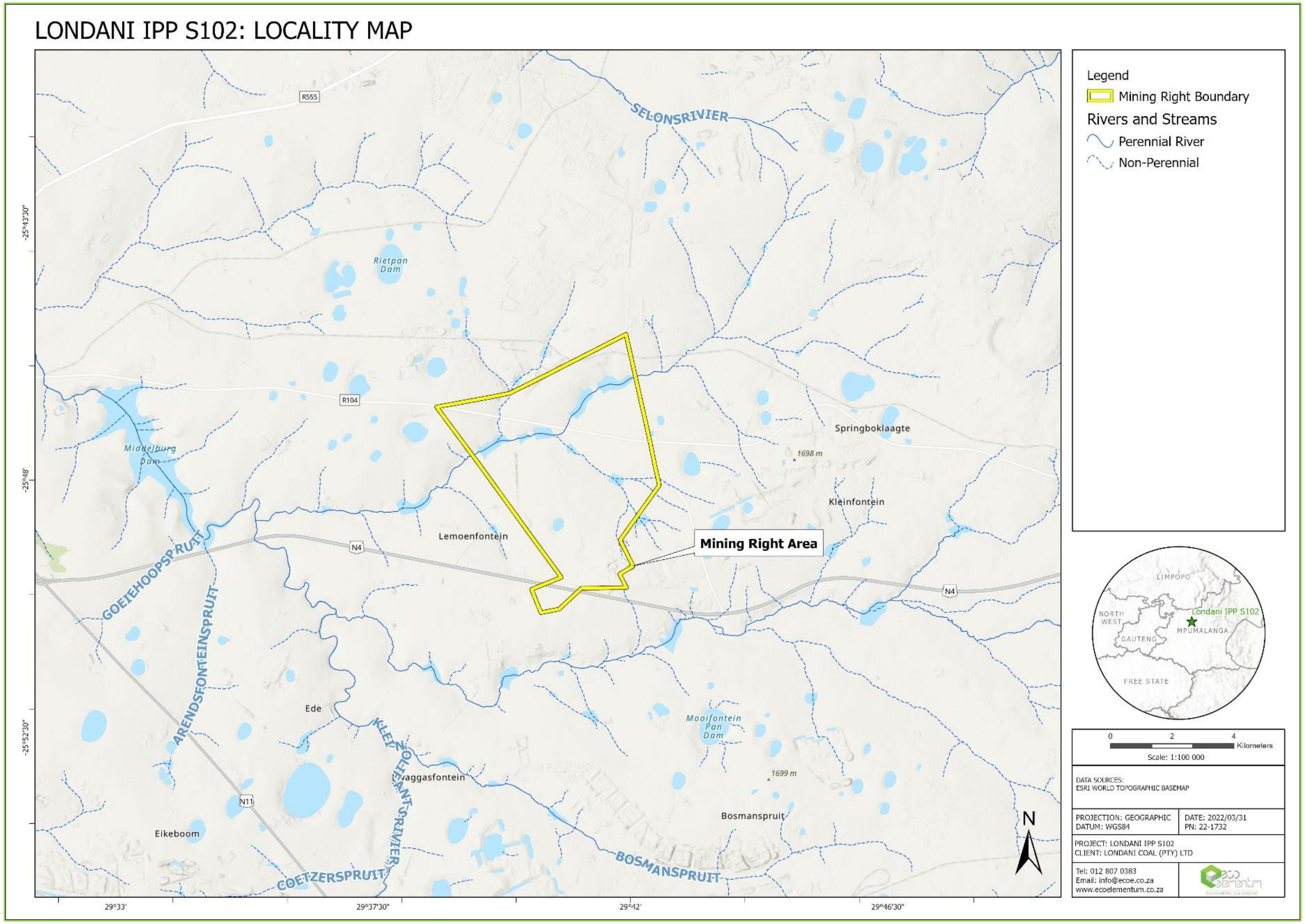


Figure 1: Nndaganeni Locality Map, Middelburg, Mpumalanga, South Africa.

2. GEOGRAPHICAL SETTING

2.1 TOPOGRAPHY AND DRAINAGE

The Nndaganeni area is located on a tributary of the Klein Olifants River. Drainage is from the site towards the west and north-west. The site is located in the B12C quaternary catchment which falls within the Klein Olifants Resource of the Olifants Water Management Area (WMA).

The area is located in the Eastern Highveld with gently rolling hills and shallow valleys. The natural topography of the area has generally been disturbed by several mining activities in the region which have been conducted over the past several decades. Typically, opencast mining and rehabilitation activities affect the natural topography. The Optimum Pit is situated approximately 5.5 km south of the proposed mining site partially in the same catchment area that has been left un-rehabilitated.

The topography within the mining area ranges between 1 710 metres above mean sea level (mamsl) in the east to 1 530 mamsl in the west. The topography in the Nndaganeni area generally dips towards the west at a gradient of 0.01.

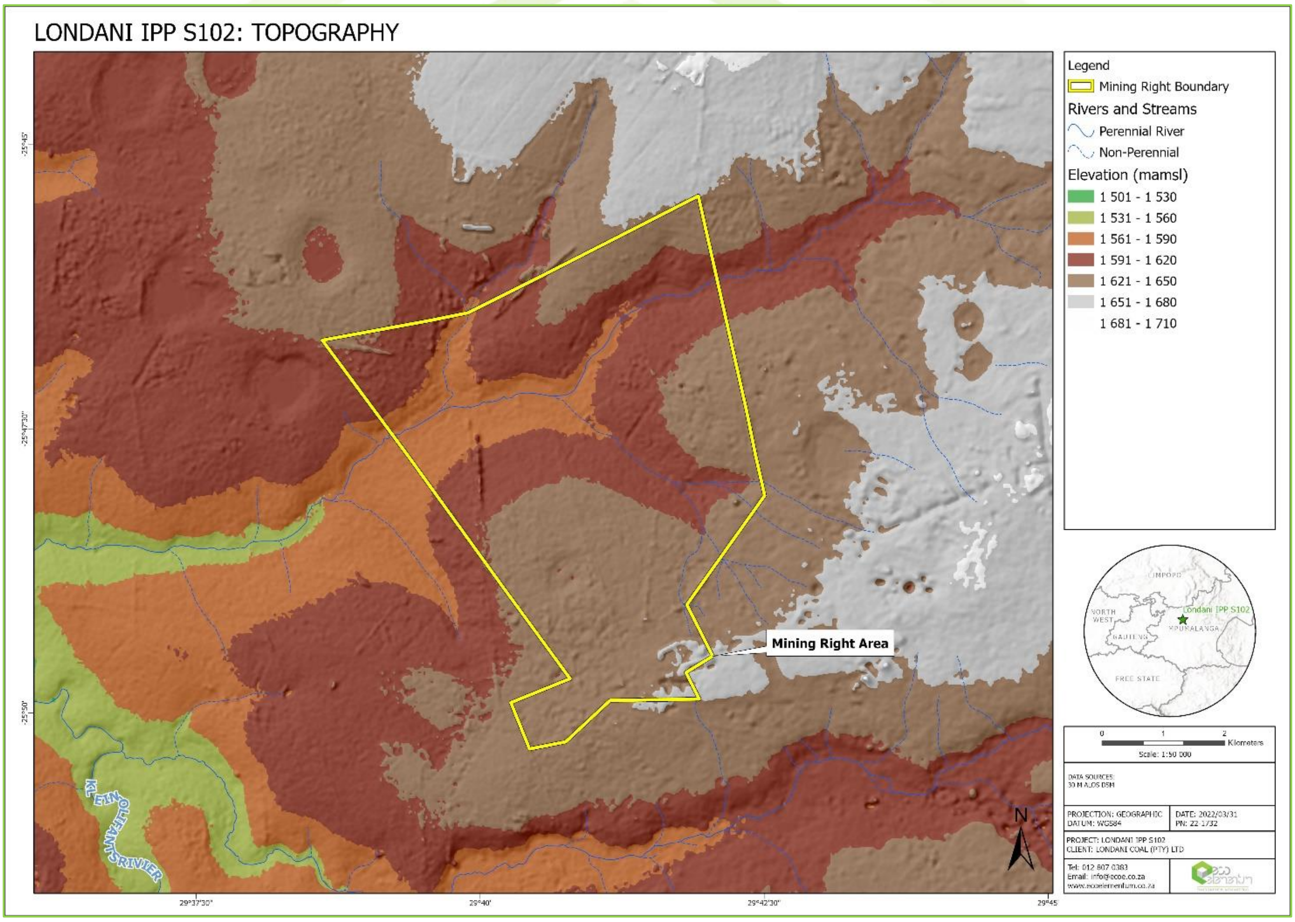


Figure 2: Topographical map for the Nndaganeni area.

2.2 CLIMATE

The Nndaganeni area falls within a climate region with warm summers and cold winters with sharp frost. Average daily maximum temperatures are approximately 27°C in January and 17°C in July, but in extreme cases, these may rise to 38°C and 26°C respectively. Average minimum range from about 13°C in January to 0°C in July, whereas extremes can sink to 1°C and -13°C respectively.

Rain in this area occurs almost exclusively as showers (mild to heavy) and thunderstorms mainly in summer (October/March), with the maximum in December to February. The winter months are normally dry.

Historical rainfall record, kept by Optimum Colliery and the South African Weather Services (SAWS) were used to determine the monthly precipitation rates. The vicinity of the Optimum Colliery comprises of rainfall gauging station from the SAWS with a record in excess of 60 years. The MAP for the Nndaganeni area is approximately 680 mm.

The Nndaganeni area falls within a region where evaporation is estimated to be between 2 000 and 2 200 mm/a (Figure 4).

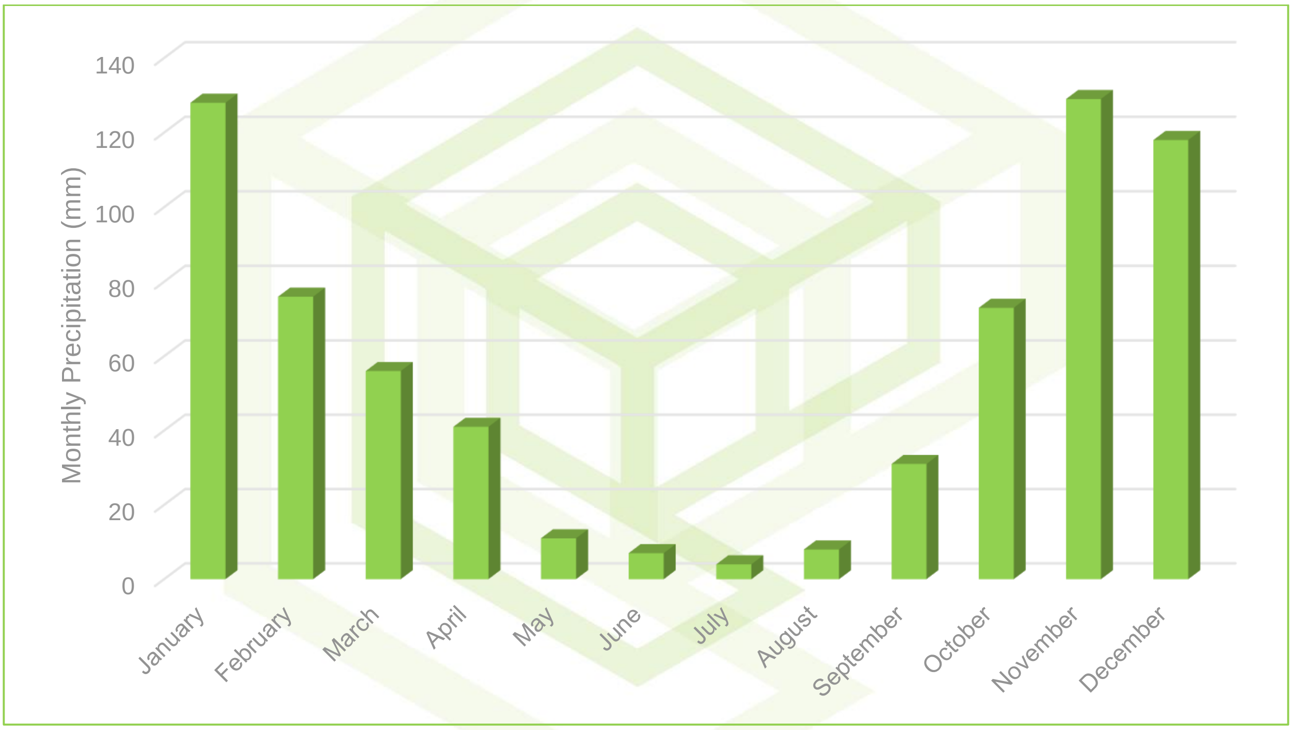


Figure 3: Monthly precipitation in the proposed Nndaganeni area (Magalela Associates, 2014)

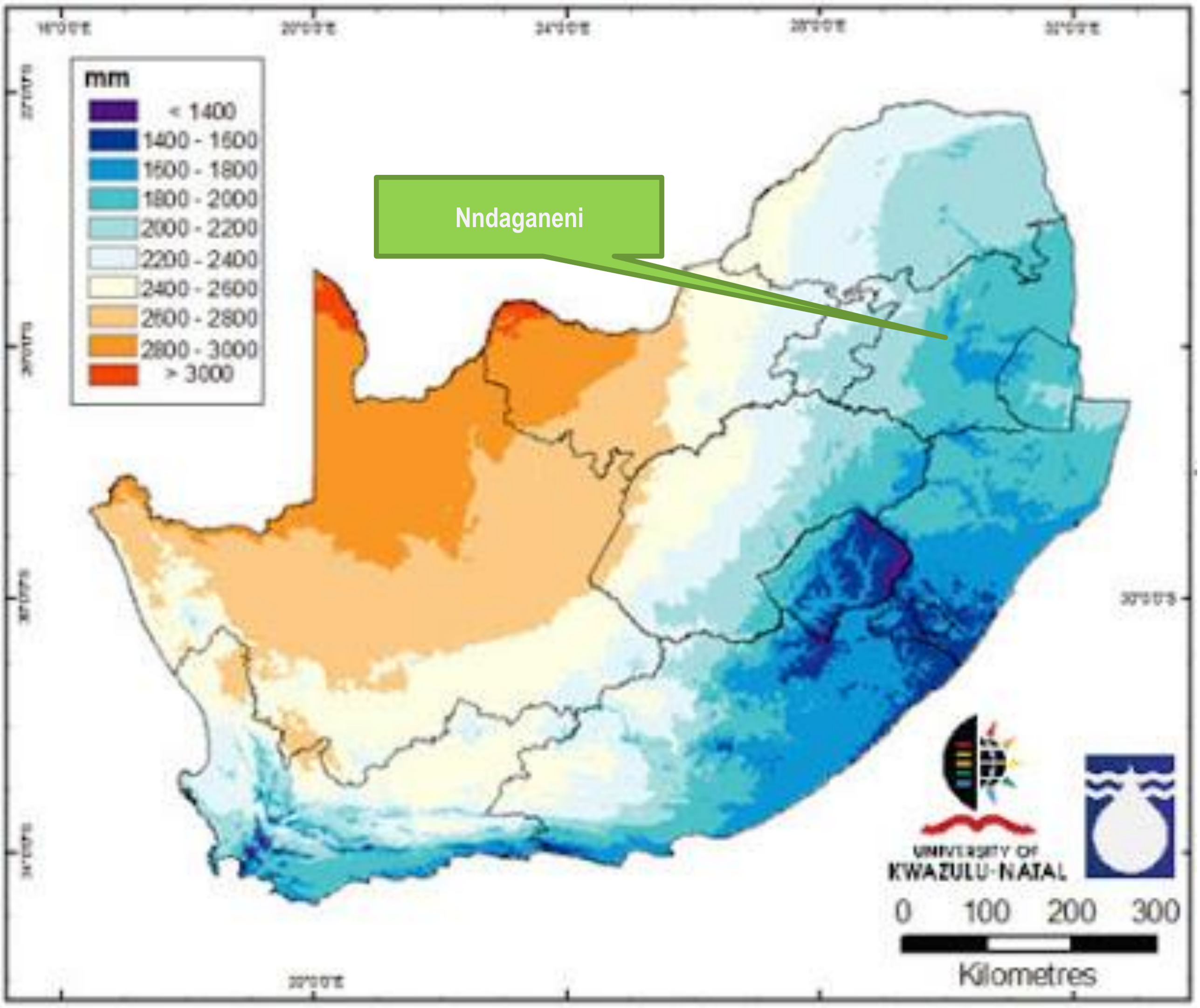


Figure 4: Annual evaporation in the proposed Nndaganeni area (Schulze et al., 2008).

3. SCOPE OF WORK

The main aim of this report is to determine and discuss the main impacts of the proposed mining at Nndaganeni area. This report will include discussions on:

- Topography;
- Climate;
- Geology; and
- Hydrogeology:
  - Unsaturated zone;
  - Saturated zone;
  - Groundwater recharge;
  - Hydraulic conductivity;
  - Groundwater levels;
  - Potential impacts on groundwater quality and quantity; and
  - Aquifer characteristics.
- Numerical Groundwater modelling;
- The groundwater monitoring system;
- Groundwater Environmental Management Programme; and
- Post-closure management plan.

The information sources for the Nndaganeni geohydrological study include:

- Mine layouts and schedules obtained from the mine;
- Topographical and geological maps as well as satellite imagery for describing the physical site properties; and
- Geohydrological and geological reports:
  - uKhozi Environmentalists, 2022. Groundwater Monitorign Report for nndanganeni Colliery Kopermyn, Nndanganeni Colliery Hartogshof Extension (NCHE) and Kopermyn Washing Plant.
  - GCS, 2015. Londani Coal Nndanganeni Colliery Hartogshof Extension: Hydrogeological Investigation.
  - GCS, 2015. Potential for Acid-mine Drainage from the Hartogshof Colliery.
  - Jones & Wagener, 2009. Optimum Colliery Environmental Management Programme Report Amalgamation.
  - V.E. Cogho and A.M. van Niekerk, 2009. Optimum Coal Mine Water Reclamation Project.
  - J N J Viljoen. Optimum Colliery : Water Management for the proposed Pullenshope Mining Area.
- DWA series of maps that include:
  - Groundwater Quality of South Africa;
  - Aquifer Classification of South Africa;
  - Aquifer Vulnerability of South Africa; and
  - Aquifer Susceptibility of South Africa.

4. METHODOLOGY

4.1 Desk Study

This geohydrological investigation is based on a desk-top study with all the information gathered from previous geohydrological investigations conducted in the nearby area as well as site-specific information. The following studies have been used as references:

- uKhozi Environmentalists, 2022. Groundwater Monitorign Report for nndanganeni Colliery Kopermyn, Nndanganeni Colliery Hartogshof Extension (NCHE) and Kopermyn Washing Plant.
- GCS, 2015. Londani Coal Nndanganeni Colliery Hartogshof Extension: Hydrogeological Investigation.
- GCS, 2015. Potential for Acid-mine Drainage from the Hartogshof Colliery.
- Jones & Wagener, 2009. Optimum Colliery Environmental Management Programme Report Amalgamation.
- V.E. Cogho and A.M. van Niekerk, 2009. Optimum Coal Mine Water Reclamation Project.
- J N J Viljoen. Optimum Colliery : Water Management for the proposed Pullenshope Mining Area.

The following map sources will be included in this report:

- 1:50 000 Topographical map: 2630AA and 2630AB.
- Quaternary Catchments.
- 1:250 000 Geological Map Series of South Africa.
- Aquifer Classification of South Africa.
- Aquifer Vulnerability of South Africa; and
- Aquifer Susceptibility of South Africa.

4.2 Results Of Hydrocensus/User Survey

A hydrocensus survey was conducted in the region of the proposed Nndaganeni area in November 2022 by Eco Elementum. Five boreholes and one fountain were located where information has been obtained (Table 1). The positions of these locations are indicated in Figure 4. Water levels were measured at three of the boreholes.

Table 1: 2022 Hydrocensus borehole information.

Locality	X-coord	Y-coord	Elevation (mamsl)	Water Level (mbs)	Collar Height (cm)	Static Water Level (mbs)	Depth (mbs)	Description
NPU01	66161	-2855474	1593	4.15	0.03	4,12	35.5	User Boreholes
NPU04	69998	-2854019	1629	-	-	-	-	User Boreholes
Pan1	67909	-2856460	1626	5.1	0.46	4,64	16.5	Monitoring Boreholes
Pan2	68248	-2856449	1626	2.6	0.58	2,02	21.5	Monitoring Boreholes
Pan3	68258	-2856440	1627	-	-	-	sealed	Monitoring Boreholes
PU-F	66549	-2857344	1601	-	-	-	-	Fountain

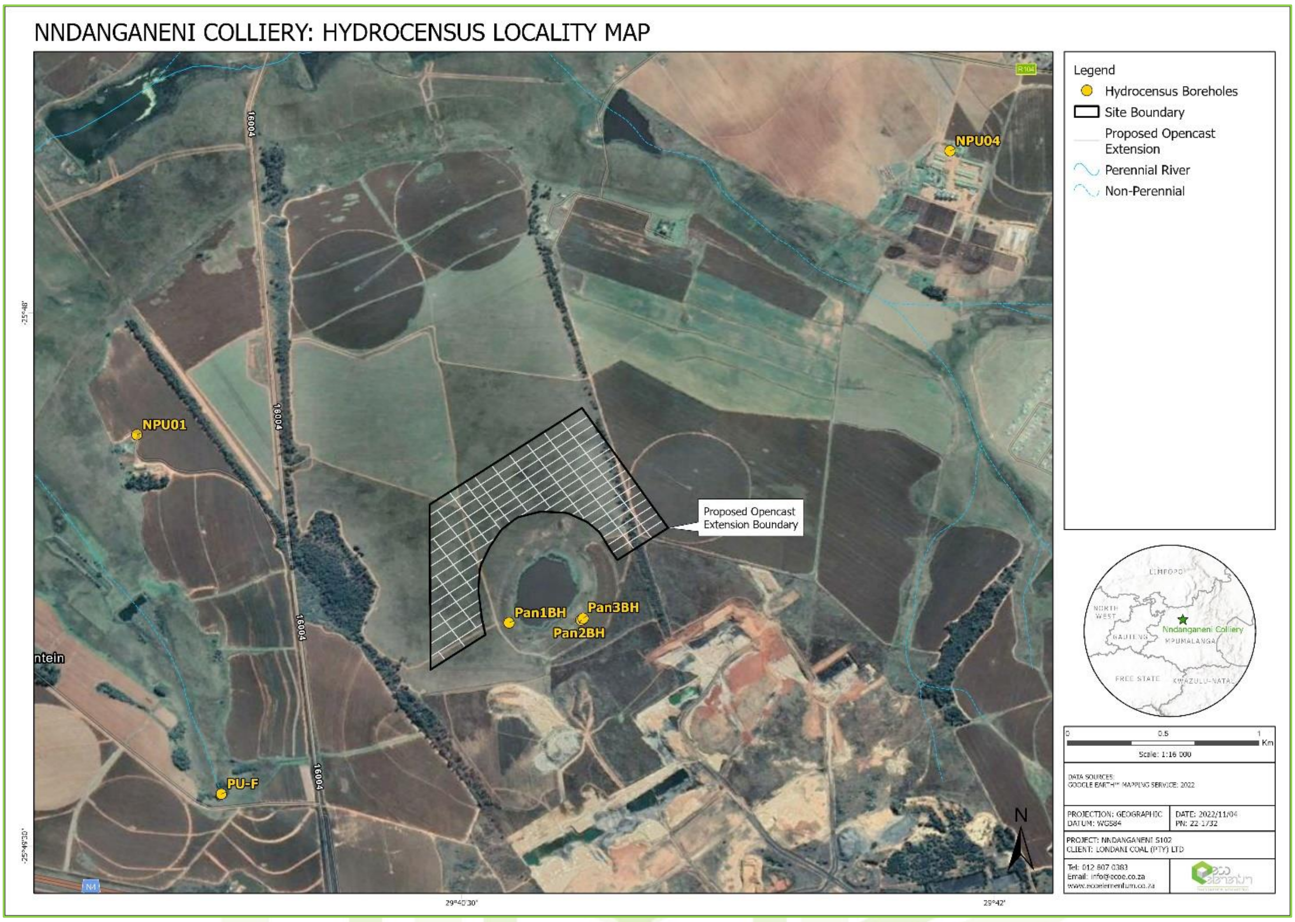


Figure 5: 2021 Hydrocensus Localities for the Nndaganeni mining project.

4.3 Geophysical Survey And Results

A geophysical survey was conducted for the proposed Nndaganeni area. The magnetometer and EM-34 were used for the survey.

A magnetometer is a scientific instrument used to measure the strength and direction of the magnetic field in the vicinity of the instrument. Magnetism varies from place to place because of differences in Earth's magnetic field caused by the differing nature of rocks and the interaction between charged particles from the sun and the magnetosphere of a planet.

EM methods make use of the fact that time-varying electromagnetic radiation of the subsurface will cause electric currents to flow. The currents thus induced in the subsurface are also time-varying in nature and give rise to time-varying magnetic fields. The behaviour of the measured magnetic fields can be analysed and interpreted to obtain information on the subsurface conductivity distribution.

No anomalies were detected during the geophysical survey and boreholes were placed according to topographical and site layout information. The monitoring boreholes proposed to cover the proposed mining areas are indicated in Figure 24. The results of the geophysical survey are indicated in Appendix A.

4.4 Drilling And Siting Of Boreholes

The positions of the proposed monitoring boreholes are presented in Table 2. Two of these boreholes are existing boreholes – NND-MON04 and MB3. NND-MON01, 02 and 03 needs to be drilled. Proposed monitoring borehole positions are indicated in Figure 24.

Table 2: Monitoring boreholes to form part of the quarterly monitoring program.

Borehole	Coordinates (WGS84-TM LO29)		Proposed Depth (m)	Status
Unit	X-coordinate	Y-coordinate		
NND-MON01	68358	-2855486		To be drilled
NND-MON02	67860	-2855598		To be drilled
NND-MON03	68207	-2856032		To be drilled
NND-MON04	67885	-2856442	30	Drilled
MB3	67470	-2856705	30	Drilled

4.5 Aquifer Testing

Aquifer testing is conducted to determine the hydraulic aquifer characteristics which include transmissivity or hydraulic conductivity. Aquifer testing is the abstraction of measured quantities of water over some time. Aquifer testing also involves the recovery of the water levels after the abstraction of groundwater has stopped. The results of the aquifer tests are important to form a conceptual model for the study area. This in turn forms an integral part of the numerical groundwater modelling.

Transmissivity is the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. It is expressed as the product of the average hydraulic conductivity and thickness of the saturated portion of an aquifer.

$$T = KhD$$

Where: T is the transmissivity,

Kh is the average horizontal conductivity (measured in length per unit time),

D is the aquifer thickness.

4.6 Sampling And Chemical Analysis

The hydrocensus boreholes have been sampled by Eco Elementum in November 2022.

Groundwater Methodology:

- Locate sampling point.
- Observe and note borehole condition.
- Mark sampling bottle with date and sampling point name.
- Complete field data sheet with relevant information.
- Take a sample.
- Take a picture of the sample at the sampling point for confirmation of monitoring done.

Taking a sample from a borehole (SANS 5667-11:2015):

- Open the borehole (if it is a cap or lid).
- Lower the bailer into the borehole until it can be heard that the bailer has reached the water table.
- Lower the bailer a further 2 – 3 meters (if possible).
- Retrieve the bailer from the borehole and empty it into the sampling bottle, using the bailer emptying tube.
- Take care to keep the bailer from hitting the sides of the borehole (to minimise contamination).

- Repeat the above steps until the sampling bottle is filled.
- Place the cap on the sampling bottle.
- Ensure that sample containers are delivered to the laboratory tightly sealed and protected from the effects of light and excessive heat.
- Submit the samples to the laboratory on the same day of sampling.
- Should you not submit the sample on the same day the sample should be cooled to 4˚C in a fridge until it is submitted at the laboratory.

Measuring the depth of the water table in a borehole:

- Lower the borehole depth meter probe into the borehole.
- Monitor the Electrical Conductivity (EC) gauge on the side of the reel until a reading shows.
- When a reading is shown on the EC gauge, stop lowering the probe.
- Determine the exact point where the probe is in contact with the water by checking the EC gauge.
- Read the depth marked on the cable (1 mm intervals).

When reading the depth of the water level, the height of the borehole casing above the ground should be considered. Readings should be up to the earth's surface/ground level and not to the top of the borehole casing

The samples from the hydrocensus boreholes that have been sampled by Eco Elementum were analysed by an ISO 17025 SANAS accredited Testing Laboratory.

The following parameters have been analysed for: pH, Electrical Conductivity, Total Dissolved Solids, Calcium, Magnesium, Sodium, Potassium, Total Alkalinity, Chloride, Sulphate, Nitrate, Fluoride, Aluminium, Iron and Manganese. It is highly recommended that quality analysis of these parameters continues in the monitoring boreholes and is conducted by a SANAS approved laboratory.

4.7 Groundwater Recharge Calculations

Groundwater recharge is mainly identified as the percentage of mean annual precipitation (MAP) that seeps through the unsaturated zone and reaches the saturated zone. Therefore, the percentage that contributes to the aquifer water make after run-off and evaporation. Recharge to the region of the Nndaganeni mining area has been estimated by the following methods (van Tonder & Xu, 2000):

- Soil cover;
- Geology;
- Vegter Acru;
- Harvest Potential; and
- Expert's Guesses.

These estimations represent the general region of the study site and the characters on-site may differ by small percentages.

Table 3: Recharge estimations for the proposed Nndaganeni region.

Method	% of MAP	Certainty level (High = 5, Low = 1)
Soil	3,4	3
Geology	4,5	3
Vegter	5,3	3

Acru	4,2	3
Harvest Potential	3,5	3
Expert's Guesses	3,0	3
Average	4.0	3

Recharge to the Nndaganeni area is estimated to be as much as 4.0%. Depending on the soil coverage, geology, and other relevant factors the recharge may be higher and lower in some areas. Based on work by Kirchner et al. (1991) and Bredenkamp (1995), the recharge can range between 1% to 3% of the mean annual precipitation (MAP).

4.8 GROUNDWATER MODELLING

Groundwater modelling is an effective tool used for groundwater management and remediation. It is a simplified representation of reality used to replicate current groundwater conditions as well as predicting future potential impacts or conditions of the groundwater regime.

Once a conceptual model has been formed, the fundamentals are used as the basis of the numerical groundwater model. Known characteristics such as the aquifer parameters including transmissivity and conductivity as well as measured water levels, qualities, recharge, etc. are used to calibrate the model.

Both flow and mass transport models were constructed for the proposed Nndaganeni area. The software, model setup, and boundaries used are discussed in more detail in Section 7 of this report.

4.9 GROUNDWATER AVAILABILITY ASSESSMENT

The proposed Nndaganeni is situated within the Olifants River Catchment area in quaternary catchment B12C. The water resource area is the Klein Olifants River. A summary of the Groundwater Resource Directed Measures (GRDM) for the quaternary catchment B12C (in which Nndaganeni is located) is presented in **Table 4**. According to the table, a total of 0.7 Mm^3 of groundwater is allocable in the catchment.

Table 4: Groundwater Resource Directed Measures (GRDM) for quaternary catchment B12C (Government Gazette, 2017).

Preliminary Groundwater Reserve Quantity Component Parameter		B12C
Recharge	Area (km^2)	529
	MAP (mm/a)	680
	Groundwater recharge (% MAP)	1.6%
	Groundwater recharge (Mm^3/a)	5.89
Use	Groundwater Use (Mm^3/a)	0.21
Reserve	Groundwater Component of Baseflow (Mm^3/a)	5.39
	Basic Human Needs Reserve (Mm^3/a)	0.04
	Total Reserve (Mm^3/a)	6.58
Allocation	Allocable Groundwater (Mm^3/a)	0.7
	Allocable Groundwater (% of reserve)	10.6
	Allocable Groundwater (% of recharge)	11.9

5. PREVAILING GROUNDWATER CONDITIONS

5.1 Geology

5.1.1 Regional Geology

The Nndaganeni is underlain by rocks from the Karoo Supergroup. The site is also situated in the Witbank Coalfields which is the most important coal-producing coalfields in South Africa (**Figure 6**). Five coal seams exist in the coalfield, but not all are economically viable. These coal seams are hosted in Vryheid Formation the middle Ecca Group sediments. The number 1 seam is the lowest or deepest while the 5 seam is the uppermost coal seam. The number 2 and 4 seams are the most exploited throughout the Witbank Coalfields.

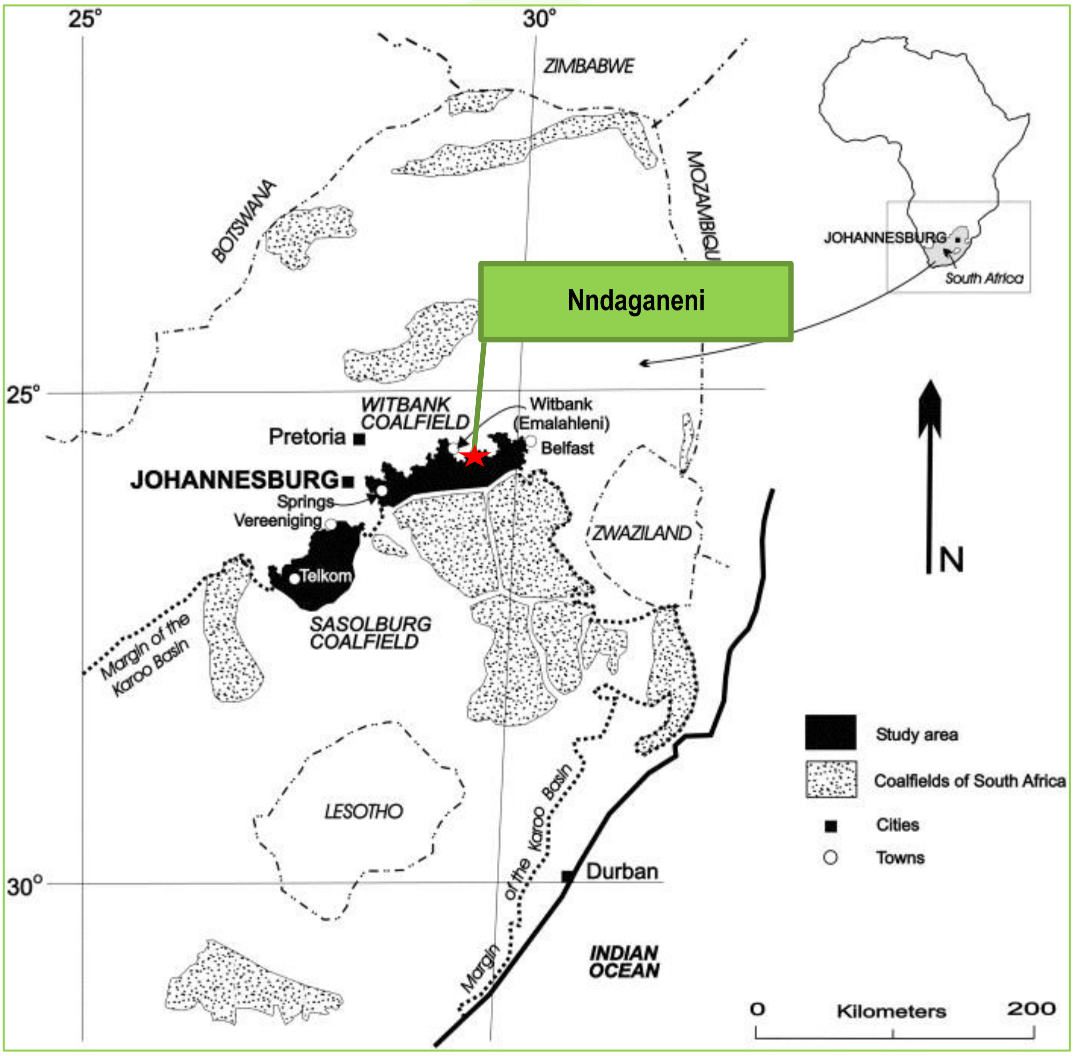


Figure 6: Witbank Coalfields and the position of Nndaganeni area in relation to it (Denis et.al., 2007).

The Karoo Supergroup mainly consists of sedimentary successions of sandstone, shale and coal. The Ecca Group is underlain by the Dwyka Formation which consists of tillites and diamictites.

Geological features such as dykes (dolerite intrusions) and faults are commonly found in the coalfield. The dolerite intrusions typically act as groundwater flow barriers due to their low permeability, while the contact zone of the intrusions acts as flow pathways due to cracks and faults leading to higher flow rates along these contact zones.

5.1.2 Local Geology

In the Nndanganeni project area, the Vryheid Formation directly overlies the Damwal Formation of the Rooiberg Group (Bushveld Complex). The Dwyka Group is absent or not well developed. As the Vryheid Formation pinches out in the study area, the thickness of the formation is only several tens of meters. Felsitic rocks of the Damwal Formation are present at surface where the Vryheid Formation has been eroded by local streams. Coal seams are strongly influenced by varied depositional environments and / or the presentday erosional surfaces.

The coal seams (and strata) are generally flat-lying to gently undulating with a regional dip to the south southeast. Due to the varied depositional environments (e.g. basement topography) and the present-day erosional surface, not all of the seams are present at any one locality. (GCS, 2015)

Table 5: Overburden and Seam Thickness Summary (GCS, 2015)

Description	Thickness (m)			Seam 1 and Seam 2 Separation Thickness (m)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Overburden (above Seam 2)	-7.2	-18.7	-15.8	na	na	na
Seam 1	-0.4	-2.8	-1	-1.8	-11.3	-4.5
Seam 2	-0.4	-4	-2			

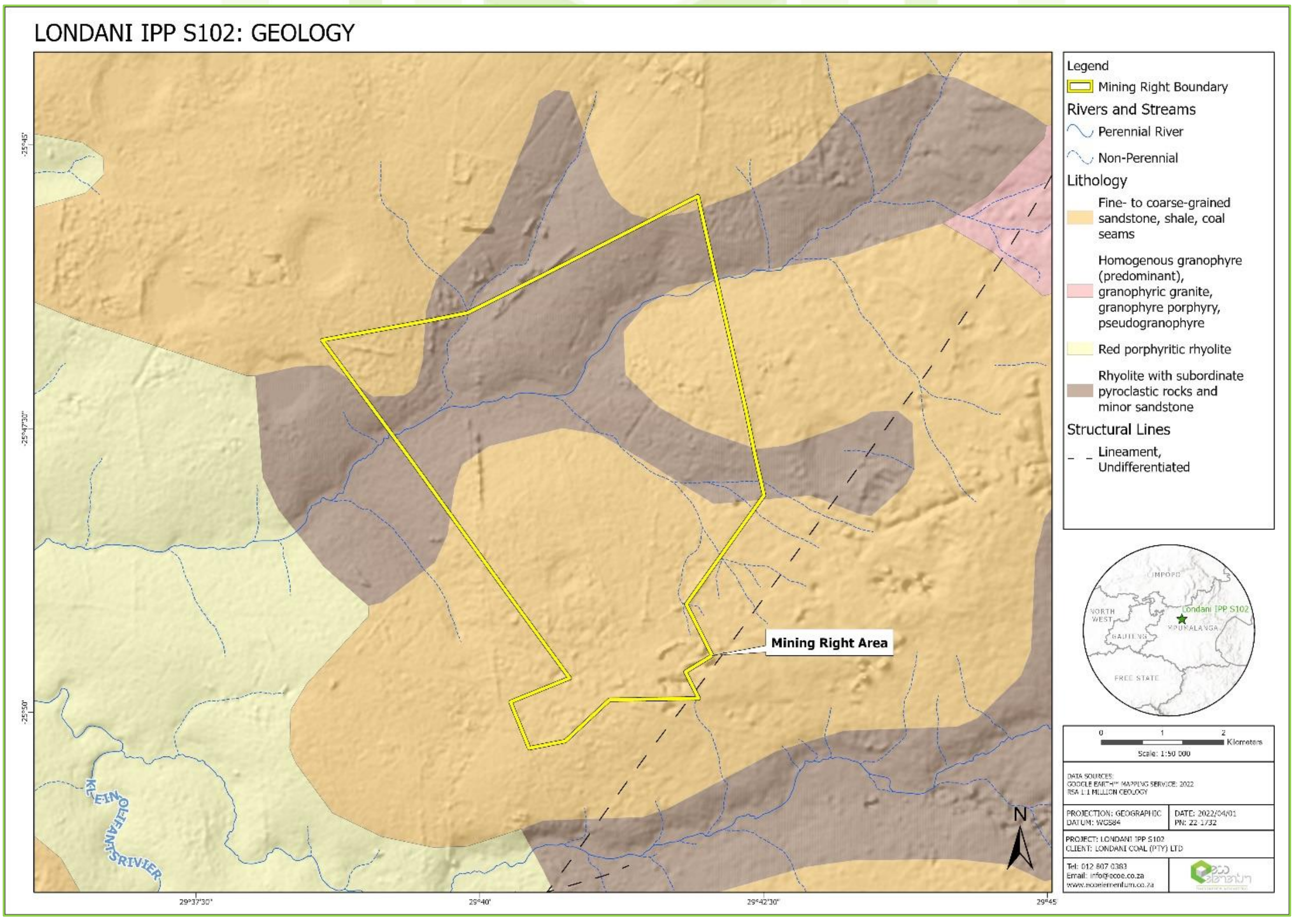


Figure 7: Nndaganeni simplified geology

5.2 Hydrogeology

5.2.1 Unsaturated Zone

The unsaturated zone is the zone between the ground surface and the static water table. In the unsaturated zone the pores between the ground particles are filled with air and water- thus below saturation. Static water levels in the region of the Nndaganeni mining area as obtained from the hydrocensus boreholes, range between 0.2 and 17 mbs. The thickness of the unsaturated zone in the area of the Nndaganeni can therefore also vary from 0.2 to 17 m in depth. The unsaturated zone may consist of soil, weathered bedrock, and even solid bedrock from the sandstone and shale of the Ecca Group.

5.2.2 Saturated Zone

The saturated zone is that part of the aquifer below the regional static water level where all pores and fractures are filled with water at a pressure greater than atmospheric pressure. The depth of the saturated zone in the Nndaganeni mining area is therefore, more than 0.2 to 17 mbs. From studies compiled in the larger region of Nndaganeni area, the saturated zone mainly consists of two aquifer systems.

- Firstly, the weathered, unconfined aquifer that typically occurs on the transition between soil and weathered bedrock (typically sandstone and shale). The groundwater flow closely mimics the surface topography. Groundwater levels are usually shallow in the low-lying topographical regions and may even daylight on a surface which is referred to as springs. The weathered aquifer is more prominent in the wet season because it is located on top of solid bedrock or clayey layers. This aquifer normally has a low yield.
- The second aquifer is known as the deeper, confined aquifer. Flow in this aquifer mainly occurs along fractures, bedding planes and other groundwater flow paths. The presence of fractures generally decreases with depth in this aquifer. The secondary aquifer, due to its heterogeneous nature, maybe higher yielding than the weathered aquifer. Due to the longer residence time of the groundwater in this aquifer, the salt load may be higher than that of the weather aquifer.

The third aquifer at great depth may occur within the pre-Karoo geology (Transvaal Group), underlying the Dwyka-tillites. Very little information of this aquifer in the area is available since very few boreholes have been drilled to this great depth. The water quality in quantity in this aquifer may be inferior to that of the overlying Karoo aquifers. Where dolomite underlays the Karoo geology, the yields of this aquifer may be significantly higher.

5.2.3 Hydraulic Conductivity

Hydraulic conductivity refers to the ease with which water passes through a porous medium at a certain time under a hydraulic gradient (m/d). Hydraulic Conductivity (K) can be determined as:

$$K = \frac{\text{Transmissivity (T)}}{\text{Aquifer thickness (d)}}$$

The aquifer characteristics in the area are expected to correspond with other similar Karoo Aquifers. The hydraulic conductivity range can vary anywhere between 10^{-4} to 10^{-2}. It is expected that:

- The hydraulic conductivity will decrease with depth.
- That the fracture zones, also along the dykes, will have a higher hydraulic conductivity than the surrounding rock matrix. These zones will act as preferred groundwater flow paths along which potential contamination will migrate at a higher rate than in the surrounding rock matrix.
- The dykes are expected to have a significantly lower hydraulic conductivity and will therefore in most cases act as groundwater flow barriers.

- The coal seams can also have a higher hydraulic conductivity than the surrounding rock matrix.

Aquifer tests were conducted on thirteen monitoring boreholes by GCS in 2015. Two constant rate discharge tests and thirteen rising head tests were conducted. The hydraulic conductivity statistics for the weathered and fractured aquifers are indicated in Table 6.

Table 6: Hydraulic Conductivity Statistics (GCS, 2015).

Description	Weathered Aquifer (m/d)	Fractured Aquifer (m/d)
Average	0.17	0.002
Geometric Mean	0.013	0.0007
Harmonic Mean	0.004	0.0002

5.3 Groundwater Levels

Water level trends in the IPP Nndanganeni monitoring boreholes over the period from March 2017 to March 2022 are presented in Figure 8 of this report. Increasing water level trends from 2017 to 2022 are observed in BH2, BH3, BH5, BH10 and KM4. No impacts in terms of dewatering on the pan from the mining activities is currently observed since the water levels in BH10 has increased over the monitoring period.

Water levels in the monitoring boreholes varied between 0.2 and 17 mbs for the 2021/2022 monitoring period. BH2 is situated in a rehabilitated opencast area. It is expected that the deeper levels in this borehole may be due to the fact that the water level has not yet recovered post-mining and may also be as a result of the very high permeability of this rehabilitated area.

Future and continuous time-series water level monitoring will result in the numerical model being a more accurate tool for predicting future groundwater level behaviour.

The water levels recorded during the hydrocensus (Table 1) varied between 2 and 4.6 mbs. The water level in the boreholes closest to the Northern pan varied between 2 and 4.6. The water level elevation is close to the water level elevation in the pan which indicates that groundwater contributes to the water make of the pan. Drawdown in the shallow aquifer in the new mining are will therefore have an impact on the pan in terms of the groundwater contribution.

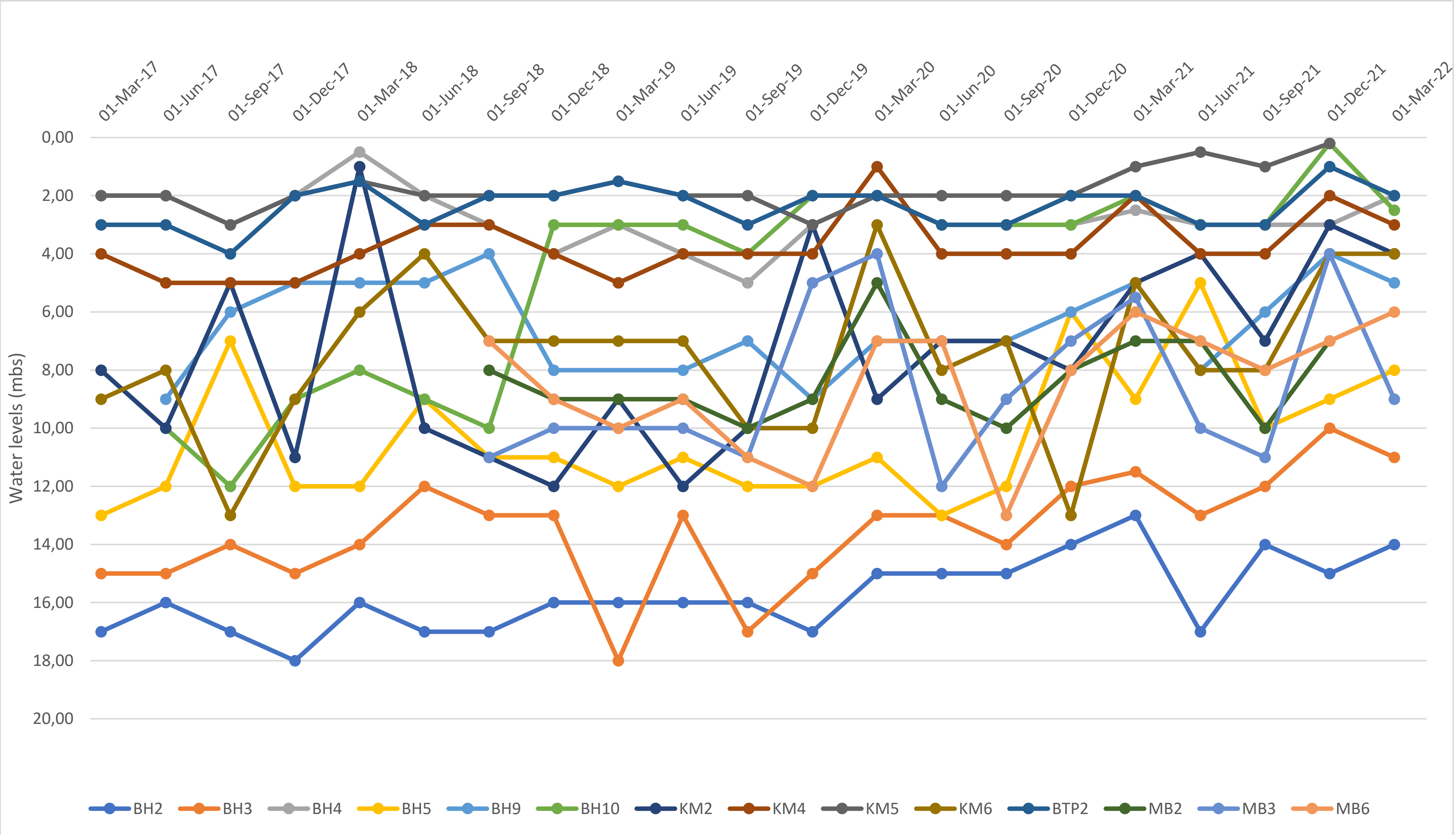


Figure 8: Water Level trends in the IPP Nndanganeni monitoring boreholes from March 2017 to March 2022.

Table 7: Measured groundwater levels for 2017 to 2022 (uKhozi Environmentalists, 2022)

Sample no.	Groundwater Level																								
	Mar 2017	Jun 2017	Sep 2017	Dec 2017	Annual Average (2017)	Mar 2018	Jun 2018	Sep 2018	Dec 2018	Annual Average (2018)	Mar 2019	Jun 2019	Sep 2019	Dec 2019	Annual Average (2019)	Mar 2020	Jun 2020	Sep 2020	Dec 2020	Annual Average (2020)	Mar 2021	Jun 2021	Sep 2021	Dec 2021	Annual Average (2021)	Mar 2022
BH 2	17m	16m	17m	18m	**17m**	16m	17m	17m	16m	**16.5m**	16m	16m	16m	17m	**16.25m**	15m	15m	15m	14m	**14.75m**	13m	17m	14m	15m	**14.75**	14m
BH 3	15m	15m	14m	15m	**14.75m**	14m	12m	13m	13m	**13m**	18m	13m	17m	15m	**15.75m**	13m	13m	14m	12m	**13m**	11.5m	13m	12m	10m	**11.63**	11m
BH 4	2m	2m	3m	2m	**2.25m**	0.5m	2m	3m	4m	**2.37m**	3m	4m	5m	3m	**3.75m**	2m	3m	3m	3m	**2.75m**	2.5m	3m	3m	3m	**2.88**	2m
BH 5	13m	12m	7m	12m	**12m**	12m	9m	11m	11m	**10.75m**	12m	11m	12m	12m	**11.75m**	11m	13m	12m	6m	**10.5m**	9m	5m	10m	9m	**8.25**	8m
BH 9	Not sampled	9m	6m	5m	**6.66m**	5m	5m	4m	8m	**5.5m**	N/A	8m	7m	9m	**8m**	**7m**	**7m**	**7m**	**6m**	**6.75**	5m	8m	6m	4m	**5.75**	5m
BH 10	Not sampled	10m	12m	9m	**10.33m**	8m	9m	10m	3m	**7.5m**	3m	3m	4m	2m	**3m**	**2m**	**3m**	**3m**	**3m**	**2.75**	2m	3m	3m	0.2m	**2.05**	2.5m
KM 2	8m	10m	5m	11m	**8.5m**	1m	10m	11m	12m	**8.5m**	9m	12m	10m	3m	**8.5m**	**9m**	**7m**	**7m**	**8m**	**7.75**	5m	4m	7m	3m	**4.75**	4m
KM 3	Infested by Bees	Infested by Bees	5m	4m	**4.5m**	N/A	3m	4m	N/A	**3.5m**	N/A	Dry	Dry	N/A	**N/A**	N/A	N/A	4m	N/A	**4m**	N/A	4m	Dry	Dry	**4m**	N/A
KM 4	4m	5m	5m	5m	**4.75m**	4m	3m	3m	4m	**3.5m**	5m	4m	4m	4m	**4.25m**	1m	4m	4m	4m	**3.25m**	2m	4m	4m	2m	**3m**	3m
KM 5	2m	2m	3m	2m	**2.25m**	1.5m	2m	2m	2m	**1.87**	1.5m	2m	2m	3m	**2.12m**	2m	2m	2m	2m	**2m**	1m	0.5m	1m	0.2m	**0.68**	Bees
KM 6	9m	8m	13m	9m	**9.75m**	6m	4m	7m	7m	**6m**	7m	7m	10m	10m	**8.5m**	3m	8m	7m	13m	**7.75m**	5m	8m	8m	4m	**6.25**	4m
BTP2	3m	3m	4m	2m	**3m**	1.5m	3m	2m	2m	**2.12**	1.5m	2m	3m	2m	**2.12m**	2m	3m	3m	2m	**2.5m**	2m	3m	3m	1m	**2.25**	2m
BTP3	Taken from tap	Taken from tap	Taken from tap	Taken from tap	**N/A**	Taken from tap	Taken from tap	Taken from tap	Taken from tap	**N/A**	Taken from tap	Taken from tap	Taken from tap	Taken from tap	**N/A**	Taken from tap	Taken from tap	Taken from tap	Taken from tap	**N/A**	N/A (Taken from tap)	N/A (Taken from tap)	N/A (Taken from tap)	N/A (Taken from tap)	**N/A (Taken from tap)**	N/A (Taken from tap)
MB 2	**Sampling started in March 2018**							8m	9m	**8.5m**	9m	9m	10m	9m	**9.25m**	5m	9m	10m	8m	**8m**	7m	7m	10m	7m	**7.75**	Bees
MB 3								11m	10m	**10.5m**	10m	10m	11m	5m	**9m**	4m	12m	9m	7m	**8m**	5.5m	10m	11m	4m	**7.63**	9m
MB 6								7m	9m	**8m**	10m	9m	11M	12m	**10.50**	7m	7m	13m	8m	**8.75**	6m	7m	8m	7m	**7m**	6m

5.4 Groundwater Potential Contaminants

Acid generation is a common response to the coal mining environment. Coal and carbonaceous material contain a mineral known as pyrite, an iron-sulphide mineral, which is the main contributor to acid rock drainage (ARD). After being exposed to oxygen and water the sulphide minerals react to form an acid. Bacteria, which increase with exposure to water and oxygen often accelerates the acidification process. The reaction can however also occur abiotically.

The general equation of pyrite oxidation is as follows:

$$2FeS_2 + 7O_2 + 2H_2O \rightarrow 2Fe^{2+} + 4SO_4^{2-} + 4H^+$$

Ferrous iron is oxidised to ferric iron:

$$4Fe^{2+} + O_2 + 4H^+ \rightarrow 4Fe^{3+} + 2H_2O$$

As mentioned previously these two reactions can occur abiotically or with the catalisation by micro-organisms. These organisms arise from the oxidation reactions. The ferric cations reduce to ferrous ions:

$$FeS_2 + 14Fe^{3+} + 8H_2O \rightarrow 15Fe^{2+} + 2SO_4^{2-} + 16H^+$$

The release of H+ lowers the pH. At the lower pH the solubility of the ferric ion continuous which increases the acid generation.

5.4.1 Acid Generation Capacity

ABA tests were not conducted in 2015 by GCS. A total of 23 samples were collected for geochemical testing which included discard, tailings, coal and waste rock. The following conclusions have been made in terms of acid mine drainage from the tests results:

- The degree to which AMD will occur in the Hartoghof pit will depend on the amount of pyrite present with respect to carbonate minerals. Waste rock does not have significant potential to generate acid mine drainage but also does not have significant potential to neutralise acid drainage. Acid-mine drainage will occur in parts (hotspots) in the backfill;
- According to the ABA test results the discard has some potential to generate acid mine drainage. Paste pH tests show that most of the discard is already acidic which explains the formation of jarosite in the one discard sample; and
- According to the NAG test results the tailings has no potential to generate acid mine drainage but saline drainage will still occur from the tailings because of the high pyrite content.

5.4.2 Waste Classification

A waste classification should be conducted in accordance with the National Environmental Management: Waste Act (NEM: WA) Regulations (2013). The assessment is undertaken by comparing the samples' leachate concentration (LC) to the leachable concentration threshold (LCT), and the total concentration (TC) to the total concentration thresholds (TCT). The results will indicate the type of waste and the type of liner, if any, required for the potential source.

Table 8: Waste Classification Criteria

Waste Type	Disposal
0	Not allowed
1	Class A or Hh:HH landfill
2	Class B or GLB+ landfill
3	Class C or GLB- landfill
4	Class D or GLB- landfill

A waste classification was not conducted for the proposed Nndaganeni mining area. Generally, the results below are expected for the coal mining environment. Please note that these are only indicative and may differ from site to site.

Coal material:

- The coal samples are generally classed as Type 3 waste and according to the NEM: WA guidelines should be Figure 9; and
- The short-term storage of the coal material on stockpiles and good storm water management should ensure that environmental impacts are kept to a minimum and contained to the stockpile sites. Based on these management protocols the liner illustrated in Figure 9 should be sufficient, however, the decision lies with the Department of Environmental Affairs.

Overburden material:

- Overburden is generally also classed as Type 3 waste and should be disposed of at Class C landfill sites or sites designed with liner requirements illustrated in Figure 9.

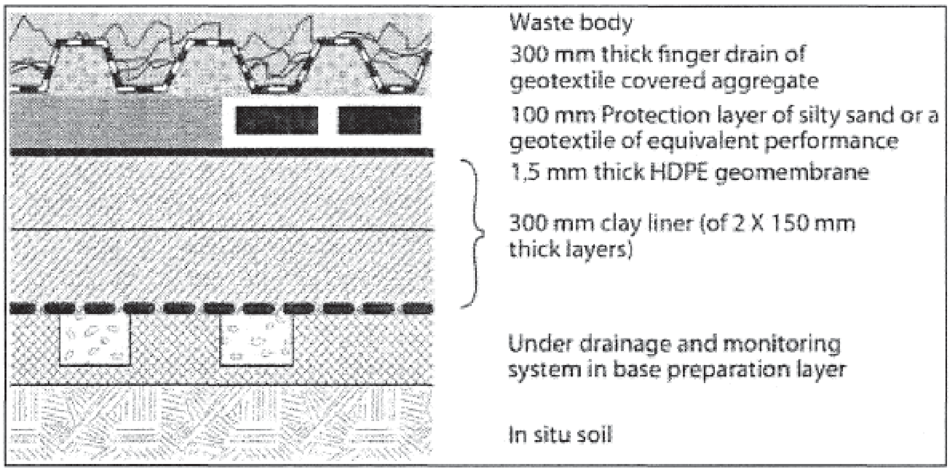


Figure 9: Class C landfill site liner requirements.

5.5 Groundwater Quality

Geochemical information was available from June 2018 to June 2022 for the monitoring boreholes at IPP Nndanganeni. The trends of Sulphate, TDS and pH over the period from 2018 and 2022 have been presented in Figure 10, Figure 11 and Figure 12.

Significant increasing sulphate concentration trends have been observed in BH2, BH3 and KM6 over the monitoring period. Increases over this period has also been observed in KM2. The increasing sulphate concentrations is evident of increasing impacts from the coal mining activities. In BH4 the sulphate concentrations have decreased from 1 830 mg/l in June 2021 to 1 070 mg/l in March 2022. Continuous monitoring will indicate whether this decrease will continue.

Acid generation is a common response to the coal mining environment. Coal and carbonaceous material contain a mineral known as pyrite, an iron-sulphide mineral, which is the main contributor to acid rock drainage (ARD). After being exposed to oxygen and water the sulphide minerals react to form an acid bacteria, which increases with the exposure to water and oxygen often accelerating the acidification process. The reaction can however also occur abiotically.

The general equation of pyrite oxidation is as follows:

$$2FeS_2 + 7O_2 + 2H_2O \rightarrow 2Fe^{2+} + 4SO_4^{2-} + 4H^+$$

Ferrous iron is oxidised to ferric iron:

$$4Fe^{2+} + O_2 + 4H^+ \rightarrow 4Fe^{3+} + 2H_2O$$

As mentioned previously these two reactions can occur abiotically or with the catalisation by micro-organisms. These organisms arise from the oxidation reactions. The ferric cations reduce to ferrous ions:

$$FeS_2 + 14Fe^{3+} + 8H_2O \rightarrow 15Fe^{2+} + 2SO_4^{2-} + 16H^+$$

The release of H+ lowers the pH. At the lower pH, the solubility of the ferric ion continuous, which increases the acid generation.

The pH in KM2 indicated a fluctuating concentration trend with pH in March 2020, March 2021 and September 2021 below the permissible SANS241:2915 limits. The pH in MB2 was also acidic at 4.7 and below the permissible SANS limits in December 2020.

The geochemistry for 2022 was discussed in detail in the Groundwater Monitoring Report by uKhosi Environmentalists in June 2022. The following summary have been extracted from the March 2022 report.

- The following was observed after assessing the water quality of the groundwater samples taken around the Nndanganeni Colliery Kopermyn, Nndanganeni Colliery Hartogshof Extension (NCHE):
    - The pH level of BTP3 exceeds the SANS Limits.
    - The manganese concentration of BH 2, BH 4 and KM 4 exceed the SANS Limits.
    - The sulphate concentration of BH 2, BH 3 and BH 4 exceed the SANS Limits.
    - The TDS concentration of BH 2, BH 3 and BH 4 exceed the SANS Limits.
    - BH10, KM2, KM4, BTP 3, MB3 and MB6 display corrosive characteristics.
    - BH3 and BH4 display scaling characteristics.

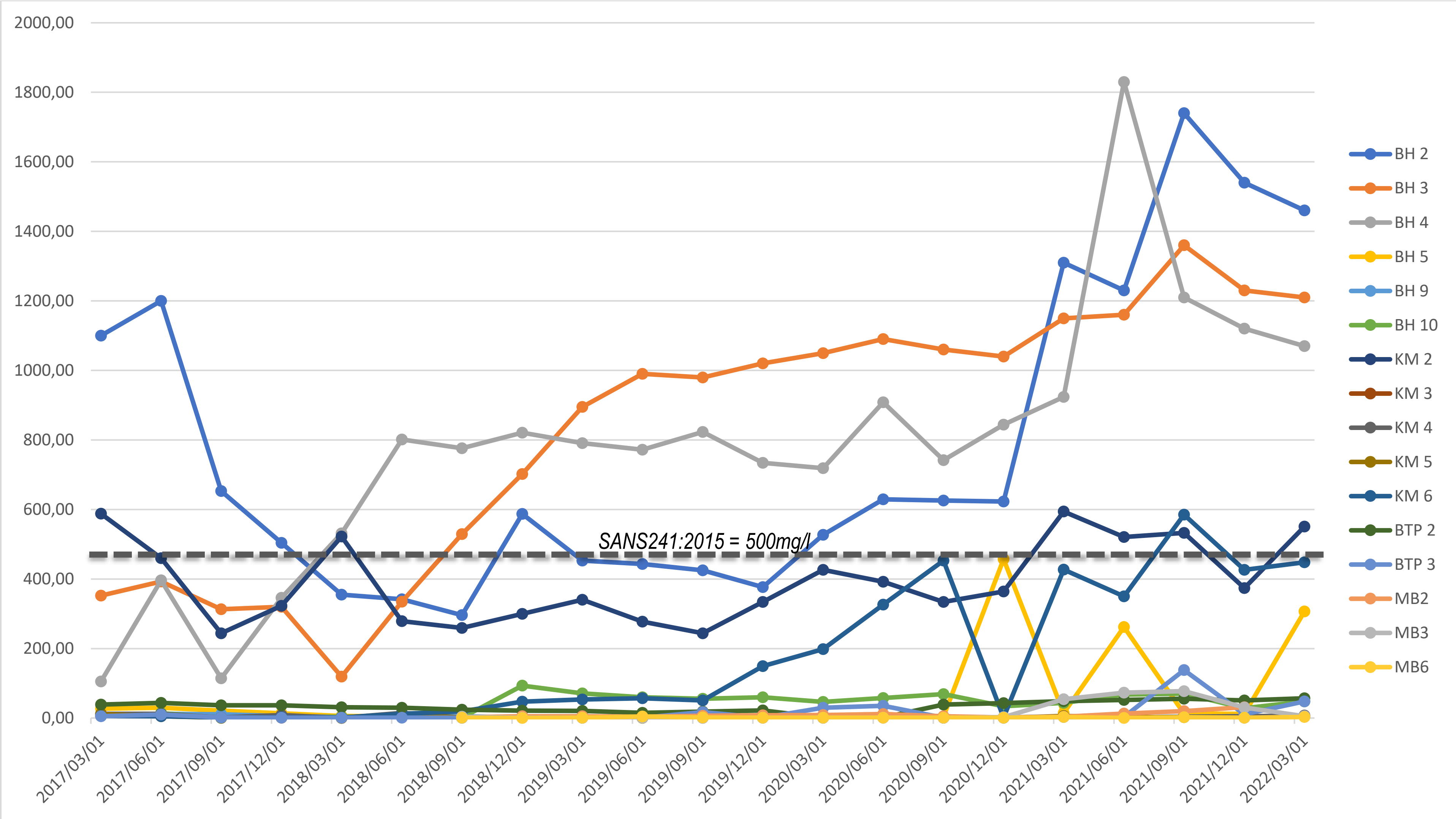


Figure 10: Sulphate concentration trends from 2018 to 2022 at IPP Nndanganeni Coal.

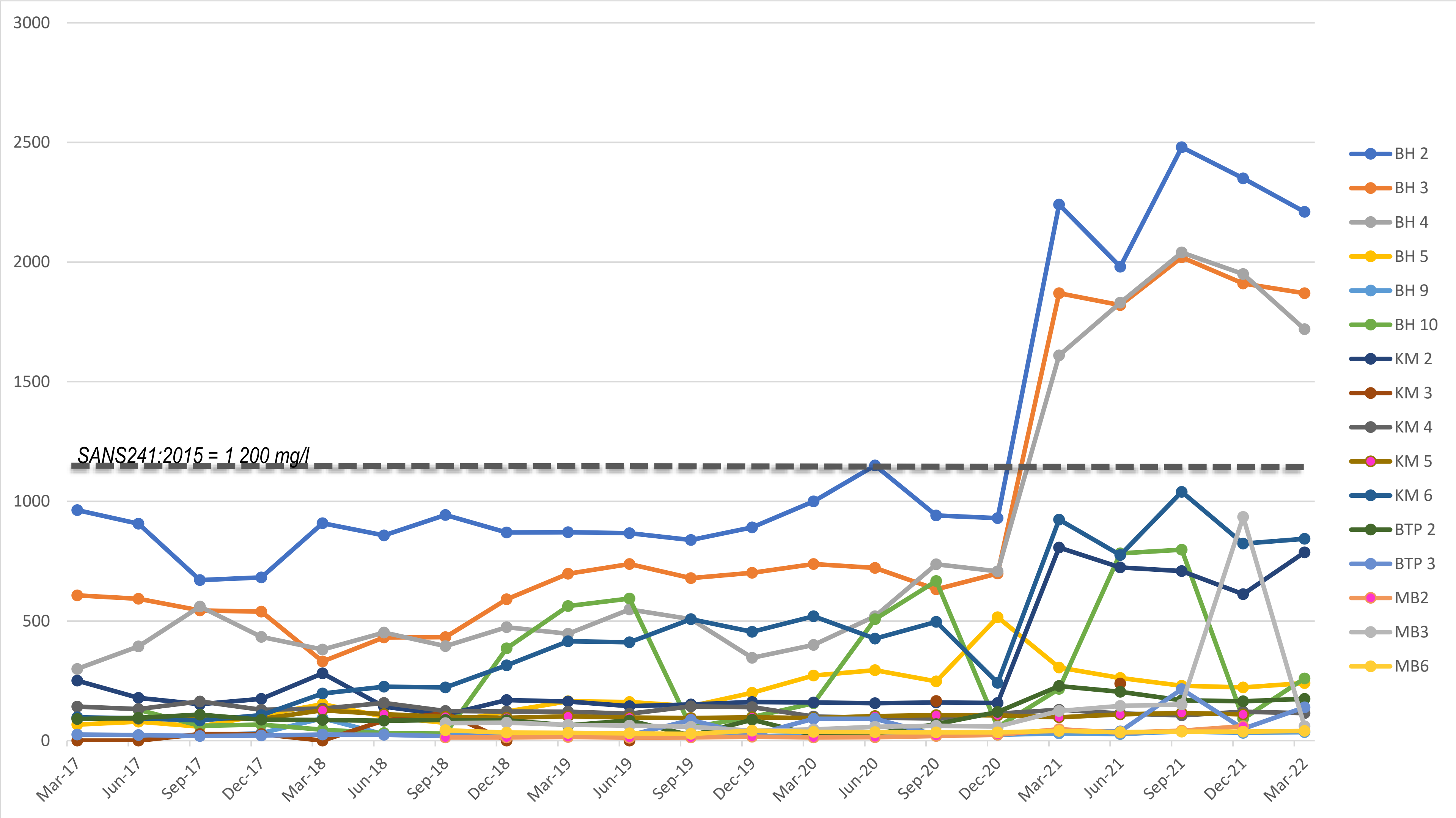


Figure 11: TDS concentration trends from 2018 to 2022 at IPP Nndanganeni Coal.

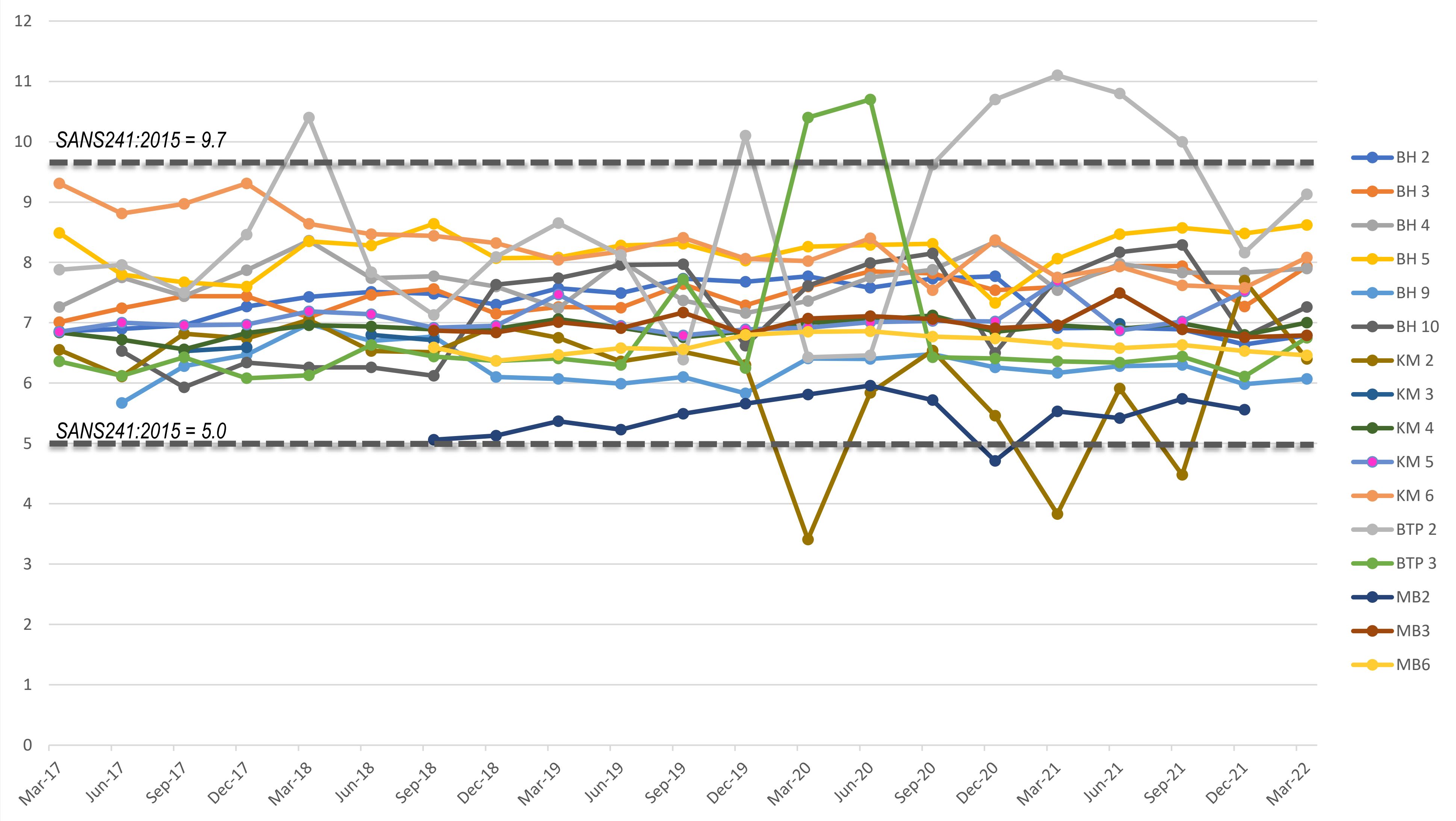


Figure 12: pH trends from 2018 to 2022 at IPP Nndanganeni Coal.

6. AQUIFER CHARACTERISTICS

6.1 Groundwater Vulnerability

Groundwater vulnerability refers to the likelihood for contamination to reach a certain area/receptor after it has been introduced to the surface. For the proposed Nndaganeni area the vulnerability was estimated from the Aquifer Vulnerability map of South Africa (DWA, 2013) and by the Groundwater Vulnerability Classification System. According to the Aquifer Vulnerability map the Nndaganeni area is located in a moderate vulnerability rating area. Therefore, an area that if continuously exposed to contamination may be vulnerable to some pollutants.

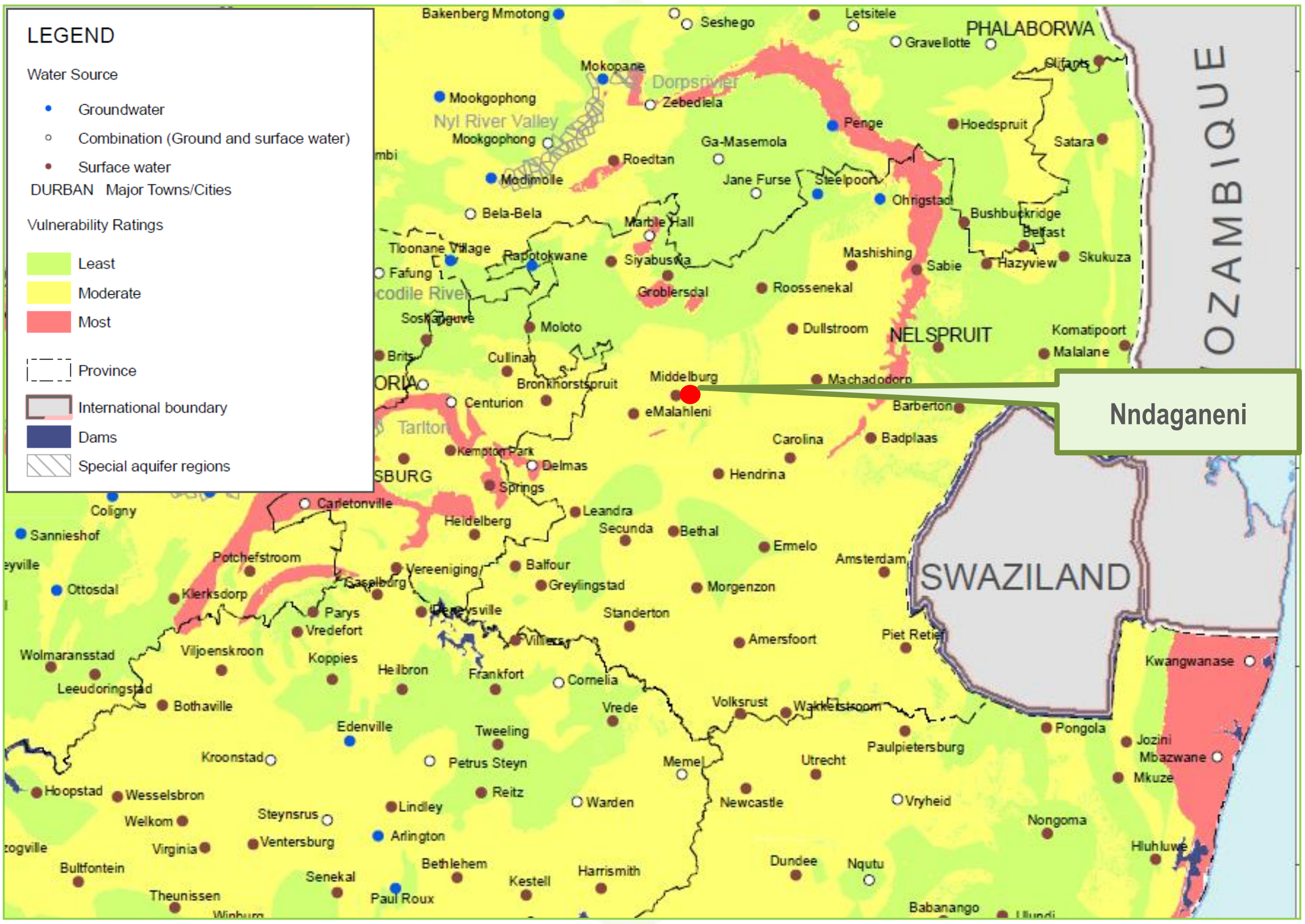


Figure 13: Aquifer vulnerability rating of the proposed Nndaganeni area (DWA, 2013)

The Groundwater Vulnerability Classification System incorporates the Parsons Aquifer Classification System (Section 6.2) and the drinking water guidelines from the Department of Water Affairs and Forestry.

Table 9: Groundwater Vulnerability Classification System

Rating	Depth to Water Level	Groundwater Quality	Aquifer Type- Parsons
1	> 10 m	Poor (TDS > 2 400 mg/l)	Non-Aquifer System
2	6 – 10 m	Marginal (TDS > 1 000 < 2 400 mg/l)	Minor Aquifer System
3	3 – 6 m	Good (TDS > 450 < 1 000 mg/l)	Major Aquifer System
4	0 – 3 m	Excellent (TDS < 450 mg/l)	Sole Aquifer System

Table 10: Groundwater Vulnerability Rating

Rating	Vulnerability
≤ 4	Low
> 4 ≤ 8	Medium
≥ 9	High

Table 11: Groundwater Vulnerability for Nndaganeni area.

Rating	
Depth to water level	3
Groundwater quality	2
Aquifer Type	2
Total Score	**7**

According to the Groundwater Vulnerability Classification System, the Nndaganeni aquifer scored a rating of 7 which is indicative of a medium vulnerable aquifer.

6.2 Aquifer Classification

According to the Aquifer Classification map (DWA, 2012), the Nndaganeni area is situated in a minor aquifer classification area. Aquifer classification is based on the Parsons System (1995). Qualities in these aquifers can vary and are typically moderately yielding aquifers.

Table 12: Aquifer System Management Classes.

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

Two main aquifer systems exist in the Nndaganeni area. Firstly, is a swallow, weathered aquifer which is found in the transitional soil and weathered bedrock zone. Due to direct recharge and dynamic groundwater flow through the weathered sediments, the natural groundwater qualities are often good. The direct recharge and dynamic groundwater flow are also the reason why this aquifer is vulnerable to pollution. Water levels in this aquifer are often shallow (few meters below ground level) and follow the surface topography.

Secondly is a deeper semi-confined to confined fractured aquifer where groundwater flow is predominantly fractured flow. The fractured Karoo aquifer consists of sedimentary successions of siltstone, shale, sandstone, and coal seams. Groundwater flow is dominated by secondary porosities like faults, fractures, joints, bedding planes, or other geological contacts. Yields can be higher in this aquifer along with these geological structures. The rock matrix is characterised by low permeability. Borehole yields in the Ecca aquifers are generally low and can be expected to be less than 2 l/s.

6.3 Aquifer Protection Classification

As part of policy and regulation development and implementation, the aquifer classification used in **Table 12** alone is not sufficient. To minimise misinterpretation, the decision support tool in **Table 13** also needs to be incorporated as part of aquifer classification (Parsons, 1995). The combination of the Aquifer System Management Classification and the Aquifer Vulnerability Classification rating is referred to as the Groundwater Quality Management (GQM) classification, which provides a level of aquifer protection.

GQM = Aquifer System Management x Aquifer Vulnerability

Table 13: GQM Classification for the Nndaganeni Area.

Aquifer System Management Classification		Aquifer Vulnerability Classification		GQM		GQM
Class	**Points**	**Class**	**Points**	**Index**	**Level of protection**	**Nndaganeni**
Sole Source Aquifer System	6	High	3	<1	Limited	
Major Aquifer System	4			1 - 3	Low	
Minor Aquifer System	2	Medium	2	3 - 6	Medium	4
Non-aquifer System	0			6 - 10	High	
Special Aquifer System	0-6	Low	1	>10	Strictly non-degradation	

The level of protection for the Nndaganeni according to the GQM Index is 4. This indicates a medium level of protection. Based on the findings of the geohydrological study it is very important that a monitoring protocol should be in place for the proposed project area.

The DWS (previously DWA – Department of Water Affairs) has also compiled a susceptibility map for South Africa (2013). This map indicates the qualitative measure of the relative ease with which an aquifer can potentially be contaminated. According to the aquifer susceptibility map, the Nndaganeni area is also classified as medium susceptible to contamination.

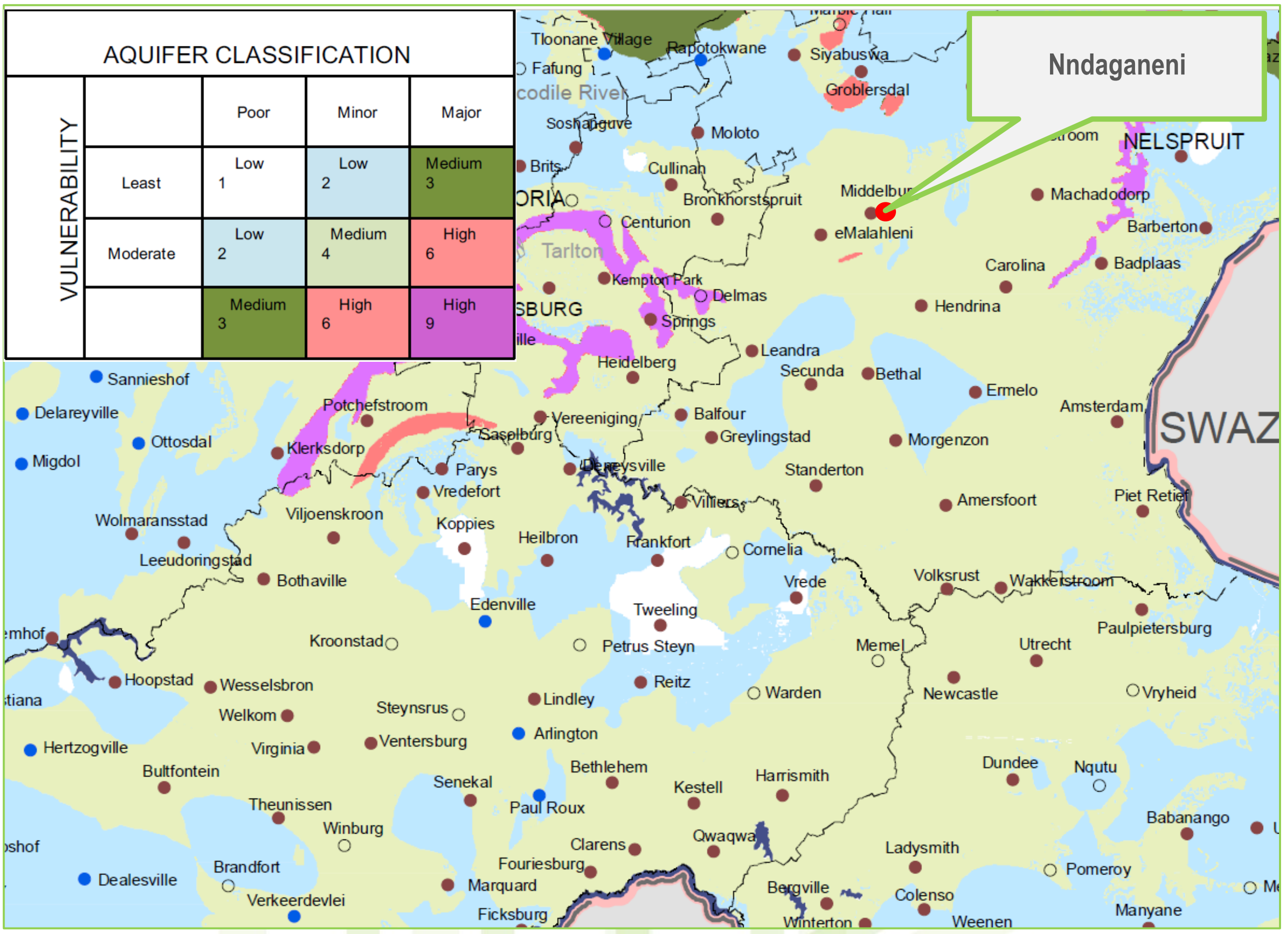


Figure 14: Aquifer susceptibility map for the Nndaganeni mining area.

7. GROUNDWATER MODELLING

7.1 Software Model Choice

The Processing Modflow 8 (PMWIN) modelling package was used for the numerical flow and mass transport simulations. PMWIN is a finite-difference modelling package where the domain is broken up into blocks or rectangular cells where the finite difference analog of the partial differential equation for flow is applied to a node within a cell.

7.2 Model Set-up and Boundaries

The numerical model grid indicating the model boundaries are presented in Figure 15. The model dimensions used for the IPP Nndanganeni numerical groundwater model is summarised in Table 14.

The following model boundaries have been used in the IPP Nndanganeni numerical model:

- No-flow boundaries: These are typically the topographical high or low regions in the model area. As the name suggests no groundwater flow occurs over these boundaries. These boundaries are found at the edge between the active and inactive cells in the model.
- River nodes were used in the northern, western and southern region of the model and act as constant head boundaries. The river node will add or remove water from the aquifer as the water level increases or decreases. The water level at the river nodes therefore remain relatively constant.

Table 14: Model extent and aquifer parameters.

Model Grid Size	Easting = 17 740 Northing = 11 240
Rows	562
Columns	887
Cell Size	20 x 20 m
Layer Thickness	Layer 1 = 15 m Layer 2 = 200 m
Layers	Layer 1 = Confined / Unconfined Layer 2 = Confined
Transmissivity	Shallow weathered aquifer = 1.5 m^2/day Deep, secondary aquifer = 0.2 m^2/day
Recharge	1.4%

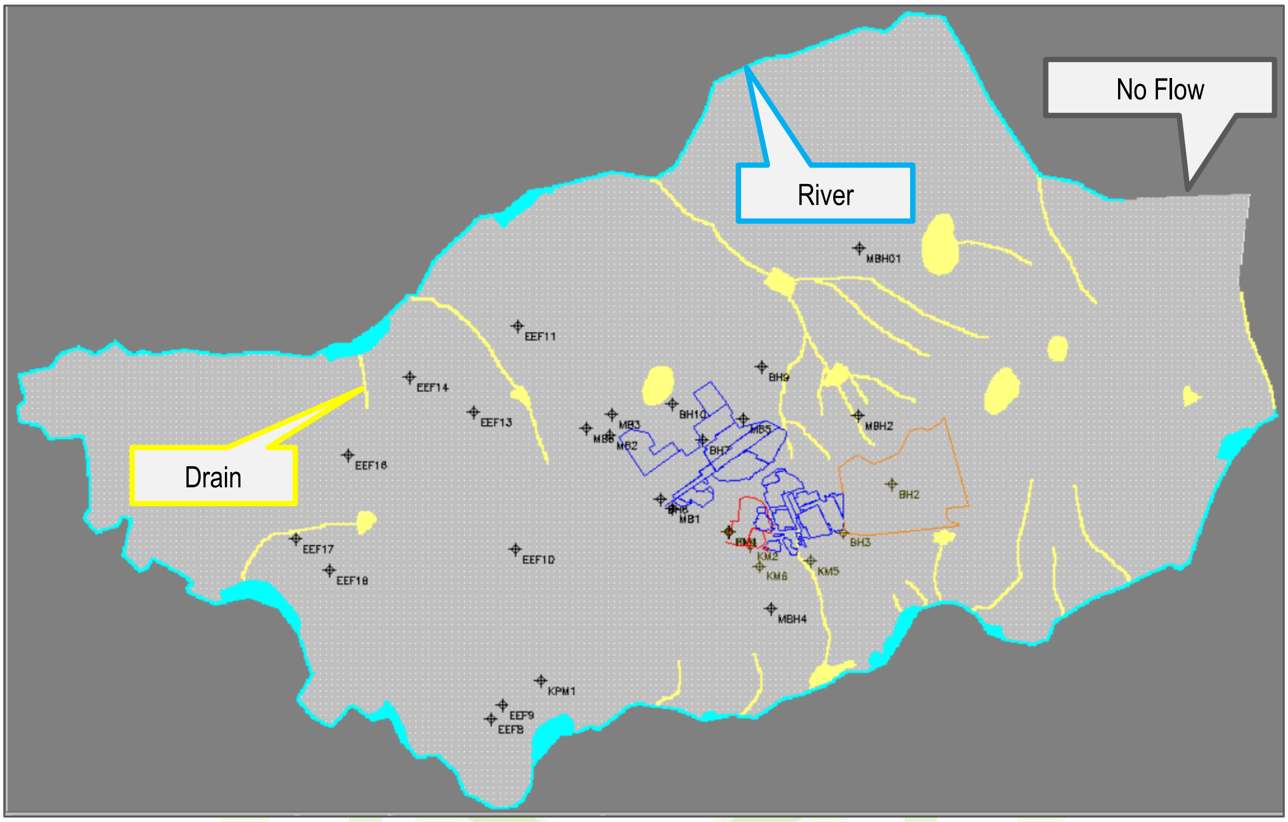


Figure 15: IPP Nndanganeni model domain and boundaries.

7.3 Groundwater Elevation and Gradient

Steady state flow model calibration involves the varying of aquifer parameters in the model until the observed water levels correlates well with the measured water levels. The measured water levels must represent the levels prior to any impacts from mining activities. Steady state water levels therefore represent "reality" prior to changes caused by mining activities.

Water level elevations used for steady state model calibration was obtained from hydrocensus information as well as some mine monitoring borehole information (GPT, 2017). Only water level information for the shallow aquifer was available for model calibration.

By adjusting the aquifer parameters in the model to the values indicated in Table 14, a very good correlation of 96% were obtained (Figure 16).

The IPP Nndanganeni mining area is situated on a groundwater divide area. Groundwater from the area will flow towards the north-north-west, and south- south-west. Groundwater within the IPP Nndanganeni model area decrease from approximately 1 635 mamsl (on highest elevation in mining area) to 1 580 mamsl in both the flow directions. Groundwater gradients over the area is approximately 1.3% (north-north-west) and 1.8% south-south-west.

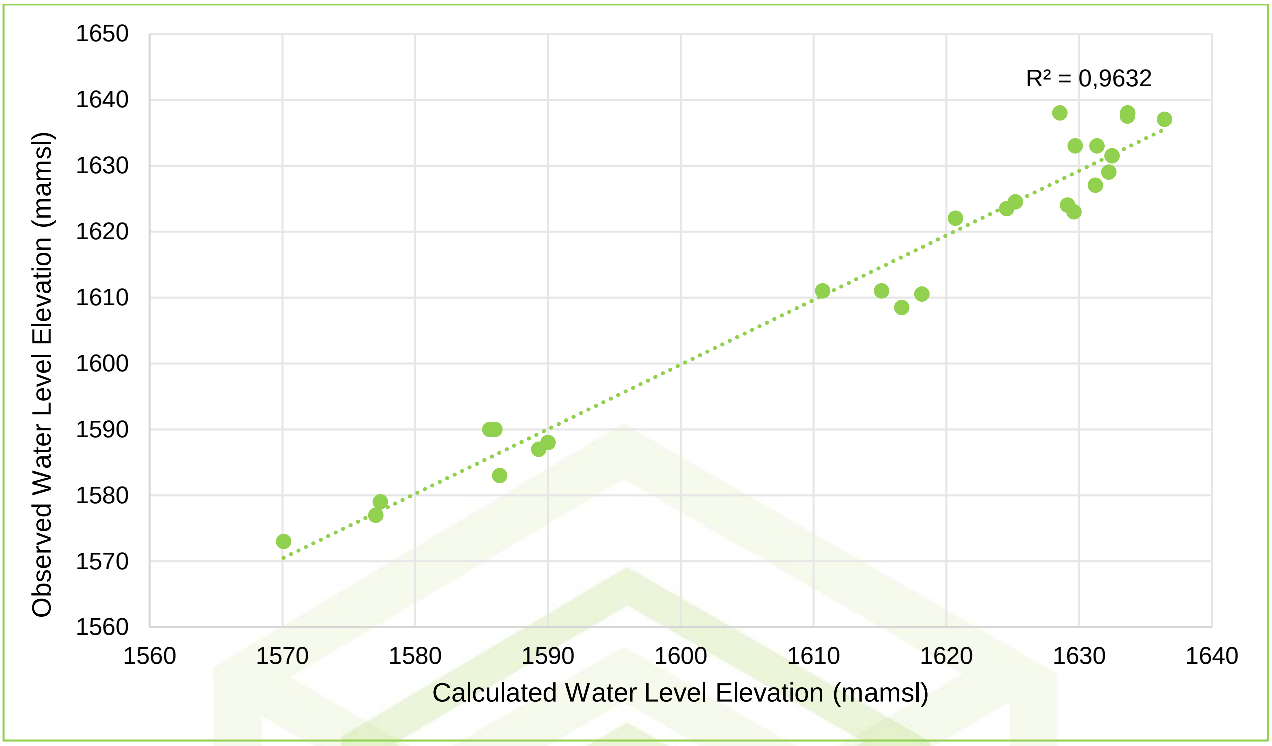


Figure 16: Model calculated water level elevations vs observed water level elevations correlation.

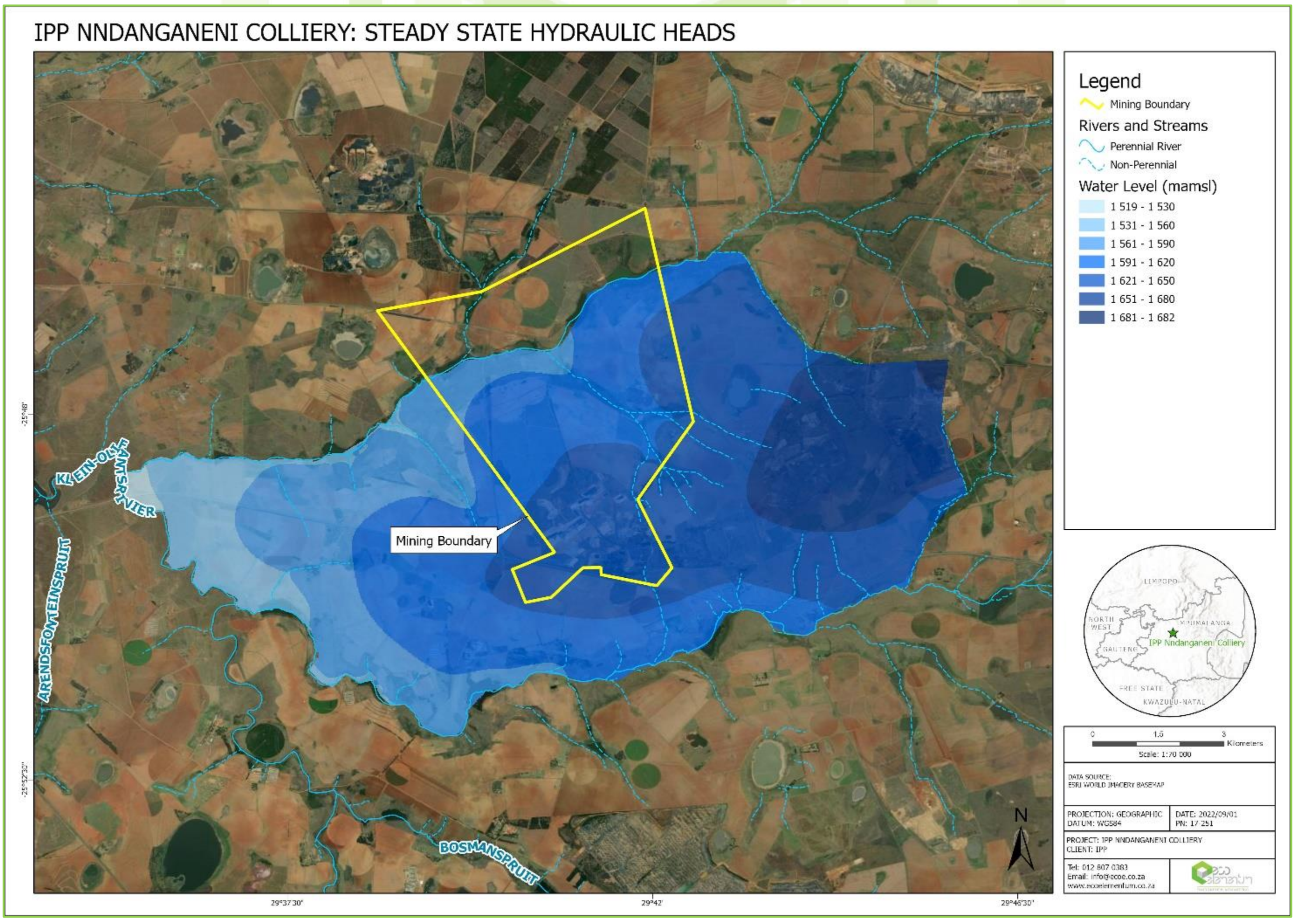


Figure 17: Steady state water level elevation contours.

7.4 Geometric Structure of the Model

Table 14 in Section 7.2 summarises the geometric set-up of the model. The model grid simulates an area of almost 200 km² (17.7 km E and 11.2 km N). The grid cells are squares with a dimension of 20 x20 m. The model grid therefore consists off 498 494 cells.

Two layers were simulated in the model. Layer 1 represents the shallow, weathered aquifer and was assigned a thickness of 15 m. The deep, secondary aquifer were simulated with Layer 2 with a thickness of 200 m.

7.5 Groundwater Sources and Sinks

Groundwater sources and sinks are features that either add (source) or remove (sink) water from the aquifer. During the steady state model calibration river nodes representing the streams to the northern, eastern and southern boundary of the model can act as either a sink or a source. Drain nodes were used to represent less prominent streams, which is not perennial and therefore mostly act as a sink.

Recharge also act as a source since it contributes to the water make in the model. A recharge of 1.4% were used for the IPP Nndanganeni model area.

During the transient model simulations, the different activities of the mine will act as sources and sinks. Sources will typically include PCD's, return water dams and other "wet" sources that add to the water make of the model (artificial recharge). The opencast mining operations will act as groundwater sinks, since groundwater flow will be towards the pits / voids due to dewatering and therefore remove water from the model.

7.6 Conceptual Model

A conceptual model involves the construction of a simplified version of the real world. All the geohydrological information gathered by different means including during the hydrocensus, aquifer tests, chemical analysis etc. are used to construct this simplified model. The conceptual model forms the basis of the numerical model and aids in understanding the geohydrological characteristics of the model area. The conceptual model was mainly summarised from the study compile for IPP Nndanganeni by GPT in 2017.

The basis of the conceptual model can be summarised as follows:

- The IPP Nndanganeni mining area is located in the highveld region of Mpumalanga and in a summer rainfall region;
- The mean annual precipitation is ± 680 mm/annum, while the evaporation is estimated at 1 797 mm/annum;
- The recharge can be up to 3 to 5% of the mean annual precipitation;
- The IPP Nndanganeni mining area is situated on a groundwater divide area. Groundwater from the area will flow towards the north-west and west;
- A large portion of the project site is covered with unconsolidated sediments. The encountered lithology's were generally similar in each hydrogeological exploration hole consisting of:
    - Weathered sandstone and / or shale – weathering is relatively shallow ranging between ~1 m (bgl) and ~6 m (bgl);
    - Coal seam – coal seams interlayered with sandstone, shale and siltstone of various thickness;
    - Interlayered Sandstone and Shale – fresh sandstone and shale; and
    - In addition to the above, rhyolite was also encountered in some boreholes.
- Geological structures such as dykes and faults are known to exist in the region of the IPP Nndanganeni mining area. These structures and the weathered zone are possible pathways of elevated groundwater flow and contamination migration;

- Two main aquifer systems are found in the IPP Nndanganeni mining region. Firstly, the shallow weathered aquifer and secondly, the deeper, secondary aquifer;
- Water levels in the monitoring and hydrocensus boreholes varied between 0.2 and 17 mbs.
- The cone of depression due to dewatering is not expected to extent more 450 400 m from the pit areas;
- Significantly elevated sulphate concentrations have been observed in BH2, BH3, BH4, KM2 and KM6 over the 2022 monitoring period. Increasing trends over this period has also been observed in these boreholes. The increasing sulphate concentrations in evident of increasing impacts from the coal mining activities;
- The following was observed after assessing the water quality of the groundwater samples taken around the Nndanganeni Colliery Kopermyn, Nndanganeni Colliery Hartogshof Extension (NCHE):
  - The pH level of BTP3 exceeds the SANS Limits.
  - The manganese concentration of BH 2, BH 4 and KM 4 exceed the SANS Limits.
  - The sulphate concentration of BH 2, BH 3 and BH 4 exceed the SANS Limits.
  - The TDS concentration of BH 2, BH 3 and BH 4 exceed the SANS Limits.
  - BH10, KM2, KM4, BTP 3, MB3 and MB6 display corrosive characteristics.
  - BH3 and BH4 display scaling characteristics.

For the risk of groundwater impacts to occur three factors should be present:

- Source – Generates and emits contamination.
  - The area at which a groundwater contaminant is released as seepage or leachate.
  - Point source can be traced to the exact location of the source. Can include PCDs, Discard dumps, Tailings Facilities, etc.
  - Diffuse source's origin is unknown.
- Pathway – the path along which the contaminant is transported.
  - For a contaminant to reach a receptor it has to move along a pathway. Aquifer characteristics such as hydraulic conductivity, and hydraulic gradient play an important role. Contamination will flow faster in the weathered zone aquifer and along the fractures and fissures in the secondary aquifer.
- Receptor – Receives the contamination.

Groundwater Sources:

- Recharge:

- Natural recharge: in the region of the proposed project the natural recharge is estimated between 1 and 3% of the MAP. Rivers and drainage systems can also be seen as potential recharge sources. Gaining or losing streams play a role here. Losing streams "lose" their water to the aquifer, making it a natural recharge source.

- Contamination Sources: At the proposed Mining the potential contamination sources include the opencast pit itself and the ROM pad.

Groundwater pathways:

- Fault zones and dykes surrounding the proposed project area may be potential pathways for groundwater contamination migration. No site-specific geological structures were recorded during the geophysical survey. Where these features are present contamination may flow further in a shorter period of time.
- The weathered zone aquifer is a major pathway for contamination transport. The aquifer parameters in this aquifer allow for greater mass transport rates.

Groundwater receptors:

- River Systems: any contamination from potential sources may be discharged in terms of baseflow into the receiving river or surface water systems in the area. The Northern pan is located 100 m from the Nndaganeni pit and is expected to be impacted on in terms of the Nndaganeni Mining activities.
- Potential groundwater users: In the area of the proposed mining operation's impact zone no known groundwater users exist. The impact zone may increase if pathways such as geological structures are present, and the activities may also impact the groundwater users within this increased impact zone.

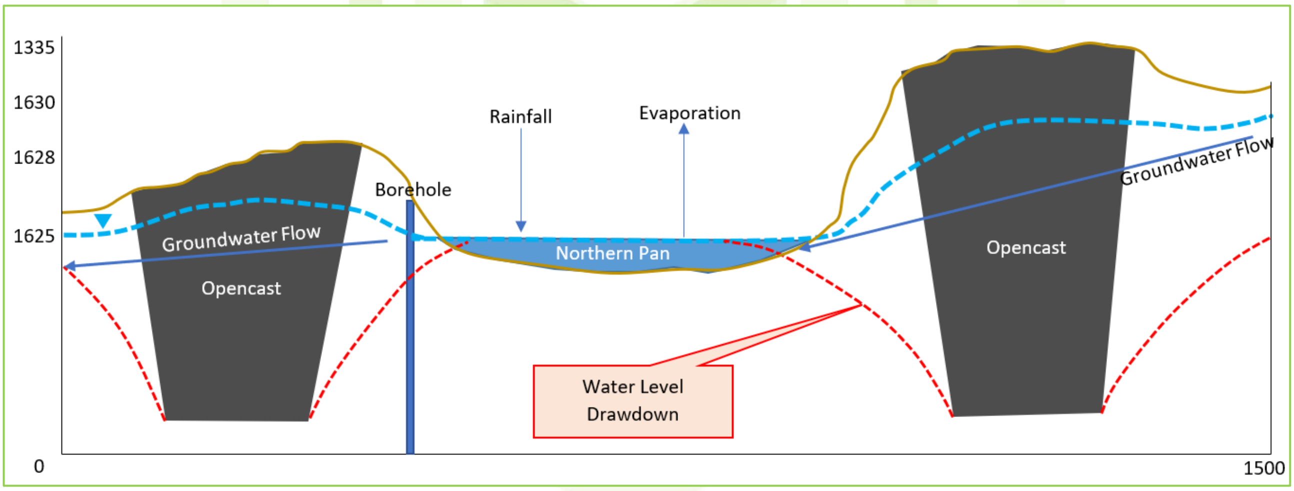


Figure 18: Conceptual model of the Nndaganeni mining operation indicating impacts on the Northern pan- West to East cross section.

7.7 Numerical Model

The numerical groundwater model is used to represent both the flow and contamination/pollution migration of the groundwater regime. The numerical model consists of:

1. Groundwater Flow model; and
2. Mass Transport Model.

7.7.1 Groundwater Flow Model

After the steady state calibration have been obtained (Section 3.3), the model is set-up for transient state simulations. The boundaries, mesh size, layer type, top and bottom of the layers and aquifer transmissivity of the model remain as defined in the steady state model. The transient state model consists of several stress periods which represents different time frames of the mining activities. The groundwater flow and mass transport conditions remain the same during a stress period. Sources and sinks can change between stress periods but not within a stress period. The groundwater low model for the IPP Ndnganeni mining area consist of 11 stress periods.

Table 15: The groundwater low model for the IPP Ndnganeni mining area

Stress Period	Duration (Years)	Description
1 - 2	1 year each	Simulates the historic opencast mining and mining during 2012.
3	3 years	Simulates the opencast mining from 2014 to 2016 in addition to potential pollution sources.
4 - 10	1 year each	Simulates opencast mining from 2017 up to 2022.
11	1 Year	Simulates the mining up to the end of the operational phase.

7.7.2 Mass Transport Model

The mass transport model is used to simulate contamination migration in the aquifer. The main contaminant and a major concern in the coal mining environment is sulphate. Sulphate contamination was simulated for the IPP Ndnganeni mining area. Available monitoring information from IPP Ndnganeni monitoring program was used to mimic the current sulphate contamination at the mine. The boreholes mostly affected is situated in rehabilitated mining areas (KM6, BH2 and BH3) and downgradient of the plant area (KM2, BH4 and KM5).

No life of mine and coal floor contour information for the southern rehabilitated opencast pit was available at the time of this study. Boreholes KM6, BH5 and KM4 are situated in this area. Sulphate concentrations in these boreholes indicate impacts from this rehabilitated opencast area.

Table 16: Average observed sulphate concentrations in 2022 versus model calibrated concentrations (mg/l).

Borehole	Model Calculated SO_4 (mg/l)	2022 Observed SO_4 (mg/l)
BH2	1458	1460
BH3	1233	1210
BH4	1077	1070
BH5	312	307
KM2	542	551
KM6	454	448

7.8 Results of the Model

7.8.1 Pre-facility

The pre-facility or steady-state water level elevations were discussed in Section 7.3 of this document. These elevations represent the conditions before any impacts from the Nndaganeni activities.

7.8.2 During Facility

The main aim of this geohydrological report is to investigate the expected impacts of the planned activities at Nndaganeni. The following activities are planned to take place at the Nndaganeni area and were also simulated in the model:

1. Opencast Pit.

The client provided information on the pit floor elevation which varied between 1 608 to 1 615 mamsl. The Life of Mine period is also simulated at 8 years.

Table 17 represents the total estimated groundwater inflow to the opencast mining void during mining. The total inflows are estimated to range between 20 and 160 m^3/day during the life of mining. The estimated groundwater inflows to the pit are presented in **Table 17**.

Table 17: Estimated groundwater inflows over the mining period (m^3/day).

Period	Estimated Average Groundwater Inflows (m^3/day)
Year 1	160
Year 2	70
Year 3	80
Year 4	100
Year 5	100
Year 6	30
Year 7	20
Year 8	20

The simulated maximum drawdown cone in the shallow aquifer as a result of the opencast mining activities is presented in **Figure 19**. The maximum extent of the drawdown cone is not expected to exceed 450 m from the opencast boundaries. The maximum depth of drawdown to the opencast is expected to be less than 11 meters towards the eastern boundary.

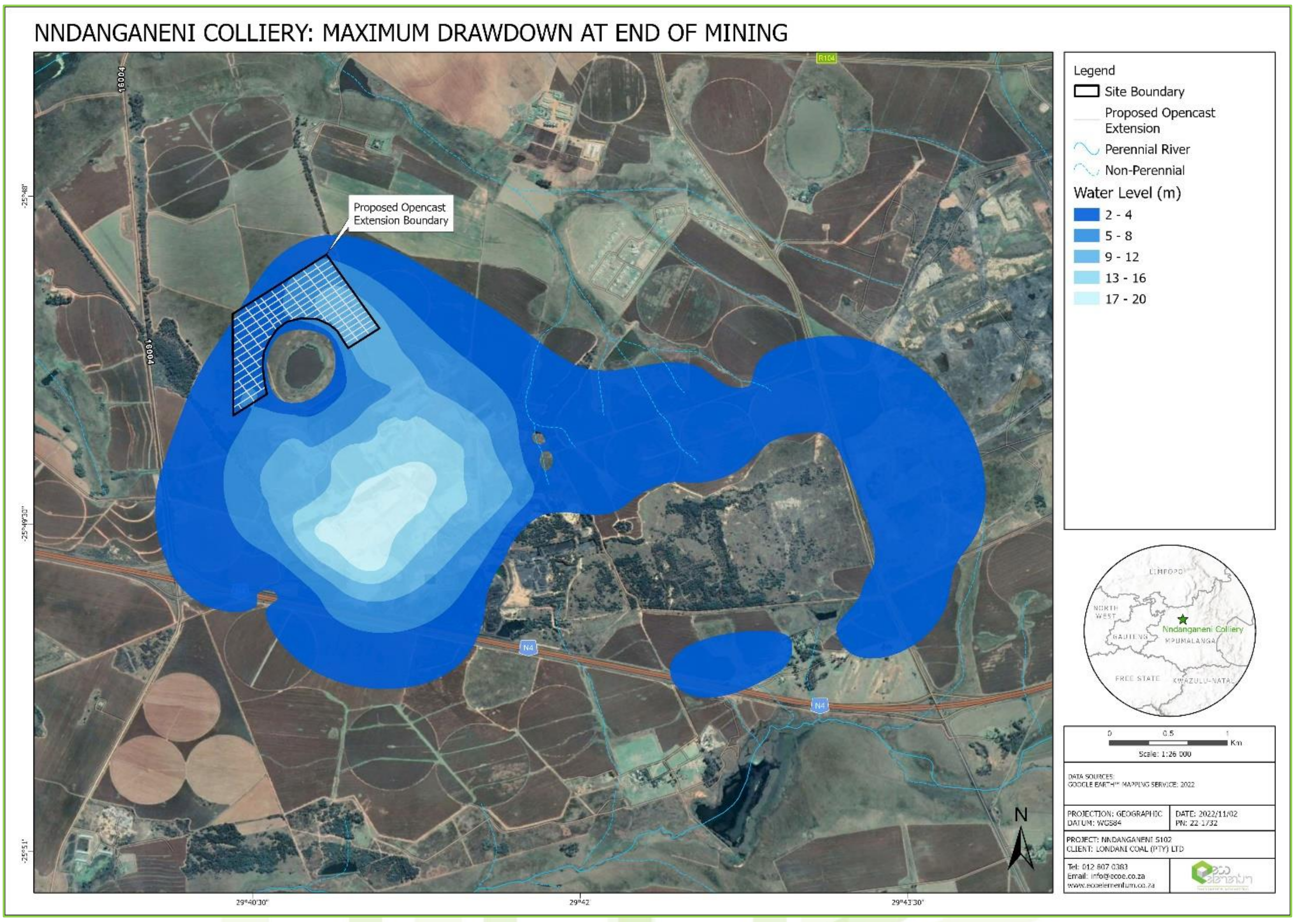


Figure 19: The simulated maximum drawdown cone in the shallow aquifer for the Nndaganeni area.

During the operational phase and for a period after, until the water level has reached equilibrium, a contamination plume will not migrate away from the opencast pit. This is because the opencast void act as a groundwater sink. Contaminated groundwater, as a result of acid mine drainage, will be contained within the opencast area. The maximum extent of the mass transport plume at the end of the operational phase is not expected to exceed 30 m from the mine boundary. The maximum simulated sulphate concentration in the pit area at the end of mining is 790 mg/l. The mass transport simulations for the shallow aquifer at the end of the proposed mining operations are presented in **Figure 20.**

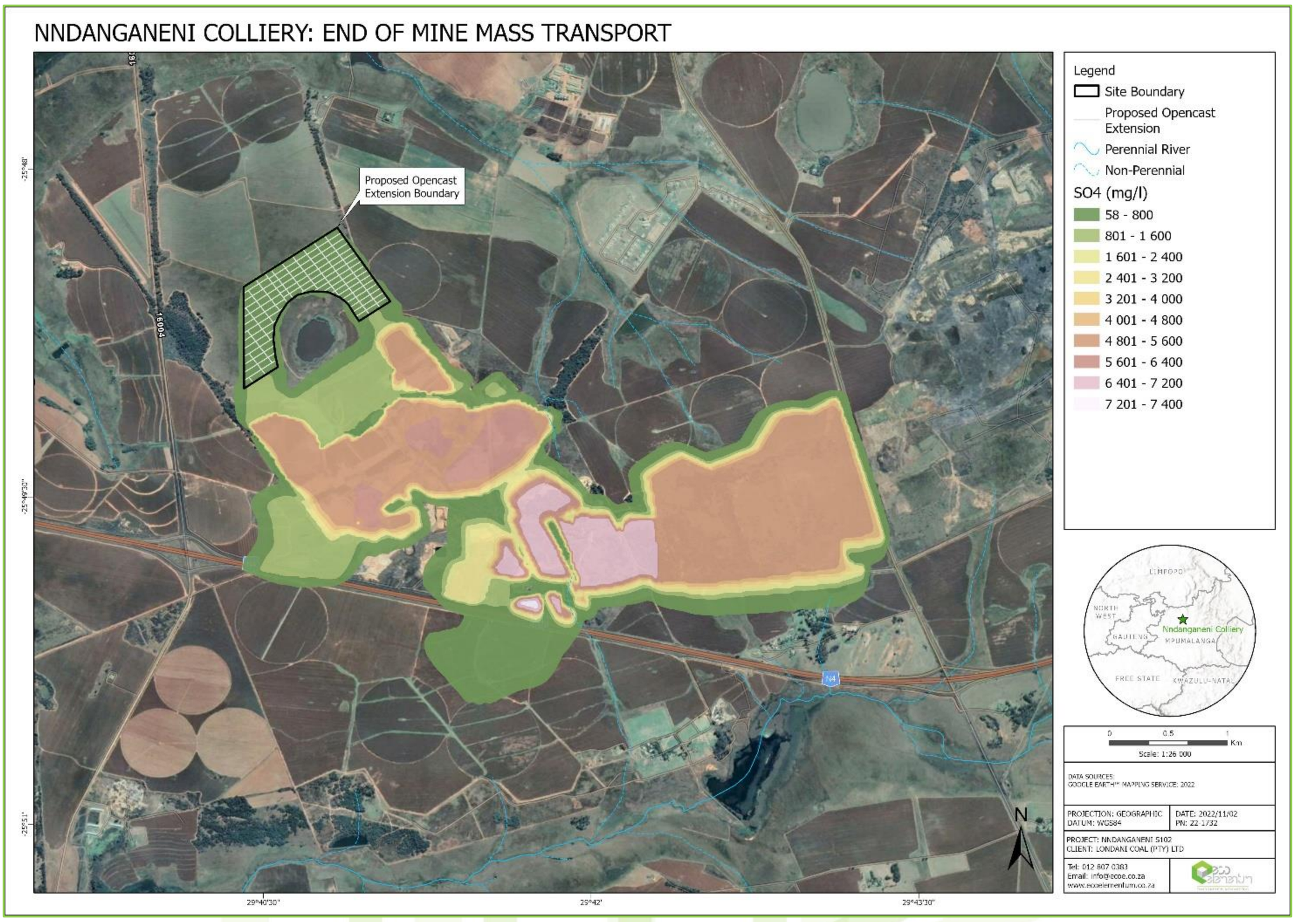


Figure 20: Simulated mass transport at end of the operational phase in the shallow aquifer at Nndaganeni area.

7.8.3 Post-Facility

For the post-facility model simulations, the model was run an additional 100 years for both the flow and mass transport models. The mass transport contours for the shallow aquifer are represented in **Figure 21.**

The most common/possible effects of a coal mining operation post-facility are:

- Decanting of the opencast into the shallow aquifer and on the surface.
- Acid generation and therefore decrease in groundwater qualities in the opencast.
- Down-gradient movement of a contamination plume.

In the case where carbonaceous material is placed at the base of the pit, the material will be covered by water at the decant elevation which leads to it not being exposed to oxygen. The exposure of carbonaceous material to oxygen will result in redox reactions and continuous potential for acid generation of exposed material.

According to GCS, 2015 the existing pit will fill to decant at 11 to 18 years with a total decant volume varying between 150 and 290 m^3/day. The estimated filling time of the new opencast mine extension void is presented in **Table 18**. The estimated filling time of the proposed pit is 35 years. The decant elevation of the pit is approximately 1 625 mamsl and is above the highest elevation of the pit floor. The pit floor will be completely covered by water at the decant elevation in the pit. The decant volume can be as high as 130 m^3/day. Decant is expected on the western boundary of the old opencast area (Figure 21).

Table 18: Estimated fill time of the Nndaganeni pit.

	Nndanganeni
Annual Rainfall (m/a)	0,68
Decant Elevation (mamsl)	1625
Mined Area (m2)	562900
Mined Volume Below Decant Elevation (m3)	6754800
Annual Recharge to Rehab Pit area (m3/y):	
10%	38277
12,50%	47847
15%	57416
Voids (m3):	
20% porosity	1350960
25% porosity	1688700
30% porosity	2026440
Average Time to Decant (years)	**35**
Average expected decant rate (m3/d)	**131**

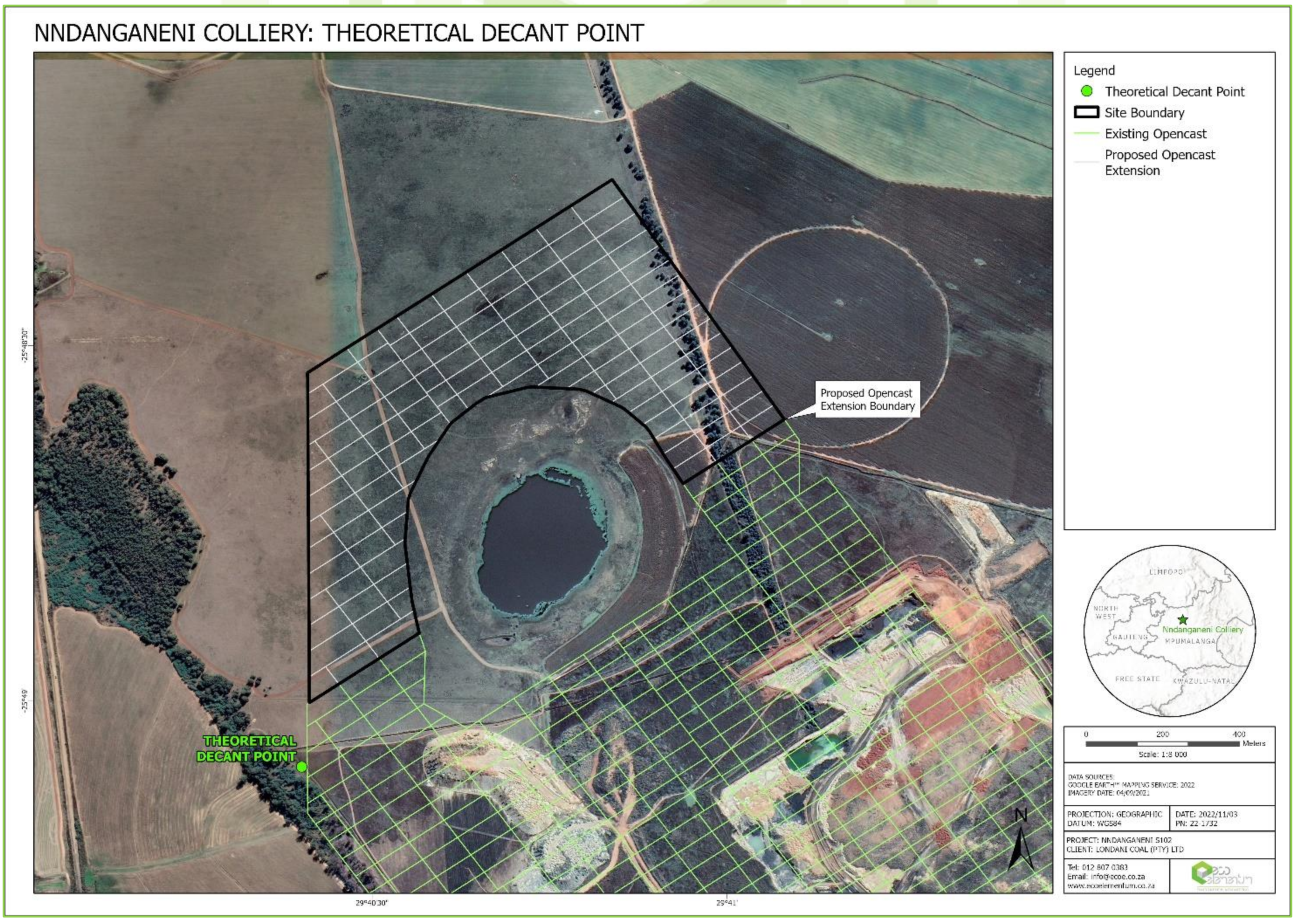


Figure 21: The potential theoretical decant point position.

The simulated groundwater contamination plume at 100 years post-facility in the shallow aquifer is presented in **Figure 22**. The plume will migrate away from the opencast area in a predominantly western, northern and north-eastern direction similar to the groundwater flow directions. The sulphate concentrations in the opencast area increase as a result of acid generation to a concentration over 2 700 mg/l. The contamination plume from the opencast is not expected to an extent more than 850 m over the period of 100 years post-mining.

The sulphate concentration reaching the Northern Pan can be as high as 5 850 mg/l but also emanating from the existing mining area.

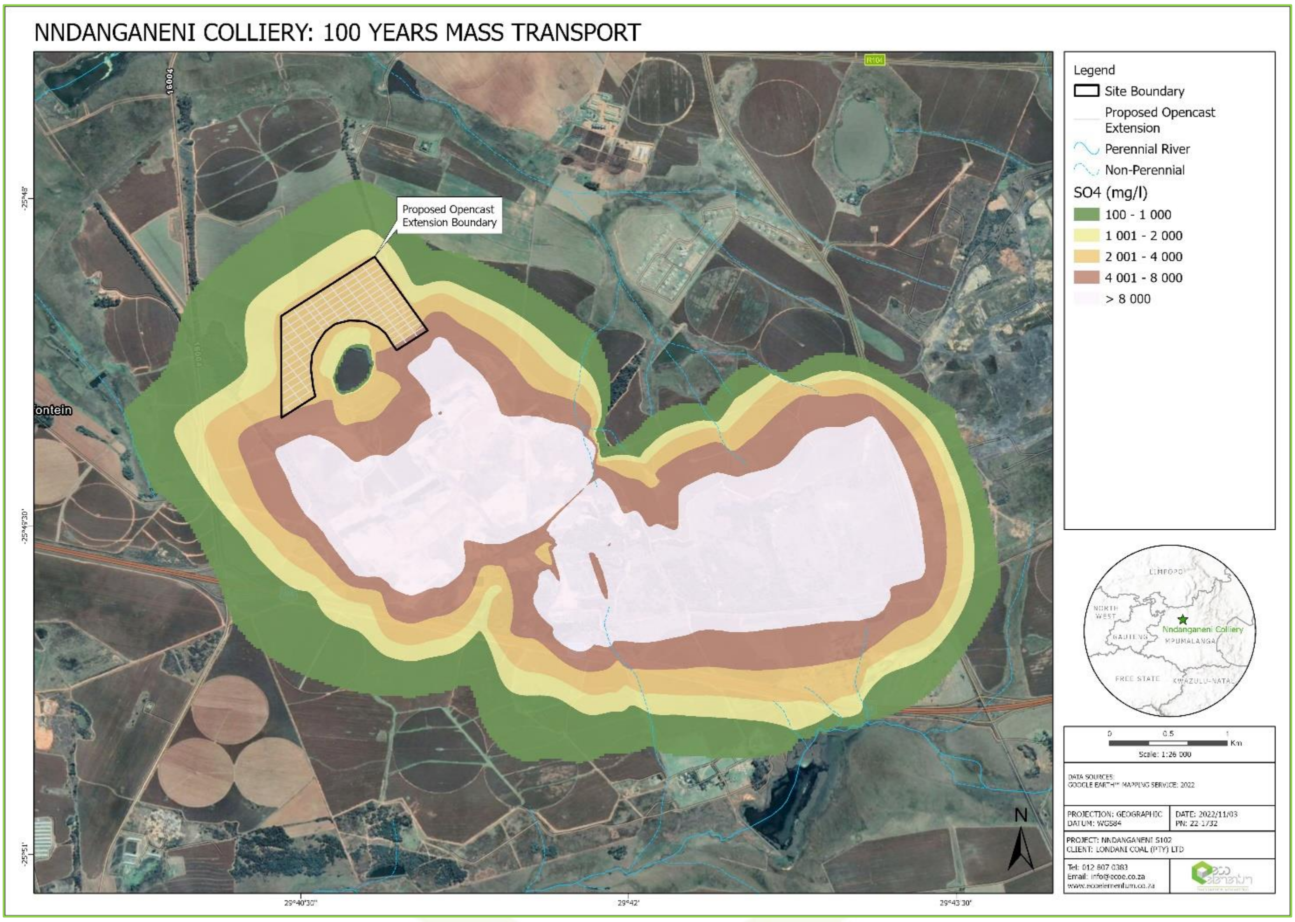


Figure 22: Model Simulated groundwater contamination plume in the shallow aquifer at 100 years post facility.

8. POTENTIAL GEOHYDROLOGICAL IMPACTS

The following methodology will be used to rank potential groundwater impacts as a result of the Nndaganeni S102 activities. Clearly defined rating and rankings scales (**Table 19)** will be used to assess the impacts associated with the proposed activities.

Each impact identified will be rated according to the expected magnitude, duration, scale, and probability of the impacts**.**

To ensure uniformity, the assessment of potential impacts will be addressed in a standard manner so that a wide range of impacts is comparable. For this reason, a clearly defined rating scale will be provided to the specialist to assess the impacts associated with their investigation.

Table 19: Potential Impacts rating and rankings scales

Intensity (Magnitude)		ASSIGNED QUANTITATIVE SCORE
The intensity of the impacts is considered by examining whether the impacts is destructive or benign, whether it has a significant, moderate or insignificant.		
(L)OW	The impacts alters the affected environment in such a way that the natural processes or functions are not affected.	**1**
(M)EDIUM	The affected environment is altered, but functions and processes continue, albeit in a modified way.	**3**
(H)IGH	Function or process of the affected environment is disturbed to the extent where it temporarily or permanently ceases.	**5**
Duration		
The lifetime of the impacts, which is measure in relation to the lifetime of the proposed development.		
(S)HORT TERM	The impacts will either disappear with mitigation or will be mitigated through a natural process in a period shorter than that of the construction phase.	**1**
(SM) SHORT - MEDIUM TERM	The impacts will be relevant through to the end of a construction phase.	**2**
(M)MEDIUM	The impacts will last up to the end of the development phases, where after it will be entirely negated.	**3**
(L)ONG TERM	The impacts will continue or last for the entire operational lifetime (i.e. exceed 20 years) of the development, but will be mitigated by direct human action or by natural processes thereafter.	**4**
(P)ERMANENT	This is the only class of impacts, which will be non-transitory. Mitigation either by man or natural process will not occur in such a way or in such a time span that the impacts is transient.	**2**
Spatial Scale/Extent		
Classification of the physical and spatial aspect of the impacts		
(F)OOTPRINT	The impacted area extends only as far as the activity, such as footprint occurring within the total site area.	**1**
(S)ITE	The impacts could affect the whole, or a significant portion of the site.	**2**

(R)EGIONAL	The impacts could affect the area including the neighbouring Farms, the transport routes and the adjoining towns.	**3**
(N)ATIONAL	The impacts could have an effect that expands throughout the country (South Africa).	**4**
(I)NTERNATIONAL	Where the impacts has international ramifications that extend beyond the boundaries of South Africa.	**5**
Probability		
This describes the likelihood of the impacts actually occurring. The impacts may occur for any length of time during the life cycle of the activity. The classes are rated as follows:		
(I)MRROBABLE	The possibility of the Impacts occurring is none, due to the circumstances or design. The chance of this Impact occurring is zero (0%).	**1**
(P)OSSIBLE	The possibility of the Impacts occurring is very low, due either to the circumstances or design. The chances of these impacts occurring are defined as 25% or less.	**2**
(L)IKELY	There is a possibility that the impacts will occur to the extent that provisions must therefore be made. The chances of these impacts occurring are defined as 50%.	**3**
(H)IGHLY LIKELY	It is most likely that the Impacts will occur at some stage of the development. Plans must be drawn up before carrying out the activity. The chances of these impacts occurring are defined as 75%.	**4**
(D)EFINITE	The impacts will take place regardless of any prevention plans, and only mitigation actions or contingency plans to contain the effect can be relied on. The chance of these impacts occurring are defined as 100%.	**5**
Weighting Factor		
Subjective scores are assigned by Impacts Assessor to give the relative importance of a particular environmental component based on project knowledge and previous experience. Simply, such a weighting factor is indicative of the importance of the impacts in terms of the potential effect that it could have on the surrounding environment. Therefore, the aspects considered to have a relatively high value will score a relatively higher weighting than that which is of lower importance.		
(L)OW		**1**
LOW- MEDIUM		**2**
MEDIUM (M)		**3**
MEDIUM-HIGH		4
HIGH (H)		5
Mitigation Measures and Mitigation Efficiency		
Determination of significance refers to the foreseeable significance of the impacts after the successful implementation of the necessary mitigation measures		
Mitigation measures were recommended to enhance benefits and minimise negative impacts and address the following:		
Mitigation objectives: what level of mitigation must be aimed at: For each identified impact, the specialist must provide mitigation objectives (tolerance limits) that would result in a measurable reduction in impacts. Where limited knowledge or expertise exists on such tolerance limits, the specialist must make "educated guesses" based on professional experience;		

Recommended mitigation measures: For each impact, the specialist must recommend practicable mitigation actions that can measurably affect the significance rating. The specialist must also identify management actions, which could enhance the condition of the environment. Where no mitigation is considered feasible, this must be stated and reasons provided;		
Effectiveness of mitigation measures: The specialist must provide quantifiable standards (performance criteria) for reviewing or tracking the effectiveness of the proposed mitigation actions, where possible; and		
Recommended monitoring and evaluation programme: The specialist is required to recommend an appropriate monitoring and review programme, which can track the efficacy of the mitigation objectives. Each environmental impact is to be assessed before and after mitigation measures have been implemented.		
The management objectives, design standards, etc., which, if achieved, can eliminate, minimise or enhance potential impacts or benefits. National standards or criteria are examples, which can be stated as mitigation objectives.		
HIGH	The impact is of major importance. Mitigation of the impacts is not possible on a cost-effective basis. The impact is regarded as high importance and taken within the overall context of the project, is regarded as a fatal flaw. An impact regarded as high significance, after mitigation could render the entire development option or entire project proposal unacceptable.	**1,00**
MEDIUM-HIGH	The impact is of major importance but through the implementation of the correct mitigation measures, the negative impacts will be reduced to acceptable levels.	**0,80**
MEDIUM	Notwithstanding the successful implementation of the mitigation measures, to reduce the negative impacts to acceptable levels, the negative impacts will remain of significance. However, taken within the overall context of the project, the persistent impact does not constitute a fatal flaw.	**0,60**
LOW -MEDIUM	The impact is of importance, however, through the implementation of the correct mitigation measures such potential impact can be reduced to acceptable levels.	**0,40**
LOW	The impact will be mitigated to the point where it is of limited importance.	**0,20**

Extent	Duration	Intensity	Probability	Weighting Factor (WF)	Significance Rating (SR)	Mitigation Efficiency (ME)	Significance Following Mitigation (SFM)
Footprint 1	Short term 1	Low 1	Probable 1	Low 1	Low 0-19	High 0,2	Low 0-19
Site 2	Short to medium 2		Possible 2	Low to medium 2	Low to medium 20-39	Medium to high 0,4	Low to medium 20-39
Regional 3	Medium term 3	Medium 3	Likely 3	Medium 3	Medium 40-59	Medium 0,6	Medium 40-59
National 4	Long term 4		Highly Likely 4	Medium to high 4	Medium to high 60-79	Low to medium 0,8	Medium to high 60-79
International 5	Permanent 5	High 5	Definite 5	High 5	High 80-100	Low 1,0	High 80-100

The following activities form / will form part of the proposed Nndaganeni MR area:

- Opencast Pit.

8.1 CONSTRUCTION PHASE

8.1.1 Impacts on Groundwater Quantity

No significant impacts are expected during the construction phase in terms of groundwater quantity. The removal of vegetation in preparation of the mining area may cause an increase in surface runoff and therefore a small decrease in aquifer recharge.

Since the pit will extent from an existing opencast pit, no box-cut will be required.

8.1.2 Impacts on Groundwater Quality

The proposed Nndaganeni activities are not expected to impact the groundwater quality during the construction phase. The only possible impacts may be from example fuel spillages from construction vehicles.

8.1.3 Groundwater Management

Should fuel spillages occur during the construction phase immediate action is required to minimise the impact on the groundwater regime. No management can be incorporated to limit the impacts of dewatering should the box-cut floor be lower than the groundwater level.

8.2 Operational Phase

8.2.1 Impacts on Groundwater Quantity

The operational phase impacts on the groundwater quantity will mainly be as a result of the dewatering of the surrounding aquifer during the opencast mining. The groundwater level in close proximity to the pit is expected to decrease since groundwater seepage to the void will be abstracted.

As simulated with the numerical model the extent of the dewatering cone in the shallow aquifer is approximately 450 m. No known groundwater users are located within this radius from the pit boundary.

8.2.2 Impacts on Groundwater Quality

If dewatering of the aquifer has occurred during the operational phase, which is expected, the opencast void will act as a groundwater sink since the water levels have not yet recovered. Groundwater gradients and therefore groundwater flow will be towards the pit area. For this reason, groundwater contamination will not be able to flow downgradient from the pit area during the operational phase.

The impacts of the proposed Nndaganeni mining activities on the groundwater quality during the operational phase have been discussed in section 7.8.2 of this document.

8.2.3 Impacts on Surface Water

Figure 21 represents the NFEPA wetlands located within the mining area of the proposed Nndaganeni project.

Two pans existed within the mining area and was previously referred to as the Northern and Southern pans. The southern pan has been mined out during the existing mining activities at Nndaganeni. The Northern pan has not been mined, but future mining is planned for the circumference of the pan. The mining will remain outside the 100m buffer area.

The Northern pan has a topographical catchment area of approximately 70ha. It is a perennial pan which is situated in a much deeper and more defined pan basin. This pan is an open water body with no vegetation in or right adjacent to it. (GCS, 2015).

Groundwater can contribute to surface drainage, baseflow to streams, pans and wetlands only if the static water level is higher or at the same elevation as the base of the surface water feature. Water levels recorded in close proximity to the northern pan were shallow at 2 - 4.6 mbs. The water levels in the boreholes in close proximity match the water elevation in the northern pan. This indicates that the pan is connected to the underlying weathered aquifer and is therefore partially dependent on groundwater for sustainability.

The groundwater levels within the catchment area of the northern pan are expected to be impacted on in terms of dewatering. Water level drawdown of up to 11 m is expected to the east of the pan.

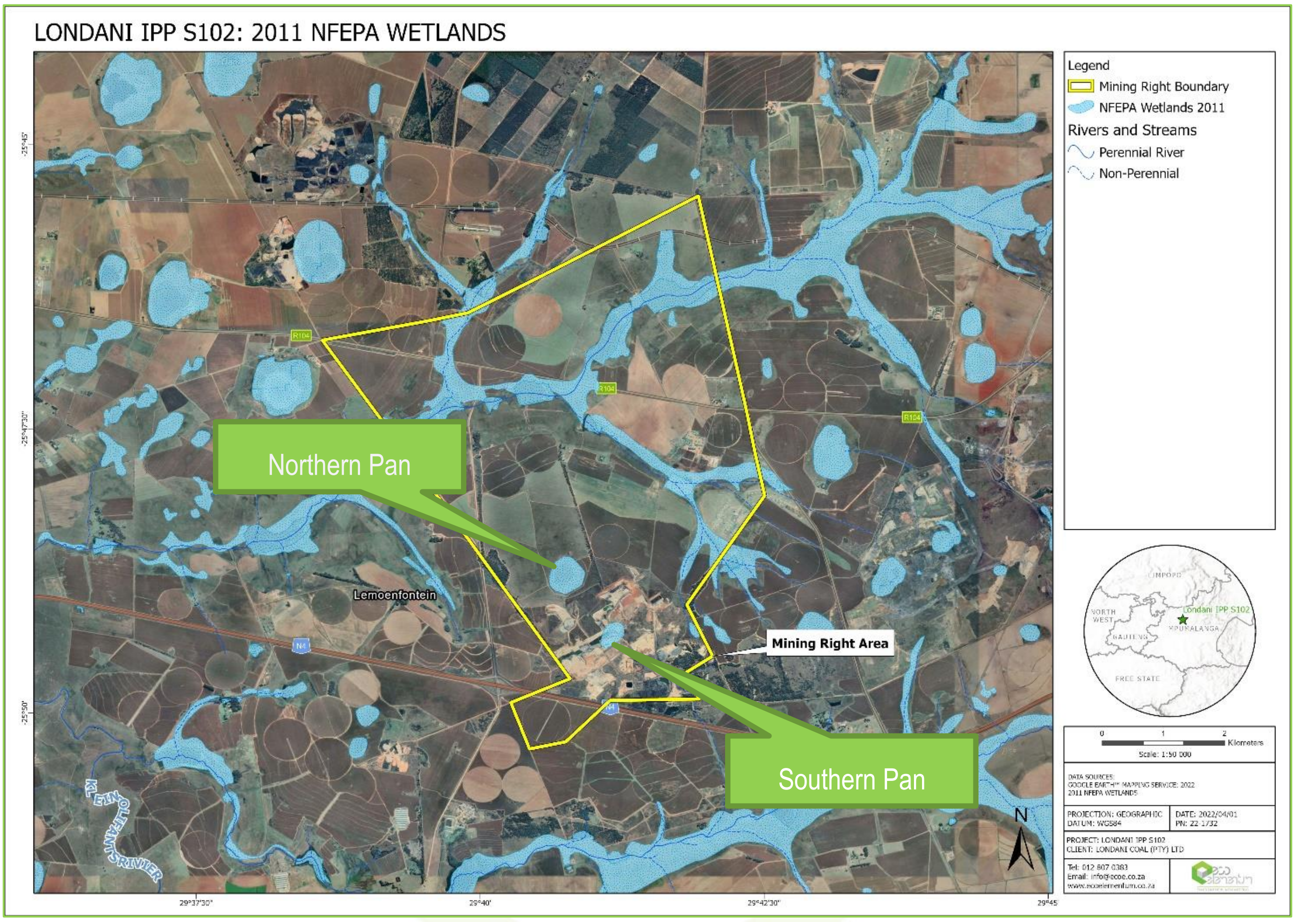


Figure 23: NFEPA Wetlands in the region of the Nndaganeni.

8.2.4 Groundwater Management

Dewatering of the mine pit is a necessity for safe mining. Dewatering as a result of the mining operations cannot be prevented. Some mitigation measures for the operational phase are indicated in Table 20 below.

Table 20: Mitigation measures for the Operational Phase

Potential Impacts	Mitigation Measures
• Impacts in terms of groundwater levels are expected during this phase. The dewatering of the pit will cause a drawdown in the water levels within the immediate vicinity of the opencast activities.	• Groundwater levels in the monitoring boreholes should be measured on at least a quarterly interval. • Should the water levels of surrounding users be influenced in terms of groundwater level or quality decline, the users should be compensated.

• The drawdown of the water levels is expected to impact on the Northern pan water make since groundwater partially contributes to the water make of the pan. • No adverse impacts on the groundwater qualities surrounding the opencast are expected during this phase.	• Monitor groundwater inflow rates on a monthly basis throughout the mining operation. • The groundwater quality in the monitoring boreholes should be analysed on a quarterly basis. • Annual reporting on the groundwater qualities and levels should be conducted and submitted to the DWA. • The numerical model should be updated once more time-series monitoring data (water levels and qualities) are available and on an annual basis. • Remove as much coal from the mining pit as possible to prevent continuous acid generation.

8.3 Decommissioning Phase

During the decommissioning phase all the potential surface contamination sources including the ROM stockpiles and other infrastructure, will be removed. These include all carbonaceous or contaminated material. This will decrease the surface sources for further groundwater contamination.

The opencast pit area will be rehabilitated which will have a positive impact on the groundwater regime in some areas since the poor-quality seepage to the groundwater will decrease. Rehabilitation should occur in such a manner as to divert as much as possible water away from the opencast areas.

8.4 Post Closure

8.4.1 Groundwater Quantity

When dewatering ceases at the end of the operational phase, the groundwater level will start to recover to a state of equilibrium. Decant from the lowest elevation on the pit boundaries may occur once the groundwater levels have recovered.

With sufficient rehabilitation, the recharge to the opencast pit may decrease to approximately 12,5%. Decant elevations and estimated rates were discussed in Section 7.8.3 of this report.

8.4.2 Groundwater Quality

The groundwater quality in the pit regions is expected to decrease as a result of the acidification. It is highly recommended that all carbonaceous material be placed on the pit floor and covered with overburden material. This will result in coverage of the carbonaceous material with water first, which will eliminate oxygen from the system to decrease the process of acid generation.

The contamination plume is expected to migrate away from the opencast area in a predominantly western, northern and north-eastern direction similar to the groundwater flow directions. The sulphate concentrations in the opencast area increase as a result of acid generation to a concentration over 2 700 mg/l. The contamination plume from the opencast is not expected to extent more than 850 m over the period of 100 years post-mining.

Please refer to Section 7.8.3 of this document for more information on the expected groundwater quality conditions post closure.

8.4.3 Cumulative Impact

The Nndaganeni area is situated in an area with several mining and agricultural activities at or near its boundaries. These include:

- Existing Nndanganeni mining pits from which the proposed pit will extent;
- Optimum Pit – 5.5 km South of Nndaganeni;
- Masemanzi Boschfontein - <2.5 km south-west of Nndaganeni;
- Mafube Colliery – 3.7km east of Nndaganeni;
- Hahhono Coal – 6km north-west of Nndaganeni; and
- Agricultural activities bordering the proposed mining area.

Dewatering of the local aquifers is not limited to the Nndaganeni mining area. The mining operations as mentioned above will have a cumulative impact on the aquifers in terms of quality and quantity. Acid mine drainage, as well as the dewatering of the aquifers as a result of all these mining activities, may decrease the groundwater qualities and have a nett loss on the water supply to the groundwater users in the area.

8.4.4 Groundwater Management

The potential impacts and mitigation measures post-closure are summaries in **Table 21** below.

Table 21: Mitigation measures for Groundwater Management

Potential Impacts	Mitigation Measures
• The water level post-closure will start to rise as the back-filled pit starts to fill. • Decant may occur once the water level in the back-filled opencast pit has recovered. • Once the water levels have recovered, a groundwater pollution plume will start to migrate down gradient away from the pit areas. • The Northern Pan is expected to be impacted on in terms of sulphate contamination at 100 years post closure.	• Carbonaceous material should be placed at the deeper base of the opencast pit to allow flooding with groundwater as soon as possible. This will reduce the redox reaction potential as oxygen is excluded from the system. • Rehabilitation should occur in such a manner that surface runoff is directed away from the rehabilitated pit and recharge to the pit minimized. • Flow paths which include fracture zones should be sealed to reduce inflow of fresh groundwater and outflow of contaminated groundwater. • Methods of handling the potential decant should be investigated and may include treatment of polluted water or a down gradient- intercepting trench. • The groundwater quality in the monitoring boreholes should continue to be analysed on a quarterly interval basis. • Monitoring of surface water features including the Northern pan should be conducted on a quarterly interval.

Table 22: Potential impacts on groundwater regime rating summary for the proposed Nndaganeni activities.

Activity	Aspect	Impact	Phase	Significance without mitigation	Significance with mitigation	Mitigation measures	Action Plan
Surface clearing and preparation.	Removal of vegetation.	Increase in surface run-off and therefore decrease in aquifer recharge.	Construction.	Low	Low	Re-vegetate.	Rehabilitation plan.
Topsoil and overburden stockpiling.	Leaching from stockpiles.	Acid generation in the case of carbonaceous material placement.	Operation.	Low-Med	Low	Should a contamination plume be detected, groundwater abstraction to contain plume.	Quarterly monitoring of monitoring boreholes.
ROM stockpiling.	Leaching from stockpiles.	Acid generation as a result of carbonaceous material.	Operation.	Low-Med	Low	Should a contamination plume be detected, groundwater abstraction to contain plume.	Quarterly monitoring of monitoring boreholes.
Hydrocarbon spills.	Plume migration.	Spills from mining vehicles can infiltrate to the aquifer and cause a down gradient plume migration.	Construction & Operation.			Clean any hydrocarbon spills in the appropriate manner.	Report any hydrocarbon spillage.
Opencast mining.	Dewatering.	The water infiltrating the voids will be removed for safe mining, causing a decrease in the water level. The drawdown will decrease the groundwater contribution volume to the Northern pan.	Operation.	High	High	No management can be incorporated to limit the impacts of dewatering.	Quarterly Monitoring. Compensate users for losses. Monitor pit inflow rates, Annual Monitoring report, Update Numerical Model.
Closure of the mine.	Groundwater rebound.	Groundwater decant is expected hold the system behave as predicted. Decant is expected to occur on the lowest elevation on the pit boundary.	Closure and Decommissioning.	Low-Med	Low	Treat decant water before release to the environment.	Establish a Passive treatment system in the form of a constructed wetland or similar.

Activity	Aspect	Impact	Phase	Significance without mitigation	Significance with mitigation	Mitigation measures	Action Plan
Closure of the mine.	Groundwater rebound.	Pollution Plume spread.	Closure and Decommissioning	Low-Med	Low-Med	Treat decant water before release to the environment.	Establish a Passive treatment system in the form of a constructed wetland or similar.

9. GROUNDWATER MONITORING SYSTEM

9.1 Groundwater Monitoring Network

9.1.1 Source, Plume, Impact and Background Monitoring

Source monitoring is the monitoring of specific and potential sources. These include the monitoring boreholes drilled strategically to detect any impact from sources as soon as possible. Once impacts in these boreholes, especially in terms of quality impacts are detected, additional boreholes downgradient of the source monitoring borehole can be included in the program and is referred to as plume monitoring.

In the Nndaganeni area, only source monitoring boreholes are proposed to form part of the monitoring network. The five monitoring boreholes to form part of the monitoring network have been indicated in **Figure 24**.

9.1.2 System Response Monitoring Network

The groundwater regime will mostly be impacted in terms of dewatering (operational) and contamination (post-closure). A quarterly monitoring programme is critical to determine the response, especially of groundwater levels during the operational phase and the qualities post-closure of the mining activities. Changes in the groundwater level will influence the flow directions and pollution migration rates. Frequent monitoring will aid in understanding the response of the system to the mining activities.

9.1.3 Monitoring Frequency

It is suggested that monitoring boreholes be monitored on a quarterly basis. Samples and water levels should be collected by an independent groundwater consultant, using best practice guidelines.

9.2 Monitoring Parameters

Groundwater samples should be analysed by a SANAS accredited laboratory for parameters normally associated with coal mining activities. The following parameters are proposed for the Nndaganeni monitoring program:

- The pH, EC, Ca, Mg, Na, K, Cl, SO4, NO4 and F, and
- Al, Fe, Mn, Alkalinity and TDS.

9.3 Monitoring Boreholes

Three new monitoring boreholes are proposed to be drilled. These boreholes with two existing boreholes, NND-MON04 and MB3, are proposed to cover the proposed mining activities at Nndaganeni (**Figure 24**). It is recommended that these new monitoring boreholes be monitored on a quarterly interval for a complete record. The monitoring results will aid in future model updates and geohydrological annual reports.

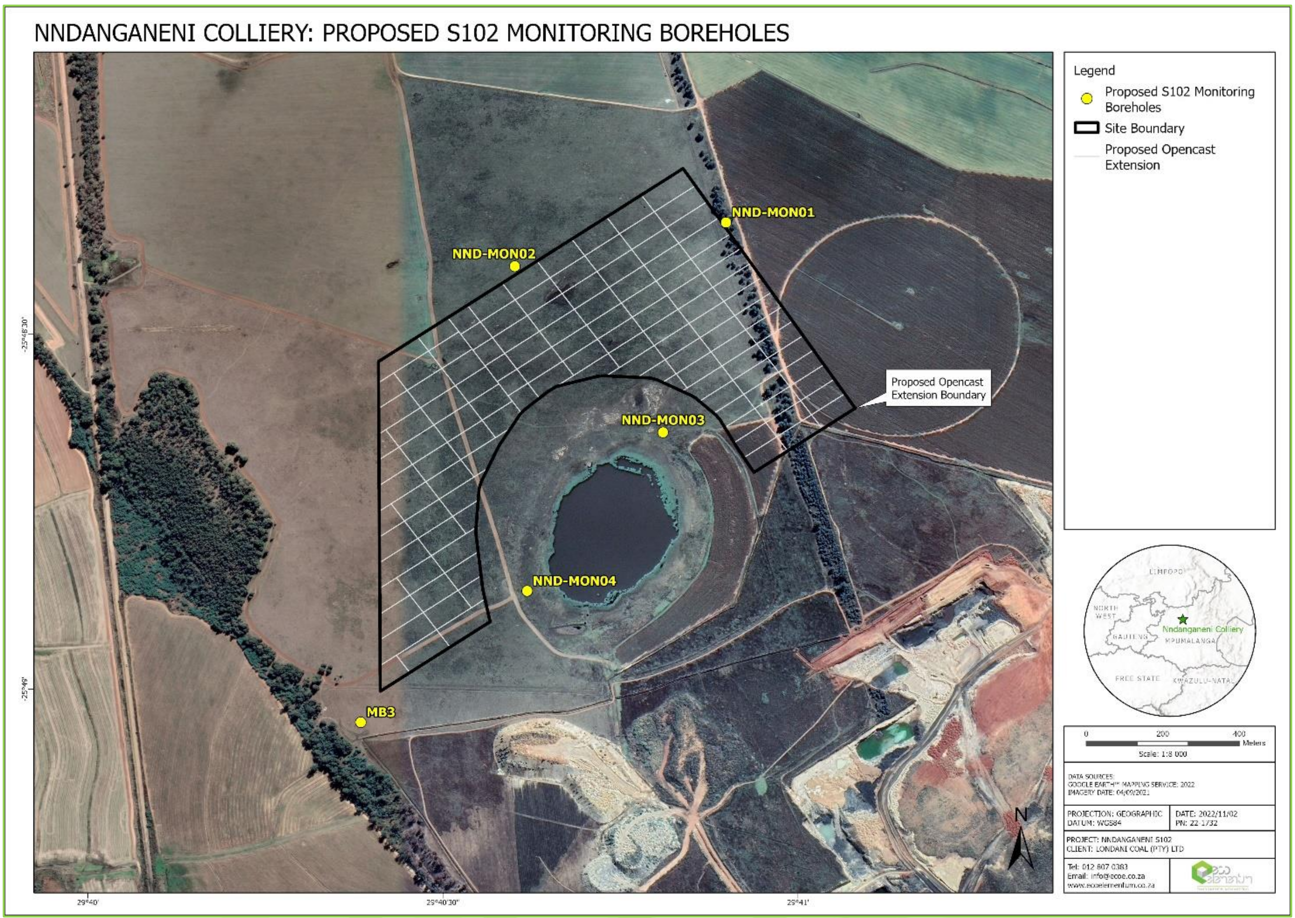


Figure 24: Positions of the monitoring boreholes drilled and to form part of the monitoring program at Nndaganeni area.

10. GROUNDWATER ENVIRONMENTAL MONITORING PROGRAMME

10.1 Current Groundwater Conditions

The overall quality of the groundwater from the monitoring results indicated significant increasing sulphate concentration trends in BH2, BH3 and KM6 over the monitoring period. Increases over this period has also been observed in KM2. The increasing sulphate concentrations is evident of increasing impacts from the coal mining activities. In BH4 the sulphate concentrations have decreased from 1 830 mg/l in June 2021 to 1 070 mg/l in March 2022. Continuous monitoring will indicate whether this decrease will continue

- The following was observed after assessing the water quality of the groundwater samples taken around the Nndanganeni Colliery Kopermyn, Nndanganeni Colliery Hartogshof Extension (NCHE):
  - The pH level of BTP3 exceeds the SANS Limits.
  - The manganese concentration of BH 2, BH 4 and KM 4 exceed the SANS Limits.
  - The sulphate concentration of BH 2, BH 3 and BH 4 exceed the SANS Limits.
  - The TDS concentration of BH 2, BH 3 and BH 4 exceed the SANS Limits.
  - BH10, KM2, KM4, BTP 3, MB3 and MB6 display corrosive characteristics.
  - BH3 and BH4 display scaling characteristics.

Water level trends in the IPP Nndanganeni monitoring boreholes over the period from March 2017 to March 2022 are presented in Figure 5 of this report. Increasing water level trends from 2017 to 2022 are observed in BH2, BH3, BH5, BH10 and KM4. No impacts in terms of dewatering on the pan from the mining activities is currently observed since the water levels in BH10 has increased over the monitoring period. Water levels in the monitoring boreholes varied between 0.2 and 17 mbs for the 2021/2022 monitoring period.

The water levels recorded during the hydrocensus varied between 2 and 4.6 mbs. The water level in the boreholes closest to the Northern pan varied between 2 and 4.6. The water level elevation is close to the water level elevation in the pan which indicates that groundwater contributes to the water make of the pan. Drawdown in the shallow aquifer in the new mining are will therefore have an impact on the pan in terms of the groundwater contribution.

10.2 Predicted Impacts of Facility (Mining)

The expected impacts as a result of the proposed mining operations (Nndaganeni) are summarised as:

- Construction phase:
  - Impacts in terms of groundwater levels are expected during this phase. The dewatering of the box-cut will cause a drawdown in the water levels within the immediate vicinity of the cut.
  - Fuel spillages from construction vehicles may occur during this phase.
- Operational phase:
  - Impacts in terms of groundwater levels are expected during this phase. The dewatering of the pit will cause a drawdown in the water levels within the immediate vicinity of the opencast activities.
  - The drawdown of the water levels is expected to impact on the Northern pan water make since groundwater partially contributes to the water make of the pan.
  - No adverse impacts on the groundwater qualities surrounding the opencast are expected during this phase.
  - The simulated results of the operational phase in terms of the water levels are indicated in the table below:

Opencast Pit	Maximum simulated drawdown (m)	Maximum drawdown cone extent from pit boundary (m)
Nndaganeni	11	450

- Post Closure:
  - The water level post-closure will start to rise as the back-filled pit starts to fill.
  - Decant may occur once the water level in the back-filled opencast pit has recovered.
  - Once the water levels have recovered, a groundwater pollution plume will start to migrate down gradient away from the pit areas.
  - The Northern Pan is expected to be impacted on in terms of sulphate contamination at 100 years post closure.

Opencast Pit	100 years Post closure maximum simulated sulphate concentrations (mg/l)	100 years Maximum plume extent from potential surface sources (m)
Nndaganeni	2 700	850

10.3 Mitigation Measures

Phase	Mitigation Measures
Construction Phase	• Should fuel spillages occur during the construction phase immediate action is required to minimise the impact on the groundwater regime. • No management can be incorporated to limit the impacts of dewatering should the box-cut floor be lower than the groundwater level.
Operational Phase	• Groundwater levels in the monitoring boreholes should be measured on at least a quarterly interval. • Should the water levels of surrounding users be influenced in terms of groundwater level or quality decline, the users should be compensated. • Monitor groundwater inflow rates on a monthly basis throughout the mining operation. • The groundwater quality in the monitoring boreholes should be analysed on a quarterly basis. • Annual reporting on the groundwater qualities and levels should be conducted and submitted to the DWA. • The numerical model should be updated once more time-series monitoring data (water levels and qualities) are available and on an annual basis. • Remove as much coal from the mining pit as possible to prevent continuous acid generation.
Post-Closure Phase	• Carbonaceous material should be placed at the deeper base of the opencast pit to allow flooding with groundwater as soon as possible. This will reduce the redox reaction potential as oxygen is excluded from the system. • Rehabilitation should occur in such a manner that surface runoff is directed away from the rehabilitated pit and recharge to the pit minimized. • Flow paths which include fracture zones should be sealed to reduce inflow of fresh groundwater and outflow of contaminated groundwater. • Methods of handling the potential decant should be investigated and may include a down gradient- intercepting trench. • The groundwater quality in the monitoring boreholes should continue to be analysed on a quarterly interval basis. • Monitoring of surface water features including the Northern Pan should be conducted on a quarterly interval.

11. POST-CLOSURE MANAGEMENT PLAN

The following suggestions are made for the post-closure management:

- Carbonaceous material should be placed at the base of the opencast pit to allow flooding with groundwater as soon as possible. This will reduce the redox reaction potential as oxygen is excluded from the system.
- Rehabilitation should occur in such a manner that surface runoff is directed away from the rehabilitated pit and recharge to the pit minimized.
- Flow paths which include fracture zones should be sealed to reduce the inflow of fresh groundwater and outflow of contaminated groundwater.
- Methods of handling the potential decant should be investigated and may include treatment of polluted water.
- Treatment options can either be passive or active.
- For smaller rates of flow/decant passive treatment options are proposed. These volumes should be less than 500 to 1 000 m^3/day.
- The estimated total decant rate at Nndaganeni is estimated to be between 320 and 380 m^3/day.
- Passive treatment options may therefore be investigated for the Nndaganeni operation.

Selection of the appropriate technology for the treatment of AMD is inherently site-specific and requires an in-depth knowledge of available technologies, both passive and active, their capabilities and their limitations.

Several of the major constraints of passive systems are the flow rate, available space and type of constituent (contaminant) to be removed.

In the past, passive treatment systems were very limited in their ability to treat effluent water containing high sulphate concentrations. However, recent advances in technologies, and combining various passive process units in sequence, have allowed for the removal of sulphates.

The selection of various passive treatment process units and their sequential configuration allows for an enhanced Passive Treatment System (PTS) that can treat numerous contaminants. To ensure the appropriate treatment process with specific unit processes is selected, the effluent water must be analysed and accordingly classified. By analysing the effluent water, the parameters that do not meet the target water quality can be identified, which allows a treatment process to be selected which can successfully produce the required target water quality.

It should be noted that sulphate removal should be given special consideration when designing a PTS. Although a Biochemical Reactor (BCR) can reduce sulphates (SO_4^{2-}) to sulphides (S^{2-}), the opposite reaction of bacterial re-oxidation of sulphides back to sulphates is also possible.

To prevent this reaction from forming, the sulphide formed needs to be scrubbed from the solution. This is normally achieved in a sulphide scrubber, or polishing unit (SPU), where sulphide ions are bound to iron (Fe) ions, allowing for the formation of iron sulphide (FeS). The iron sulphide is retained in the SPU media, which is normally filled with a mixture of cheap, readily available iron substrates (ferricrete soils, magnetite, scrap metal, etc.). The iron substrate is normally blended with organic material such as wood chips to prevent clogging and to retain anaerobic conditions.

To achieve the target water qualities, the following passive treatment unit processes can be incorporated:

- Primary Settling Pond (PSP).
- Biochemical Reactor (BCR).
- Sulphide Polishing Unit (SPU).
- Aeration Cascade (AEC).

- Manganese Removal Bed (MRB); and
- Aerobic Polishing Wetland (APW).

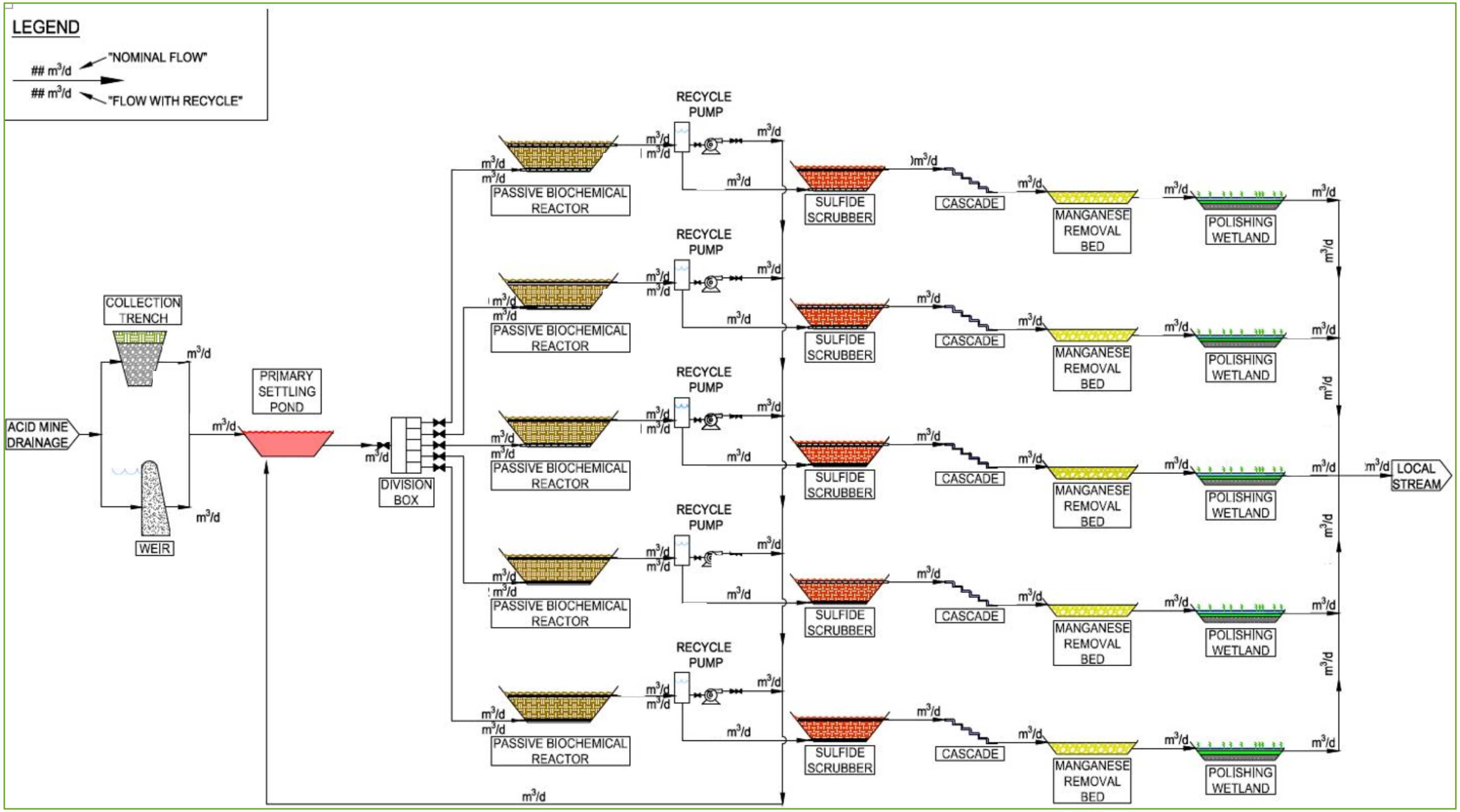


Figure 25: Typical passive treatment system design model for treatment of coal mine effluent (Eco Elementum, 2022).

12. CONCLUSIONS AND RECOMMENDATIONS

The geohydrological environment at Nndaganeni mining area can be summarised as follows:

- The IPP Nndanganeni mining area is located in the highveld region of Mpumalanga and in a summer rainfall region;
- The mean annual precipitation is ± 680 mm/annum, while the evaporation is estimated at 1 797 mm/annum;
- The recharge can be up to 3 to 5% of the mean annual precipitation;
- The IPP Nndanganeni mining area is situated on a groundwater divide area. Groundwater from the area will flow towards the north-west and west;
- A large portion of the project site is covered with unconsolidated sediments. The encountered lithology's were generally similar in each hydrogeological exploration hole consisting of:
    - Weathered sandstone and / or shale – weathering is relatively shallow ranging between ~1 m (bgl) and ~6 m (bgl);
    - Coal seam – coal seams interlayered with sandstone, shale and siltstone of various thickness;
    - Interlayered Sandstone and Shale – fresh sandstone and shale; and
    - In addition to the above, rhyolite was also encountered in some boreholes.
- Geological structures such as dykes and faults are known to exist in the region of the IPP Nndanganeni mining area. These structures and the weathered zone are possible pathways of elevated groundwater flow and contamination migration;
- Two main aquifer systems are found in the IPP Nndanganeni mining region. Firstly, the shallow weathered aquifer and secondly, the deeper, secondary aquifer;
- Water levels in the monitoring and hydrocensus boreholes varied between 0.2 and 17 mbs.
- The cone of depression due to dewatering is not expected to extent more 450 400 m from the pit areas;
- Significantly elevated sulphate concentrations have been observed in BH2, BH3, BH4, KM2 and KM6 over the 2022 monitoring period. Increasing trends over this period has also been observed in these boreholes. The increasing sulphate concentrations in evident of increasing impacts from the coal mining activities;
- The following was observed after assessing the water quality of the groundwater samples taken around the Nndanganeni Colliery Kopermyn, Nndanganeni Colliery Hartogshof Extension (NCHE):
    - The pH level of BTP3 exceeds the SANS Limits.
    - The manganese concentration of BH 2, BH 4 and KM 4 exceed the SANS Limits.
    - The sulphate concentration of BH 2, BH 3 and BH 4 exceed the SANS Limits.
    - The TDS concentration of BH 2, BH 3 and BH 4 exceed the SANS Limits.
    - BH10, KM2, KM4, BTP 3, MB3 and MB6 display corrosive characteristics.
    - BH3 and BH4 display scaling characteristics.

The following impacts may be expected from the proposed Nndaganeni mining operations:

- Construction phase:
    - Impacts in terms of groundwater levels are expected during this phase. The dewatering of the box-cut will cause a drawdown in the water levels within the immediate vicinity of the cut.
    - Fuel spillages from construction vehicles may occur during this phase.
- Operational phase:
    - Impacts in terms of groundwater levels are expected during this phase. The dewatering of the pit will cause a drawdown in the water levels within the immediate vicinity of the opencast activities.
    - The drawdown of the water levels is expected to impact on the Northern pan water make since groundwater partially contributes to the water make of the pan.
    - No adverse impacts on the groundwater qualities surrounding the opencast are expected during this phase.

- The simulated results of the operational phase in terms of the water levels are indicated in the table below:

Opencast Pit	Maximum simulated drawdown (m)	Maximum drawdown cone extent from pit boundary (m)
Nndaganeni	11	450

- Post Closure:
  - The water level post-closure will start to rise as the back-filled pit starts to fill.
  - Decant may occur once the water level in the back-filled opencast pit has recovered.
  - Once the water levels have recovered, a groundwater pollution plume will start to migrate down gradient away from the pit areas.
  - The Northern Pan is expected to be impacted on in terms of sulphate contamination at 100 years post closure.

Opencast Pit	100 years Post closure maximum simulated sulphate concentrations (mg/l)	100 years Maximum plume extent from potential surface sources (m)
Nndaganeni	2 700	850

The proposed mitigation measures for the proposed mining operation are summarised below:

Phase	Mitigation Measures
Construction Phase	• Should fuel spillages occur during the construction phase immediate action is required to minimise the impact on the groundwater regime. • No management can be incorporated to limit the impacts of dewatering should the box-cut floor be lower than the groundwater level.
Operational Phase	• Groundwater levels in the monitoring boreholes should be measured on at least a quarterly interval. • Should the water levels of surrounding users be influenced in terms of groundwater level or quality decline, the users should be compensated. • Monitor groundwater inflow rates on a monthly basis throughout the mining operation. • The groundwater quality in the monitoring boreholes should be analysed on a quarterly basis. • Annual reporting on the groundwater qualities and levels should be conducted and submitted to the DWA. • The numerical model should be updated once more time-series monitoring data (water levels and qualities) are available and on an annual basis. • Remove as much coal from the mining pit as possible to prevent continuous acid generation.
Post-Closure Phase	• Carbonaceous material should be placed at the deeper base of the opencast pit to allow flooding with groundwater as soon as possible. This will reduce the redox reaction potential as oxygen is excluded from the system. • Rehabilitation should occur in such a manner that surface runoff is directed away from the rehabilitated pit and recharge to the pit minimized. • Flow paths which include fracture zones should be sealed to reduce inflow of fresh groundwater and outflow of contaminated groundwater. • Methods of handling the potential decant should be investigated and may include a down gradient- intercepting trench.

	• The groundwater quality in the monitoring boreholes should continue to be analysed on a quarterly interval basis. • Monitoring of surface water features including the Northern Pan should be conducted on a quarterly interval.

13. REASONED OPINION

A reasoned opinion-

i. as to whether the proposed activity or portions thereof should be authorized and

ii. if the opinion is that the proposed activity or portion thereof should be authorised, any avoidance, management and mitigation measures should be included in the EMPR, and where applicable, the closure plan.

It is the opinion of the Geohydrologist that the proposed prospecting activities should be authorised.

- The environmental impacts associated with the mining activities are limited provided that the proposed mitigation is implemented.
- The impact zone in terms of water levels is not expected to extent more than 450 m from the mining pit boundaries during the operational phase.
- The impact zone in terms of groundwater quality is not expected to extent more than 30 m from the mining pit boundaries during the operational phase.
- The worst-case scenario impact zone in terms of groundwater qualities is not expected to extent more than 850 m from the mining pit boundaries at 100 years post-closure.
- These impact zones represent the impact of the mining activities without mitigation measures in place. Thus, worst-case scenario.
- No known groundwater users are expected to fall within this simulated impact zone.
- Sufficient financial provision should be provided for the treatment of acid mine drainage (AMD) or decant of polluted water.
- The impacts on the groundwater regime are inevitable, but with the proper proposed mitigation measures in place the impact can be limited.

14. KNOWLEDGE GAPS, LIMITATIONS, ASSUMPTIONS

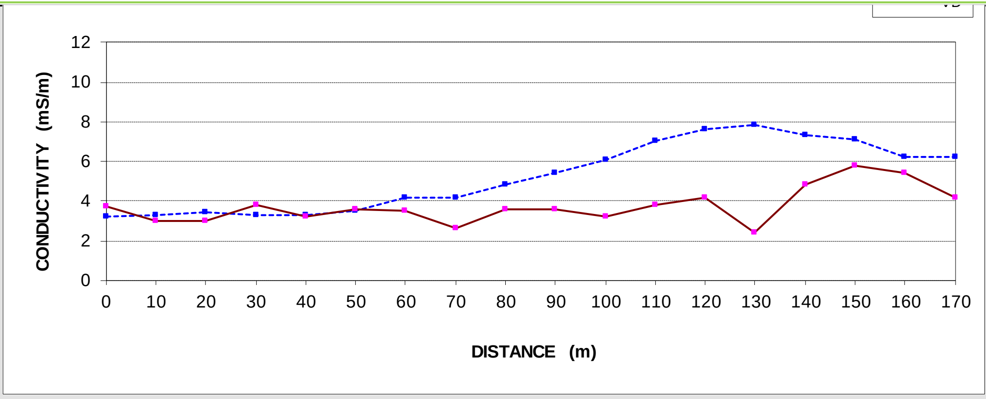
The following knowledge gaps, limitations and assumptions apply to the Nndaganeni study area in terms of the groundwater study:

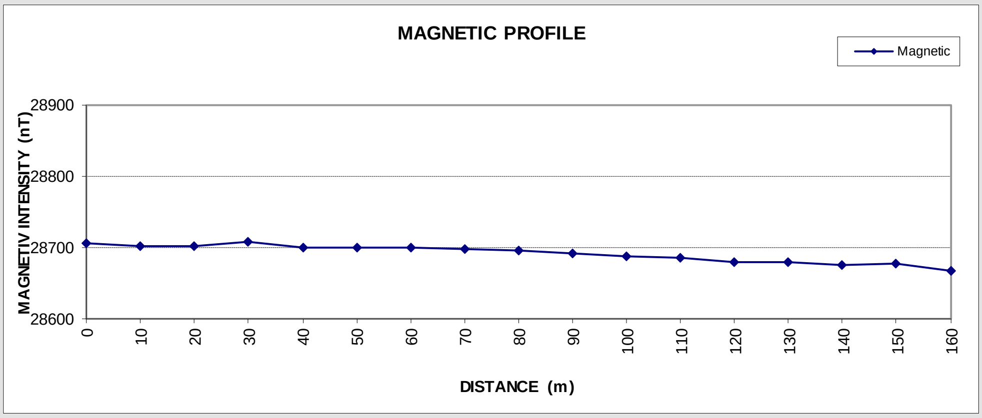
- A detailed mining schedule indicating which area will be mined during which period were not available. The mining period was however 8 years and the calculations and modelling were conducted using an average area over the period.

15. REFERENCES

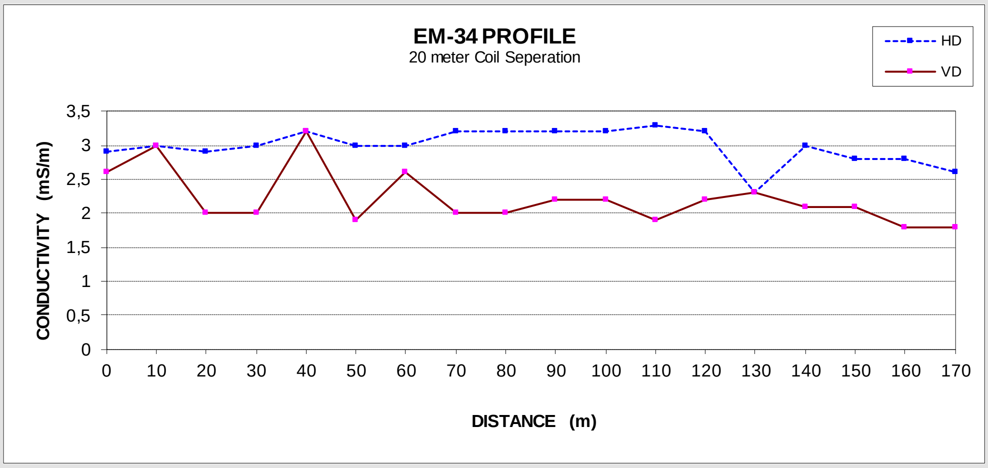
- DWA, 2012. *“Groundwater Quality of South Africa“map*.
- DWA, 2012. *“Groundwater Classification of South Africa” map*.
- DWA, 2013. *“Groundwater Susceptibility map of South Africa”.*
- DWA, 2013. *“Groundwater Vulnerability of South Africa” map.*
- *GCS, 2015. Londani Coal Nndanganeni Colliery Hartogshof Extension: Hydrogeological Investigation.*
- *GCS, 2015. Potential for Acid-mine Drainage from the Hartogshof Colliery*
- Government Gazette, 20147. *Reserve Determination of Water Resources for The Catchments of the Olifants and Letaba in terms of Section 16(1) and (2) of The National Water Act,* 1998 (ACT NO. 36 of 1998). No. 41132.
- Jones & Wagener, 2009. Optimum Colliery Environmental Management Programme Report Amalgamation
- Parsons, R.P, 1995. *A South African aquifer system management classification*, WRC Report No KV 77/95, Water Research Commission, Pretoria.
- uKhozi Environmentalists, 2022. *Groundwater Monitorign Report for nndanganeni Colliery Kopermyn, Nndanganeni Colliery Hartogshof Extension (NCHE) and Kopermyn Washing Plant.*
- Van Tonder & Xu, 2000. *Program to Estimate Groundwater Recharge*.
- V.E. Cogho and A.M. van Niekerk, 2009. *Optimum Coal Mine Water Reclamation Project*.

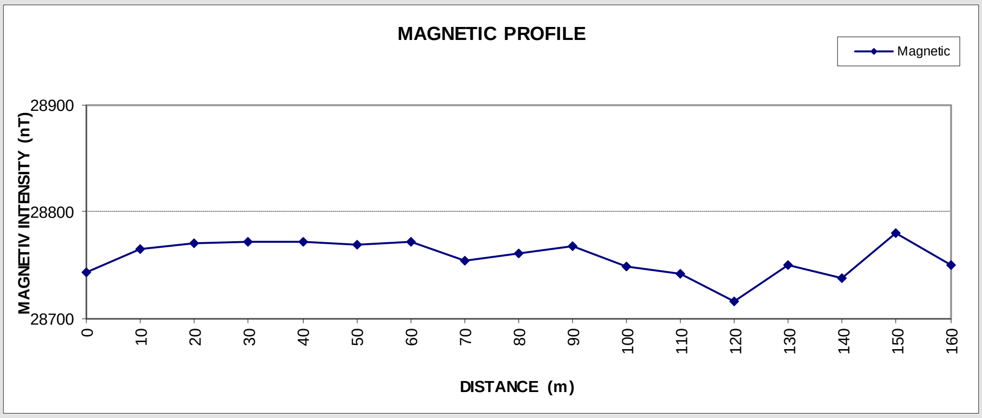
APPENDIX A - GEOPHYSICAL SURVEY RESULTS



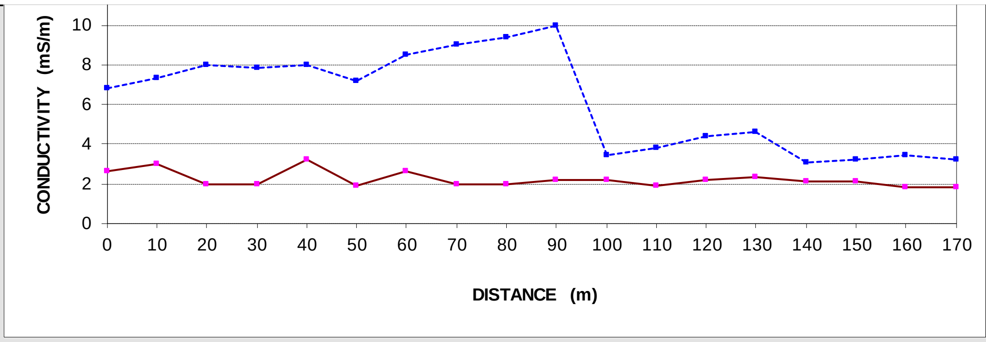


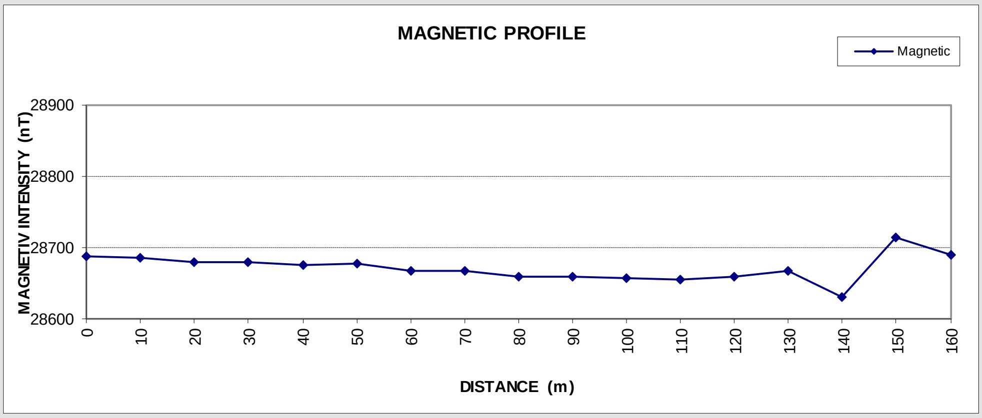
Project:	Nndanganeni	**Profile Number:**	Traverse 1	**Remarks:**
Project Number:	Nndanganeni	**Profile Direction:**	S_N	
Survey Area:	Middelburg	**Station Spacing:**	10	
Date of Survey:	28/10/2022	**Operator:**	0	





Project:	Nndanganeni	**Profile Number:**	Traverse 2	**Remarks:**
Project Number:	Nndanganeni	**Profile Direction:**	S_N	
Survey Area:	Middelburg	**Station Spacing:**	10	
Date of Survey:	28/10/2022	**Operator:**	0	





Project:	Nndanganeni	**Profile Number:**	Traverse 3	**Remarks:**
Project Number:	Nndanganeni	**Profile Direction:**	N_S	
Survey Area:	Middelburg	**Station Spacing:**	10	
Date of Survey:	28/10/2022	**Operator:**	0	